

## Sound Absorption Wall

<b>Grade Level:</b> 3	<b>Total Time Required:</b> Approximately 6 30-minute sessions
--------------------------	---

**Prepared By:** Larry Braile, John Lumkes, Kendra Erk, Anne Brickler, and Anna Matthys

### Lesson Objectives:

*In this lesson, students will be able to*

1. Investigate and recognize that sound travels in waves through materials, but is eventually absorbed.
2. Identify materials that are effective sound absorbers.
3. Apply understanding of effectiveness of sound absorbing materials to create a sound absorbing wall using the engineering design process.

### Indiana Standards:

- 3.PS.3** Generate sound energy using a variety of materials and techniques, and recognize that it passes through solids, liquids, and gases (i.e. air).
- 3.PS.4** Investigate and recognize properties of sound that include pitch, loudness (amplitude), and vibration as determined by the physical properties of the object making the sound
- 3-5.E.1** Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.
- 3-5.E.3** Construct and perform fair investigations in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

### Next Generation Science Standards:

- 3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

## Next Generation Science Standards cont.:

### Science/Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence

### Crosscutting Concepts

2. Cause and effect: Mechanism and explanation.

## Common Core Mathematics:

- 3.NBT.2 Fluently add and subtract within 1000 using strategies and algorithms based on place value, properties of operations, and/or the relationship between addition and subtraction.
- 3MD.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units – whole numbers, halves, or quarters

## Common Core English and Language Arts:

- 3.W.8 Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.
- 3.RI.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.  
/3.RL.1
- 3.L.1 Demonstrate command of the conventions of Standard English grammar and usage when writing or speaking.
- 3.L.2 Demonstrate command of the conventions of Standard English capitalization, punctuation, and spelling when writing.
- 3.L.6 Acquire and use accurately grade-appropriate conversational, general academic, and domain-specific words and phrases, including those that signal spatial and temporal relationships (e.g., After dinner that night, we went looking for them).

## Concepts and Vocabulary

<i>Term</i>	<i>Defined by a scientist or engineer</i>	<i>Defined by a student</i>
<b>Words for Students</b>		
acoustics	the science of studying and controlling sound	science of sound
acoustical engineer	an engineer who uses the properties of sound to design environments that allow us to hear the noises we want to hear and block out the noises we do not want to hear	person who designs things about sound
sound	vibrations traveling through air, water, or some other medium, especially those within the range of frequencies that are perceived by the human ear	noise
sound wave	a mechanical wave that is an oscillation of pressure transmitted through a solid, liquid, or gas composed of frequencies within the range of hearing	how sound travels
absorption	the act of something being consumed by, or absorbed into, something else	soak up
reflection	the act of sending something back or redirecting something that strikes a surface.	bouncing back
decibels	a unit of relative loudness	measures how loud or soft sound is
sound volume	a description of how loud a sound is	when a sound gets louder or softer

## Equipment, Materials, and Tools

<b>Materials</b>		
1 shoe box	cotton balls	zip lock plastic bags
manila folders	popsicle sticks	hard plastic (milk jug)
masking tape	newspaper	styrofoam (egg carton)
aluminum foil	construction paper	fabric
cardboard	paper towel	large plastic or paper cup
Plastic wrap	Tissue paper	Paper towels
Styrofoam packing peanuts	Ceramic coffee mug	Styrofoam cup
Paper cup	Glove or hat	Cardboard box
Paperback books		

<b>Tools</b>		
sound generator – 9-volt alarm or small timer	scissors	ruler
sound meter - dB/microphone/laptop sound meter or sound meter smart-phone app		

- The suggested sound generator is a 9-volt single tone alarm and related wiring (see photo and additional information in Figure 6 below) which can be purchased at Radio Shack.
- The suggested smart-phone app is “dB Volume” (app for iPhone), a free app that has a “Hold” button which records the highest dB reached. Other apps include “SPL Meter” and “VUMeter.” To find smart phone dB meters for iPhone or Android phones, search on “dB meter.” Many are free or cost \$0.99.

**Safety Guidelines:** May need to help students cut some of the materials (or prepare materials before the activity).

## Science Content - Basics

### The Basic Science of Sound

**Sound** is caused by vibrating solids (example: the vibration of the vocal chords in your throat, the vibration of a guitar string) and rapid expansions/compressions of gases (example: explosions during a fireworks show, thunder resulting from a thunderstorm). Sound travels in **sound waves** that begin at the source of a sound and travel outward in all directions (see Figure 1). The **sound volume** or “loudness” of a sound will decrease as you move further away from the source of the sound because the sound energy spreads out as it travels through the material or matter (solid, liquid or gas). So for example, a ringing alarm clock located right next to your bed sounds much louder than a ringing alarm clock located on the opposite side of your room.

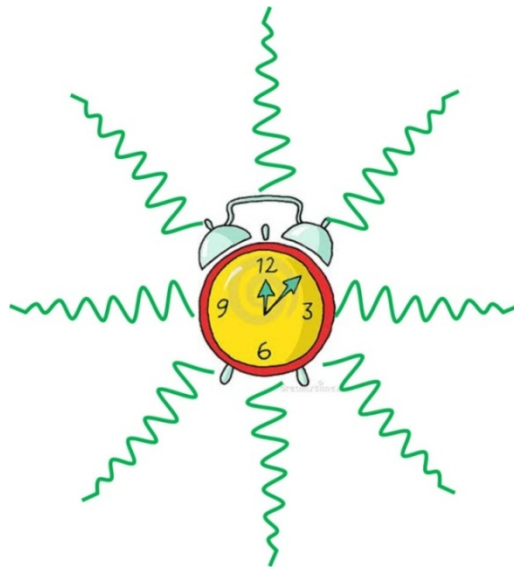


Figure 1: The ringing sound of your alarm clock. The clock is the source of the sound. The sound waves travel out in all directions from the source and decrease in volume with distance travelled.

Sound waves must travel through *something* – a solid material, a liquid, or even a gas (example: air). Sound waves travel faster through materials that are dense (see supplemental Table S-1). In general, sound travels fastest through dense solids and slowest through less dense gases. For example, in old Western movies, cowboys often put their ears to a railroad track to hear if a train is coming. Sound travels 15 times faster (and more efficiently) through the metal railroad tracks than through the air, giving the cowboy an early warning of the train’s arrival.

When sound waves come in contact with different materials, the waves are typically **reflected** or **absorbed** (see Figure 2). When a sound is reflected by a material, the sound wave’s forward motion is changed by the material and it bounces back towards the source of the sound (example: an echo response) or in a different direction. When a sound wave is absorbed by a material, the energy of the sound wave is reduced and the sound will appear to be quieter or possibly disappear entirely to a person listening nearby.

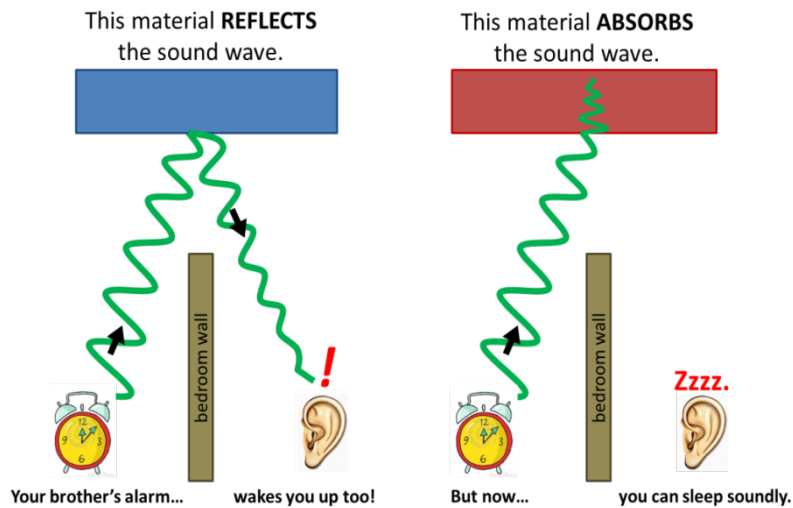


Figure 2: The blue material at left REFLECTS almost all of the sound of your brother’s alarm clock in the neighboring room into your room and wakes you up! Some sound will travel into and through the reflecting material. The red material at right ABSORBS the sound so that your brother’s alarm doesn’t wake you up anymore and you can sleep soundly.

**Acoustics** is the science of studying and controlling how sounds is produced, transmitted and received. **Acoustical engineers** use their knowledge of sound to design quiet environments (example: classrooms, libraries) as well as to design environments that are supposed to be loud (example: concert halls, football stadiums, gymnasiums). They also design sound barriers, such as the walls along busy roadways that decrease the traffic noise heard by neighboring houses.

A sound can be loud or soft. This **sound volume** is measured in **decibels (dBs)**, which can be detected and measured using a sound meter. The following figure illustrates the range of decibels with corresponding sound-producing activities (see Figure 3). The range of typical human hearing is from 0 dB (absolute silence) to the onset of ear pain, 120-140 dB.

Our ears are very sensitive to loud noises, which can cause permanent damage to our hearing ability, so it is important to wear good ear protection whenever exposed to loud noises (ex, like when attending an air show that may have loud airplanes and jet fighters). It is also possible to damage your hearing ability simply from listening to music at full volume levels.

## Sound Level (Decibel Scale)

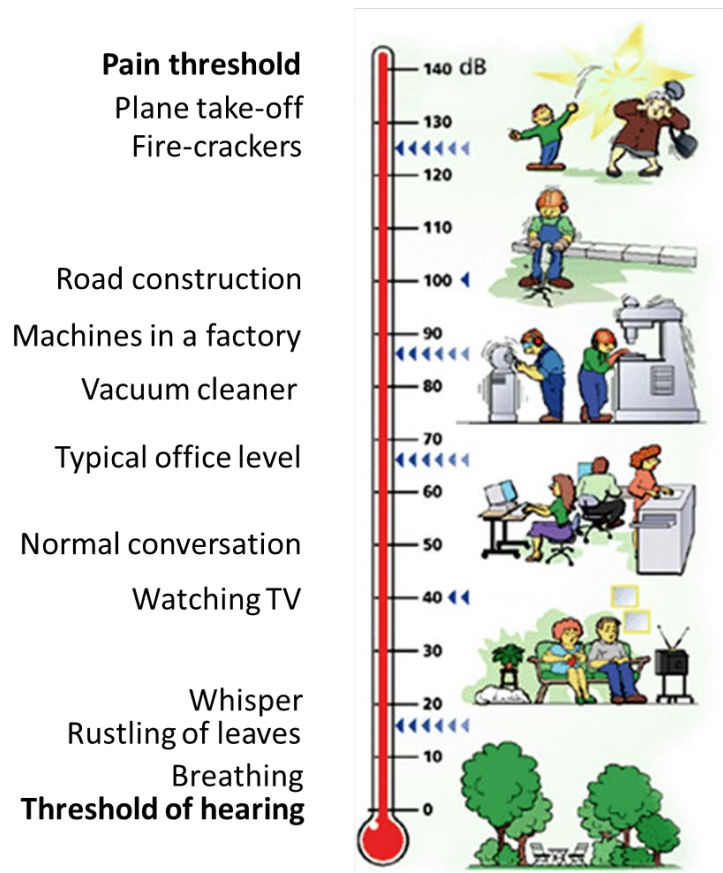


Figure 3: Cartoon representation of the volume or intensity of sound as measured in decibels (dB). Adapted from Reference [2].

*References and supplemental information related to the science and the understanding of sound are presented in the “Lesson Extensions and Resources” section at the end of this document.*

## Engineering Design

### Synopsis of the Design Activity:

Problem:	The noise level coming from the music room is too loud affecting the concentration level of Ms. Hush's students as they prepare for the many local and state tests.
Goal:	Design and construct a "soundproof" (or sound absorbing) wall so that loud sounds in one room will not be heard in the room next to it.
Who is the client:	Mr. Muffle, the Principal of Echo Canyon Elementary School.
End-User:	Mr. Muffle and the students
What is the design:	The wall between the quiet room and a room next to it needs to have sound absorbing qualities.
Criteria:	<p>Loud noises from the room next to the quiet room must be reduced or not heard in the quiet room. Loudness will be measured with a sound meter, also called a decibel (dB) meter.</p> <p>Wall must not take up more than 4.5 cm (1 ¾ in.) of space. Because the wall takes up space in the new room, a thin wall, that reduces sound, is desired. Students can choose wall thicknesses of 2.5 cm (1 in.) or 4.5 cm (1 ¾ in.).</p> <p>Wall must be constructed from no more than 3 different materials. At least two different materials, in addition to the manila folder "sleeve" that is provided, must be used in the wall.</p>
Constraints:	<p>Material provided</p> <p>Time</p>



## Lesson Plan #1

### Guiding Question – What are the room characteristics of a quiet area and of a noisy area?

**Time:** One 30 minute class session

**Procedures:**

1. Ask the class: Can you think of a time when noise bothered you or caused you problems? What did you do?

What areas of our school need to have a quiet atmosphere? (Record on board.)

What areas of our school permit louder noise levels? (Record on board.)

Explain that sound level (**volume**) is measured in dB using a meter or smart phone app.

2. Take the class on a walking tour of some of those areas. Students should take notebooks and list room features that might affect the noise level. (Ex: size, shape, floor covering, wall covering, type of ceiling).

Measure the sound level of each area and have students record in notebooks.

Discuss and list characteristics of the visited quiet and noisy areas.

3. What other areas have students been to that have loud or soft sound environments (sports stadiums, construction sites, music halls, churches, offices) – why are these sound environments different (include sound generation as well as absorption and reflection).

Discuss the meaning of **absorption** and **reflection**.

Classify the materials used in the two areas as better “sound **absorbers**” or “sound **reflectors**.”

Draw a diagram of **sound waves** in a quiet area and sound waves in a noisy area.

Discuss the meaning of **acoustics** and explain the role of **acoustical engineers**.

## Lesson Plan #2

### Inquiry

#### Guiding Question – Which materials most effectively absorb sound?

**Time:** One 30 minute class session

**Materials List:**

- Textbook or Paper Pad (used as a common platform for placing objects on that cover the speaker)
- Large plastic or paper cup
- Various materials, which will be used to fill the cup: newspaper, plastic wrap, tissue paper, paper towels, aluminum foil, fabric, Styrofoam packing peanuts
- Sound generator: 9-volt alarm (see Note below) or small timer
- Sound meter: dB/microphone/laptop sound meter or sound meter smart-phone app (see Note)

**Objectives:**

1. Students should observe and record the effects of different materials on reducing the sound level from the speaker.
2. Students should be able to rank the best material, with respect to reducing the sound, at the end of the task.

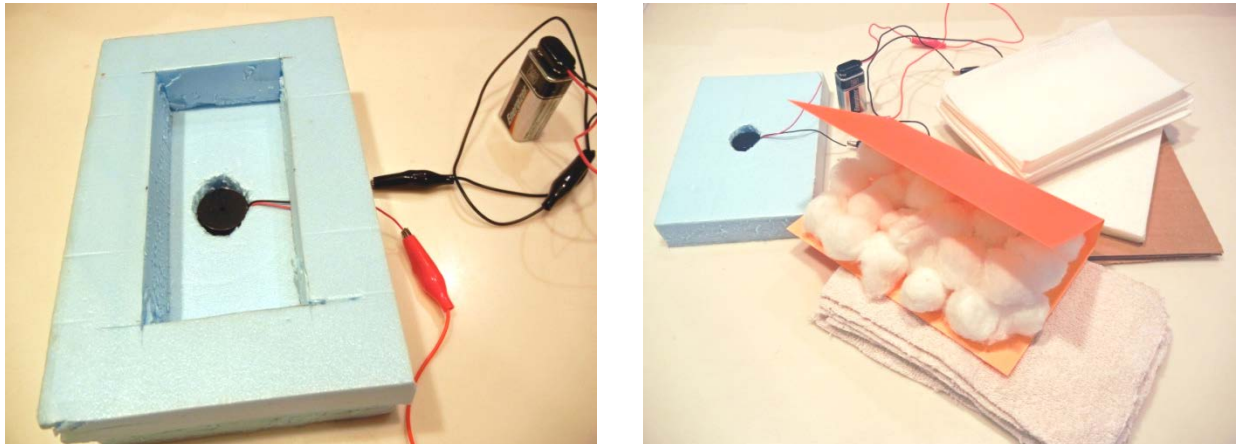
**Procedures:**

1. Instruct the students to place the microphone/dB meter on the edge of the ‘platform’ and to keep the location the same during this activity. (The inquiry can also be performed by simply listening to the loudness of the sound, “by ear,” instead of using the sound meter.)
2. Place the sound generator in the middle of the platform and leave it in this location during the activity.
3. Fill the cup with one type of material (example: crumpled newspaper).
4. Turn the sound generator on and measure the starting volume in dB. Record this value on the board.
5. Cover the sound generator with the material-filled cup (which should muffle the sound) and record the new sound volume value on the board.
6. Repeat for each different type of material.
7. Ask the students to discuss why the materials were different and what characteristics did the quietest materials have in common.

*Notes:*

- *Multiple ‘containers’ can be used to cover the ringing alarm. Try to find a variety of different materials (ceramic, plastic, paper, foam, etc.) from around the classroom. Possible items: Coffee mug, Styrofoam cup, paper cup, glove, hat, foam cup warmer, winter boot, cardboard box, box made from paperback books, etc.*
- *The suggested sound generator is a 9-volt single tone alarm and related wiring (see photo and additional information in Figure 6 below) which can be purchased at Radio Shack.*
- *The suggested smart-phone app is “dB Volume” (app for iPhone), a free app that has a “Hold” button which records the highest dB reached. Other apps include “SPL Meter” and “VUMeter.” To find smart phone dB meters for iPhone or Android phones, search on “dB meter.” Many are free or cost \$0.99.*
- *If sound measuring equipment is not available for this exercise, have the students compare the material-filled cups and subjectively rank how loud the speaker is, from softest to loudest.*

An alternative approach (preferred) to the inquiry activity is to mount the sound source in a hole carved out of a Styrofoam rectangle (Figure 4) cut to the size of the wall opening in the shoebox model (Figure 5). Add an additional layer of the Styrofoam that includes a cut out rectangular area (Figure 4). Pre-cut pieces of different insulating materials (Figure 4) can then be tested, as well as the effect of thickness, by placing the materials on top of the Styrofoam.



*Figure 4. Left – Styrofoam block (1 inch thick) and “cut out” rectangle layer of Styrofoam (to form a sound testing space) with sound generator placed in cut-out area. Insulating materials can be placed on top, covering the cut out area for testing (with sound meter or “by ear”). Right – Styrofoam block and test materials – cardboard, foam, paper towels, cloth (old towel cut into rectangles), and cotton balls.*

## Design Challenge Preparation

*Note: for this activity, a microphone should be used with the sound meter. For example, the small mic attached to the head phone cord of a smart phone could work.*

### Prior preparation:

The shoe box will be used to simulate the two neighboring classrooms, which are separated by the empty wall that the students will fill with various materials in order to create the best sound absorbing wall. Prior to starting this activity, the instructor needs to prepare the shoe box to be used for testing, and the manila folders to be used as the 'empty wall'. The shoe box should be prepared to resemble the following schematics (see Figure 5).

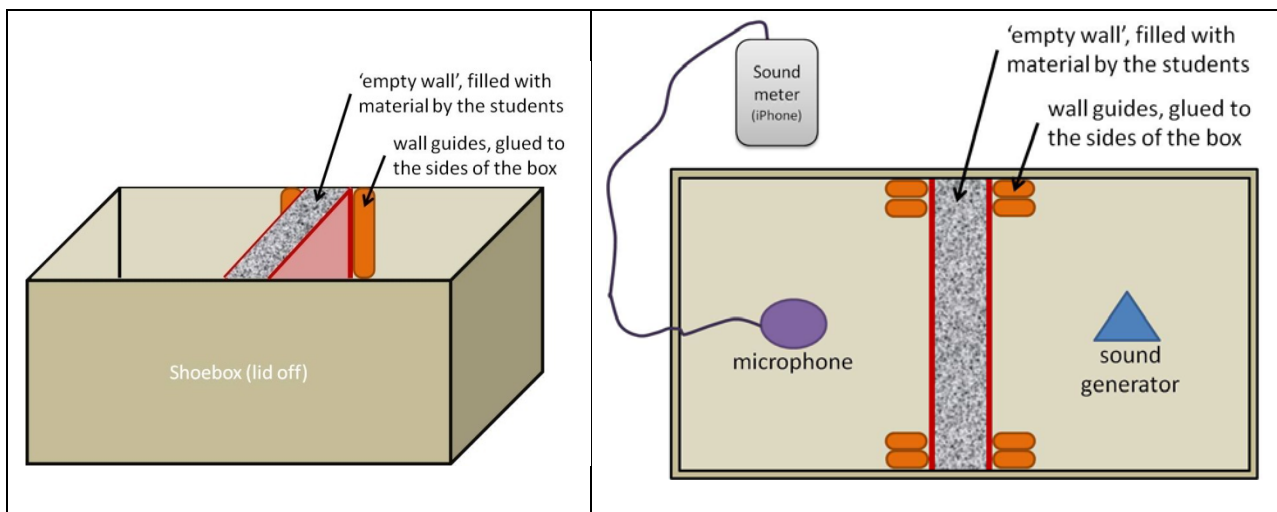


Figure 5: The left schematic shows the shoebox in side view, containing a filled wall. The right schematic shows the top view of the shoe box, illustrating the location of the sound generator in one 'room' of the box and the sound meter's microphone in the other 'room' of the box.

To create the 'empty wall' that the students will fill with various materials in order to make their sound absorbing classroom wall, the manila folder should be cut to the appropriate size needed (see Figure 4) in order to completely bisect the inside of the shoebox, thus creating the two separate 'rooms' within the box. As shown in Figures 6 and 7, one room will contain the microphone of the sound meter, and the other room will contain the sound generator.

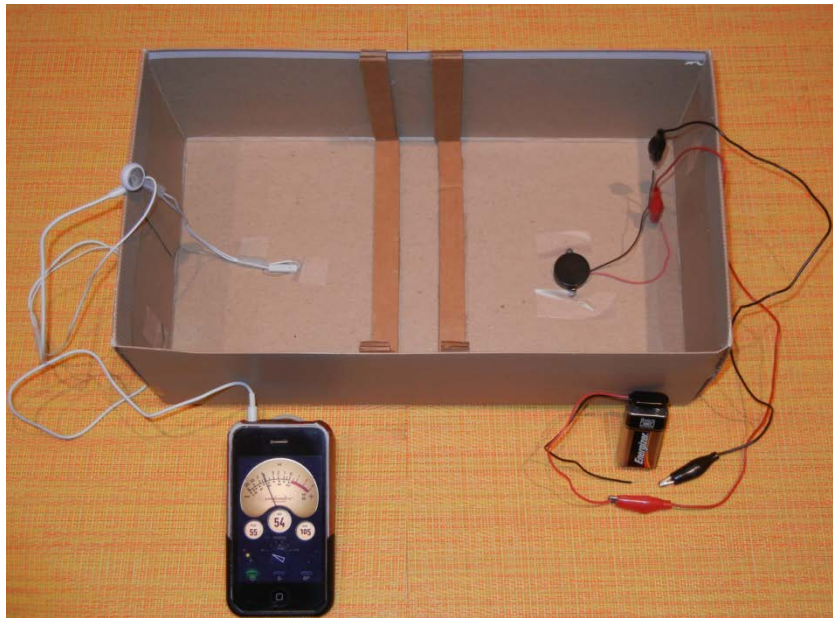


Figure 6: Photo of shoebox with cardboard “wall guide” strips glued to the sides and bottom of the box. On the left is a microphone (headset with mini-microphone) or equivalent connected to an iPhone with the dB meter app (VUmeter) opened. On the right is the sound generator in the box (alarm or mini 12V buzzer; Radio Shack part number 273-059, \$3.59) connected with alligator clip extender wires to a 9V battery clip (Radio Shack part number 270-0324, \$2.69) and battery. Connecting the red alligator clip to the black wire battery clip completes the circuit and turns on the sound generator. A digital kitchen timer can also be used as the sound source. Mark the locations of the sound generator and the microphone in the box so that the positions remain the same for all tests. Use transparent tape to attach the sound generator and the microphone to the bottom of the shoebox as shown. For testing (recording the sound level) with or without the wall, the lid to the shoebox is attached to minimize sound from other sources and mimic the conditions actual rooms with walls and ceilings.

To hold the student’s filled wall in a vertical position for testing, four wall guides are glued on the sides of the box such that the empty wall can simply be inserted from the top and will remain supported during the test. A double-layer of Popsicle sticks or cardboard strips, glued in place on the sides of the box, can be used as the wall guides (as illustrated in Figures 5 and 6).

The following photograph in Figure 7 show a fully assembled box, containing the wall (manila folder cut to size), filled in this example, with paper towels cut to size. Details of the manila folder wall are illustrated in Figure 8.

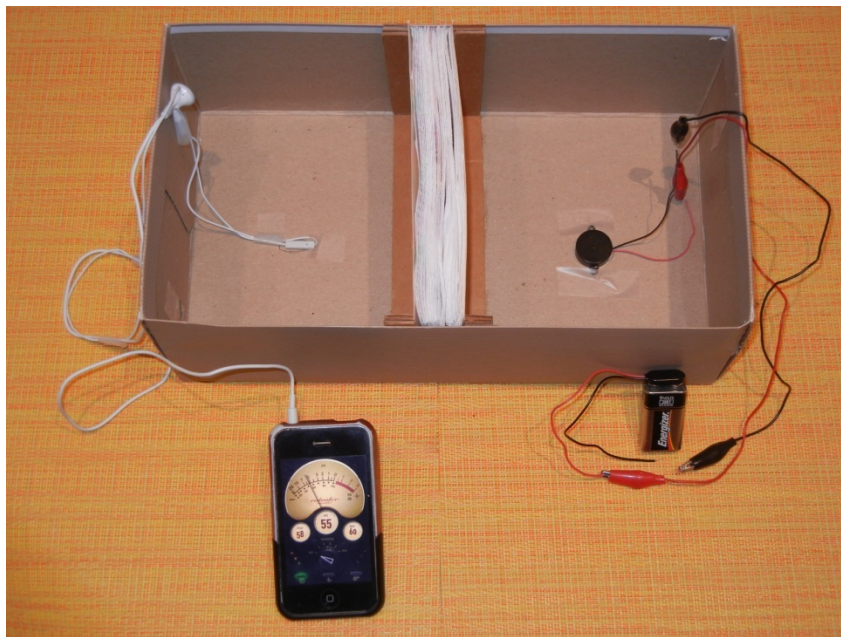


Figure 7: Photo of shoebox, microphone (left side of box), dB meter (iPhone and VUmeter app) and sound source (right side of box) with wall (containing many layers of paper towels to absorb sound) inserted. After attaching the shoebox lid (hold down or add a book for weight on top of the lid), the testing of the sound level can be performed and the result compared with the sound level with no wall and with walls with different materials. Sample sound level results for this shoebox and insulation: no wall, 103 dB; wall only (no insulation), 100 dB; wall with many layers of paper towel insulation, 77 dB.

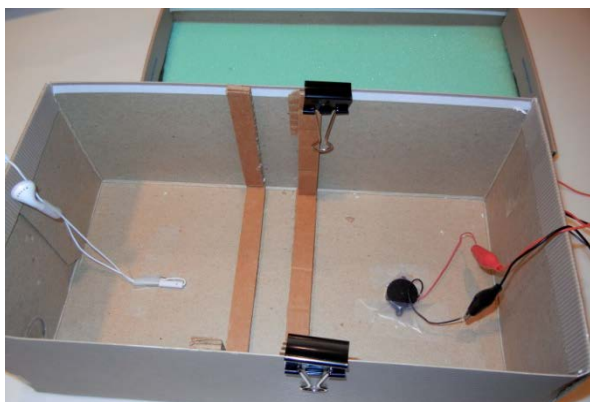
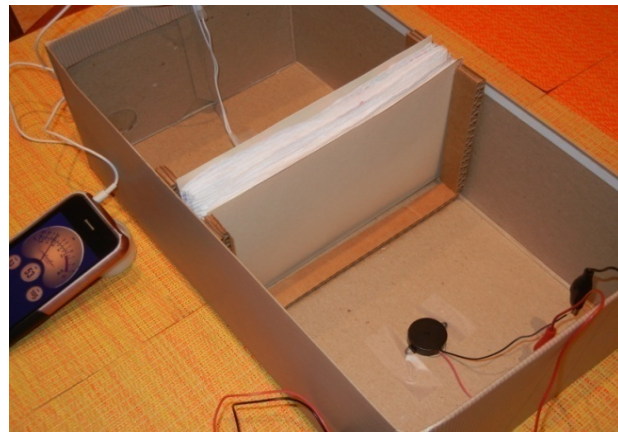
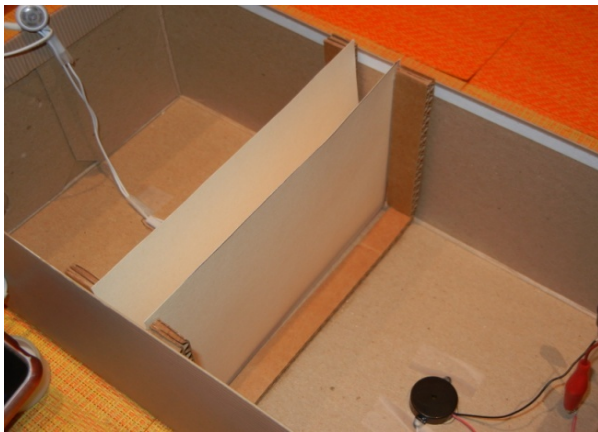


Figure 8: Upper Left – Close-up view of manila folder, cut to size and folded, forming (empty) wall between two “rooms” of the shoebox model. Upper Right – trimmed manila folder with layers of paper towel insulation inserted. Left – Shoebox model with moveable (not glued) cardboard strips (on right) that allow the two wall widths (2.5 cm and 4.5 cm) used in this activity. The strips on the right and the inserted wall are held in place by the medium size binder clips. Shoebox lid (above box) has a ½ inch thick piece of soft foam in it so that there is a tight fit of the “ceiling” to the top of the wall for sound testing.

## Lesson Plan #3

### Guiding Question – Can you design a sound absorbing wall?

**Time:** one 30 minute class session

**Procedures:**

1. Review with students:

*What is the job of acoustical engineers?*

*How does sound travel?*

*What is the difference between sound absorption and sound reflection?*

*What object in the classroom is a good sound absorber? A good sound reflector? Why?*

*What is a material that is a good sound absorber? A good sound reflector? Why?*

2. Display divided shoe box, the empty wall, and the wall-filling materials so students can see them. Distribute, read aloud, and discuss the design brief.

*What is the problem?*

*Who is the client?*

*Who is the user?*

*What are the criteria or desired needs?*

*What are the constraints or limitations?*

*What materials and tools have been provided?*

Have students respond to the above questions in their notebook. Discuss responses with class.

3. Instruct students to individually brainstorm design ideas applying what they have learned in previous lessons. List or sketch the ideas in their notebooks. Then have them choose one idea to use in an individual design plan. Remind students that sketches should be large, neatly drawn, and clearly labeled showing dimensions and materials.
4. Students should share their plans within their teams, explaining how materials were used and why they were chosen. Each team should choose a group design which can be a combination of ideas or a specific design from an individual within the group. Each team member is to sketch the group design. The sketches within a team should be identical and detailed so anyone could construct the design by looking at the drawing.

## Lesson Plan #4

### Guiding Question – How well did your wall absorb sound?

**Time:** one 30 minute session

**Procedures:**

1. As shown previously in Figures 4 and 5, the sound generator (alarm or timer) should be placed in one section of the shoe box (Ms. Hush’s classroom), and the microphone of the sound meter (example: the microphone headset for an iPhone) should be placed in the other section of the shoe box (the Music classroom).
2. Using the adjustable wall guides, insert and vertically position a empty wall (manila folder “sleeve” cut to size of the wall and allowing a thickness of 2.5 cm or 4.5 cm) into the shoe box. Put the lid on the box and turn on the sound generator. Use the sound meter to determine the approximate volume of the sound in decibels that is detected *with only an empty wall in place*. This is the value of sound heard in Ms. Hush’s classroom before a sound absorbing wall is constructed by the students (record this value in the data table described below).
3. Give an identical empty wall to each student group so that the groups can fill their empty walls with the materials of their choosing in order to design and construct a better sound-absorbing wall. All students should actively participate in the construction of their group design. Changes made in construction should be indicated in their notebooks, along with wall width.
4. After the wall is completed, each group should bring their filled wall to the instructor so that it can be tested in the shoe box. Using the wall guides in the shoe box, insert and vertically position the empty wall that the students have now filled with their materials of choice.
5. Put the lid on the box and turn on the sound generator. Use the sound meter to determine the approximate volume of the sound in decibels that is detected through the sound-absorbing wall. Students should record the dB value in a data table in their notebooks.

Data Table: Decibel level in Ms. Hush’s classroom

Description	Sound dB
Before wall construction	
After wall construction	
dB absorbed by wall (difference)	



## Lesson Plan #5

### Guiding Question – Can you design a sound absorbing wall?

**Time:** One to two 30 minute class sessions

**Procedure:**

1. Have the students respond in their notebooks to the following questions:  
*What was the dB level before wall construction?*  
*What was the dB level after wall construction?*  
*How many dB did your wall absorb?*  
*What materials did you use in your wall construction? Why?*  
*How were the materials arranged? Why?*  
*How effective (good) was your design? How do you know?*  
*What would you change in your design? Why?*
  
2. Give each team a few minutes to discuss their answers to the above questions and prepare an oral presentation to the class. The presentation should include the information discussed, and each team member should actively participate?
  
3. Make/display a table to collect data from each team (example shown below)

Class Data – Sound Absorbing Wall

Team	Materials Used in Wall Construction and Arrangement	Sound dB Before	Sound dB After	Sound dB Absorbed

Also, for comparison, record the sound meter reading (in dB) for your classroom with everyone being very quiet, and with several people talking. Write the results on the board.

4. After presentations, ask the following questions to the class:  
*Which design had the best sound absorbing wall? How do you know?*  
*Order the designs from most to least sound absorbing.*  
*What do you observe about the materials used in the more sound absorbing walls?*  
*What do you observe about the arrangement of materials in the better sound absorbing walls?*  
*What other design features may have affected the sound absorption? (Ex: how materials were used, space between materials)*
  
5. Have students individually sketch a redesign in notebooks that reflects what they learned about sound absorbing materials and arrangement. Students should also write sentences explaining what they changed and why.

6. If time permits, groups should construct and test the new design.
7. Challenge question: Examine the model room (shoebox with sound absorbing wall). What could be done to the room to reduce the sound level further? (For example, apply sound absorbing material to the ceiling, such as acoustical tile, walls and floor.)

## Assessment

The following are possible sources of formative and summative assessment:

Use a simple rubric to assess student notebooks for the following Design Process Standards:

- Identify a need or problem to be solved. (Lesson Plan #3)
- Document the design throughout the entire design process. (individual, group, redesign sketches)
- Create the solution through a prototype. (Lesson Plan #4)
- Evaluate and test the design using measurement. (Lesson Plan #4)
- Communicate how to improve the solution. (Lesson Plan #5)

Individual participation within group

- Note level of engagement
- Ability to work well with other team members during design process
- Contribution during team presentation

Create a short pre- and post-test

- Student must classify a list of materials as “Better Sound Absorber” or “Better Sound Reflector”.
- Student must solve a new problem similar to the design challenge. Ex: What materials would be used to design headphones that protect the hearing of employees in a noisy factory.

## Lesson Extensions and Resources

### Supplemental Information on Sound

What is the **definition of sound**?

- Sound is a longitudinal, mechanical wave (see Figure S-1).
- Sound waves are caused by vibrating molecules and rapid expansions/compression of gases.
- Sound can travel through any medium via wave propagation – examples are through a solid, liquid or gas but not in a vacuum, so there is no sound in outer space.

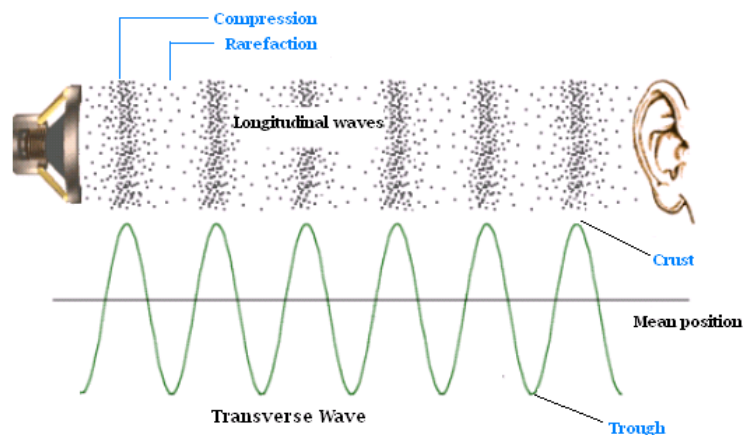


Figure S-1: Cartoon representation of a longitudinal sound wave and illustration in terms of a transverse wave. From Reference [5].

Sound can be **loud** or **soft** (this is the **intensity** of the sound), which results from variation in the sound wave's amplitude – large amplitude waves have more energy and are louder than small amplitude waves (see supplemental Figure S-2). Sound intensity is typically measured by using a **sound meter** that measures how loud a sound is in terms of **decibels (dB)**, a unit of measure.

### Amplitude of Sound Waves

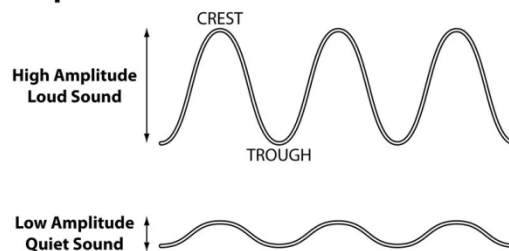


Figure S-2: Cartoon representation of a loud and soft sound wave. From Reference [4].

Supplemental content related to the **inquiry** activity:

How does sound change when traveling through different materials?

Table S-1: Typical values of speed for a sound wave traveling through different materials. From Reference [1].

Type of Material	Solid / Liquid / Gas	Velocity (m/s)
Air (T = 25°C)	G	343
Water	L	1497
Rubber	S	1830
Brick	S	3650
Wood (oak)	S	3850
Glass (Pyrex)	S	5640
Stone (granite)	S	5950
Metal (aluminum)	S	6420

- **Sound travels at different speeds** when moving through different materials, as shown in the above table. In general, sound travels fastest through dense solids and slowest through gases.
- Examples:
  - The sound of a train can be detected by placing your ear to the railroad tracks before it can be heard normally (that is, the sound waves travel faster through the metal railroad tracks than through the air).
  - Dolphins and whales under water, the noises they make travel faster underwater than they would above water.
  - Lightning and thunder: the speed of light (~300,000,000 m/s) is much, much faster than the speed of sound in air (343 m/s), thus you will see the flash of a lightning bolt before hearing the sound.
- **The intensity/loudness of the sound can be reduced** when traveling through different materials.
  - Some materials can **absorb** the energy of the sound waves, converting that energy into other non-sound forms (such as heat) and causing a reduction in intensity.
  - The greater the distance a sound has to travel, the more the sound waves can spread out, which causes a reduction in intensity. Ex, talking to a friend next to you vs. a friend on the other side of the room.

Supplemental content related to the **design** activity:

Which types of materials and designs create the best sound absorbing wall?

- The most effective sound absorbing materials are typically materials that are porous (that is, materials containing air pockets). These materials are typically soft and flexible but not always (example: Styrofoam is porous but very stiff).
- Thicker materials are more effective at absorbing sound than thinner materials because the sound waves have a greater distance to travel and thus are able to spread out during their journey through the material.
- The least effective sound absorbing materials are typically very dense materials, like a sheet of metal or a ceramic plate.

**Example of sound reflection – an echo**

You can download a video (<http://web.ics.purdue.edu/~braile/new/echo.mp4> or <http://web.ics.purdue.edu/~braile/new/echo.avi>) that can be used to illustrate the reflection of sound from a cliff face (see Figure S-3), creating an echo. Because the distance of the sound source (a yell) to the cliff face is known (see map in Figure S-4), the time difference between the original sound and the echo (about 0.8 s) can be measured with a stopwatch by listening to the video playback to calculate (to reasonable accuracy) the speed of sound in air.



Figure S-3: Photo of cliff face near road (see Figure S-4) in El Malpais National Monument (<http://www.nps.gov/elma/index.htm>) in New Mexico.

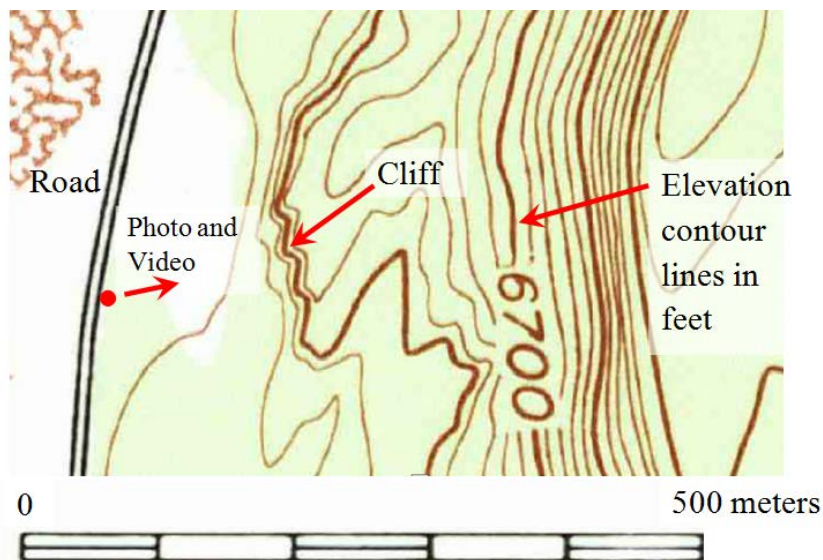


Figure S-4: Enlarged section of a topographic map (USGS 7.5 minute quadrangle Grants SE, New Mexico, contour interval 20 ft.) showing photo location (red dot) and cliff (see photo in Figure S-3). The cliff is about 130 meters from the person who yelled so the sound wave echo traveled about 260 meters (to the cliff where it reflected back and traveled to the person) in 0.8 seconds providing speed of sound in air estimate of 325 m/s (a reasonably accurate value of the speed of sound in air; [http://en.wikipedia.org/wiki/Speed\\_of\\_sound](http://en.wikipedia.org/wiki/Speed_of_sound)). To listen to the sound and the echo, just play the video from either of the video files (mp4 or avi) listed above. To obtain a better measurement of the delay time of the echo and the speed of sound in air, you can open the mp4 video in the QuickTime player (<http://www.apple.com/quicktime/download/>) and play it back at one-half speed. You can set the speed (fps) in QuickTime to  $\frac{1}{2}$  of the actual speed to increase (by factor of 2) the time between the original sound and the echo. This makes it easier to measure the echo time delay with a stop watch or timer. To set the speed in QuickTime, select the Window menu and clicking on Show A/V Controls. Then select a playback speed of  $\frac{1}{2}x$ . Also note that the sound level (loudness) of the echo is much lower than the original sound. This is mostly caused by the spreading out of the sound wave energy as it travels to the cliff and back, but is also due to the incomplete reflection (echo) from the cliff face. This observation provides an excellent challenge question for students.

### Recommended trade books on sound

Table S-2 is a list of recommended trade books on sound. Several are non-fiction and provide information on sound, and sound generation, propagation, reflection and absorption. The fiction books are interesting stories that relate to sound and noisy and quiet environments. The books provide a useful connection of the science and engineering activities in these lessons to reading and literature. The *Be Quiet, Mike!* book has a useful discussion of engineering design for elementary students. The *Loud Sounds, Soft Sounds* book discusses quiet and noisy environments, soundproofing and reasons for controlling sound level and noise.

Table S-2 Some third grade age appropriate trade books related to sound.

<b>Trade Books - Sound</b>				
<b>Title</b>	<b>Author</b>	<b>Publisher, Date</b>	<b>F/NF</b>	<b>Comments</b>
Loud Sounds, Soft Sounds	Patricia Whitehouse	Rourke 2007	NF	Construction site sounds, sound barrier, soundproof
Sounds All Around	Wendy Pfeffer	HarperCollins 1999	NF	Vibrations, waves, echo, activities
Sound: Loud, Soft, High, and Low	Natalie M. Rosinsky	Picture Window Books 2003	NF	Vibrations, waves, echo, volume, pitch, fun facts, activities
Sound	Kay Manolis	Bellwether Media 2008	NF	Vibrations, waves, pitch, decibels, echo, fun facts
Be Quiet, Mike!	Leslie Patricelli	Candlewick Press 2011	F	Engineering design process, onomatopoeia
The Quiet Book	Deborah Underwood	Houghton Mifflin 2010	F	Adjectives, similes
The Loud Book	Deborah Underwood	Houghton Mifflin 2011	F	Adjectives, similes
Too Much Noise	Ann McGovern	Sandpiper Books 1992	F	Story about loud and quiet sounds

### **References**

[1] The Physics Hypertextbook website, (2012): <http://physics.info/intensity/> , <http://physics.info/sound/>.

[2] California Department of Transportation website, Typical Noise Levels (2011): [http://www.dot.ca.gov/hq/maint/Pavement/Offices/Pavement\\_Engineering/Noise\\_Levels.html](http://www.dot.ca.gov/hq/maint/Pavement/Offices/Pavement_Engineering/Noise_Levels.html).

[3] Wikipedia website, (2012): <http://en.wikipedia.org/wiki/Soundproofing>.

[4] National Energy Education Development Project website (2012): [http://need-media.smugmug.com/Graphics/Graphics/17024036\\_Bdmf8C/1289376535\\_b9XXTHT#!i=1289376535&k=b9XXTHT](http://need-media.smugmug.com/Graphics/Graphics/17024036_Bdmf8C/1289376535_b9XXTHT#!i=1289376535&k=b9XXTHT).

[5] TutorVista.com website (2012): <http://physics.tutorvista.com/waves/sound-reflection.html>

### **Additional Resources**

[www.TeachEngineering.org](http://www.TeachEngineering.org)

[www.pppst.com](http://www.pppst.com) (Pete's Powerpoints – Ocean Odyssey under Sound /Games for Kids is a great interactive game for reviewing sound concepts.)

# Design Activity

## Build a Sound Absorbing Wall



Mr. Muffle, principal at Echo Canyon Elementary, has just learned that the school has enough money in its budget to hire a full-time music teacher. His happiness quickly turned to concern when he realized that the only empty room was right next to Ms. Hush's third grade classroom. Worried that the noise level coming from the music room would affect the concentration level of Ms. Hush's students as they prepare for the many local and state tests, Mr. Muffle decided to hire the *Silence Is Golden Company* to design a sound absorbing wall for Ms. Hush's classroom.

As one of the *Silence Is Golden Company* acoustical engineers, you and your team must plan, build, and test a **wall that absorbs as much noise as possible, given the thickness of the wall, from the music room.**

- Each team must use the box provided to represent the classrooms and only the supplied building materials for the wall.
- The wall must **not** take up more than 4.5 cm ( $1 \frac{3}{4}$  in.) of space. You have the **choice** of a thin wall (which takes up less space in the room) - 2.5 cm (1 in.) thick - or, a thicker wall, 4.5 cm ( $1 \frac{3}{4}$  in.) thick.
- The wall must be constructed from no more than 3 different materials; you must use at least two different materials (in addition to the manila folder "sleeve" that is provided for your team).
- Tape may be used to hold materials together.