INTEGRATED SCIENCE UNIT

TEACHER GUIDE

ACOUSTICS: THE SCIENCE OF SOUND

SCIENCE

DIGITAL MEDIA ARTS

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Education Development Center, Inc.

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Education Development Center, Inc.

Carissa Baquiran, Kristen Bjork, Jen Clarke, Jennifer Davis-Kay, Maria D'Souza, Eliza Fabillar, Roser Giné, Ilene Kantrov, Nahia Kassas, Patricia Konarski, Emily McLeod, Kate McQuade, Katie Loesel, Cynthia Orrell, Elena Palnzi, Susan Timberlake, Jason Tranchida, Susan Richmond.

Contact
Education Development Center, Inc.
55 Chapel Street, Newton, MA 02458-1060, USA
Phone: 617.969.7100 · Fax: 617.969.5979 · TTY: 617.964.5448
www.edc.org

ISBN
978-0-89292-611-4

Web Site
dma.edc.org

Development Partners

The James Irvine Foundation

Anne Stanton, Rogéair Purnell, Kathryn Furano, Matt Kelemen

ConnectEd: The California Center for College and Career

Gary Hoachlander, Paula Hudis, Pier Sun Ho, Khahn Bui, Dave Yanofsky

Advisors

Industry and Community Advisors

Deborah Brooks
The ACME Network

Milton Chen, PhD
The George Lucas Educational Foundation

Michael Feldman
Independent Sound Editor

Marilyn Friedman
DreamWorks Animation LLC

Pete Galindo
Independent Video Consultant and Educator

Kate Johnson
EZTV

Melissa Malinowsky
Independent Photo Editor

Erik Mason
Imaginary Forces

Dave Master
The ACME Network

Kathleen Milnes
The Entertainment Economy Institute

Dan Norton
Filament Games

Scot Osterweil
The Education Arcade

John Perry
The ACME Network

Chris Runde
Bay Area Video Coalition (BAVC)

Jessica Sack
Yale University Art Gallery

John Tarnoff
DreamWorks Animation LLC

Moriah Ulinskas
Bay Area Video Coalition (BAVC)

Eric Zimmerman
Gamelab

Secondary Educators and Pilot Teachers

*We are particularly grateful for the suggestions and guidance of the teachers who pilot tested the curriculum.

George Burdo*
Grant Communications Technology Magnet, Los Angeles, CA

Joel Buringrud*
Harmony Magnet Academy, Strathmore, CA

Pam Carter
Santa Susana High School, Simi Valley, CA

Deborah Claesgans
Arts Education Branch, Los Angeles Unified School District

Cathee Cohen
Grover Cleveland High School, Los Angeles, CA

Virginia Eves
Office of College, Career & Technical Education, San Diego Unified School District

Soma Mei-Sheng Frazier
Oakland School for the Arts, Oakland, CA

Shivohn Garcia
Paul Cuffee School, Providence, RI

Lorena Guillen*
John Muir High School, Pasadena, CA

John Hammelmann*
Harmony Magnet Academy, Strathmore, CA

Shawn Loescher
Office of College, Career & Technical Education, San Diego Unified School District

Caroline Lorimer*
Metropolitan High School, Los Angeles, CA

Gail Marshall*
Van Nuys High School, Los Angeles, CA

Matt Maurin*
Edison High School, Stockton, CA

Jack Mitchell
California Department of Education

Frank Poje
History-Social Science Educator

Carlos Robles*
Media Arts Lead Teacher, Los Angeles, CA

Nicholas Rogers
Career Development Unit, DACE, Los Angeles Unified School District

Mark Rosseau*
Richmond High School, Richmond, CA

Shawn Sullivan
Sheldon High School, Elk Grove, CA

Post-Secondary Educators

Kristine Alexander
The California Arts Project, California State University

John Avakian
Community College Multi-media and Entertainment Initiative
College of San Mateo, CA

Brandi Catanese
University of California, Berkeley

Elizabeth Daley
School of Cinematic Arts, University of Southern California

Amy Gantman
Otis College of Art and Design, CA

Evarist Giné
Professor of Mathematics, University of Connecticut

Samuel Hoi
Otis College of Art and Design, CA

David Javelosa
Santa Monica Community College, CA

Jack Lew
Center for Emerging Media, University of Central Florida

Sue Maberry
Otis College of Art and Design, CA

Tara McPherson
University of Southern California

Carol Murota
University of California, Berkeley

Casey Reas
University of California, Los Angeles

Carl Rosendahl
Carnegie Mellon University-Silicon University Campus

Guy Smith
Santa Barbara City College, CA

Matt Williams
Institute for Multimedia Literacy, University of Southern California

Holly Willis
Institute for Multimedia Literacy, University of Southern California

Ellen Winner
Project Zero, Harvard Graduate School of Education, MA

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Unit Overview

Voices, music, and sound effects can be used to evoke emotion and tell a story. To maximize sound's potential for communication, it helps to know about the underlying science. What is sound, *and what are its properties? How does it travel from its origin to our ears?*

In this unit, the goal of producing the best possible audio component for a media project serves as the context for learning about sound waves and about mechanical waves in general. Students dissect speakers to learn how sound is produced. They measure the speed of sound and explore how sound and other waves interact with their environments. Through investigations of waves in water and in a Slinky®, students learn how sound waves propagate. Finally, they apply what they have learned to the creation of a sound effect and write an article about a topic related to audio production.*

Unit Length

10 50-minute sessions

Unit Project Description

Students apply what they have learned about sound and waves to complete two projects:

- A sound effect created with sound editing software, with a written explanation of how wave properties, such as amplitude and frequency, were manipulated to produce the sound effect.
- An illustrated article explaining a topic in audio production in terms of the properties and behavior of waves, such as reflection, diffraction, and interference.

* Slinky® is a registered trademark of POOF-Slinky, Inc.

Assessment

Unit activities can serve as formative assessment tools. Use student work to gather information about students' progress and to identify concepts or skills to reinforce within your instructional practice. The following are particularly useful for formative assessment:

- **Handout 6: Where Does Sound Go?** (Activity 2A)
- **Handout 9: Measuring the Speed of Sound** (Activity 2B)

This unit allows students to demonstrate their learning through authentic and relevant applications. This unit's summative assessment includes the following:

- A sound effect, produced using a sound editing program, and a short explanation, in scientific terms, of how the effect was created
- A short article with appropriately labeled diagrams explaining the science underlying a topic related to audio production.

The unit's Assessment Checklists provide criteria for assessment and a suggested weight for each. If you wish to use a rubric, work with same-grade-level or subject-area teachers to develop a tool that is consistent with your school's assessment system.

Framing Questions

- How are sound waves produced, and how do they travel?
- How can I make use of my knowledge about sound waves when creating the audio component of my media and digital design projects?

Understandings

- Sound is a mechanical wave, produced by a vibrating object, that can be described in terms of its frequency, velocity, and amplitude.
- Sound waves interact with the environment in numerous ways, including reflection, absorption, and diffraction.
- An understanding of the science of sound is essential for many careers in the field of audio production.

Where the Unit Fits In

This unit should follow a unit or lesson on simple harmonic motion, if that topic is being taught in your science course.

Integration with Foundations Courses

This unit integrates physics content and career and technical education (CTE) knowledge and skills. It can be taught before, at the same time as, or after the related units in *Foundations in Media and Digital Design: Audio and Video*.

Unit 1: Using Sound to Tell Stories. Students create audio stories targeted at teenagers, telling the story through recorded sound, including interviews, ambient sound, and narration. Discuss with the *Foundations in Media and Digital Design* course teacher the possibility of integrating *Using Sound to Tell Stories* with Part 3 of *Acoustics: The Science of Sound*:

- Students can use their Sound Scavenger Hunt recordings from Unit 1 during Activity 3A.1 of this unit, in which they use sound editing software to look at the waveforms of various sound samples.
- In Activity 3A.2 of this unit, students can create a sound effect for the audio story they produce in Unit 1.

In Activity 3B of this unit, students use the physics they have learned to explain topics related to audio production. Topics are listed in **Handout 16: *Acoustipedia* Topics**, but the *Foundations in Media and Digital Design* course teacher may have ideas for additional topics to include.

Unit 2: Telling Stories with Moving Images. Students explore the power of the moving image as a medium for telling stories. For their unit projects, students create a three- to five-minute video story that illustrates a strength of their community or a challenge that it faces, using their audio production skills to create soundtracks for their community stories. Discuss with the *Foundations in Media and Digital Design* course teacher the possibility of having students create a sound effect for this soundtrack during Activity 3A.2 of this physics unit.

Multi-Disciplinary Teams

Use the following integrated units and integration suggestions for a school- or pathway-wide multi-disciplinary project.

Functions and Sound (Algebra 2, Trigonometry, Pre-Calculus). Students investigate and compare functions and the equations and graphs that represent them, including the trigonometric functions that model sound waves.

Everyone Has a Story (English Language Arts). Students learn to write about themselves by first analyzing audio stories and excerpts from published memoirs and then developing their own short memoirs about an incident they have never forgotten. They examine how writers apply literary techniques, such as narrative arc, point of view, characterization, and figurative and sensory language, to narrate true stories that enlighten, amuse, and emotionally move their readers.

Podcasting the Past (U.S. History). Students conduct independent research to uncover the history of their communities. They create podcasts for walking tours, with interviews and narration to explain the historical significance of each stop on the way.

Table of Activities

Part 1: What Is Sound? (2 sessions)

Students begin their explorations of waves and sound with demonstrations and activities intended to stimulate curiosity and generate questions about sound.

Activity 1A: Sounds All Around (1 session)

Students are introduced to the unit and the unit project.

Activity 1B: Sound—From Production to Perception (1 session)

Students "dissect" and experiment with a speaker to see firsthand how these devices convert electrical impulses into physical vibrations, and they learn how these vibrations are perceived by the ear.

Part 2: Exploring Waves (5 sessions)

Students explore the properties of waves, such as wavelength, frequency, amplitude, and speed, and behaviors of waves, such as reflection, diffraction, and interference.

Activity 2A: Where Does Sound Go? (1 session)

Students investigate the behavior of water waves as a model for the behavior of sound waves. They share their observations about waves and learn the scientific terms to use to describe these observations. They consider how these behaviors influence the placement of audio equipment and the design of recording studios and live performance venues.

Activity 2B: The Speed of Sound (2 sessions)

Students learn what factors affect the speed of sound and conduct an investigation in which they measure the speed of sound in air.

Activity 2C: Making Waves (2 sessions)

Students use Slinkys to explore the properties of mechanical waves, creating and observing both longitudinal and transverse waves. Students learn how to use the equation that quantifies the relationship between frequency, wavelength, and wave speed.

Part 3: Acoustics in Action (3 sessions)

Students use sound editing software and their knowledge of sound waves to create a sound effect. They apply what they have learned in this unit by writing an article for a classwide *Acoustipedia*.

Activity 3A: Sound Editing Software (1.5 sessions)

3A.1: Seeing Sound Waves	Students use sound editing software to explore the relationship between a wave's properties and how the wave sounds.
3A.2: A Sound of Your Own	Students use a sound editing program to produce a sound effect for a media and digital design project. They write a concise explanation, in scientific terms, of how they manipulated wave properties to produce this effect.

Activity 3B: The Science of Sound (1.5 sessions)

Students write articles, with labeled illustrations, on topics related to sound and audio production. Students' articles are combined into a mini-encyclopedia, the *Acoustipedia*, that all students can refer to when working on media and digital design projects.

Advance Preparation

RESOURCES

- Web sites recommended for in-class or student use throughout the unit are listed in *Media & Resources*. These Web sites have been checked for availability and for inappropriate content. However, because Web site policies and content change frequently, we suggest that you preview the sites shortly before using them. Address any issues, such as firewalls and filtering software, related to accessing these sites from within your school.
- Begin collecting speakers for Activity 1B (from computers, home theater systems, stereos, electronic toys, etc.). See *Appendix A: Sources for Speakers* for suggested sources.
- Activity 3A requires students to use sound editing software during class. Reserve a computer lab and install sound editing software (such as the freely available program Audacity) on all computers. You can test that the software is correctly installed by playing some of the sound files for Activity 3A.1. (See *Media & Resources* for instructions on using Audacity to perform common sound editing tasks.)
- For Activity 3B, students will need computers with Internet access. Ideally, each student will have his or her own computer.
- The final project, the *Acoustipedia* article, is a challenging one. Students are unlikely to find information sources that cover their topics from the perspective required by the assignment. Rather, they will need to apply the physics they have learned in order to synthesize an explanation of their topic.
    - Look over the project requirements (**Assessment Checklist 2: *Acoustipedia* Article**) and list of topics (**Handout 16: *Acoustipedia* Topics**) well in advance and decide whether your students need additional time or additional structure beyond what is described in the unit. For example, you may want to require students to submit an outline or a draft to you or you may want to collaborate with an English language arts teacher.
    - For an overview of many of the *Acoustipedia* topics, see the "Sound and Hearing" section of the Web site *HyperPhysics* (http://hyperphysics.phy-astr.gsu.edu/hbase/HFrame.html). The subsections on auditorium acoustics and sound reproduction are particularly helpful, since they contain information unlikely to be found in a high school physics textbook.

Part 1: What Is Sound?

Students begin their explorations of waves and sound with demonstrations and activities intended to stimulate curiosity and generate questions about sound.

Length

2 50-minute sessions

RESOURCES

Advance Preparation

- Before Activity 1A:
    - Preview the *Sounds All Around* video clips. (See *Media & Resources* for links to the clips.)
    - Test the tuning fork demonstration. Strike the tuning fork and insert the prongs into the bowl of water. If water splashes are not easily visible, try striking the tuning fork more forcefully. If the splashes still aren't visible, try a different tuning fork. Larger and higher-quality tuning forks generally produce more splashing.
    - Decide whether to replace any of the demonstrations in the video (such as the bell in a vacuum jar) with a live demonstration or whether to perform other sound demonstrations and gather any needed materials.
- Preview the *Sound as Touch* audio clip from 4:39 until 6:53. (See *Media & Resources* for a link to this clip.) The clip describes how the vibrations that carry sound set off a series of electrochemical reactions that stimulate neural pathways linked to emotion and memory. Decide whether you want to play the clip for your students, and if so, whether to play it at the end of Activity 1A or during the discussion of how sound is perceived in Activity 1B. Note that if any of your students are taking *Foundations in Media and Digital Design*, they may have already heard this clip.

Activity 1A: Sounds All Around

Students are introduced to the unit and the unit project. They observe live (teacher-performed) or video demonstrations of interesting sound phenomena, and generate questions about sound.

Understandings

- Sound is produced by vibrating objects.
- Sounds need a medium (for example, air, water, or rock) to travel through.
- Learning about the science of sound can help you create better soundtracks for media projects.

Materials Needed

- Tuning fork
- Bowl of water
- **Handout 1: Sounds All Around**
- Optional: Materials for any demonstration(s) you will perform
- *Sounds All Around* video clips (see *Advance Preparation*)
- Computer with projector, Internet access, and speakers
- **Handout 2: Unit Overview**
- Optional: *Sound as Touch* audio clip, 4:39–6:53 (See *Media & Resources*)

1. Introduce the topic of the unit.
Explain that the class is beginning a unit on sound and waves with some live or video demonstrations related to sound. Ask students:

- What do you already know about sound?
- Have you ever heard sound described as a wave? If so, what does that mean to you?

Strike the tuning fork and immerse the tips of the tines in the bowl of water. Discuss the demonstration, using the following questions:

- What do you see?
- What does this demonstration tell you about sound?
- Does this demonstration raise any questions about sound?

Record students' responses on chart paper.

2. Distribute Handout 1: Sounds All Around.
Explain that students will use this handout to record their observations, comments, and questions about a variety of demonstrations related to sound.

3. Optional: Perform one or more sound demonstrations.
Perform one or more of the demonstrations included in the video, or other demonstrations on the topic of sound. Have students answer the questions from Handout 1 for each demonstration.

4. Show *Sounds All Around* video clips.
Explain to students that they will see the video clips twice, to give them enough time to record their observations of and questions about sound on Handout 1. Show the clips twice and give students a few minutes to complete the handout.

5. Discuss observations and questions.
For each demonstration performed by you or in the video, ask a few students to share their answers to the questions on Handout 1. Record on chart paper any information about the nature of sound and any questions provoked by the video clips. Save this chart paper and let students know that they will return to these questions later in the unit.

Teacher's Notes: Sound Misinformation

When your students share their ideas about what the video clips tell them about sound, it's possible that they may draw conclusions that are scientifically inaccurate. Record on chart paper *all* student responses and then revisit this record throughout the unit as you confirm or disprove these ideas.

6. Introduce the unit and distribute Handout 2: Unit Overview.
Distribute the handout and give students time to read it. Describe the projects that students will work on during this unit.

If your students are taking or have taken *Foundations in Media and Digital Design*, ask them to share any challenges they have faced in creating the audio component of their media and digital design projects. What would they like to know about sound that would help them in future projects?

If time permits, you may want to have students listen to the audio story *Sound as Touch*. Explain that the story will encourage them to think about how we perceive sound, which they will learn about in the next session.

Handout 1:
Sounds All Around

The clips in this video show some of the interesting ways that sound behaves. For each clip, describe what you observed. Then describe one thing the clip tells you about sound or something that the clip makes you wonder about sound.

Clip Description	**What did you observe?**	**What does the clip tell you about sound? *or* What do you wonder about sound?**
Bell in vacuum jar		
Spaceship		***In space, there is no medium for sound to travel through, so, although science fiction movies usually show otherwise, an observer would not hear a spaceship go by.***
Horn or whistle from a moving vehicle		
Tree falling		
Wine glass shattering		
Lightning and thunder		
Mosquito tone		
Orchestra tuning up		
Echo		

Handout 2:
Unit Overview

Voices, music, and other sounds can enhance your media and digital design projects by evoking emotion, establishing a setting, helping to develop characters, and moving the plot along.

Whether you are recording sound for a radio, television, or film production, working in a music recording studio, or setting up the sound system for a live concert or a campaign speech, understanding the science of sound will help you do your job better and get better results. Imagine . . .

. . . an interview that captures the nuances of the speaker's voice
. . . a recorded song where every voice and instrument meld together seamlessly
. . . sound effects for a movie that make you feel like you are in the middle of the action
. . . a live concert in which everyone can hear the performers' music as it was meant to be heard

A good understanding of the science of sound—which is also known as acoustics*—can help you choose and set up audio equipment for any recording task. You'll know what causes feedback, and how you can set up equipment to avoid it; what happens when speakers are out of phase, and how you might you fix them; and what microphones are best for recording interviews versus recording music.*

In this unit, you will learn about sound by conducting hands-on investigations, using sound editing software, and exploring computer simulations of waves.

Your work in this unit will revolve around the following questions:

- *How are sound waves produced, and how do they travel?*
- *How can I make use of my knowledge about sound waves when creating the audio component of my media and digital design projects?*

Unit Project

You will create a sound effect by using sound editing software to manipulate sound waves and then write an explanation of what you did in terms of wave properties, such as frequency and amplitude. You will collaborate with classmates in the production of a mini-encyclopedia, the *Acoustipedia*; each student will write an illustrated article explaining a topic in audio production in terms of the properties and behavior of waves (such as reflection, diffraction, and interference) and will revise the article based on feedback from other students.

What You Will Do in This Unit

Explore mechanical waves. Create waves in water and with a Slinky and observe how these waves behave.

Look at and create sound waves. Use sound editing software to "see" sound waves on the computer screen and observe the characteristics that make one sound different from another. Create or manipulate sound waves to produce a sound effect.

Share what you have learned. Write an article for the class *Acoustipedia* about the science behind a topic in the field of audio production.

Vocabulary Used in This Unit

Acoustics: The branch of physics dealing with sound. (Also, the characteristics of a physical space that determine the fidelity and audibility of sound transmitted there.)

Frequency: The number of wavelengths that pass a given location during a unit of time. Usually measured in cycles/second (also called *Hertz*).

Wave: A disturbance that carries energy, but not matter, from one place to another. The disturbance may be mechanical or electromagnetic. Mechanical waves, such as ocean waves, sound waves, and seismic waves (earthquakes), must travel through a medium, such as water, air, or earth, and gradually lose energy to that medium as they travel.

Wavelength: The length of one complete cycle of a wave; the distance from a point on one wave to the same point on the next wave. Often represented using the Greek letter *lambda* (λ).

Activity 1B: Sound—From Production to Perception

Students experiment with and "dissect" a speaker to see firsthand how these devices convert electrical impulses into physical vibrations. This provides a concrete example of the fact that vibrating objects produce sound, and also demonstrates the relationship between wave amplitude and sound volume.

Understandings

- Sounds are produced by vibrating objects.
- The ear converts the vibration of air molecules into a signal to the brain.

Materials Needed

- Optional: Functioning speaker
- Speakers to take apart (1 per team—see Advance Preparation for the unit)
- **Handout 3: Anatomy of a Speaker**
- Materials for dissecting speakers:
  - Safety goggles (1 pair per student)
  - Small screwdrivers in a variety of sizes (several per team)
  - Scissors (1 pair per team)
  - Craft knife or utility knife (1 per team)
  - Wire cutters/strippers (1 per team)
  - Alligator clip cables (2 per team)
  - 9-volt battery (1 per team)
  - Voltmeter, ammeter, or multimeter (1 per team)
- **Handout 4: From There to Ear**
- **Handout 5: Playing the Eardrum**
- Optional: Audio clip, *Sound as Touch*, 4:39–6:53 (see Advance Preparation)
- Optional: Computer with Internet access and speakers
- Students' completed copies of Handout 1
- Chart paper from Activity 1A with questions and observations about sound

1. Introduce the activity.

Explain that learning about how speakers work will help students understand sound and, since the soundtrack for any media project reaches the audience through speakers, can help them create better soundtracks. Ask students:

- What do you already know about how speakers work?

If you have a functioning speaker available, you can ask a few students to put their hands on it while you play a loud, low-frequency sound and have them describe what they feel to their classmates. Otherwise, ask students:

- Have you touched a speaker while it was in use or stood next to a large speaker at a concert? If so, what did you feel? What do you think caused this sensation?

2. Have students perform the "dissection."

Distribute **Handout 3: Anatomy of a Speaker** and divide the class into teams of two to four students. (Base team sizes on the number of speakers for dissection you were able to obtain.) Have students work in teams to complete the steps described in the handout and answer the questions.

3. Share results.

Discuss the questions from Handout 3 and ask students to share their observations. See how much students were able to figure out about how the speaker works and then fill in any details.

Teacher's Notes: How Speakers Work

When an electric current is applied to the voice coil, the coil becomes an electromagnet. Depending on the direction of the current, the coil is either attracted to or repelled by the permanent magnet. Since the cone is connected to the voice coil, it moves in when the coil moves in and moves out when the coil moves out. The moving cone pushes against adjacent air molecules. Handouts 4 and 5 explain more about what happens once these molecules are in motion.

A simple speaker can be used in reverse as a microphone. If you have ever used a simple intercom or walkie-talkie that doesn't let you talk and listen at the same time, it's because it was constructed with one device to serve as both the microphone and the speaker.

For further detail about how speakers and microphones work, see *Additional Resources for Teachers.*

4. Explain how sound travels to the ear.

Distribute **Handout 4: From There to Ear** and **Handout 5: Playing the Eardrum**. Explain that any source of sound, such as a tuning fork, a loudspeaker, or a musical instrument, vibrates. This causes vibrations in whatever separates the vibrating object from our ears—usually air, but vibrations can pass through solids and liquids as well. If the vibrations are strong enough to travel to our ears, and if the rate of vibration is within the range our ears are sensitive to, our ears turn that vibration into a signal that our brains perceive as sound.

Note: If you have time and wish to cover the topic of sound perception in more detail, play the audio clip from *Sound as Touch*.

Teacher's Notes: Radio Waves and Sound Waves

This session may be a good opportunity to correct a common misconception among students, which is that radio waves and sound waves are the same thing.

- *Sound waves* are mechanical waves—molecules vibrating back and forth, causing the adjacent molecules to move back and forth, and so on. Sound waves make our eardrums vibrate, which is why we can hear sound.
- *Radio waves* are a type of electromagnetic wave, like light. Unlike mechanical waves, radio waves and other electromagnetic waves do not need a medium to travel through—they can travel through a vacuum. Since our ears are sensitive to molecules moving back and forth and radio waves do not make molecules move back and forth, we cannot hear radio waves.

You may want to show again, or just refer back to, the video clip of the bell in the vacuum jar. When there was no air in the jar, no sound waves could travel from the bell to observers' ears. But the fact that the bell could still be seen demonstrates that electromagnetic waves such as light waves could travel to and from the bell, even through the vacuum.

5. Discuss connections to the *Sounds All Around* video clips.

Ask students to apply what they've learned to the *Sounds All Around* video clips and the questions they noted on Handout 1 and the chart paper from Activity 1A. What parts of the video could the activities you did in this session help explain? You may want to prompt them to think about these clips in particular:

1. Bell in a vacuum jar, spaceship

   Possible answer: *If sound travels by air molecules bumping into each other, then sound can't travel where there are no molecules.*

2. Wine glass shattering

   Possible answer: *The vibrating air molecules make the glass vibrate so forcefully that it breaks.*

3. Orchestra tuning up

   Possible answer: *Musical instruments produce sound by making the air vibrate.*

Handout 3:
Anatomy of a Speaker

A microphone takes sound and converts it into an electrical signal that can be stored for later playback. A speaker takes this electrical signal and converts it back into sound. Learn more about how this works and exactly what sound is by "dissecting" a speaker.

Background Information

Speaker is short for *loudspeaker*. A loudspeaker consists of some kind of cabinet or enclosure with one or more drivers inside, along with any electronics needed to process the incoming electrical signal. A *driver* is the part of the speaker that converts the electrical signal into physical vibrations.

Loudspeaker with cover removed to show two drivers inside.

Speakers work because they receive electrical signals from a computer, television, or other sound system component. In this activity, since the speakers being dissected are no longer connected to one of these systems, you will use a battery to provide the electrical signal. While a sound system sends a signal consisting of a varying electrical voltage, the battery can only send a very simple signal—it's either on or off!—so there won't be much variety in the sounds produced during this investigation.

Materials

- Safety goggles
- Small screwdrivers in a variety of sizes
- Scissors
- Craft knife or utility knife
- Wire cutters/strippers
- 2 alligator clip cables
- 9-volt battery
- Voltmeter, ammeter, or multimeter

Procedure

Note: Try to do as little damage as possible to the speaker at each stage, so that it continues to function throughout as much of the procedure as possible.

1. Put on your safety goggles.
You may need to pry the speaker apart using a screwdriver, and pieces of the speaker may go flying through the air. Even if your team is not prying apart the speaker, other teams may be, and the flying pieces can travel several feet.

2. Remove the driver.
What needs to be done to expose the driver varies widely from speaker to speaker. Here are some general guidelines:

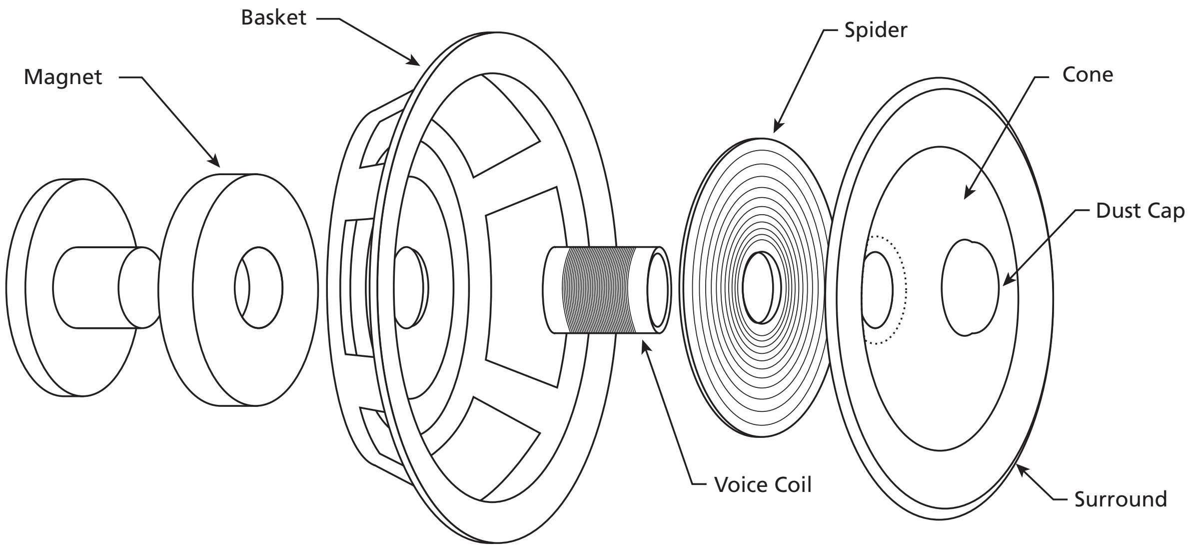
- Most speakers have some kind of mesh or grill cover on the front. Try to remove this.
  - If this cover is screwed on, remove the screws and lift the cover off.
  - If there are no visible screws, you may be able to pry the cover off with a screwdriver.
  - A mesh cover can be cut away with scissors or a knife.
- Once the cover has been removed, you will see the front of the driver.
  - If the driver is held in place with screws, unscrew them and carefully remove the driver.
  - If there are no visible screws, see if you can simply lift the driver out.
  - If you are not able to remove the driver from the front of the speaker, you will need to take apart the speaker cabinet. Look for small screws on the front and back. If there are no screws, or if removing the screws does not enable you to open the cabinet, you may need to pry the cabinet apart with a screwdriver. Once the cabinet is open, remove the driver.

If you are unable to remove the driver, you should still try to complete as much as possible of the remaining steps.

A loudspeaker driver that has been removed from its cabinet.
Image by Richard Wheeler (Zephyris), licensed under Creative Commons Attribution ShareAlike 3.0

3. Disconnect the driver wiring from the rest of the speaker and connect it to the battery.
Two wires connect the underside of the speaker cone to the inside of the speaker cabinet. (Any other wires can be cut and then ignored.)

- The wires leading from the cone may be connected to the rest of the speaker by small plugs. If this is the case, unplug the wires, and attach an alligator clip cable to each plug remaining on the driver.
- If the wires leading from the cone cannot be unplugged, use wire cutters/strippers to cut the wires. Then strip some insulation off the ends of the wires and attach an alligator clip cable to the end of each wire. Attach the free end of one alligator clip to one battery terminal.



Parts of a driver

Touch the free end of the other alligator clip to the other battery terminal to complete the circuit. Try this repeatedly and answer the following questions:

- What do you hear?
- What does the cone do?
- What do you see and hear if you connect the wires to the opposite terminals of the battery?

Leave the alligator cables attached to the driver, and leave one alligator clip attached to the battery.

4. Expose the spider and voice coil.

Use a craft knife or utility knife to remove part of the cone by cutting halfway around the surround and then across the cone and dust cap. (Remove the half of the cone that does not have wires attached to it.) Again, use the free end of the alligator clip cable to complete the circuit with the battery.

- What do you hear?
- What parts of the driver move?
- What changes if you connect the alligator clip cables to the opposite terminals of the battery?

Use the knife to remove half the spider. Again, connect the free end of the alligator clip cable to the battery. Look for the voice coil (a coil of very fine copper wire).

- When you complete the circuit with the battery, what does the voice coil do?

5. See what you can determine about how a speaker works.

- Based on your observations, what have you figured out about how a speaker works?
- What questions about how a speaker works do you still have?

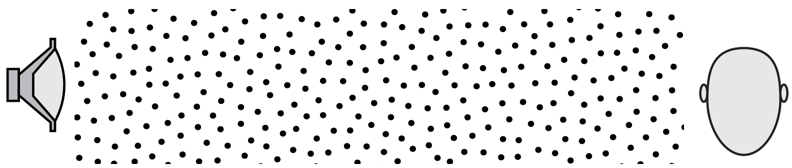
6. Connect the speaker wires to a voltmeter or ammeter.

Movement of the needle on a voltmeter or ammeter indicates that electricity is flowing.

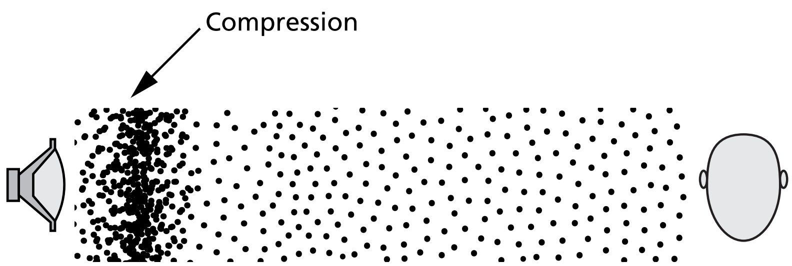
- Move the cone in and out with your fingers. How does the meter respond?
- Can you make the cone move by blowing on it or shouting near it?
- Given your observations, what ideas do you have about how microphones work?

Handout 4:
From There to Ear

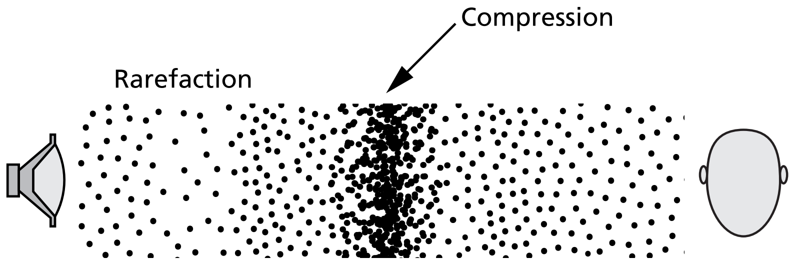
Any source of sound, such as a tuning fork, a loudspeaker, or a musical instrument, vibrates. This causes vibrations in whatever separates the vibrating object from our ears—usually air, but vibrations can pass through solids and liquids as well. If the vibrations are strong enough to travel to our ears, and if the rate of vibration is within the range our ears are sensitive to, our ears turn that vibration into a signal that our brains perceive as sound.



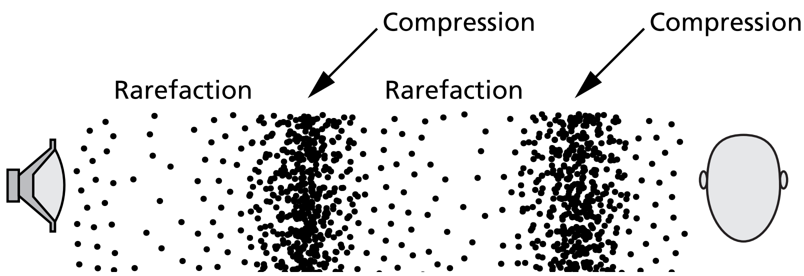
In the absence of sound, the air molecules between the speaker and the ear are spread out evenly.



In response to an electrical signal, the speaker cone moves to the right, hitting the nearby air molecules and resulting in a region of compressed air.



The air molecules bump into other molecules, and so on, resulting in a region of compression that moves away from the speaker. Meanwhile, as the speaker cone moves to the left, a region of lower air pressure, called a *rarefaction*, forms.



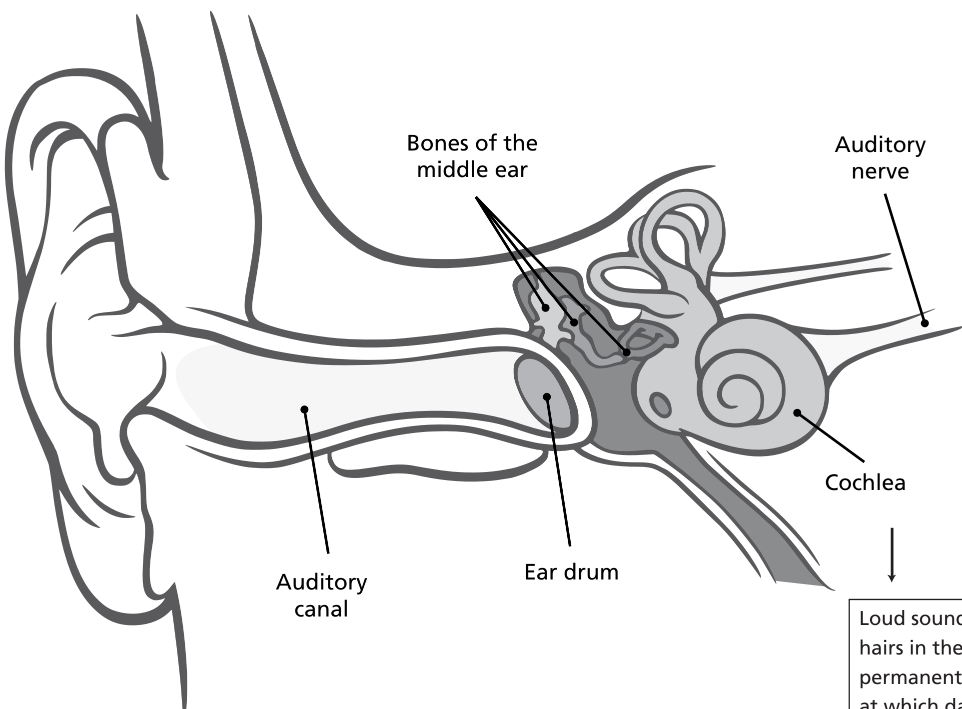
The speaker cone continues to move in and out, creating alternating regions of compression and rarefaction that travel to a listener's ear.

Handout 5:
Playing the Eardrum

When you listen to sound from a speaker, vibrations travel this path to your ear:

diaphragm of the speaker
↓
air molecules between you and the speaker
↓
air molecules in your auditory canal
↓
eardrum (tympanic membrane)
↓
tiny bones in the middle ear
↓
fluid in the cochlea
↓
tiny hairs in the fluid

The motion of these hairs results in an electrical signal being sent along the auditory nerve to your brain.



Loud sounds can damage the tiny hairs in the cochlea, resulting in permanent hearing loss. The volume at which damage occurs is much lower than the volume at which a listener feels pain.

Credit: Chittka L, Brockmann; Creative Commons Attribution Generic 2.5

Part 2: Exploring Waves

Students explore the properties of waves, such as wavelength, frequency, amplitude, and speed, and behaviors of waves, such as reflection, diffraction, and interference.

Length

5 50-minute sessions

Advance Preparation

RESOURCES

- For Activity 2A, download the slide presentation "Where Does Sound Go?" (See *Media & Resources*.)
- For Activity 2B:
  - Find a large vertical wall on the outside of your school building and test the production of echoes required in order to complete **Handout 9: Measuring the Speed of Sound.**
  - Obtain blocks of wood to use for making a clapping sound.
  - Procure 25–50-foot tape measures, which will make the measurement process easier and faster.
  - Download the slide presentation "How Sound Travels Through Different Media." (See *Media & Resources*.)
- For Activity 2C, preview the animations of superposition and standing waves and choose which one(s) to show your students. (*See Media & Resources.)*

Activity 2A: Where Does Sound Go?

As a model for the behavior of sound waves in an enclosed space, students investigate the behavior of water waves in a ripple tank. They consider how these behaviors influence the placement of audio equipment, such as microphones and speakers, and the design of recording studios and live performance venues.

Understandings

- Characteristic behaviors of waves include reflection, interference, and diffraction.
- A *periodic wave* can be described by its frequency, wavelength, and amplitude.

Materials Needed

- Students' copies of Handout 4
- Slide presentation "Where Does Sound Go?" (see *Advance Preparation*)
- Computer with projector and Internet access
- **Handout 6: Where Does Sound Go?**
- **Handout 7: Water Waves Exploration**
- Materials for the investigations (for each team of 3 to 4 students):
  - Ripple tank (such as an 8 x 8 clear Pyrex® baking dish)
  - Pencil with eraser
  - Blocks of various sizes, small enough to fit in the ripple tank
- **Handout 8: Properties of Waves**
- Chart paper of questions from Activity 1A
- Students' completed copies of Handout 1

1. Introduce the activity.
Ask students to look at their copies of Handout 4. Point out that the simplified illustration shows sound waves traveling from the speaker to the ear, but going nowhere else. Show students the first slide from "Where Does Sound Go?" and explain that in general, sound waves move out in all directions from their source until they reach boundaries. Waves then interact with these boundaries in a variety of ways. Understanding these interactions can help you make decisions about microphone and speaker placement, thereby helping you create the best possible soundtrack for media projects.

Distribute **Handout 6: Where Does Sound Go?** Ask:

- What in the room is producing sound?
- In what directions will the sound waves travel?

- What will happen when the sound waves reach obstacles or walls?
- What will the listeners at points A, B, C, and D hear?

Ask students to draw their predictions for the behavior of the sound waves. Will the sound waves reach all four listeners?

Note: Handout 6 provides a useful opportunity for formative assessment.

Ask students:

- Have you ever observed anything that resembles the pattern shown on the slide?

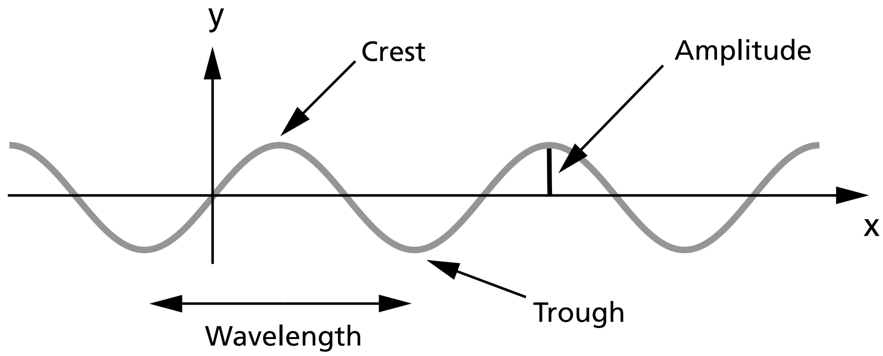
  Answer: *A pattern like this is produced when something is dropped into a body of water. Ripples move outward from the disturbance in the center.*

Explain that to learn more about how sound waves interact with their environment, and to be able to make a better prediction about how the sound waves in Handout 6 behave, they will use water in a shallow container as a model for sound in an enclosed space. Water waves don't behave exactly the same way that sound waves do, but there are enough similarities that investigating one can help us understand the other.

2. Have students perform the investigations.
Distribute **Handout 7: Water Waves Exploration**. Have students work in teams to complete the investigations. Explain that in addition to the specific investigations listed in the handout, students should try any other setups needed to help them test the predictions they recorded on Handout 6.

3. Discuss observations and introduce scientific terms.
After students have completed the investigations described in Handout 7, explain that there are scientific terms for the parts of the waves they created and for the way these waves interacted with each other and with their environment. **Distribute Handout 8: Properties of Waves**, on which students can record the meanings of these terms. Draw an unlabeled sine wave on the board.

Have a few students share their responses to each question on Handout 7. As students share their observations, introduce the corresponding scientific term. For example, if a student says that some of the waves were higher or taller than others, introduce the term *amplitude* and label the amplitude on the sine wave you've drawn on the board. When a student describes a ripple bouncing off the edge of the tray, tell students that this behavior is called *reflection*.



Through this discussion, the following terms should be defined:

Parts/properties of a wave:

- crest
- trough
- amplitude
- wavelength
- frequency

Wave behaviors:

- reflection
- diffraction
- interference

When discussing reflection, show the first slide from "Where Does Sound Go?" again. Explain that there are many other ways to draw waves. One way is to draw the wave fronts, using lives to show the location of the wave crests as viewed from above.

Show the second slide from "Where Does Sound Go?" and explain that another way to draw waves is a ray diagram. Rays are lines perpendicular to the wavefronts. They show the direction in which the wave is travelling.

Show the third slide, and explain that just looking at a single ray makes it easier to predict where a reflected wave will go.

Show the fourth slide. Introduce and define the terms *angle of incidence* and *angle of reflection*. Explain that this principle is essential for figuring out how sound waves—whether from a loudspeaker, musical instrument, or voice—travel in an auditorium or recording studio.

Note: The relationship between the angle of incidence and the angle of reflection is difficult to observe in a ripple tank. Ideally, students will have the opportunity to experience this directly (it is fairly easy to see using laser pointers and mirrors) during a subsequent unit on electromagnetic waves.

Teacher's Notes: Sound Waves and Polarization

A widespread piece of misinformation about sound waves is that they are always longitudinal waves and that therefore polarization of sound waves does not occur. Though it is true that sound is always a longitudinal wave in gases and liquids, in solids, sound can travel as both a longitudinal wave and as a transverse wave. In such cases, polarization (a phenomenon that occurs only in transverse waves) can occur.

4. Have students revise their predictions on Handout 6.

Ask students to look again at Handout 6 and to use the bottom half of the handout to draw their revised predictions of how sound waves would behave, based on what they learned during their investigations and the class discussion. Ask for a few students to share their drawings and explain their predictions.

Note: The fifth slide in "Where Does Sound Go?" can be projected onto the board rather than a screen, so that students can share their predictions by drawing over the projected image from the slide.

Show students the final slides in "Where Does Sound Go?" Explain that the slides show approximations of how the waves will behave. In reality, the waves will reflect off the walls many times, creating a very complicated pattern.

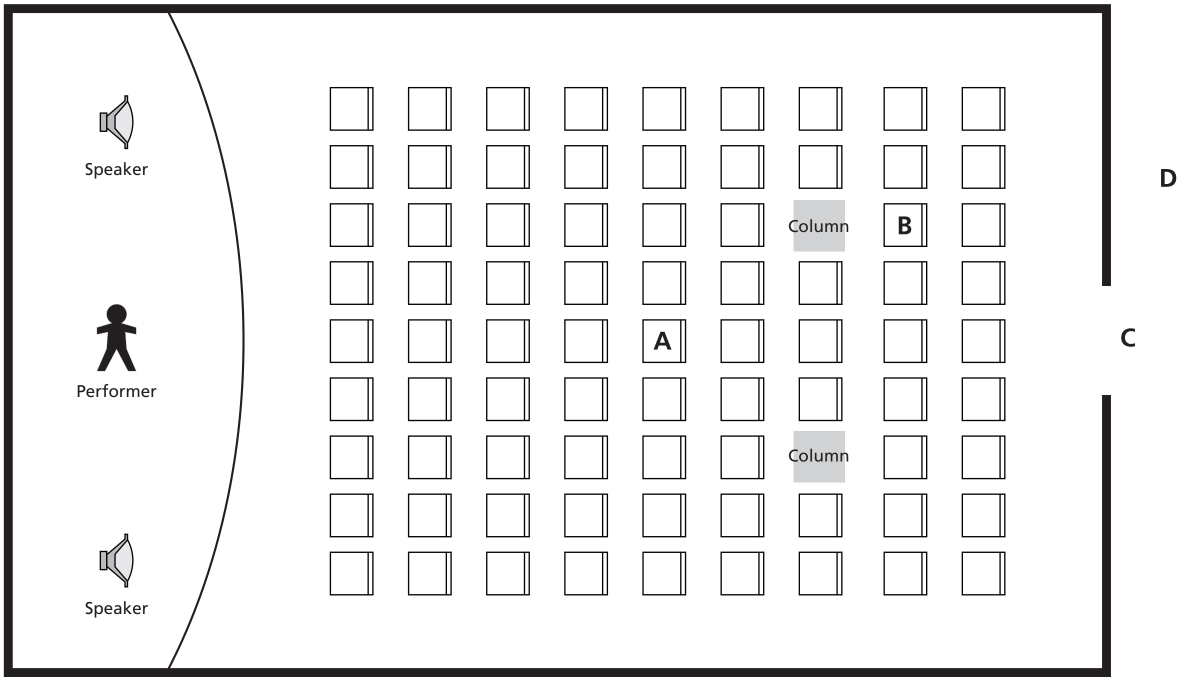
5. Discuss connections to the *Sounds All Around* video clips.

Refer to the chart paper from Activity 1A and to students' completed copies of Handout 1. Ask students:

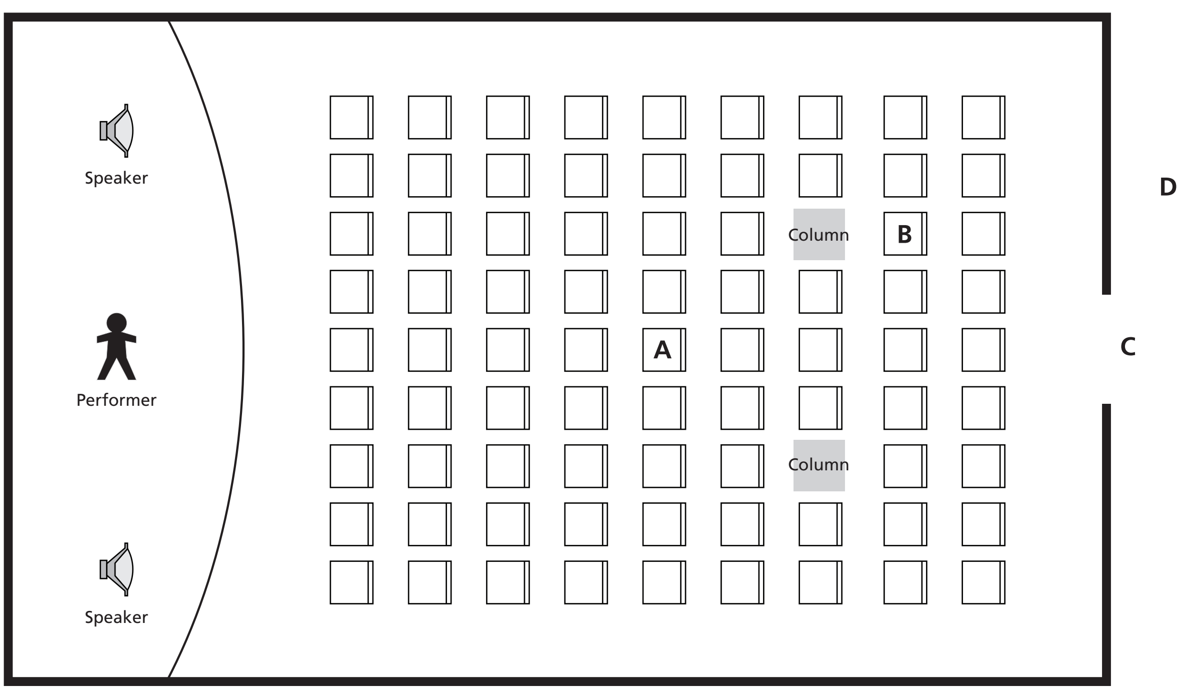
- Does what you learned today help answer any of these questions?

Handout 6:
Where Does Sound Go?

Where will the sound waves go? Will they reach listeners at locations **A**, **B**, **C**, and **D**? Draw your prediction.



After you have investigated the behavior of water waves, draw your revised prediction of how the sound waves in this room will behave.



Handout 7:
Water Waves Exploration

In this investigation, you will create waves in water and observe how these waves interact with each other and with their environment. You will then use what you have learned to predict how sound waves will behave in an enclosed space.

Materials

- Ripple tanks (such as an 8 x 8 clear Pyrex® baking dish)
- Pencil with an eraser
- Blocks of various sizes, small enough to fit in the ripple tank

1. Circular Pulses

A. Make a ripple in the water by poking the surface with the eraser end of a pencil. This singular disturbance is called a *pulse*. Describe (in words) and draw what you observe. Add arrows to your drawing showing the direction of movement. How does what you see change over time?

B. Create another pulse with the eraser. What happens when the ripple reaches the sides of the tank? Describe and draw what you observe. Does the ripple reach all sides of the tank at the same time? Why or why not?

C. Make two pulses by poking the surface of the water in two different locations at the same time. Describe and draw what you observe. How do the height and depth of the ripples change when two ripples meet each other? Draw another picture showing what the waves would look like from the side (imagining that you can see through the side of the tank).

2. Circular Periodic Wave

Periodic waves can be created by repeatedly poking the surface of the water in the same location at a constant pace.

A. Make two circular periodic waves by repeatedly poking the surface of the water in two different locations at the same time. Describe and draw what you observe.

B. Place one of the blocks in the ripple tank. (You will probably need to hold it down to keep it from floating away.) Create a periodic wave. What happens when the wave reaches the block? Draw what you see.

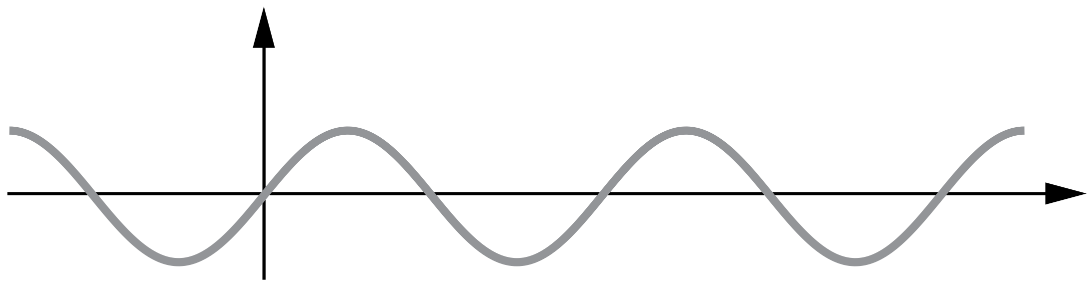
C. Position two of the blocks so that there is a small gap between them. Create another periodic wave. What happens when the wave reaches the gap? Change the size of the gap and see how that affects the behavior of the wave. Describe and draw what you see.

3. Refining Your Prediction

In addition to the specific steps listed in this handout, try any other setups needed to help test your predictions on Handout 6.

Handout 8:
Properties of Waves

Label the following parts and properties of the wave: wavelength, amplitude, crest, and trough.



Use the space below to take notes or make sketches of the following parts, properties, and behaviors of waves.

Parts/properties of a wave:

- crest
- trough
- amplitude
- wavelength

Wave behaviors:

- reflection
- diffraction
- interference

Activity 2B: The Speed of Sound

Students collect distance and time data for an echo and use this data to calculate the speed of sound in air.

Understandings

- Sound takes time to travel from one location to another.
- Sound travels differently in different media.

Materials

- **Handout 9: Measuring the Speed of Sound**
- Materials for the procedure on Handout 9:
  - 2 wooden blocks (one set for the whole class as a demonstration, or one set per team of 3 to 4 students if teams will work separately)
  - Stopwatch (1 per team)
  - Tape measure (1 per team—see Advance Preparation)
- Slide presentation "How Sound Travels Through Different Media" (See *Advance Preparation*)
- Computer with projector and Internet access

1. Introduce the idea that sound takes time to travel and discuss examples.
Remind students that in the previous session, they learned about the paths that sound waves travel in an environment. Explain that people who design and equip performance and recording venues need to take into account not only the path traveled by the sound waves, but also how fast the sound waves travel. Explain that in today's session students will measure the speed of sound.

2. Ask students if they have observed any situations in which sound took a noticeable amount of time to travel.
If students have trouble coming up with examples, you might suggest the following:

- Many students will have heard echoes, though they may not make the connection that this phenomenon results from the travel time of sound.
- Students who are seriously involved in the performing arts may have observed time delays in a large auditorium or other venue.
- The time difference between seeing lightning and hearing thunder is due to the fact that sound travels much more slowly than light does.

3. Discuss the time difference between seeing lightning and hearing thunder.
Ask students what they have observed or heard about the time difference between lightning and thunder. They may be familiar with a rule of thumb that says that if you can count to five between the lightning and thunder, the lightning is a mile away. Ask students if they think this is true.

4. Brainstorm how students might measure the speed of sound.
Ask students for their ideas about how they might test the rule of thumb about lightning and thunder. Let students know that, for now, the class is not going to critique or reject any ideas. Building on others' ideas is encouraged. Write down all the ideas.

Teacher's Notes:
Scaffolding Students' Development of a Procedure to Measure Sound

The following hints can be used to scaffold students' development of a procedure like the one in **Handout 9: Measuring the Speed of Sound:**

- Measuring the speed of any sound, not just thunder, would help them answer this question.
- They can take their measurement outdoors.
- There are ways to measure the speed of sound that require no high-tech equipment, just a stopwatch and a tape measure.
- Ask students what they know about echoes and whether they can think of a way to use echoes to measure the speed of sound.

Note: If you have LabPro, ULI (Universal Lab Interface), or other microcomputer-based lab equipment available, you may wish to have students use a procedure to measure the speed of sound that takes advantage of these resources. See *Additional Resources for Teachers.*

5. Have students carry out the procedure and collect data.
Distribute **Handout 9: Measuring the Speed of Sound**.

Note: If students come up with workable ideas that you have the necessary equipment for, you can have them carry out these procedures; if not, they can use the procedure outlined in Handout 9.

Regardless of the procedure being used, students will need copies of Handout 9 so they can answer the questions in the Analysis section.

If students will use the procedure in Handout 9 or something similar to it, take the class outside so students can collect their data. (The procedure cannot be carried out indoors, because the sound will reflect off too many surfaces.)

If you have a large enough area of wall space, each team of students can carry out the procedure described in Handout 9—producing the sounds, measuring the times, and measuring the distances. If you have only a small area in which to work, you may want to produce the sounds yourself, but have each team collect its own data about time and distance.

6. Have students analyze their data and share results.
Return to the classroom. Have student teams calculate the speed of sound based on their measurements and answer the questions in the Analysis section of the handout. Have each team post its result for the speed of sound on the board or chart paper.

> **Note:** For purposes of comparison, the actual speed of sound in dry air at 20°C (68°F) is 343 meters per second (1,125 ft/s).

Ask students to share their proposed rule for calculating the distance to a lightning strike.

> **Note:** Handout 9 provides a useful opportunity for formative assessment.

7. Show the slide presentation "How Sound Travels Through Different Media."

- Show Slide 1: A tin can telephone.
  Ask students to think about this question:
  - Why do tin can telephones work?

- Show Slide 2: Ball and spring model.
  Explain that the speed of sound depends on two properties of the medium it travels through. These two properties can be illustrated using a ball and spring model.
  - The mass of the balls represents the density of the medium.
  - The stiffness of the springs represents the elasticity of the medium.

  > **Note:** Explain to students that the elasticity has a different meaning in physics than they might expect given how the word is commonly used. A material is said to have a high elastic modulus if it is stiff and returns quickly to its original shape after being stretched or squeezed.

  Ask students to imagine pushing the first ball in the model and to think about how long it takes that motion to reach the other end.
  - What effect does the mass of the balls have on the speed of the motion?

    Answer: *The larger the mass, the slower the pulse.*

- What effect does the stiffness of the springs have on the speed of the motion?

  Answer: *The stiffer the spring, the faster the pulse.*

- Based on the effects of mass and stiffness, what effect would you predict density and elasticity have on the speed of sound?

  Answer: *Increased density results in a slower speed of sound. Increased elasticity results in a faster speed of sound.*

- Show Slide 3: Speed of sound chart
Explain that the factors of density and elasticity often work against each other. For example, water is denser than air, which would decrease the speed of sound, but it is much more elastic, which increases it. The overall result is that the speed of sound is faster in water than in air.

- Show Slide 4: A tin can telephone.
Ask students:

  - Why do tin can telephones work?

    Answer: *The telephone string is denser than air, but much, much more elastic than air. So the speed of sound through the tin can telephone is faster than the speed of sound in air.*

  - Why does the tin can telephone work better when the string is stretched tighter?

    Answer: *A taut string is more elastic (stiffer) than a loose string.*

Handout 9:
Measuring the Speed of Sound

In this activity, you will measure how fast sound travels in air.

Note: This procedure cannot be carried out indoors because the sound will reflect off too many surfaces.

Materials

- Two wooden blocks
- Tape measure
- Stopwatch

Procedure

1. Give one team member the wooden blocks (the "Clapper"), one the tape measure (the "Measurer"), and one the stopwatch (the "Timer"). Have the Clapper stand about 10 meters away from a large vertical wall.
2. Have the Clapper clap the blocks together quickly and loudly. If you don't hear an echo, have the Clapper take a large step away from the wall and clap the blocks again. The Clapper should continue to step away from the wall and clap the blocks until you all hear an echo that is easily distinguished from the original sound.
3. Have the Timer stand next to the Clapper, at the same distance from the wall. Have the Clapper clap the blocks again. The Timer should then measure the time from the original sound until the echo.
4. Have the Measurer measure the distance from the blocks to the wall.
5. Repeat steps 3 and 4 a few times. You can have the Clapper stand in the same spot or you can take a measurement from farther away if the echo can be clearly heard.
6. As a team, calculate the speed of sound using the following formula:

$$\textit{speed} = \frac{\textit{distance}}{\textit{time}}$$

Data

Trial	Time	Distance from Wall	Total Distance Traveled by Sound	Speed of Sound
1				
2				
3				
Average				

Analysis

Based on the value you calculated for the speed of sound, is the following a good rule?

> *If you can count to 5 from the time you see the lightning to the time you hear the thunder, the lightning strike was a mile away. [One mile equals 1,609.3 meters.]*

If so, why? If not, what rule would you suggest and why?

Activity 2C: Making Waves

Students use Slinkys to explore the properties of mechanical waves. They create both longitudinal and transverse waves and observe various wave properties and behaviors, including wavelength, frequency, reflection, and interference. They record their observations, using drawings and verbal descriptions. Students also learn how to use the equation that quantifies the relationship between frequency, wavelength, and wave speed.

RESOURCES

Understandings

- A *wave* is a disturbance that carries energy, but not matter, from one place to another.
- In a *transverse wave*, the matter in the medium oscillates at right angles to the direction that the wave travels.
- In a *longitudinal wave*, the matter in the medium oscillates in the same direction that the wave travels.
- A *standing wave* arrives from intereference between a wave and a reflected wave.

Materials

- **Handout 10: Waves on a Slinky**
- Materials for the investigations (for each team of 3 to 4 students):
  - Original Slinky or other metal coil expansion spring
  - Optional: Monofilament (such as fishing line)
  - Other Slinky, such as Slinky Jr. or plastic Slinky
  - Masking tape
- Students' copies of Handout 4
- Students' notes and illustrations from Handout 7
- **Handout 11: Wavelength, Frequency, and Speed**
- Computer with projector and Web access
- Animations of superposition and standing waves (see *Media & Resources*)

Note: Ideally, Activity 2C will be conducted during an extended lab period, but it can be split across two separate class periods if needed. If your extended lab period is long enough, you may want to have students investigate waves in another medium, such as rope or elastic strings. (See *Additional Resources for Teachers* for some options.) If so, you can minimize the amount of supplies needed by setting up enough stations for each activity for half the student teams; halfway through the lab period, have teams at the Slinky stations move to the other activity stations and vice versa.

1. Introduce the activity.
Ask students:

- How can we learn more about sound waves when we can't see them?

Explain that one way to do this is to study similar phenomena that *can* be seen. In this activity, students will investigate waves using a Slinky. Explain that these investigations will help them do several things:

- Observe, in a different context, some of the same behaviors as the water waves.
- See some additional wave properties that are hard to see in the water waves.
- Compare waves on the Slinky to the vibrations of the speaker cone from the "dissection."

The Slinky waves have much in common with sound waves. After completing the investigation, students will compare these waves with the waves shown in Handout 4.

2. Demonstrate how to generate waves.
Show students how to generate two different kinds of waves on the Slinky. Have a student hold one end of the Slinky while you hold the other.

- To create a transverse wave, give one end of the Slinky a quick jerk to the left or right, and then return the end to its starting point.
- To create a longitudinal wave, hold the end of the Slinky with one hand, grab several coils with your other hand, pull them toward you, and then release them.

3. Have students perform the investigations.
Distribute **Handout 10: Waves on a Slinky**. Have students work in teams of three to four students to complete the investigations.

4. Discuss observations and introduce scientific terms.
Draw an unlabeled sine wave on the board. Go through each question on Handout 10. As students share their observations, review the scientific terms they learned in Activity 2A and introduce new terms as necessary. When discussing the net movement of a single coil of the Slinky, explain that this demonstrates that waves do not transmit matter, only energy.

Terms to review:

- amplitude, crest, and trough
- frequency and wavelength
- reflection and interference

Terms to introduce:

- traveling waves
- standing waves
- anti-nodes
- nodes

When discussing standing waves, explain how they result from superposition of a wave and a reflected wave. Use one of the animations listed in *Media & Resources* to illustrate superposition and standing waves in more detail.

5. Connect the behavior of the observed waves to the speaker dissection.
Ask students to apply what they learned in the speaker dissection to the waves they created today and in Activity 2A. In what ways are the waves they created—the longitudinal waves on the Slinky, the transverse waves on the Slinky, and the water waves—similar to sound waves? In what ways are they different? You may want to have students look at Handouts 4 and 7, and then pose the following questions for them to consider:

- In which waves did they see regions of compression and rarefaction?

  Answer: *The longitudinal waves on the Slinky.*

- In which waves was the force students applied most similar to the in-and-out motion of the speaker cone?

  Answer: *The longitudinal waves on the Slinky.*

- In which waves did the wavefronts spread out in all directions from the source?

  Answer: *The water waves.*

6. Introduce the wave equation.
Distribute **Handout 11: Wavelength, Frequency, and Speed**. If time permits, you can take your students through the chain of reasoning described in the handout. Otherwise, have students read the handout on their own during class time or for homework.

7. Prepare for Activity 3A.
In the next activity, students will use sound editing software to listen to and look at recorded sound waves.

- If you will have microphones available during the next activity, tell students that if they play a musical instrument, they can bring it the next time the class meets.
- If the computer lab you will use for the next activity does not have enough headphones for all students, ask students to bring headphones or earbuds. Earbuds are especially helpful if each computer has only has one audio output jack, because two students can share a single pair of earbuds (one earbud in one student's ear and the other earbud in another student's ear).

Handout 10:
Waves on a Slinky®

How can you learn more about sound waves when you can't see them? One way is to study similar phenomena that you *can* see. In this investigation, you will create and observe waves in a Slinky® and record your observations in words and sketches.

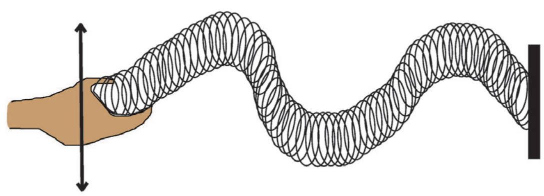
Materials

- Original Slinky
- Optional: Monofilament (such as fishing line)
- Other Slinky, such as Slinky Jr. or plastic Slinky
- Masking tape

Background Information

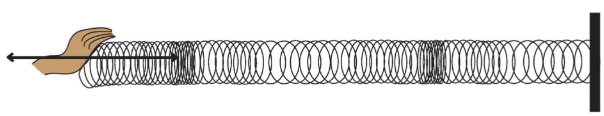
In this investigation, you will create two types of waves in the Slinky®, called *transverse waves* and *longitudinal waves*.

Transverse Waves



To create a transverse wave, give one end of the Slinky a quick jerk to the left or right, and then return the end to its starting point.

Longitudinal Waves



To create a longitudinal wave, hold the end of the Slinky with one hand, grab several coils with your other hand, pull them toward you, and then release them.

To observe some of the wave properties, you may need to change the amount of tension in the Slinky—the more you stretch it, the greater the tension. However, be careful not to stretch the Slinky so far that it will not return to its original shape.

Procedure

For most of the steps in this procedure, you will create both transverse and longitudinal waves. Be sure to draw and describe your observations for both types of waves.

1. Set up the Slinky.

Option A: Lay the Slinky on the floor and stretch it out to a length of several feet. Have two team members hold the Slinky in this position, one at each end. A third team member should stand where he or she has a good view of the whole Slinky.

Option B (for longitudinal waves only): Thread a piece of monofilament through the center of the Slinky, and tie each end of the monofilament to a fixed object so that the middle of the Slinky does not sag. (There is less friction between the Slinky and the monofilament than there is between the Slinky and the floor, which makes it easier to observe some wave properties.) Stretch the Slinky out to a length of several feet. Have two team members hold the Slinky in this position, one at each end. A third team member should stand where he or she has a good view of the whole Slinky.

2. Make pulses.

A. Hold one end of the Slinky fixed and use a single jerk or pull to send a disturbance along the Slinky. This non-repeating disturbance is called a pulse. Draw and describe what you see for both the transverse pulse and the longitudinal pulse.

B. Send another pulse down the Slinky, making sure that the pulse has enough energy to reach the other end. For both the transverse and the longitudinal pulses, describe what happens when the pulse reaches the end of the Slinky.

C. Send two pulses down the Slinky at the same time, one from each end. Draw and describe what happens for both the transverse and longitudinal pulses.

D. What affects the speed at which the pulse travels along the Slinky? Here are some factors to test:
   - The size of the pulse
   - The surface on which the Slinky rests (bare floor, carpet, monofilament)
   - The size or material of the Slinky (Compare an original Slinky to a Slinky Jr. or plastic Slinky)
   - The tension in the Slinky (determined by how much the Slinky is stretched)

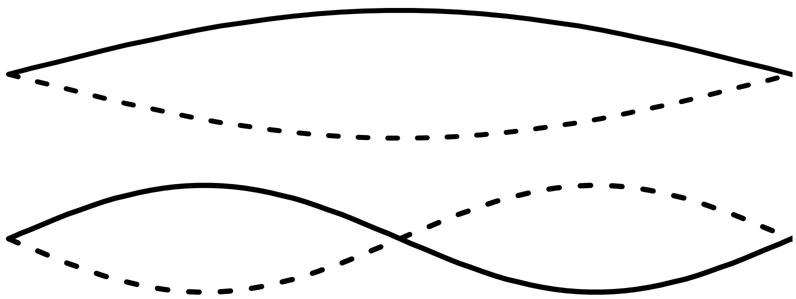
E. How much and in what direction does a single coil of the Slinky move as the pulse travels? (To make this easier to see, mark one coil and the table or floor directly beneath that coil with small pieces of masking tape.)
   - How does the movement vary based on the size of the jerk or pull you use to get the pulse started?

3. Make periodic waves.

Using repeated motions to send pulses along the Slinky at regular intervals produces a *periodic wave*.

A. Generate a periodic wave by jerking or pulling the Slinky at a frequency of once per second. Draw and describe what you see for both transverse and longitudinal waves.

B. Try to produce the following patterns in the Slinky:



Notice that in the first pattern, the Slinky is almost motionless at two points; in the second pattern, the Slinky is almost motionless at three points. Can you create a pattern in which the Slinky is motionless at four points? Draw this pattern.

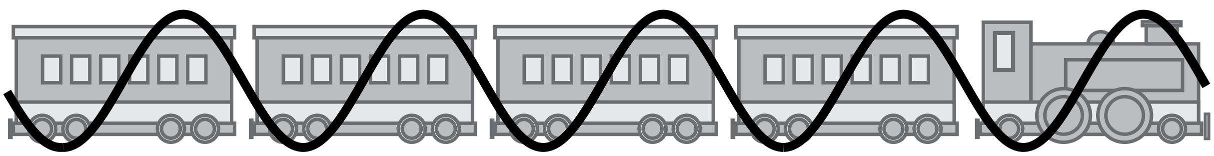
Handout 11:
Wavelength, Frequency, and Speed

Wavelength and frequency are related to each other and to wave speed according to this equation:

$$v = f\lambda$$

where v is the speed of the wave, f is the frequency, and λ (lambda) is the wavelength.

To see where this equation comes from, think of a wave as a train with many cars.



Imagine that you are watching this train go by and you want to know its speed. One way to find out is to measure the distance between two points on the track and then time how long it takes for any one part of the train to get from the first point to the second point. You can then calculate the speed using this equation:

$$\textit{speed} = \frac{\textit{distance}}{\textit{time}}$$

That's the same equation you used in Activity 2B to calculate the speed of sound.

But there's also another way to calculate the speed of that train. If you know the length of the train cars, you can count how many cars pass by in a given unit of time. The train speed can then be calculated like this:

speed = number of train cars passing by per second × length of a train car

The speed of a wave can be calculated in the same way:

speed = number of waves passing by per second × length of a wave

Since the number of waves passing by per second is the frequency, f, and the length of a wave is the wavelength, λ, this gives us the wave equation:

$$v = f\lambda$$

In general, the frequency of a wave is set by the vibrating object, such as the speaker cone that sets a sound wave in motion or the hand that shakes the Slinky. The speed of the wave is determined by the medium, such as air or water, that the wave is traveling through. This means that the wavelength depends on both frequency and speed.

Part 3: Acoustics in Action

Students use sound editing software and their knowledge of sound waves to create a sound effect. They apply what they have learned in this unit by writing an article for a classwide *Acoustipedia*.

Length

3 50-minute sessions

Note: Students may need additional time outside of the two-week unit to complete the written portions of the assessments as homework or in class.

Advance Preparation

- For Activity 3A:
  - Reserve a computer lab and install sound editing software on the computers. (See *Media & Resources* for a link to the recommended software.)

  Note: *Media & Resources* includes links to instructions on how to perform common sound editing tasks using Audacity, a free, downloadable sound editing program. If your school has already installed a different sound editing program in its computer lab, you should test that program in advance to find out how to do the tasks in Activity 3A. You may want to ask the computer or audio teacher for a quick demonstration.

  - Download the file of sound samples to each computer that students will use, and unzip the file.
  - Download the slide presentation "Graphing Sound" (See *Media & Resources* for a link.)
  - If microphones are available in the computer lab, invite students to bring musical instruments to class.
  - If the computer lab does not have enough headphones for all your students, ask your students to bring headphones or earbuds to class.
- For Activity 3B, download **Handout 16: *Acoustipedia* Topics** (see *Media & Resources*). The handout includes recommended Web sites for students to use in their research and is available online so that the Web sites are current. You can either make a copy of Handout 16 for each student or cut a single copy of the handout into strips, with one topic per strip.

RESOURCES

Activity 3A: Sound Editing Software

Students use sound editing software to "see" invisible sound waves by representing these waves as graphs of sound pressure level.

RESOURCES

Sequence

3A.1: Seeing Sound Waves	Students use sound editing software to explore the relationship between a wave's properties and how the wave sounds.
3A.2: A Sound of Your Own	Students create a sound effect for a media and digital design project by using a sound editing program to manipulate waveforms. They write a concise explanation, in scientific terms, of how they manipulated wave properties to produce this effect.

Understandings

- Sound waves can be represented as graphs of sound pressure levels over time.
- Humans perceive a change in the frequency of a sound wave as a change in pitch.
- Humans perceive a change in the amplitude of a sound wave as a change in volume.
- Sound effects can be created by editing the graph of a sound wave.

Materials Needed

- Computer with projector, Internet access, and speakers
- Slide presentation, "Graphing Sound" (see *Advance Preparation*)
- **Handout 12: Seeing Sound Waves**
- Computer with sound editing software (1 per pair of students)
- Sample sound files (see *Media & Resources*)
- Optional: Tuning fork (1 per pair of students, if possible)
- Optional: Musical instruments brought to class by students
- Optional: Microphone (1 per pair of students, if possible)
- Earbuds or headphones (1 per student or pair of students)
- **Handout 13: A Sound of Your Own**
- **Assessment Checklist 1: A Sound of Your Own**

3A.1: Seeing Sound Waves

1. Describe the activity.
Tell students that they will listen to various sound samples, both pre-recorded samples provided with this curriculum unit and sounds that they produce and record themselves. Explain that the sound editing software enables students to "see" invisible sound waves by representing these waves as graphs of sound pressure vs. time. The purpose of this activity is to show how scientific properties of waves, such as frequency and amplitude, relate to the characteristics of sound that we hear, such as pitch and volume. The activity will also reinforce what students have learned about wave interference.

2. Explain how sound editing software represents sound waves as transverse waves.
Display the first slide from "Graphing Sound." Explain that drawing sound waves by using dots or shading to represent compression and rarefaction of molecules is imprecise and impractical. Show the second slide, and explain that a more convenient method is to represent sound waves as a graph of sound pressure level, which is what sound editing programs do.

Advance to the next slide. Click on the link to launch the Web page, and scroll down to the animation. Tell students that the sound pressure level (SPL) is the change in the local air pressure due to the transmission of a sound wave. Regions of the wave where the molecules are close together, which are high pressure, are peaks on an SPL graph. Rarefactions, which are regions of low pressure, are troughs on the graph.

Point out that when sound waves are represented this way, the graph looks like a transverse wave, but sound is still a longitudinal wave.

3. Demonstrate how to use the sound editing software.
Spend a few minutes showing students how to perform the following tasks:

- Open a sound project and play it.
- Copy a track or part of a track.
- Change the scale of the horizontal axis so that the individual crests and troughs of the sound wave are visible.
- Change the scale of the vertical axis to make the wave amplitudes easier to see.
- Compare two waves side by side.
- Record sounds.
- View the plot of the frequency spectrum.

> **Note:** As students view the plot, point out the peaks representing the harmonics.

- Modify a wave envelope.

4. Distribute Handout 12: Seeing Sound Waves and have students complete the activities.

Have students work in pairs to complete the activities listed in the handout. If there is not a microphone available at each computer, have some pairs start with the activities that require a microphone while the remaining pairs start with the other activities.

5. Discuss students' results and observations.

Ask a few students to share their observations for each task listed in Handout 12. Building on their observations, bring out the following points:

- All the sounds we hear can be represented as waves or as combinations of waves.
- Musical sounds are composed of *periodic waves*, which are waves with a repeating pattern of crests and troughs. The less musical a sound is, the less regularity will be seen in the graphs of the sound pressure level.
- A single musical note consists of sound waves of many different frequencies:
    - The lowest of these frequencies is called the *fundamental frequency*.
    - Other frequencies that are multiples of the fundamental frequency are called *harmonics*.
    - Other frequencies that are not multiples of the fundamental frequency are called *partials*.
- At a given frequency, the ear perceives an increase in amplitude as an increase in volume.
- Musical notes of the same pitch sound different when played on different musical instruments or sung by different people.
    - These differences can be seen by looking at graphs of sound waves and at plots of the frequency spectrum.
    - Musical notes of the same pitch from different instruments will have the same fundamental frequency, but different partials and harmonics.

Handout 12:
Seeing Sound Waves

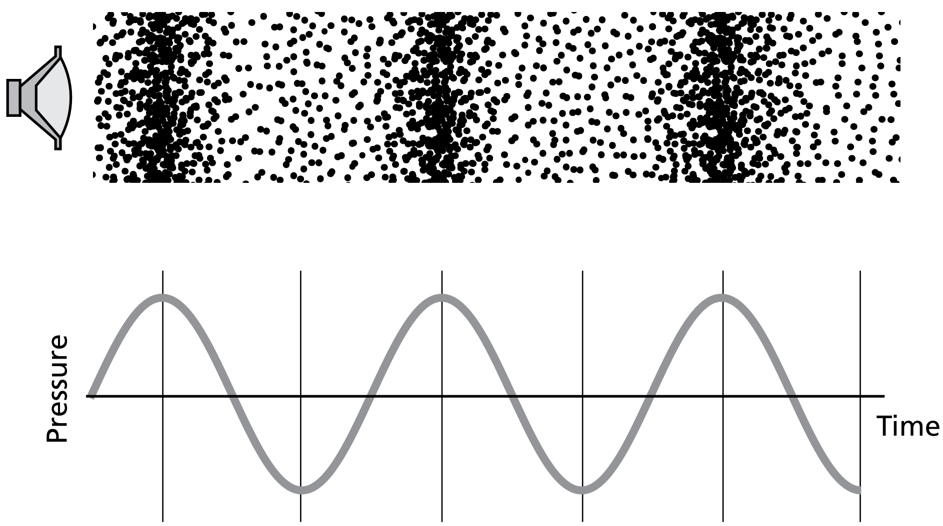
How do scientific properties of waves, such as frequency and amplitude, relate to the properties of sound that you can hear, such as pitch, volume, and the difference between two instruments or voices? In this activity, you will answer this question by using sound editing software to "look" at the sound waves that make up speech, music, and sound effects.

Background

Sound editing programs show sound waves as a graph of sound pressure level (SPL).

The SPL is the change in the local air pressure due to the transmission of a sound wave. Regions of the wave where the molecules are close together, which are high pressure, are peaks on an SPL graph. Rarefactions, which are regions of low pressure, are troughs on an SPL graph.

Notice that when sound waves are represented this way, the graph looks like a transverse wave.



Materials

- Computer with sound editing software and sample sound files
- Optional: Microphone (can be shared among several teams of students)
- Tuning fork(s) (can be shared among several teams of students)
- Optional: Musical instrument(s)

Procedure

After completing step 1, you can do the other steps in any order. (It may be necessary for teams to work on different steps at the same time, if there aren't enough tuning forks and microphones available for each team to have its own.)

1. The basics

Open one of the sample sound files and familiarize yourself with the sound editing software by trying the following:

- Play the sound.
- Modify your view of the sound:
  - Zoom in closer to see more detail.
  - Stretch or shrink the vertical axis.
  - Use the scroll bars at the bottom and side to look at different parts of the file.

After making each change to your view of the sound, play the sound again to confirm that you are not changing the sound itself, just the way it looks on the screen.

- Connect a microphone to the computer. Record a musical tone and play it back. You can use a musical instrument, a tuning fork, or your voice to produce the note.
- Create a track using the sound editing program's built-in tone generator.
- Turn different tracks on and off.
- View the plot of the frequency spectrum.

2. Comparing different instruments

- Open one of the sample sound files from a musical instrument (e.g., Oboe_Middle_C.wav or Violin_Middle_A.wave).
- If you have a microphone and a musical instrument available, record the instrument playing the same pitch as the sample sound file. Otherwise, open another sample sound file of a different instrument playing the same note.
- Use the tone generator to create another sample at the same pitch.
- Zoom in on the graphs until you can see the wave crests and troughs. What similarities do you see among the graphs? What's different?
- Plot the frequency spectrum for each sound. What similarities and differences do you observe?
- For each sound, at what frequency do you see the highest peak? What other peaks do you see? Record your observations in the table below. If time permits, look at recordings of other instruments as well.

Pitch (look at the same pitch for each instrument)	**Musical instrument (e.g., oboe, violin)**	**Frequency of highest peak**	**Other peaks**

3. Comparing different pitches

If you have a musical instrument available, record it playing two different notes. Otherwise, open two sound files of the same instrument playing different notes (e.g., Oboe_Middle_C.wav and Oboe_High_A.wav).

Musical instrument (Observe the same instrument at different pitches)	Pitch (e.g., middle A, high C)	Fundamental frequency (lowest frequency at which there is a peak)	Frequency of tallest peak	Other peaks

4. Changing amplitude

Use the sound editing program's envelope tool to alter the amplitude of a sound sample. Try altering the amplitude of the whole track, then try altering the amplitude for parts of the track but not others. Play the sound each time you make a change to the envelope. Describe the changes you made to the envelope and the resulting changes in the sound:

Change made	Differences heard

5. Sound effects

Open some of the sample sound effects. If a microphone is available, you can also record some sound effects of your own. Look at the graphs of the sound pressure levels for these sound effects. How do they differ from the graphs of the musical notes?

6. Speech

Record yourself and your partner saying the same word or sound. (If a microphone is not available, use the speech samples provided with the sample sound files.) Describe the similarities and differences between the graphs of the resulting sound waves.

How do you think people are able to recognize a person's voice without seeing who's speaking?

3A.2: A Sound of Your Own

1. Describe the assignment.
Tell students that all kinds of sounds—not just words—can be part of telling a story. Explain that sound editing programs can enhance storytelling by making it possible to create sounds that would otherwise not exist. Distribute **Handout 13: A Sound of Your Own** and **Asseessment Checklist 1: A Sound of Your Own**. Tell students that for this assignment they will use sound editing software to create something for a media or digital design project. Their final product will consist of two parts: a sound file and a short written explanation of how they created that sound.

2. Show students additional features of the sound editing program.
Briefly demonstrate how to do the following:

- Add multiple tracks to a single file.
- Remove sound data that fall outside a chosen amplitude or frequency range.
- Apply special effects built into the program.
- Save their work and export it to the format in which you want them to submit their final product.

3. Have students create their sounds and written explanations.
Give students class time to complete their sound files.

You can either have students use class time to write their explanations or assign this as homework. Ask them to complete the Student Comments on Assessment Checklist 1 and submit the checklist with their sound files.

Handout 13:
A Sound of Your Own

Sound editing software is a powerful tool that makes it possible for you to create sounds that don't occur in the real world.

Think about a media project you are familiar with—your favorite movie or video game, an audio story or animation created for another class, or something else, whether real or imagined. Could the fantasy world of the game seem more authentic with the addition of some otherworldly sound effects? Would your animated character sound more believable if his voice didn't sound just like yours (because it *is* yours!)?

1. Use the sound editing software to create a sound effect—something unique that you couldn't have created purely by recording sound.
   - Your starting point could be material you have already recorded, sounds you record now, public domain sound files you find on the Web, or tones generated entirely from within the sound editing software.
   - Manipulate the sound any way you choose—modify the wave envelope, invert or reverse the waves, add harmonics, change frequencies, or do something else the program makes it possible for you to do. You can also use the software to clear up problems in a recorded sound, such as background noise or popping and clicking sounds.

2. Write a short explanation (75–125 words) of the entire process you used to create the sound. Describe the sounds you started with, how you transformed them, what effect you were hoping to achieve, and the context in which the sound would be used.

   In your description, make sure to incorporate the relevant wave vocabulary you've learned in this unit, for example:

   - amplitude
   - frequency
   - frequency spectrum
   - harmonics
   - interference
   - wavelength
   - wave envelope

Assessment Checklist 1:
A Sound of Your Own

Requirements	Percentage of Total Grade	Comments	
Sound		**Student Comments**	**Teacher Comments**
File is in the correct format and is playable.	**25%**		
Sound produced takes advantage of the sound editing software's capability.	**30%**		
Written Explanation			
Explains the editing process using appropriate scientific vocabulary.	**30%**		
Describes the context in which the sound will be used and the effect the student was trying to achieve.	**15%**		
Total	**100%**		

Activity 3B: The Science of Sound

Students write short articles, with labeled illustrations, on topics related to sound waves. These are combined into a mini-encyclopedia, the *Acoustipedia*, which all students in the class can refer to when they are working on media and digital design projects.

RESOURCES

Teacher's Notes: Assembling the *Acoustipedia*

There are a number of ways that you might ask students to submit their articles. If you choose to have students turn in print copies of their articles and you don't plan to retype them, you may want to give them some formatting guidelines so that all the articles will be in the same font and the pages will have consistent margins. However, putting the mini-encyclopedia together will be easier if students can submit their work electronically, for example, by e-mailing the articles to you or placing them on a file server. Alternatively, you could have students create a wiki, an easily edited collaborative Web site. (See *Media & Resources* for information on setting up a wiki.)

Understandings

- Understanding the science of sound can help you create better audio soundtracks for media and digital design projects.

Materials Needed

- **Handout 14: Explaining Sound with Science**
- **Assessment Checklist 2: *Acoustipedia* Article**
- **Handout 15: Drawing Sound**
- **Handout 16: *Acoustipedia* Topics** (see *Advance Preparation*)
- Computers with Internet access (1 per student)

1. Describe the *Acoustipedia* article assignment.

Distribute **Handout 14: Explaining Sound with Science**, **Assessment Checklist 2: *Acoustipedia* Article**, and **Handout 15: Drawing Sound**. Tell students that they will write articles on topics in acoustics, to combine into an *Acoustipedia* that they can refer to when working on media and digital design projects. Tell them what format the article needs to be submitted in and answer any questions they have about the assignment.

> **Note:** The length limit, which is appropriate for this assignment, challenges students to clarify and focus their ideas, rather than simply throw in everything that might be related.

2. Assign topics.

Assign each student one of the topics from **Handout 16: *Acoustipedia* Topics**. Be sure to assign topics in the order they are listed, i.e., in order of importance rather than alphabetical; this way, if there are more topics than students, the most important topics will be covered.

3. Have students research and write drafts of their articles.

During this session, students should conduct research and take notes. They can write their first drafts for homework or during the next session.

4. Have students share their drafts with a partner.

Have students meet in pairs to read the draft of their partner's article and provide feedback, using the following sentence prompts:

- Based on what I read in your draft, I would explain your topic in my own words by saying . . .
- One aspect of the topic that is not completely clear to me is . . .
- The illustration helped me understand (or did not help me understand) the topic because it . . .

Remind students that these prompts are also included in Handout 14.

5. Have students complete their articles.

Depending on the amount of time you have available and your students' access to computers, give students class time to complete their articles or assign them to do so for homework. Students should then complete the Student Comments portion of Assessment Checklist 2 and submit the checklist with their articles.

If time permits (an additional session would likely be required), you may want to do either or both of the following:

- Have the students share with their classmates some reflections on the process of writing the article and receiving feedback from a peer.
- Have students present their articles and answer questions.

Handout 14:
Explaining Sound with Science

So that what you've learned so far will be available for you to draw on during media and digital design projects, the class is going to create an *Acoustipedia* explaining the science behind a number of important audio terms and concepts. Each student will write one article for the *Acoustipedia*.

1. Read the requirements for the project.
Carefully read the requirements listed on the next page of this handout. Look at **Assessment Checklist 2: *Acoustipedia* Article** to see how your work will be assessed.

2. Do your research.
Your teacher will direct you to one or more online resources to help you get started. You can also use books and other Web sites—and you might see if your physics textbook has anything to say about your topic. As you take notes for your article, be sure to keep track of the source of each piece of information.

3. Write a draft.
Decide what information from your notes to include in the article and in what order to present it. Write a detailed outline that includes all the information you plan to include. Then write a first draft.

4. Sketch your illustration(s).
Look at the examples on **Handout 15: Drawing Sound**. Choose the method or methods that work best for your topic and sketch and label a rough draft of your illustration(s).

5. Pair and share.
Pair up with another student to read each other's drafts and look at each other's illustrations. Give your partner feedback, using the following sentence starters:

- Based on what I read in your draft, I would explain your topic in my own words by saying . . .
- One aspect of the topic that is not completely clear to me is . . .
- The illustration helped me understand (or did not help me understand) the topic because it . . .

6. Finish your article.
Revise your article and illustration(s) based on the feedback you received and submit it in the format required by your teacher.

Requirements for Your *Acoustipedia* Article

- *Explain your topic in terms of what you learned in this unit.* Use at least one of the following words correctly and in a way that will help your readers understand the topic of your article: amplitude, diffraction, frequency, interference, reflection, standing wave, or wavelength.
- *Include at least one labeled illustration of sound waves that helps explain your topic.* Consult **Handout 15: Drawing Sound** for some examples of different ways that sound waves can be visually represented.
- *Make sure that your article doesn't go over or under the word limit.* Your article must be between 150 and 200 words, excluding text that is part of your illustration.
- *Explain everything in your own words.* Refer to online or print resources to help you understand your topic, but do not put direct quotes from these sources in your article.
- *Consult at least three sources.* Be sure to list all of your sources at the end of your article.

Assessment Checklist 2: *Acoustipedia* Article

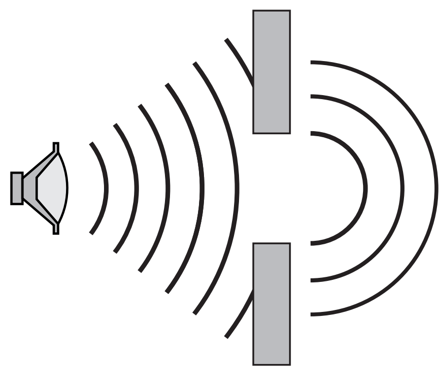
Requirements	Percentage of Total Grade	Comments	
		Student Comments	Teacher Comments
Text of article accurately explains the assigned topic in the student's own words.	**25%**		
Article explains the topic in terms of material studied in this unit and uses at least one of the following terms correctly and appropriately: *amplitude*, *diffraction*, *frequency*, *interference*, *reflection*, *standing wave*, *wavelength*.	**20%**		
Article is between 150 and 200 words.	**10%**		
An appropriate, labeled illustration supports the text.	**30%**		
At least three sources were consulted and are cited.	**15%**		
Total	**100%**		

Handout 15:
Drawing Sound

For your *Acoustipedia* article, you will need to draw diagrams that show properties of sound waves. Waves can be represented in many different ways, and different methods work better than others for illustrating different properties and behaviors. As you plan what you will write and draw for your article, think about which method shown below will best communicate your ideas.

Wave Fronts

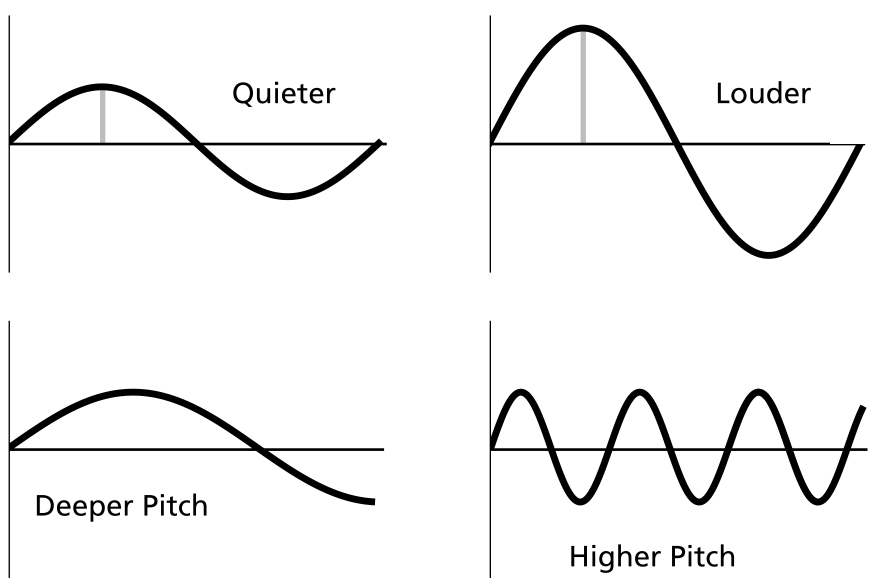
Some wave properties and behaviors, such as diffraction, are best illustrated with a drawing of the wave fronts. Wave fronts are lines, curved or straight, that show the positions of the crests of the wave.



Diffraction

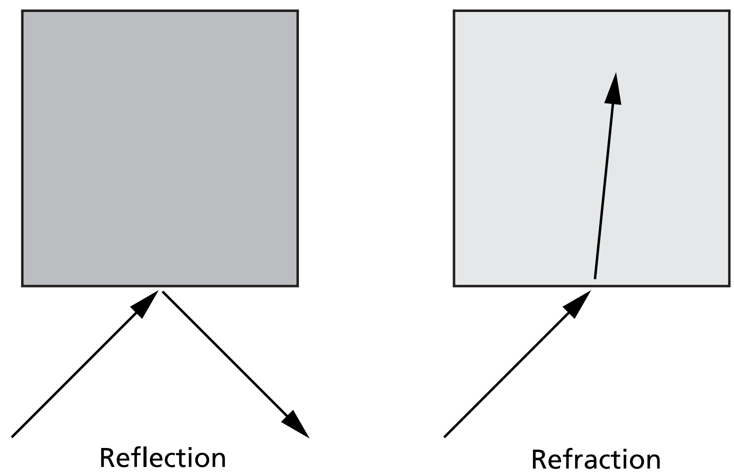
Sound Pressure Graphs

When comparing amplitudes and frequencies, a graph of sound pressure over time is a good method to use. You worked with this type of graph in the sound editing program.



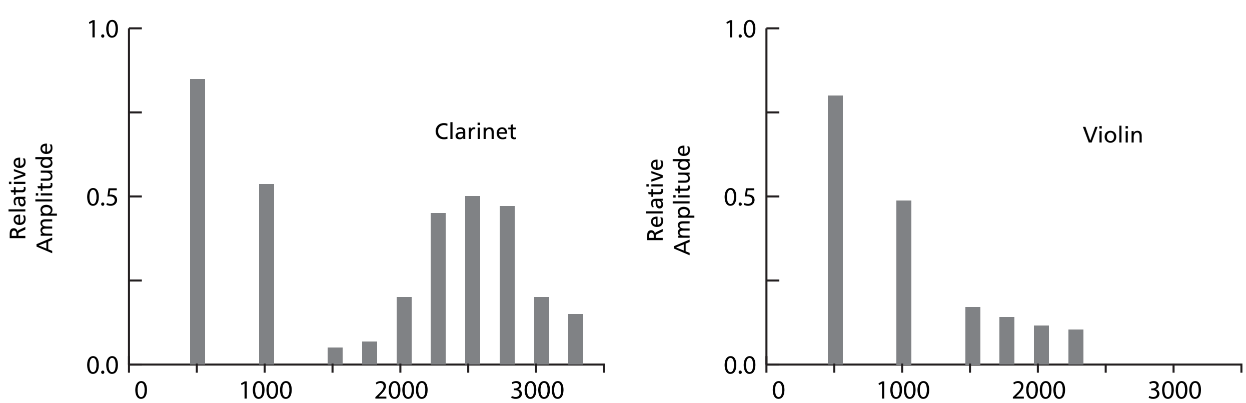
Rays

Representing waves as rays—line segments with arrows to show the direction of travel—is the clearest way to show some wave behaviors, such as reflection.



Frequency Spectra

When comparing the timbres of two musical instruments, a graph showing the amplitude of each frequency clearly illustrates the harmonics and overtones.



Appendix A: Sources for Speakers

Computer speakers, home theater system speakers, and stereo speakers are suitable for dissection in Activity 1B. Boomboxes and electronic toys may also contain speakers that can be removed and dissected.

Speakers, and devices containing speakers, are often thrown away. If you begin collecting speakers a few months in advance, you should have no problem acquiring enough for the whole class. Some good sources:

- **Craigslist** (www.craigslist.com)**:** Click on the link for your city or state. In the "for sale" section, click on "free." Search for "speaker" or scroll through the list of ads to look for items that may include speakers even though speakers are not specifically mentioned in the ad.
- **Freecycle** (www.freecycle.org)**:** Search for a Freecycle mailing list in your area. Join the mailing list and post a "Wanted" ad. Read "Offer" posts to look for speakers and speaker-containing devices that are being given away.
- **School or district IT department:** Ask the IT department to contact you if they are throwing away any speakers.
- **Your students:** Ask them to bring in any speaker-containing devices their households are planning to throw away.

Materials Needed

Throughout the Unit

- Computer with projector and Internet access
- Chart paper and markers, or board and writing implements, for recording student responses and displaying information

Part 1: What Is Sound?

Supplies and Equipment

- Tuning fork
- Bowl of water
- Optional: Materials for any demonstration(s) you will perform
- Speakers to connect to the computer with projector and Internet access
- Optional: Functioning speaker
- Materials for dissecting speakers:
    - Safety goggles (1 pair per student)
    - Small screwdrivers in a variety of sizes (several per team)
    - Scissors (1 pair per team)
    - Craft knife or utility knife (1 per team)
    - Wire cutters/strippers (1 per team)
    - Alligator clip cables (2 per team)
    - 9-volt battery (1 per team)
    - Voltmeter, ammeter, or multimeter (1 per team)

Handouts

- **Handout 1: Sounds All Around**
- **Handout 2: Unit Overview**
- **Handout 3: Anatomy of a Speaker**
- **Handout 4: From There to Ear**
- **Handout 5: Playing the Eardrum**

Media Resources

- *Sounds All Around* video clips (see *Advance Preparation*)
- Optional: *Sound as Touch* audio clip, 4:39–6:53

Advance Preparation

- For Activity 1A:
  - Preview the *Sounds All Around* video clips. (See *Media & Resources* for links to the clips.)
  - Test the tuning fork demonstration. Strike the tuning fork and insert the prongs into the bowl of water. If water splashes are not easily visible, try striking the tuning fork more forcefully. If the splashes are still not visible, try a different tuning fork. Larger and higher-quality tuning forks generally produce more splashing.
  - Decide whether to replace any of the demonstrations in the video (such as the bell in a vacuum jar) with a live demonstration or whether to perform other sound demonstrations. Gather any needed materials.
- Preview the audio clip *Sound as Touch* from 4:39 until 6:53 (see *Media & Resources* for a link to this clip). The clip describes how the vibrations that carry sound set off a series of electrochemical reactions that stimulate neural pathways linked to emotion and memory. Decide whether you want to play the clip for your students, and if so, whether to play it at the end of Activity 1A, or during the discussion of how sound is perceived in Activity 1B. Note that if any of your students have taken or are enrolled in *Foundations in Media and Digital Design*, they may have already heard this clip.

Part 2: Exploring Waves

Supplies and Equipment

- Materials for the water waves investigations (for each team of 3 to 4 students):
  - Ripple tank (such as an 8 x 8 clear Pyrex® baking dish)
  - Pencil with eraser
  - Blocks of various sizes, small enough to fit in the ripple tank
- Materials for the procedure on Handout 9:
  - 2 wooden blocks (one set for the whole class as a demonstration or one set per team of 3 to 4 students if teams will work separately)
  - Stopwatch (1 per team)
  - Tape measure (1 per team—see Advance Preparation)
- Materials for the Slinky investigations (for each team of 3 to 4 students):
  - Original Slinky or other metal coil expansion spring
  - Optional: Monofilament (such as fishing line)
  - Other Slinky, such as Slinky Jr. or plastic Slinky
  - Masking tape

Handouts

- **Handout 6: Where Does Sound Go?**
- **Handout 7: Water Waves Exploration**
- **Handout 8: Properties of Waves**
- **Handout 9: Measuring the Speed of Sound**
- **Handout 10: Waves on a Slinky**
- **Handout 11: Wavelength, Frequency, and Speed**

Items Students Need to Bring

- Students' completed copies of Handout 4 from Part 1
- Students' completed copies of Handout 1 from Part 1

Media Resources

- Slide presentation "Where Does Sound Go?" (see *Advance Preparation*)
- Slide presentation "How Sound Travels Through Different Media" (see *Advance Preparation*)
- Animations of superposition and standing waves (see *Media & Resources*)

Advance Preparation

- For Activity 2A, download the slide presentation "Where Does Sound Go?" (See *Media & Resources*.)
- For Activity 2B:
    - Find a large vertical wall on the outside of your school building and test the production of echoes required in order to complete **Handout 9: Measuring the Speed of Sound**.
    - Obtain blocks of wood to use for making a clapping sound.
    - Procure 25–50-foot tape measures, which will make the measurement process easier and faster.
    - Download the slide presentation "How Sound Travels Through Different Media." (See *Media & Resources.*)
- For Activity 2C, preview the animations of superposition and standing waves and choose which one(s) to show your students. (See *Media & Resources*.)

Part 3: Acoustics in Action

Supplies and Equipment

- Computer with projector, Internet access, and speakers (for teacher use)
- Computers with sound editing software (1 per pair of students)
- Optional: Tuning fork (1 per pair of students, if possible)
- Optional: Musical instruments brought to class by students
- Optional: Microphone (1 per pair of students, if possible)
- Earbuds or headphones (1 per student or pair of students)
- Computer with Internet access (1 per student)

Handouts

- **Handout 12: Seeing Sound Waves**
- **Handout 13: A Sound of Your Own**
- **Assessment Checklist 1: A Sound of Your Own**
- **Handout 14: Explaining Sound with Science**
- **Assessment Checklist 2: *Acoustipedia* Article**
- **Handout 15: Drawing Sound**
- **Handout 16: *Acoustipedia* Topics** (see *Advance Preparation*)

Media Resources

- Slide presentation "Graphing Sound" (see *Advance Preparation*)
- Sample sound files (see *Media & Resources*)

Advance Preparation

- For Activity 3A:
    - Reserve a computer lab and install sound editing software on the computers. (See *Media & Resources* for a link to the recommended software.)

    Note: *Media & Resources* includes links to instructions on how to perform common sound editing tasks using Audacity, a free, downloadable sound editing program. If your school has already installed a different sound editing program in its computer lab, you should test that program in advance to find out how to do the tasks in Activity 3A. You may want to ask the computer or audio teacher for a quick demonstration.

    - Download the file of sound samples to each computer that students will use and unzip the file.
    - Download the slide presentation "Graphing Sound" (See *Media & Resources* for a link.)
    - If microphones are available in the computer lab, invite students to bring musical instruments to class.
    - If the computer lab does not have enough headphones for all your students, ask your students to bring headphones or earbuds to class.
- For Activity 3B, download **Handout 16: *Acoustipedia* Topics** (see *Media & Resources*). The handout includes recommended Web sites for students to use in their research and is available online so that the Web sites are current. You can either make a copy of Handout 16 for each student or cut a single copy of the handout into strips, with one topic per strip.

Media & Resources

These recommended Web sites have been checked for availability and for advertising and other inappropriate content. However, because Web site policies and content change frequently, we suggest that you preview the sites shortly before using them.

Media & Resources are also available at http://dma.edc.org and at http://dmamediaandresources.pbworks.com, a Wiki that allows users to add and edit content.

Part 1: What Is Sound?

Activity 1A: Sounds All Around

Video Clips: Sounds All Around

This collection of video clips shows the sound phenomena listed in **Handout 1: Sounds All Around**. For a list of links to the clips, go to the DMA Web site page for *Acoustics: The Science of Sound* and click on *Media & Resources* for Part 1.

Audio Clip: Sound As Touch

You may want to play a portion of this audio clip (from 4:39 until 6:53), which discusses how sound waves set off a series of electrochemical reactions that stimulate neural pathways linked to emotion and memory.

www.wnyc.org/shows/radiolab/episodes/2006/04/21

Part 2: Exploring Waves

Activity 2A: Where Does Sound Go?

Slide Presentation: Where Does Sound Go?

Use this slide presentation to show students different ways to draw sound waves on Handout 6: Where Does Sound Go? For a link to the slide presentation, go to the DMA Web site page for *Acoustics: The Science of Sound* and click on *Media & Resources* for Part 2.

Activity 2B: The Speed of Sound

Slide Presentation: How Sound Travels Through Different Media

This slide presentation discusses sound traveling through liquids and solids. For a link to the slide presentation go to the DMA Web site page for *Acoustics: The Science of Sound* and click on *Media & Resources* for Part 2.

Activity 2C: Making Waves

Animations of Superposition and Standing Waves

Use one or more of these animations to show how superposition of reflected waves can produce standing waves.

www.walter-fendt.de/ph14e/stwaverefl.htm

http://phet.colorado.edu/simulations/sims.php?sim=Wave_on_a_String

http://paws.kettering.edu/~drussell/Demos/superposition/superposition.html

http://zonalandeducation.com/mstm/physics/waves/standingWaves/standingWaveDiagrams1/StandingWaveDiagrams1.html

Part 3: Acoustics in Action

Activity 3A: Sound Editing Software

Slide Presentation: Graphing Sound

This presentation shows the relationship between the movement of molecules in a sound wave and a plot of sound pressure levels. For a link to the slide presentation, go to the DMA Web site page for *Acoustics: The Science of Sound* and click on *Media & Resources* for Part 3.

Audacity Software

You can download this free sound editing software here:

audacity.sourceforge.net

Audacity Instructions

Quick Reference Guide

http://audacity.sourceforge.net/onlinehelp-1.2/contents.htm

Tutorials

http://audacity.sourceforge.net/manual-1.2/tutorials.html

Sample Sound Files

These sound files include samples of a variety of instruments playing different pitches. They should be used in conjunction with **Handout 12: Seeing Sound Waves**. For a link to the sound files, go to the DMA Web site page for *Acoustics: The Science of Sound* and click on *Media & Resources* for Part 3.

Activity 3B: The Science of Sound

HyperPhysics Web Site

The "Sound and Hearing" section of this Web site provides an overview of many of the topics that students will research for their *Acoustipedia* articles. The subsections on auditorium acoustics and sound reproduction are particularly helpful, since they contain information unlikely to be found in a high school physics textbook.

http://hyperphysics.phy-astr.gsu.edu/hbase/HFrame.html

Handout 16:* Acoustipedia *Topics

This handout lists one or more recommended Web sites for each topic. It is available online in order to ensure that the recommended Web sites are current. For a link to the handout, go to the DMA Web site page for *Acoustics: The Science of Sound* and click on *Media & Resources* for Part 3.

How to Set Up a Wiki

If you decide to have your students create the *Acoustipedia* in the form of a wiki, these sites provide free Web-based resources.

Using PBworks in Education
http://pbworks.com/content/edu+overview?utm_campaign=nav-tracking&utm_source=Home%20navigation

Wikidot in Education
http://www.wikidot.com/learnmore:education

Wikispaces for Educators
http://www.wikispaces.com/site/for/teachers

Additional Resources for Teachers

Part 1: What Is Sound?

Activity 1B: Sound—From Production to Perception

How Speakers and Microphones Work

These sites provide additional information about different types of speakers and microphones.

http://electronics.howstuffworks.com/speaker3.htm

www.mediacollege.com/audio/microphones/how-microphones-work.html

http://electronics.howstuffworks.com/gadgets/audio-music/question3091.htm

Part 2: Exploring Waves

Activity 2B: The Speed of Sound

Microcomputer-based Laboratories for Measuring the Speed of Sound

This site includes instructions for LabPro and ULI microcomputer-based laboratories for measuring the speed of sound.

www.science-house.org/teacher/empower/SpdSound.html

Activity 2C: Making Waves

Exploring Waves in Other Media

These sites include instructions or suggestions for demonstration and student investigations of waves in other media.

Simulated waves on a string:
http://phet.colorado.edu/teacher_ideas/view-contribution.php?contribution_id=131

Standing waves in a variety of media:
http://www.practicalphysics.org/go/Collection_21.html;jsessionid=aCmf0TcdL-r4?topic_id=1&collection_id=21

Standards

This unit was developed to meet the following standards.

California Academic Content Standards for Science, Grades 9–12

Physics

4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:

a. Students know waves carry energy from one place to another.
b. Students know how to identify transverse and longitudinal waves in mechanical media, such as springs and ropes, and on the earth (seismic waves).
c. Students know how to solve problems involving wavelength, frequency, and wave speed.
d. Students know sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.
f. Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

Career and Technical Education AME Industry Sector Foundation Standards

1.2 Science

Specific applications of Physics standards (grades nine through twelve):

(4.d) Students know sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.

(4.f) Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

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