

# Science and Innovation

A Boeing/Teaching Channel Partnership

DESIGN A QUIETER CABIN
Teacher Handbook



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The Boeing Company and Teaching Channel teamed in 2014 to create problem-based curricula inspired by science and engineering innovations at Boeing and informed by globally competitive science, math, and literacy standards. This two-week curriculum module and the companion video series are designed to help teachers in grades 4–8 integrate the engineering design process, aligned to science standards, into their classrooms. The collection of Teaching Channel curricula is one part of a collection of K–12 education resources intended to mark Boeing's centennial anniversary and prepare the next generation of innovators.



The materials created by this collaboration were taught by the authoring teachers in Puget Sound and Houston, and in 2015, a second group of teachers taught the lessons and provided feedback to improve the modules. As part of a second iteration of the modules, the senior science editor at Teaching Channel worked with Achieve to integrate the teachers' feedback while more closely aligning the modules to The Next Generation Science Standards (NGSS) call for significant shifts in the way science is taught and learned. In 2016, a panel of science experts from around the country convened for a two-day training with Achieve to learn how to incorporate the Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for Science. As part of the iterative process of improvement, the expert reviewers then completed an EQuIP Rubric for each module. Teaching Channel's senior science editor combined the reviewers input to create a third iteration of the modules that promotes a close alignment to standards while honoring the original expertise of the authoring teachers and engineers.

Partners at both the University of Washington's Institute for Science and Math as well as Educate Texas were instrumental in teacher recruitment for this project. Teachers and engineers in the project received training from learning scientists at the University of Washington's Institute for Science and Math Education, led by Dr. Philip Bell. He and his team also created a design template to support curricula development to promote alignment to standards and research on science learning and teaching.



Please note that the resource links provided in these lessons are intended as helpful illustrations to teachers adapting the unit for their classrooms and are not an endorsement of specific products or organizations.

# Design a Quieter Cabin

# **Background and Overview**

Acoustics is the study of the properties of sound and how sound is transmitted through space. Engineers working on airplane design pay close attention to the acoustics of the airplane cabin in an effort to keep passengers as comfortable as possible. In this module, students develop, test, and modify designs for a quieter airplane cabin. Students develop a conceptual understanding of science ideas related to sound waves. Students apply these ideas during the engineering design process.

#### **Module Overview**

In this module, students develop an understanding of core science ideas related to sound waves as they work to engineer a quieter airplane cabin. In the final design challenge, students use a large PVC pipe to simulate an airplane cabin. Students line the cabin with various materials and test the materials using a decibel meter to determine how well the materials abate sound transfer. Students continually redesign and test their cabins, justifying and grounding their revisions in key science ideas.



#### **Module Authors**

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At the beginning of the module, students are challenged to model how an airplane engine generates sound and how the sound travels to the passengers' ears. Students engage in a variety of investigations in order to construct and revise their models. For example, students use a Slinky<sup>®</sup> to explore the relationship between energy and amplitude, they design a homemade speaker, and they examine how sound waves travel through various materials.

After the introduction to sound waves, students collect data to support the claim that sound travels better through solids than through gases. Students use this understanding in their design solutions.

Students also explore how humans hear sounds by examining the student ear. Students design and conduct an investigation to determine if humans hear all pitches at the same volume. Students learn that humans hear some pitches better than others. This informs the design criteria and constraints in that the design solution does not necessarily need to block all sound, but only sound that humans are most sensitive to.

After developing a conceptual understanding of the properties of sound waves and how humans hear, students engage in a design challenge in which they design, build, test, and modify a model airplane cabin to create a quieter cabin. Through the design challenge, students learn the importance of modifying and redesigning technologies in order to optimize a design solution.

# Design a Quieter Cabin

# **Background and Overview**

#### Engineering Design in the Module

Sounds can be generated and also abated in many ways. In this module, students explore various materials and design options while they create and optimize sound-creating and sound-abating devices, such as string-and-cup telephones. After learning about the generation and the propagation of sound waves, students work to develop a quieter airplane cabin modeled by a container that will help shield a microphone from exterior sounds. They then use an iterative design process to continuously improve their sound-abating airplane cabin design. Students record and document their engineering process, including each design iteration in an engineering design notebook.

#### Sequencing

Design a Quieter Cabin is intended as an early middle school (6th grade) engineering and physical science module. This module is designed to help students make progress on five performance expectations: MS-ETS1-1, MS-ETS1-4, MS-PS4-1, MS-PS4-2, and MS-LS1-8. The performance expectations address the engineering design process, wave properties, and information processing.

Prior to beginning this module, students should have already mastered the following *performance expectations*, *disciplinary core ideas*, *science and engineering practices*, and *crosscutting concepts*:

- Students should have mastered <u>4-PS3-1</u>, <u>4-PS3-2</u>, and <u>4-PS3-4</u>, which address energy and energy transfer. Students should have also mastered <u>5-PS1-1</u>, which addresses the particulate nature of matter. Ideally, students should already have had exposure to <u>MS-PS4-1</u>, which addresses the properties of waves. This module is best placed after students have started to explore mechanical waves but have not yet explored sound waves.
- Beyond the physical science performance expectations, students should have already demonstrated deep conceptual understanding for all of the <u>3-5 Engineering Design</u> performance expectations and associated science and engineering practices, disciplinary core ideas, and crosscutting concepts.
- Students should have made grade-appropriate progress on the following science and engineering practices: <u>Asking Questions and Defining Problems</u>, <u>Developing and Using Models</u>, <u>Planning and Carrying Out Investigations</u>, <u>Constructing Explanations and Designing Solutions</u>, and <u>Engaging in Argument from Evidence</u>.
- Students should also have made grade-appropriate progress on the following crosscutting concepts: <u>Influence of Science</u>, <u>Engineering</u>, <u>and Technology on Society and the Natural World</u>, and <u>Structure and Function</u>.

#### **Performance Expectations**

MS-ETS1-1. Define criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

# Design a Quieter Cabin

# Connecting to the Next Generation Science Standards

The lessons and activities outlined in this module are one step in the learning progression toward reaching the performance expectations listed below. Additional supporting lessons and activities will be required.

Specific connections between the performance expectations, three dimensions, and classroom activities are articulated at the beginning of each lesson.



#### **Important Note**

The grade level and associated performance expectations, disciplinary core ideas, science and engineering practices, and crosscutting concepts identified throughout the unit were selected to align with the Next Generation Science Standards. In classrooms using local or state standards, this unit may fall within a different grade band and may address different standards. Teachers should adapt this unit to meet local and state needs.

Furthermore, teachers should adapt the unit to extend student learning to additional grade levels, performance expectations, disciplinary core ideas, science and engineering practices, and crosscutting concepts to meet student needs.

#### **Performance Expectations**

The lessons and activities in this module contribute toward building understanding of the following *engineering* performance expectations:

MS-ETS1-1. Define criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

The lessons and activities in this module contribute toward building understanding of the following *physical science* performance expectations:

MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Dimension	NGSS Element
Science and Engineering Practices	2 0 m 10 di dio 1 g 1 p 1 0 0 0 m 1 di

- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.
- Develop and use a model to describe phenomena.
- Develop a model to describe unobservable mechanisms.

#### Planning and Carrying Out Investigations

- Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation.
- Collect data about the performance of a proposed object, tool, process, or system under a

Construct a scientific explanation based on valid and reliable evidence obtained from sources (including students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do

Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.

The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible

- A solution needs to be tested, and then modified on the basis of the test results, in order to
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

#### Influence of Science, Engineering, and Technology on Society and the Natural World

The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.

- Energy may take different forms (energy in fields, thermal energy, energy of motion)
- The transfer of energy can be tracked as energy flows through a designed or natural system.

#### Structure and Function

Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.

# range of conditions. Constructing Explanations and Designing Solutions so in the future. **Engaging in Argument from Evidence** ETS1.A: Defining and Delimiting Engineering Problems ETS1.B: Developing Possible Solutions Disciplinary Models of all kinds are important for testing solutions. Core Ideas **PS4.A: Wave Properties** A sound wave needs a medium through which it is transmitted. LS1.D: Information Processing Systems and System Models Crosscutting Concepts Energy and Matter: Flows, Cycles, and Conservation



## Connections to the Common Core State Standards

In addition to connecting to the *Next Generation Science Standards*, this unit can support student growth in multiple *Common Core State Standards*. This unit can be easily adapted to support growth in the following standards:

#### English Language Arts

- ► <u>CCSS.ELA-Literacy.W.6.1</u>: Write arguments to support claims with clear reasons and relevant evidence.
- CCSS.ELA-Literacy.SL.6.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
- ➤ <u>CCSS.ELA-Literacy.SL.6.4</u>: Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

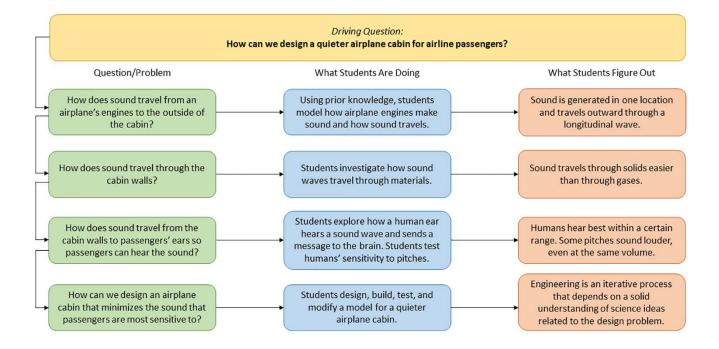
#### Math

- ➤ <u>CCSS.Math.Content.6.SP.A.3</u>: Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.
- ► <u>CCSS.Math.Content.6.SP.B.4</u>: Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

# Design a Quieter Cabin

# **Module Storyline**

This module is designed as a coherent set of learning experiences that motivate a progressive building of understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts. The following storyline demonstrates how ideas are built across the lessons. You may find it helpful to continually reference the storyline to help frame lessons.



# Design a Quieter Cabin

## Days 1 and 2: How Sound Travels Away from an Airplane Engine

Grade Level	Early Middle School (Grade 6)
Lesson Length	Two 50-minute sessions (if possible, consider adding another day)



#### **Lesson Overview**

In this two-day lesson, students are introduced to the design problem of creating a quieter cabin for airplane passengers. First, students create a Driving Question Board (DQB) to drive their learning throughout the module. Next, students engage in a series of investigations to figure out how airplane engines make sound and how the sound travels from the engine to the passengers' ears. Finally, students develop and revise models to show how sound waves travel.



## Connecting to the Next Generation Science Standards

On Days 1 and 2, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Asking Questions and Defining Problems,
   Developing and Using Models, Constructing Explanations and Designing Solutions,
   Engaging in Argument from Evidence
- Disciplinary Core Ideas: ETS1.A Defining and Delimiting Engineering Problems, PS4.A Wave Properties
- Crosscutting Concepts: Influence of Science, Engineering, and Technology on Society and the Natural World, Systems and System Models

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

#### **Performance Expectations**

This lesson contributes toward building understanding of the following *engineering* performance expectations:

MS-ETS1-1. <u>Define criteria and constraints of a design problem with</u> sufficient precision to ensure a successful solution, <u>taking into account relevant scientific principles</u> and potential impacts on people and the natural environment that may limit possible solutions.

This lesson contributes toward building understanding of the following *physical science* performance expectations:

MS-PS4-1. Use mathematical representations to <u>describe a simple model for waves that includes how</u> the amplitude of a wave is related to the energy in a wave.

MS-PS4-2. <u>Develop and use a model to describe that waves are</u> reflected, absorbed, <u>or transmitted</u> <u>through various materials.</u>

#### **Specific Connections to Classroom Activity**

In this lesson, students are introduced to the engineering design problem of creating a quieter cabin for airplane passengers. Students consider the criteria and constraints of the design problem. Students develop models for how sound waves travel from an airplane's engines to the cabin. Students build on their knowledge of matter developed in 5th grade (PS1.A) and their initial understanding of waves (PS4.A) to develop an initial understanding of longitudinal waves. Students use a model to explore amplitude and energy.

Dimension	NGSS Element	Connections to Classroom Activity
	Asking Questions and Defining Problems     Define a design problem that can be solved through the development of an object, tool, process, or system, and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	When students are introduced to the design problem of creating a quieter cabin, they are given an initial list of criteria and constraints. Throughout the module, students develop an understanding of the science ideas surrounding the design problem to further define the criteria and constraints.
Science and Engineering Practices	<ul> <li>Develop and use a model to describe phenomena.</li> <li>Develop a model to describe unobservable mechanisms.</li> <li>Constructing Explanations and Designing Solutions</li> <li>Construct a scientific explanation based on valid and reliable evidence obtained from sources (including students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.</li> <li>Engaging in Argument from Evidence</li> <li>Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.</li> </ul>	In this lesson, a heavy emphasis is placed on developing models to describe how airplane engines make sound and how the sound travels to airplane cabins. Students construct an initial model for the phenomenon and revise the model based on engagement with additional investigations, explanations, and reasoning.  As part of the modeling process, students work to construct an initial scientific explanation for how airplane engines make sound and how the sound travels to cabins. Students engage in whole class consensus discussions, in which they support arguments for their scientific explanations and revise explanations based on others' arguments.
Disciplinary Core Ideas	<ul> <li>ETS1.A: Defining and Delimiting Engineering Problems</li> <li>The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions.</li> <li>PS4.A: Wave Properties</li> <li>A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.</li> <li>A sound wave needs a medium through which it is transmitted.</li> </ul>	In this lesson, students are introduced to the design problem and the associated criteria and constraints. In later lessons, students further refine their criteria and constraints based on science ideas developed throughout the module.  Students engage in significant work related to PS4.A. Ideally, students should have already explored mechanical waves, such as waves in water, prior to engaging in this exploration of sound waves.  In this lesson, students create models for how sound waves are generated and how the waves travel through air.  Students consider the ways by which changes in energy can change the amplitude of a sound wave.

		Students also gain an initial understanding of the idea that sound waves must travel through a medium (in this case, air).
Crosscutting Concepts	Influence of Science, Engineering, and Technology on Society and the Natural World  • The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.  Systems and System Models  • Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems.	The goal of the design challenge is to minimize the noise inside an airplane cabin. The problem (noise in the cabin) is related to using the technology of flight and is driven by societal desires to have a quieter flight experience.  When students develop their initial model for how sound waves travel, they use the model to represent a system and how energy flows from one part of the system to another.



## **Basic Teacher Preparation**

This lesson sets the stage for much of the exploration and concept discussion that occurs later in the module. To prepare to introduce the design problem, build a prototype cabin prior to class. See the Suggested Teacher Resources for this lesson for detailed instructions.

Students need to be organized into design teams of three or four. They work in their design teams throughout this module. Establish these teams before beginning the first lesson.

Review the <u>Talk Science Primer</u>, the <u>Transmission of Sound Designmaster</u> video, and the <u>ScienceMan Sound Waves</u> video to help you prepare to lead the class consensus discussions.

Make a copy of the Design a Quieter Cabin Student Handbook for each student in your class. Bind the Design a Quieter Cabin Student Handbook so it will last throughout the module. You may find it helpful to give students a daily "stamp" of completion as they work through the lessons. Refer to the Design a Quieter Cabin Student Handbook ahead of time so you can address any questions students might have. All Day 1 documents can be found on pages 1–4 in the Design a Quieter Cabin Student Handbook. The documents used in this lesson are:

- Engineering Design Process (page 1)
- Introduction to the Engineering Design Problem (page 2)
- Engineering Design Problem (page 3)
- How Airplane Engines Make Sound (page 4)

Required Preparation		Links/Additional Information	
	Sather or purchase the required materials or the lesson	Refer to the Materials List below	
Q	Download, print, and copy the Design a Quieter Cabin Student Handbook (1 copy or each student)	Design a Quieter Cabin Student Handbook [Resource Link]	

Review the videos, software, and resources in the Suggested Teacher Resources	Refer to the Suggested Teacher Resources at the end of this lesson
Build a cabin model to demonstrate the model to students	Refer to the Suggested Teacher Resources at the end of this lesson



# Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Design a Quieter Cabin Student Handbook	Download, print, copy, and bind	1 per student	[Resource Link]
Audio source	Phone or mp3 player to provide signal to speaker (a small PA system [audio amplifier] makes a more impressive effect, as depicted in the How To video)	1 per class, or more if there will be multiple testing sites	Small PA system available in some schools, or bring phone or mp3 player from home
Decibel meter		1 per class, or more if there will be multiple testing sites	Decibel meter [Web Link]
PVC pipe selection	4 inches diameter x 4 inches length	1 per class (more if multiple testing sites will be set up)	PVC pipe [Web Link]
PVC cap	4 inches diameter x 4 inches length	1 per class (more if multiple testing sites will be set up)	PVC cap [Web Link]
Cardboard	4 inches diameter with a hole in the middle to insert the decibel meter	1 per class (more if multiple testing sites will be set up)	Office supply store
Box fan	Any size fan large enough for the entire class to see	1 per class	Local store
Slinky		1-3 per class	Slinky [Web Link]
Pebble or marble		1 per team	Marbles [Web Link]
Sink or container	For holding water	1 per team	Bucket [Web Link]

## Day 1: How Sound Travels Away from an Airplane Engine



### Introduction (10 minutes)

Begin the module by explaining that students will assume the roles of engineers who have been hired by an airline to minimize the amount of engine noise passengers hear when they are inside an airplane cabin. As engineers, students must develop and test prototype airplane cabins (using PVC pipe) that are quieter than existing airplane cabins. Introduce students to the Driving Question for the module:

How can we design a quieter airplane cabin for airline passengers?

Post the Driving Question to the Driving Question Board (DQB).

Tell students they will work through the engineering design process as they design quieter airplane cabins. Review the Engineering Design Process on page 1 in the Design a Quieter Cabin Student Handbook (also available in Appendix A).

To help students think more deeply about the design problem, have students respond individually to the first Introduction to the Engineering Design Problem prompt on page 2 in their Design a Quieter Cabin Student Handbook. The prompt is:

 Once seated in an airplane, what are some of the sounds passengers might hear coming from outside of the aircraft?

If some students have never flown in an airplane, play the <u>Boeing 777 takeoff</u> video. Guide students to listen closely to hear the various sounds.

Once students complete their responses in their student handbooks, have them share their ideas with the class.



#### **Important Note**

The Driving Question Board is used throughout the module to guide student learning. Make sure the DQB is placed in a prominent location and can be easily accessed by students.



## NGSS Key Moment

Engineers often refer to the engineering design process when they discuss their work. In NGSS, the Science and Engineering Practices are used in place of the engineering design process. Students should understand that the engineering design process is not linear in practice. Rather, engineers engage in all of the steps, often jumping between steps. Students may want to think of the engineering design process as a web of practices.



#### Video Link

Show the 1 minute portion from 5:00–6:00.

Boeing 777 takeoff [YouTube Link]

Share with students that aircraft manufacturers go to great lengths to ensure the comfort of their passengers. This includes shielding the cabin (the area where the people sit) from exterior sounds. Instruct students to take several minutes of silent response time to individually respond to the

second Introduction to the Engineering Design Problem prompt on page 2 in their Design a Design a Quieter Cabin Student Handbook. The prompt is:

 Describe how you think airplane cabins are constructed to keep out as much sound as possible.

Give students several minutes to share their responses with their design teams. Each student should record their team's responses below the third Introduction to the Engineering Design Problem prompt on page 2 in their Design a Quieter Cabin Student Handbook. The prompt is:

• Describe how you think airplane cabins are constructed to keep out as much sound as possible. Shared team responses:



#### Extension

As an optional extension, consider having students read more about creating quieter airplane cabins.

- Quieter Airplanes through Science [Web Link]
- ► The Quiet Cabin: No Simple Solution [Web Link]
- ▶ BBC: How to Cut Noise in a Plane Cabin [Web Link]



### Design Work: The Design Problem (10 minutes)

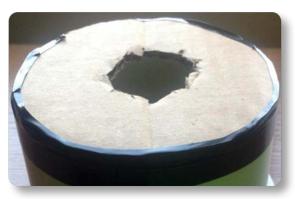
Tell students their engineering design challenge is to shield a passenger's ears (represented by a decibel meter) from exterior sounds (represented by a sound source 3 feet away). The cabin that surrounds the passenger will be a 4-inch length of a 4-inch diameter piece of PVC pipe (see Figure 1). Directions for setting up the model cabin are provided in the **Suggested Teacher Resources** for this lesson.

Demonstrate the use of the decibel meter by having all students clap or stomp. Show students the reading on the decibel meter. Have students repeat the sound three times and take an average reading. Discuss with students why the decibel meter readings varied.

Show students the cabin model and the final testing setup (see Figure 2, PVC Cabin Placed in Cap, and Final Setup). Refer to the Cabin Assembly Guide in the Suggested Teacher Resources at the end of this lesson for directions for cabin assembly. Place the decibel meter in the cabin. Have students repeat the sound and show the new decibel reading. Repeat three times and take an average reading. Discuss with students why the readings inside the cabin differed from the readings outside the cabin.



▲ Figure 1



▲ Figure 2



▲ PVC Cabin Placed in Cap



▲ Final Setup

After demonstrating the cabin model, refer students to the Engineering Design Problem on page 3 in their Design a Quieter Cabin Student Handbook. Review the initial constraints of the engineering design problem:

- You have a \$10,000 budget to add materials to the interior of an airplane cabin to make it more resistant to sound.
- All materials must be fastened or laid inside the cabin so they are no more than 1.5 inches away from the container's walls.
- Materials can be placed on the cardboard lid, but the height of the lid should not exceed .5 inches.
- At no point should the material come in direct contact with the decibel meter.
- You must consider the properties, cost, and placement of each material.
- You must justify all design decisions using science ideas developed throughout the module.



### Whole Group Discussion: Our Questions (10 minutes)

Tell students they need to know more about the engineering design problem before beginning the design work. Have students develop a list of questions about the design problem. Start by developing one question as a class and then have students work with their design teams to develop the remaining questions. Questions might include:

- How does the engine of a plane make sound?
- How does sound travel from the engine to passengers' ears?
- How does sound travel through cabin walls?
- What materials block or amplify sound?
- Do we need to block all sounds?

Engage the class in a whole group discussion. The goal of this discussion is to organize student questions into a few main categories. Start by having students share the questions developed by their design teams. Guide students to categorize the questions into a few main categories. Guide the class to reach consensus about the categories.

At a minimum, develop the following three categories, although additional categories might emerge:

- How does sound travel from an airplane engine to the outside of the cabin?
- How does sound travel through cabin walls?
- How does sound travel from the cabin wall to passengers' ears?

Tell students that these three (or more) questions will drive their work over the next several days. In addition, these questions will help students answer the overarching Driving Question, *How can we design a quieter airplane cabin for airline passengers?* Post the questions on the DQB so students can clearly see them. Leave space under the questions to add sticky notes.

#### **DRIVING QUESTION BOARD**

How can we design a quieter airplane cabin for airline passengers?

How does sound travel from an airplane engine to the outside of the cabin?

How does sound travel through cabin walls?

How does sound travel from a cabin wall to passengers' ears?



## **Investigation: How Airplane Engines Make Sound (15 minutes)**

Tell students they are going to start with the first question, *How does sound travel from an airplane engine to the outside of the cabin?* First, students consider how airplane engines generate sound. Next, students consider how sound travels from an engine to an airplane cabin.

Begin the investigation by asking students to think about how they think airplane engines make sound. Consider showing students an image of an airplane engine. Instruct students to record their ideas in the How Airplane Engines Make Sound space provided on page 4 in the Design a Quieter Cabin Student Handbook.

Set up a fan so all students can see it. Tell students that the fan operates in a similar way to an airplane engine. Turn the fan on low and instruct students to listen carefully to the sound produced by the fan.

Instruct students to develop an initial model to explain how turning on an airplane engine creates sound that we can hear. Prompt students to think about this phenomenon in terms of the particulate nature of air. Remind students that in 5th grade, they should have developed the idea that air is made of particles too small to see and air particles move freely around in space. Tell students to use these ideas in their initial model. At this point in the lesson, student models do not have to be "correct." Rather, this modeling activity is designed to draw out student ideas.



## NGSS Key Moment

To develop explanations for how a fan produces sound, students must have made grade-appropriate progress on PS1.A. Specifically, students should understand that air is made of particles that are too small to see and move freely around in space. Students should also have a beginning understanding of the science ideas related to air pressure. In this exercise, students build on science ideas related to PS1.A by arguing that the air particles move when the fan turns and our ears somehow "feel" that movement.

As students begin creating their models, prompt them to explain how the sound travels from the engine to their ears. At this point, students do not need to know how the ear processes the sound.

As students work on their models, they will likely generate new questions. Prompt students to include a section of the model called "Questions I still have" and to list their questions.



## Lesson Close (5 minutes)

Give students several minutes to share their initial models with their design teams. Students should share their reasoning and explanations. Encourage students to revise their own models after sharing with their classmates. During Day 2, students continue to work on their models.

## Day 2: How Sound Travels Away from an Airplane Engine



## Introduction (5 minutes)

Tell students they are going to revisit their models for how an airplane engine makes sound. At the end of Day 1, students shared their models with their teams. Students should have revised their models based on their team's input. Instruct students to share their revisions with their teams.



# Whole Class Discussion: How Airplane Engines Make Sound (15 minutes)

Gather students in a circle for a whole group discussion. Remind students that their goal is to develop a model to explain how an airplane engine (or fan) generates sound. Their models should use science ideas related to the particulate nature of air.

The goal of the whole class discussion is to come to a class consensus model about how the fan generates sound. During the discussion, encourage students to share, challenge, and revise their ideas.

By the end of the discussion, students should have generated a class consensus model that



#### NGSS Key Moment

Whole group discussions, particularly consensus discussions, can be an effective way to engage students in the science practices of *argumentation* and *explanation*. Leading whole group discussions requires proper preparation. Refer to the <u>Talk Science Primer</u> for useful strategies.

demonstrates that the fan causes a change in the movement of particles (in this case, air particles). The change in the movement of particles travels to our ears, and our ears "feel" the change. Students should conceptually understand that sound is a longitudinal wave. Once students have developed the concept of a longitudinal wave, give students the word *longitudinal* to refer to sound waves.

During the discussion, new questions might emerge. Capture these questions on the consensus model as "Questions we still have."

The <u>Transmission of Sound—Designmaster</u> video and the <u>ScienceMan Digital Lesson—How Sound Waves Travel</u> video can help you prepare to lead the class consensus discussion. The videos also help in Days 3 and 4, as students consider the ways by which sound waves travel through liquids and solids. You might want to use clips of these videos to support the class during their consensus discussion, but recognize that the core science ideas should be generated by the students.



#### Video Links

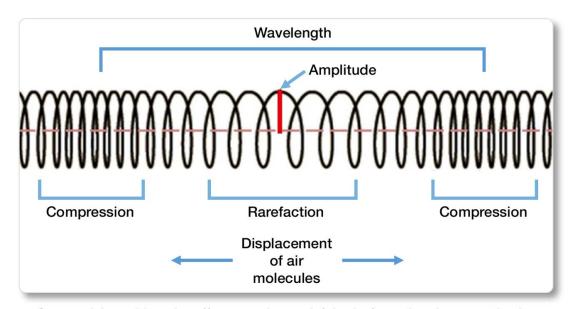
- Transmission of Sound —Designmaster [YouTube Link]
- ScienceMan Digital Lesson—How Sound Waves Travel [YouTube Link]



# Investigation: Model Longitudinal Waves with a Slinky® (10 minutes)

To further expand on the idea of a longitudinal wave, model longitudinal wave behavior with a Slinky. Direct two students to lay a Slinky<sup>®</sup> flat on the floor and apply slight tension to each side. Have the rest of the class gather around the students. While one of the two students tightly holds the Slinky<sup>®</sup> against the floor, have the other student push forward so the energy from the student's hand is transferred into the Slinky. As the energy moves throughout the Slinky, facilitate a discussion relating the Slinky to sound waves.

You might want to touch on key vocabulary, but the most important takeaway for students is to develop a conceptual understanding of how waves work.



Source: Adapted from http://www.studypage.in/physics/sound-and-communication

After the initial demonstration, ask the class how the two students on the floor could increase the amplitude of the wave. Tell students *amplitude* refers to the distance a Slinky coil travels away from its resting position. The students should test their classmates' theories until they add additional energy by giving the Slinky a harder push. Manipulating wavelength or other properties can also be demonstrated in this fashion.

Keep in mind that students should be demonstrating longitudinal waves, as they might consider ways to change the wave by making it a transverse wave (moving the Slinky up and down as opposed to pushing it).

Relate the discussion back to sound waves. Help students consider the idea that when energy increases, the amplitude of a wave increases. Relate this finding to a discussion about sound volume.



Teaching Channel



#### Investigation: How Sound Waves Travel (5 minutes)

Ask students to think about how a sound wave travels from its source. Organize students into their design teams to drop a marble or a pebble into a small body of water (sink or container). It should be wide enough to allow the students to witness the ripple effect and the energy flow away from the center. Engage students in a discussion in which they consider the following questions:

- What happens to the energy of the water when you drop the pebble into the water and the wave spreads out from the source of the ripple?
- How is this similar to sound energy as it travels through the air after being generated by an airplane engine?



#### Extension

During the discussion, listen for students' current understanding of wave properties, especially how they travel. If students exhibit confusion or uncertainty, strongly consider including the **Day 3: Shake, Rattle, and Roll (Optional Extension)**.



#### Lesson Close (15 minutes)

Ask students to revise their models to show how sound waves travel. For now, focus only on the volume (or amplitude) of the source (On Day 7, students explore the relationship between amplitude and frequency, and how the human ear "hears" each). As students work on their models, they will likely generate new questions. Prompt students to include a section of the model called "Questions I still have" and to list their questions.

Reference the lesson question on the DQB, *How does sound travel from an airplane engine to the outside of the cabin?* Ask students if they think they made progress in answering the question. Tell students to record their progress on sticky notes. They should answer the question with as much evidence as they can. When students are finished, have them read their sticky notes out loud to the class and post them to the DQB.

Listen to students read their sticky notes, and/or read the sticky notes that students post to assess their progress in answering the questions on the DQB.



#### **Assessment**

Several opportunities for formative assessment exist in this lesson:

- Design a Quieter Cabin Student Handbook entries can be used to monitor student progress during the module.
- Initial student models on page 4 can be used to track student progress on the key physical science performance expectations.

 Consider gathering evidence of student progress through small group and whole group discussions.

Student contributions to the Driving Question Board can be monitored.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.



## **Community Connections**

Connect with the 5<sup>th</sup>-grade students who are working on (or who have already developed) an understanding of PS1.A. Have students share their ideas about how sound waves travel through air particles, which are too small to see and freely moving.



#### **Suggested Teacher Resources**

Engineering Design Process	Design a Quieter Cabin Teacher Handbook, Appendix A	
Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B	
Design a Quieter Cabin Student Handbook	[Resource Link]	
Talk Science Primer	[Web Link]	
Boeing 777 takeoff video	[YouTube Link]	
Transmission of Sound—Designmate (video)	[YouTube Link]	
ScienceMan Digital Lesson—How Sound Waves Travel (video)	[YouTube Link]	
Quieter Airplanes through Science	[Web Link]	
The Quiet Cabin: No Simple Solution	[Web Link]	
BBC How to Cut Noise in a Plane Cabin	[Web Link]	



### Cabin Assembly Guide

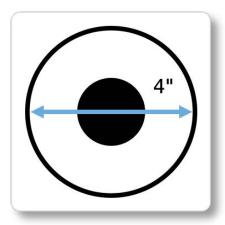
The "cabin" that surrounds the passenger will be a 4-inch length of a 4-inch diameter piece of PVC pipe (see Figure 1). To make the PVC cabin, visit the local hardware store and have 4-inch lengths of 4-inch diameter PVC pipe cut.

Next, cut a 4-inch diameter circle out of cardboard and cut a hole in the middle to allow for the insertion of the decibel meter (see Figure 2). The hole should be just large enough to allow for the insertion of the decibel meter. Use any tape to fasten the cardboard to the PVC pipe (see Figure

3). On the other end of the PVC pipe, place a PVC cap. The PVC cap can be purchased at a local hardware store.



▲ Figure 1



▲ Figure 2



▲ Figure 3



▲ PVC Cabin Placed in Cap



▲ Interior of Completed Test Cabin



▲ Final Setup

# Design a Quieter Cabin

## Day 3: Shake, Rattle, and Roll (Optional Extension)

Grade Level	Early Middle School (Grade 6)
Lesson Length	One 50-minute session



#### **Lesson Overview**

In this optional Day 3 extension, students further explore the idea that energy can flow from one form to another as they continue to build their understanding of sound generation and transmission in preparation for their final design challenge of designing a quieter airplane cabin. As part of this extension, students examine sound waves created with simple electromagnetic tools. Eventually, they create a very simple speaker using a paper plate. Connecting energy flow and transfer to students' experiences building a speaker out of a paper plate deepens the conceptualization of energy transfer and flow for students.



#### Helpful Tip

The Day 3: Shake, Rattle, and Roll (Optional Extension) can be used to help students develop an understanding of the concepts of energy transfer and wave amplitude. Consider including this day if students need extra support understanding waves. It can also be included to provide students with experience engaging in a design "build." This may help students with their design solution builds throughout the unit.



## **Connecting to the Next Generation Science Standards**

On Day 3, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Planning and Carrying Out Investigations
- Disciplinary Core Ideas: PS4.A Wave Properties
- Crosscutting Concepts: Energy and Matter: Flows, Cycles, and Conservation, Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

#### **Performance Expectations**

This lesson contributes toward building understanding of the following *physical science* performance expectations:

MS-PS4-1. Use mathematical representations to <u>describe a simple model for waves that includes how</u> the amplitude of a wave is related to the energy in a wave.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

#### Specific Connections to Classroom Activity

This lesson can be used as an optional lesson to reinforce the ideas of energy transfer and wave properties. Students design a speaker to show that electrical energy can be transferred to sound energy. Students also realize that sound waves can be transmitted through materials, such as paper plates. Finally, students explore the relationship between wave amplitude and energy by pouring sand on their paper plate speakers.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	Planning and Carrying Out Investigations  • Collect data about the performance of a proposed object, tool, process or system under a range of conditions.	Students generate a speaker model to test differences in wave amplitude. Students collect qualitative data on the performance of the speaker under a range of conditions.
Disciplinary Core Ideas	<ul> <li>PS4.A: Wave Properties</li> <li>A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.</li> <li>A sound wave needs a medium through which it is transmitted.</li> </ul>	Using the speaker and sand poured on a paper plate, students explore what happens when they turn up the volume of a speaker. Through this investigation, students recognize the relationship between energy and amplitude. Students also realize that sound waves can be transmitted through various materials, such as a paper plate.
Crosscutting Concepts	<ul> <li>Structure and Function</li> <li>Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.</li> <li>Energy and Matter: Flows, Cycles, and Conservation</li> <li>Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).</li> <li>The transfer of energy can be tracked as energy flows through a designed or natural system.</li> </ul>	As students build paper plate speakers, they recognize the relationship between structure and function of the speaker.  In this lesson, students consider how energy is transferred from one form to another.  Students construct a device (the speaker) that is capable of demonstrating energy transfer.



## **Basic Teacher Preparation**

Before students can design and build their quieter airplane cabins, they need to understand how sound is generated and travels, and how energy can be transferred from one form to another.

During Day 3, students gain an understanding of how energy is converted from one form to another by building paper plate speakers. This allows students to see the actual wave action.

Preparation needs to be done prior to class. Review the <u>Speaker Build</u> video prior to instruction. Check the following <u>Materials List</u> for necessary components and preparation guidelines.



The <u>Speaker Build</u> video is 15 minutes long. Preview it before class, and choose sections to show, or demonstrate the build for students yourself. Consider making a student handout with build instructions.

Required Preparation		Links/Additional Information	
	Gather or purchase the required materials for the lesson	Refer to the Materials List below	
	Review suggested teacher preparation resources	Refer to the Suggested Teacher Resources at the end of this lesson	



## **Materials List**

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Paper plates	Used to build speakers	1 or 2 per team	Local store
Styrofoam plates	Used to build speakers	1 per team	Local store
Plastic plates	Used to build speakers	1 per team	Local store
AAA batteries		1 per team	Local store
AA batteries		1 per team	Local store
C batteries		1 per team	Local store
D batteries		1 per team	Local store
Plain paper	For speaker mount	A few sheet per team	Available in schools
Rare earth magnets	For speakers, 20 in a pack	1-3 per team	General option online [Web Link]
.5-inch wood dowel	Can be cut into several sections	1 per team	Wood dowel [Web Link]
Colored sand	Used to show sound waves on paper plate speaker	Small amount (1 tablespoon) per team	Colored sand [Web Link]

Headphone extension cable	Cut cables in half	Half a cable per team	Headphone extension cable [Web Link]
Simple DC motors	Can use to explore and/or harvest materials	1 or 2 per team	DC motor [Web Link]
Hot glue gun and glue	To assist with speaker build and other activities in the module	1 per class	Hot glue gun and glue [Web Link]
Audio source	Phone or mp3 player to provide signal to speaker; small PA system (audio amplifier) makes for a much more impressive effect (as depicted in the Speaker Build video)		Small PA system available in some schools, or bring phone or mp3 player from home
Decibel meter		1 per class, or more if there will be multiple testing sites	Decibel meter [Web Link] (used Day 1)

## Day 3: Shake, Rattle, and Roll (Optional Extension)



## Introduction (5 minutes)

Pose the following question to students. Engage in a whole class discussion to answer the question.

• Pretend you are listening to a radio that is plugged into the wall. Model the flow of energy from the wall outlet to your ear. How many changes occur in this system?

Explain to students that today's activities will help them refine their response to this question. Tell students that in previous lessons, they explored the movement of sound waves. In this lesson, they will focus on the energy aspects of sound.



# Investigation: How to Build a Paper Plate Speaker (15 minutes)

Explain to students that they are going to work with their design teams to create a speaker to learn more about how sound travels. To begin, demonstrate the steps.

Next, give each team the following supplies, and then guide students through the process:

- Ruler
- Plain paper
- Rare earth magnet
- Pin or dowel slightly larger in diameter than the magnet
- Paper or polystyrene plate
- One of each battery: AAA, AA, C, D



All of the demonstrations and builds in this section can be seen in the Speaker Build video.

Speaker Build [YouTube Link]

#### First Steps

- 1. Cut a strip of paper approximately 5 inches x 1 inch.
- 2. Roll the paper to form a tube. The paper tube needs to be wide enough to slip over the magnet easily (not tight).
- 3. Tape the paper tube together. As noted in the video, the dowel can be used for support. (See the <u>Speaker Build</u> video.)
- 4. Mark the center of the backside of the paper plate with a dot.

#### **Second Steps**

- 1. Wrap wire around the paper tube near one end of the tube, leaving approximately 6 inches of wire leads at both ends, as shown in the video.
- 2. Tape the coil to the paper tube. The type of tape doesn't matter, but clear tape lets you see the coil within.
- 3. Put a magnet on a table, and slip the coil on top of the magnet.
- 4. Trim the paper tube so it is just a bit taller than the magnet, about 1 inch above the coil. The video provides a clear demonstration of this step.
- 5. Use a hot glue gun to attach the paper tube (with the attached wire coil) to the center of the paper plate.

#### Third Steps

- 1. Be sure the paper tube is over the magnet and connected to the paper plate speaker.
- 2. Touch one of the wires from the paper tube and coil to a battery. The plate will either stay in place or jump off the magnet—depending on the polarity.
- 3. Reverse the polarity, and the plate will either stay in place or jump off the magnet.



#### Helpful Tip

Reversing the polarity demonstrates the electromagnet and the permanent magnets interacting and in some cases "fighting" each other. This is an example of the energy in an electromagnet.

#### **Fourth Steps**

- 1. Connect the speaker plate to an audio source, like a phone or PA system amplifier. Several options for connections are modeled in the demonstration video. The paper plate acts like a speaker. If you use an amplifier as part of the connection, you will hear the music even better and see the plate vibrate.
- 2. Hold the speaker up slightly and at different alignments or angles. Find the angle that makes the speaker play loudest. This changes how well-aligned the magnetic field is with the battery. It also changes how much friction is between the magnets and the paper tube.
- 3. Put the coil next to the magnet to vary the distance between the magnet and electromagnetic field.
- 4. Put a small spacer (such as a cardboard disc) under the magnet to raise it a bit higher inside the coil. See how it changes the performance.



## Investigation: View Sound Waves on the Speaker (20 minutes)

Now that students created speakers, they can use them to develop a better understanding of the energy aspects of sound. Students use their paper plate speakers as a way to view sound waves.

#### Sound Wave Viewer

- Have one student from each team tightly cover their paper plate speaker with plastic wrap. Be sure the speaker is hooked up to a music source.
- Give each team a tablespoon of colored sand.
- Have students pour the sand on the wrap. Students should be able to see the sand bounce—helping students understand that this is mechanical energy.



## NGSS Key Moment

When students test what happens to the sand when they turn up the volume, they develop an understanding of the relationship between energy and amplitude (PS4.A).

 Allow students to experiment with turning up and down the volume to determine what happens to the sand Students should be able to see the sand bounce higher when the volume is louder, helping students relate amplitude to energy.

 Have students develop an explanation to describe the transfer of sound from the electrical current, to the speaker, and to the bouncing sand.



#### Extension

To extend this investigation, incorporate the Science and Engineering Practice *Planning and Carrying Out Investigations*. Have students develop ways to test the relationships among electrical energy, sound energy, and movement of sand. Have students report their findings in a consensus discussion.



## Lesson Close (10 minutes)

Relate the investigation to the design problem of designing a quieter cabin. Lead a class discussion aimed at understanding how the speaker investigation can help students with the design problem.

At this point in the module, you might want to recap information about sound waves. The <a href="Transmission of Sound—Designmaster">Transmission of Sound—Designmaster</a> and <a href="ScienceMan Digital Lesson—How Sound">ScienceMan Digital Lesson—How Sound</a> <a href="Waves Travel">Waves Travel</a> videos provide grade-level appropriate information about sound waves. <a href="Preview and choose one to show to the class,">Preview and choose one to show to the class,</a> if time permits. After viewing the video—summarize some key points from all the activities students have experienced thus far in the module.



#### Video Links

- Transmission of Sound —Designmaster [YouTube Link]
- ➤ ScienceMan Digital Lesson—How Sound Waves Travel [YouTube Link]

#### Key points:

- Energy can change forms. Examples of various kinds of energy can include mechanical energy, electric energy, and sound energy—all forms explored in this module.
- Energy can flow from one form to another. Can students provide some examples of how various forms of energy flowed from one form to another form, such as wind turbines, motors, generators, and sound systems?
- Other types and forms of energy exist that we have not explored in this module (such as light energy, heat energy, gravitational energy, atomic energy, chemical energy, and so forth). Do students think these forms of energy can be transferred into a different form? If yes, could that be put to good use?



#### **Assessment**

Several opportunities for formative assessment exist in this lesson:

- Consider gathering evidence of student progress through small group and whole group discussions.
- Consider adding an exit ticket for students to demonstrate their understanding of how energy flows from one form to another and to provide an opportunity to ask any unanswered questions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.



#### **Community Connections**

Students may have family members who work with sound or sound systems. Ask students to bring in anecdotal examples about how their family member's understanding of sound energy impacts their work.



## **Suggested Teacher Resources**

Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B	
Speaker Build	[YouTube Link]	
Transmission of Sound—Designmate	[YouTube Link]	
ScienceMan Digital Lesson—How Sound Waves Travel	[YouTube Link]	

# Design a Quieter Cabin

## Days 4 and 5: How Sound Travels through Cabin Walls

Grade Level	Early Middle School (Grade 6)
Lesson Length	Two 50-minute sessions (if possible, consider adding another day)



#### **Lesson Overview**

On Day 4, students engage in a modeling activity and an investigation to determine how sound waves travel through solids. Through the investigation, students realize it is easier for sound waves to travel through solids than through air. Students test a variety of solids to determine which solids best transmit sound waves.

On Day 5, students build on the ideas developed on Day 4 to design, test, and redesign a tin can telephone. Students consider the science ideas behind their design choices and modifications.



### Connecting to the Next Generation Science Standards

On Days 4 and 5, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Developing and Using Models, Engaging in Argument from Evidence
- Disciplinary Core Ideas: ETS1.B Developing Possible Solutions, PS4.A Wave Properties
- Crosscutting Concepts: Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

#### **Performance Expectations**

This lesson contributes toward building understanding of the following *engineering* performance expectations:

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

This lesson contributes toward building understanding of the following *physical science* performance expectations:

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

#### **Specific Connections to Classroom Activity**

On Days 4 and 5, students engage in an investigation exploring how sound waves travel through solids as compared to gases. Students compare various materials to show how sound waves travel through each material. As a mini-design challenge, students design, test, and redesign tin can telephones. By testing different materials to use in the telephone, students develop an understanding of which materials best transmit sound waves. Further, students develop an understanding that design solutions must be built, tested, and revised. Both understandings will be essential for the final design challenge of designing a quieter cabin.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	<ul> <li>Developing and Using Models</li> <li>Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.</li> <li>Develop and use a model to describe phenomena.</li> <li>Engaging in Argument from Evidence</li> <li>Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.</li> </ul>	Students engage in two types of modeling in this lesson. First, students model, with their bodies, how a sound wave might travel through solid, liquid, and gas. Second, students develop written models to explain how a sound wave travels through an airplane cabin wall.  When students initially consider the idea of a sound wave traveling through a solid, liquid, or gas, students develop a hypothesis about whether it will be easier for the sound wave to travel through a solid. Students argue their side before testing their hypothesis.
Disciplinary Core Ideas	<ul> <li>ETS1.B: Developing Possible Solutions</li> <li>A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.</li> <li>PS4.A: Wave Properties</li> <li>A sound wave needs a medium through which it is transmitted.</li> </ul>	When students design the tin can telephones, they test, modify, and retest their design solutions.  On Days 4 and 5, students engage in a series of investigations and modeling activities to develop the idea that sound can be transmitted through different mediums and sound waves behave differently in different mediums.
Crosscutting Concepts	Structure and Function  • Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.	Students experiment with structure and function relationships when they design their tin can telephone. Students consider the intended functions of the phone in order to determine the materials used for the structure.



### **Basic Teacher Preparation**

Ensure all supplies are laid out. Students need to have access to the proper measuring equipment and other supplies. Review the <u>Talk Science Primer</u> to prepare for leading class discussions.

Refer to the Design a Quieter Cabin Student Handbook ahead of time so you can address any questions students might have. All Day 4 and 5 documents can be found on pages 5–8 in the Design a Quieter Cabin Student Handbook. The documents used in this lesson are:

- How Sound Travels through Materials (page 5)
- How Sound Travels from an Airplane Engine to *Inside* the Cabin (page 6)
- Design Challenge: Can You Hear Me Now? (pages 7 and 8)

Required Preparation		Links/Additional Information	
C	Gather or purchase the required materials for the lesson	Refer to the Materials List below	
C	Review suggested teacher preparation resources	Refer to the Suggested Teacher Resources at the end of this lesson	



# **Materials List**

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Tin cans	Standard 12-inch	2 per team	Have students bring from home or buy online [Web Link]
Disposable plastic cups		2 per team	Plastic cups [Web Link]
Disposable polystyrene cups		2 per team	Polystyrene cups [Web Link]
Masking/duct tape		1 roll per team	Hardware store
Nail		1 per team	Nails [Web Link]
Hammer	Lightweight	1 per team, or 1 for instructor use	Hammer [Web Link]
Yarn		1 skein of yarn per class	Craft store
Kite string		1 roll per team	Kite string [Web Link]
Fishing line		1 spool	Fishing line [Web Link]
Aluminum foil		1 roll	Local store
Plastic wrap		1 roll	Local store
Wax paper		1 roll	Local store
Corkboard		1 pack per class	Cork tiles [Web Link]
Rubber liner		1 roll	Rubber liner [Web Link]
Heavy duty trash bag		1 box	Local store
Cotton washcloth or T-shirt fabric			Local store or thrift shop
Cotton balls		1 bag	Local store
Duct tape		1 roll	Local store
Masking tape		1 roll	Office supply store
Playdoh® or modeling clay		1 large tub	Local store

## Day 4: How Sound Travels through Cabin Walls



## Introduction (5 minutes)

Reference the Driving Question Board. At this point in the module, students should have a good sense of how airplane engines produce sound and how sound travels to the cabin wall. Tell students that their goal now is to figure out how sound travels through the cabin wall.

Remind students that we know that sound waves travel through air because the sound waves vibrate air particles. Also remind students that solids and liquids are also made up of particles, but the particles are more closely packed. The particles in solids are very tightly packed, and the particles in liquids are not packed as tightly as solids but are packed more tightly than air (or gas). The goal in today's lesson is to figure out how sound moves through various materials.



# Whole Group Discussion: How Sound Travels through Cabin Walls (10 minutes)

Using their bodies to represent particles, have students model how a sound wave travels through air. To do so, students should stand with about an arm's length apart from other students. The teacher should model the source of the sound. As the sound wave travels, students should model the spread of the vibration. Because students are standing far apart from one another, it should be difficult (but still possible) to pass the vibration along.

Next, have students move closer together to represent a liquid. Ask students what they think will happen when a sound wave travels through a liquid. Students may say it is easier for the sound wave to travel in the liquid because the particles are closer together. Students may also argue it is harder for a sound wave to travel through a liquid (likely based on personal experience or developing conceptions). Some students may argue that the sound wave stays the same. Draw out all three stances and encourage students to support their stances.

Continue the modeling activity by modeling how a sound wave passes through a solid. Again, encourage students to present arguments for all three stances (easier, harder, or stays the same). In the upcoming investigation, students investigate what happens when sound travels through solids and gases.



#### NGSS Key Moment

Students should present their ideas for how sound waves travel through different materials because it motivates the next investigation. In the next investigation, students experiment with various materials to determine how sound waves travel. By presenting arguments and testing them, students engage in the practices of modeling, argumentation, explanation, and investigation.



# Investigation: How Sound Travels through Cabin Walls (10 minutes)

Tell students they are going to investigate what happens to sound waves when they pass through various materials. At this point, some students might feel strongly that it is harder for sound waves to pass through a solid than a gas, some might believe it's easier for sound waves to pass through a solid, and some might believe that there is no difference between a solid and a gas.

Tell students that to test their hypotheses, they will tap on different materials, such as a desk, and listen with their ear pressed against the material (to hear a sound wave traveling through a solid) and then with their ear in the air (to hear a sound wave traveling through a gas). Prompt students to consider what kinds of evidence they might find to indicate whether it's easier for sound waves to travel through a solid or gas.

Have students test how sound travels through solids. Instruct students to work in pairs. One student closes his or her eyes while the other taps lightly on the material or desk. Next, the listening student places his or her ear against the material or desk while the other student taps lightly again. Students then switch roles.

Ask students to discuss what they heard. Students should notice that they heard the sound more easily when their ear was pressed against the material or desk. This provides evidence for the stance that sound waves travel through solids more easily than through gases. To reinforce the point, have students model (with their bodies) how sound waves move through solids.



# Investigation: How Sound Travels through Various Materials (20 minutes)

Allow students time to explore how sound travels through different types of materials. Provide students with the materials that will be available to them in the design challenge (cotton balls, corkboard, and so forth). Instruct students to conduct tests to compare the materials to each other. Students can manipulate variables as they see fit. For instance, students can tap on the materials or place a speaker behind the material. Students should record notes the on How Sound Travels through Materials on page 5 in their Design a Quieter Cabin Student Handbook. Encourage students to include notes that explain why they think sound travels through some materials better than others.



#### NGSS Key Moment

This investigation is a key investigation for helping students develop an understanding of PS4.A. Students explore the ways different materials transmit sound waves and develop ideas about why some materials may be better than others. This investigation is also key because it helps students link the science ideas embedded in PS4.A back to the design problem.

Remind students their goal is to find a material that can prevent sound from entering the cabin.

Now that students have developed an understanding for how sound travels through solids, instruct them to develop a revised model for how sound travels from an airplane engine to inside the cabin. Direct students to How Sound Travels from an Airplane Engine to *Inside* the Cabin on page 6 in their Design a Quieter Cabin Student Handbook. Have students incorporate components of their previous models in the current model.



## Lesson Close (5 minutes)

Reference the lesson question on the DQB, *How does sound travel through cabin walls?* Ask students if they think they made progress in answering the question.

Tell students to record their progress on sticky notes. They should answer the question with as much evidence as they can.

When students are finished, have some read their sticky notes out loud to the class and post them to the DQB.

Listen to students read their sticky notes or read the sticky notes posted by students to assess their progress in answering the questions on the DQB.

## Day 5: How Sound Travels through Cabin Walls



#### Introduction (5 minutes)

Begin today's lesson by having students share their models on page 6 in the Design a Quieter Cabin Student Handbook with their design teams. Students should revise their models based on their team's feedback.

Prompt students to discuss how their models inform their understanding of designing a quieter cabin, which is their ultimate design challenge.

Tell students they are going to engage in an engineering design challenge that builds on their understanding of how sound travels. Have students sit with their teams as they watch the Man vs. Wild: Big Sky Country Tunnel video. Discuss the following question:

 How can people tell that a train is coming by touching a railroad track with their hands before they can hear the same train with their ears?



Show the portion from 1:15-2:15

Man vs. Wild: Big Sky Country Tunnel [YouTube Link]



#### Investigation: How to Design a 20-Foot Telephone Line (10 minutes)

Explain to students that they are to create a simple speaker/microphone system. Their goal is to choose the best available materials to use for the speaker/microphone along with a 20-foot telephone line. Display the available materials for students (tin can, plastic cup, polystyrene cup, fishing line, kite string, and yarn). Direct students to draw their Individual Design on page 7 in the Design a Quieter Cabin Student Handbook. As part of their individual design, students must justify their choices. Justifications must include science ideas developed on Days 1 through 4. Students should specifically reference evidence from Day 4. Remind students to include labels and measurements with their drawings.

Have students take turns in their design teams to share their designs and reasons for their selected materials. Design teams must then come to consensus on a team design.

Each student must draw the Team Design (with labels and measurements) and record the team rationale for their choices of materials on page 7 in their Design a Quieter Cabin Student Handbook. Each team must have the teacher sign off on their design before beginning construction.



Ensure that each student has a safe and uninterrupted environment in which they can share their designs and justifications.



# Design Work: Build and Test a String and Cup Telephone (10 minutes)

Students construct their initial telephone solutions. This is done by using a nail to poke a small hole in the center of the bottom of each cup or can. Students then use their choice of "telephone wire" to thread through each hole and tie a knot on each end.

Have students pull the telephone wire taut. Then, one student speaks into one of the cups while the other student listens through the cup on the other end of the wire. Students then reverse roles. Instruct students to record their Initial "Telephone Solution" Observations on page 8 in their Design a Quieter Cabin Student Handbook.



▲ String and Cup Telephone



### Helpful Tip

- You might want to use the hammer and nail prior to class to puncture the cups and cans.
- ➤ Students might want to use the nail to help thread their choice of "wire" through their cups or cans.
- Students might need to use tape over the knot to ensure the wire does not slide through the hole.



### Design Work: Team Discussion and Redesign (10 minutes)

Have students take turns with their team members and share their observations from the previous test. Ask students to think about which materials they might change and why. Remind students to manipulate only one variable at a time so they can determine the impact of the change on the effectiveness of their telephone. The new material selection for one of the components should then be discussed with team members, using the same process as before.

Once the team has reached a consensus, they should diagram and explain the Team Redesign "Telephone Solution" on page 9 in their Design a Quieter Cabin Student Handbook. Teams must have their redesigns signed off by the teacher before beginning construction.



### Design Work: Rebuild and Test a Second Telephone (10 minutes)

Have students construct a second iteration of their telephone solutions. Once students have completed constructing their second iterations, have them test their redesigns. Students pull their telephone wires taut and take turns speaking and listening through the cups. Instruct students to record their Redesign "Telephone Solution" Observations on page 8 in their Design a Quieter Cabin Student Handbook. As part of the observation, students should compare their two designs and make note of how the material change and/or modification altered the performance of their design.



#### **NGSS Key Moment**

Students need to have the opportunity to rebuild and test a second (or even a third) telephone solution. By iteratively testing and revising their designs, students build an understanding that models must be built, tested, and revised in order to reach an optimal design (ME-ETS1-4).



### Lesson Close (5 minutes)

As a class, have students share the modifications and results they recorded in their **Design a Quieter Cabin Student Handbook.** Have students identify common observations that occurred throughout these informal presentations. Relate the observations to the science ideas developed during Days 1–4 and to this module's design challenge.



#### Assessment

Several opportunities for formative assessment exist in this lesson:

- Design a Quieter Cabin Student Handbook entries can be used to monitor student progress throughout the module. Focus specifically on the Design Challenge: Can You Hear Me Now? on pages 7 and 8.
- Student models and notes on pages 5 and 6 can be used to track student progress on the key physical science performance expectations.
- Consider gathering evidence of student progress through small group and whole group discussions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.



## **Community Connections**

If any student's family members have a background in engineering or an audio/visual field, invite them into the classroom to assist as a volunteer or to share their work experiences related to sound generation and/or transmission.



## **Suggested Teacher Resources**

Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B
Design a Quieter Cabin Student Handbook	[Resource Link]
Man vs. Wild: Big Sky Country Tunnel video	[YouTube Link]
Talk Science Primer	[Web Link]

## Design a Quieter Cabin

## Day 6: Sounds Passengers Are Most Sensitive To

Grade Level	Early Middle School (Grade 6)
Lesson Length	One 50-minute session (if possible, consider adding another day)



#### **Lesson Overview**

Students participate in a variety of activities focusing on how humans receive sound input. Students design and conduct an investigation to answer the question, *Do we hear all pitches at the same volume?* Students figure out that humans hear certain pitches better than other pitches. Students revise their design criteria to include the idea that the airplane cabin only needs to block certain pitches.



#### Connecting to the Next Generation Science Standards

On Day 6, students make progress toward developing understanding across the following three dimensions:

- Science and Engineering Practices: Planning and Carrying Out Investigations
- Disciplinary Core Ideas: ETS1.A Defining and Delimiting Engineering Problems, LS1.D Information Processing
- Crosscutting Concepts: Structure and Function

In the following table, the specific components addressed in this lesson are underlined and italicized. The specific connections to classroom activity are stated.

#### **Performance Expectations**

This lesson contributes toward building understanding of the following *engineering* performance expectations:

MS-ETS1-1. <u>Define criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.</u>

This lesson contributes toward building understanding of the following *life science* performance expectations:

MS-LS1-8. *Gather* and synthesize *information that sensory receptors respond to stimuli* by sending messages to the brain for immediate behavior or storage as memories.

#### Specific Connections to Classroom Activity

On Day 6, students explore the science of hearing. Students figure out that sensory receptors in the ear respond to sound waves by sending messages to the brain. In addition, students design an investigation to determine if humans hear all pitches at the same volume. Students realize that humans hear certain pitches as "louder" than others, even when they are played at the same volume. Students add the idea that only certain pitches need to be blocked by the airplane cabin wall to their criteria list.

Dimension	NGSS Element	Connections to Classroom Activity
Science and Engineering Practices	Planning and Carrying Out Investigations  • Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation.	Students plan and carry out an investigation to answer the question, <i>Do we hear all pitches at the same volume?</i>
Disciplinary Core Ideas	<ul> <li>ETS1.A: Defining and Delimiting Engineering Problems</li> <li>The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions.</li> <li>LS1.D: Information Processing</li> <li>Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.</li> </ul>	After figuring out that humans hear some pitches better than others, students are able to further refine their design problem. Students add that only certain pitches, not all pitches, need to be blocked from the airplane cabin. Students figure out how the human ear "feels" sound waves and how the message from sound waves is transmitted to the brain.
Crosscutting Concepts	Structure and Function  Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.	Students relate the structures in the inner ear to their hearing functions.



### **Basic Teacher Preparation**

This lesson presents the fundamental science of hearing. Review the videos listed in the Suggested Teacher Resources prior to the lesson.

Review the <u>Talk Science Primer</u> to prepare for leading class discussions.

Refer to the Design a Quieter Cabin Student Handbook ahead of time so you can address any questions students might have. The Day 6 document can be found on page 9 in the Design a Quieter Cabin Student Handbook. The document used in this lesson is:

• Do We Hear All Pitches at the Same Volume? (page 9)

Required Preparation	Links/Additional Information
☐ Gather or purchase the required materials for the lesson	Refer to the Materials List below
□ Review suggested teacher preparation resources	Refer to the Suggested Teacher Resources at the end of this lesson



## Materials List

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Computer	To use the Online Tone Generator (onlinetonegenerator.com)	1 per team, if possible	Available in most schools

## Day 6: Sounds Passengers Are Most Sensitive To



### Introduction (5 minutes)

Reference the Driving Question Board, and add the question, *What sounds are passengers most sensitive to?* At this point in the module, students should have a good sense of how airplane engines produce sound and how sound travels through cabin walls into airplanes. Tell students that their goal now is to figure out how humans hear sound and what sounds passengers are most sensitive to.



#### Mini-Lesson: Do We All Hear the Same Sounds? (15 minutes)

Ask students if they think that all humans hear the same sounds. Students might suggest that younger people can hear more than older people.

Show the How Old Are Your Ears? (Hearing Loss) video about frequency and hearing loss to the class. Have students raise their hand when they can hear the tone played in the video. Engage the class in a discussion about the video. Ask students to consider the question:

• Why are higher pitches more difficult to hear than lower pitches?

To answer the question about pitches, show the <u>Auditory Transduction (Ear Physiology)</u> video about the composition of the ear, and then discuss the video as a class. Focus on the first 2 minutes of the video, but show all of the video if time permits. Focus specifically on the following prompts:

- How are sound waves converted into messages that our brain understands?
- Why are high pitches more difficult to hear than low pitches?



#### Video Links

- How Old Are Your Ears? (Hearing Loss) [YouTube Link]
- Auditory Transduction (Ear Physiology) [YouTube Link]



### **NGSS Key Moment**

This investigation marks a key moment in the development of MS-LS1-8. Students learn that sound waves cause structures in the ear to move, which sends a signal to the brain.



#### Investigation: Do We Hear Pitches at the Same Volume? (15 minutes)

Ask students if they think that we hear all pitches at the same volume. Accept all ideas. Tell students that they are going to design an investigation to test their hypotheses.

Demonstrate the <u>online tone generator</u> by changing the pitch and the volume.



Instruct students to meet with their design teams to design an investigation to answer the question, *Do we hear all pitches at the same volume?* 

Give students enough time to design an investigation and test their hypotheses. Students should record their investigation and results on page 9 in the Design a Quieter Cabin Student Handbook.



# Whole Group Discussion: Do We Hear Pitches at the Same Volume? (10 minutes)

After students conduct their investigation, gather students into circle for a whole group discussion. Have students share their investigations and findings. In general, students should have noticed that some pitches sound louder than others, even when they are played at the same volume. Ask students why they think our brains hear some pitches louder than others. Guide students to the idea that humans have a range of pitches that they hear better than others. Have students consider why this is an advantage or a disadvantage.

Relate the discussion back to the design challenge. Ask students what their findings tell them about their design challenge. Students should recognize that they don't need to block out all sounds from the airplane engine. Rather, they need to block out sounds that humans are most sensitive to. Add this idea as an additional criteria for the design problem.



## Lesson Close (5 minutes)

Reference the lesson question on the DQB, *What sounds are passengers most sensitive to?*Ask students if they think they made progress in answering the question. Tell students to record their progress on sticky notes. They should answer the question with as much evidence as they can. When students are finished, have them read their sticky notes out loud to the class and post them to the DQB.

Listen to students read their sticky notes, and/or read the sticky notes that students post to assess their progress in answering the questions on the DQB.



As an optional extension, consider having students read about human perceptions of sound in airplane cabins in an article called "Sound of Silence" published by Boeing. [Web Link]



#### **Assessment**

Several opportunities for formative assessment exist in this lesson:

- Design a Quieter Cabin Student Handbook entries can be used to monitor student progress during the module. Focus specifically on student-developed investigations and results on page 9.
- Consider gathering evidence of student progress through small group and whole group discussions.
- Student contributions to the Driving Question Board can also be monitored.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.



## **Community Connections**

If any students have family members who work as musicians, engineers, or doctors, invite the family members into the classroom to assist as volunteers or to share their work experiences related to sound and the biology of hearing.



### **Suggested Teacher Resources**

Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B	
Design a Quieter Cabin Student Handbook [Resource Link]		
Talk Science Primer	[Web Link]	
Online Tone Generator	[Web Link]	
How Old Are Your Ears? (Hearing Loss)	[YouTube Link]	
Auditory Transduction (Ear Physiology)	[YouTube Link]	
Boeing: Sound of Silence	[Web Link]	

# Design a Quieter Cabin Days 7, 8, and 9: Design a Quieter Cabin

Grade Level	Early Middle School (Grade 6)
Lesson Length	Three 50-minute sessions



#### **Lesson Overview**

On Days 7–9, students develop and test prototype designs for a quieter airplane cabin. Students simulate the cabin by shielding an object from sound waves. As they design their cabin, students integrate and apply their knowledge of sound gained from Days 1–6. Design constraints include a specific list of supplies to choose from, a budget of \$10,000, and a weight limit. Students engage in the iterative engineering design process as they work through the challenge.

All students are given the same sized piece of PVC pipe to simulate their cabin. Each piece of PVC will have a cardboard disk taped to one end of the pipe. The cardboard will have a hole removed to allow for the insertion of the decibel meter. The students then design and construct various materials around the container in their efforts to mitigate the sound energy that is allowed to reach the decibel meter's microphone.



#### Connecting to the Next Generation Science Standards

On Days 7–9, students demonstrate understanding consistent with the performance expectations and three dimensions developed throughout the module. This lesson serves as a performance assessment in which all performance expectations and dimensions are addressed in the final presentation. Please reference the performance expectations, disciplinary core ideas, science and engineering practices, and crosscutting concepts referenced in the front matter of this module.



## **Basic Teacher Preparation**

Days 7–9 engage students in iterative design and experimentation to create a quieter airplane cabin experience. Organize the supplies so students can access them easily. Have all materials precut for the PVC cabin and base. Refer to the materials list for additional information. Refer to the Design a Quieter Cabin Student Handbook ahead of time so you can address any questions students might have. All Day 7–9 documents can be found on pages 3 and 10–15 in the Design a Quieter Cabin Student Handbook. The documents used in this lesson are:

- Engineering Design Problem (page 3)
- Design a Quieter Cabin: Individual Design (page 10)
- Design a Quieter Cabin: Team Design (page 11)
- Modification after Private Test (page 12)
- First Class Trial (page 13)
- Modification Trial (page 14)
- Final Class Trial (page 15)

Required Preparation	Links/Additional Information
☐ Gather or purchase the required materials for the lesson	Refer to the Materials List below
☐ Review suggested teacher preparation resources	Refer to the Suggested Teacher Resources at the end of this lesson



## **Materials List**

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Decibel meter		1 per team	Decibel meter [Web Link]
PVC pipe selection	4 inches in diameter x 4 inches in length	1 per team	PVC pipe [Web Link]
PVC cap	4 inches in diameter x 4 inches in length	1 per team	PVC cap [Web Link]
Ruler		1 per team	Office supply store
Copy paper		1 ream	Office supply store
Aluminum foil		1 roll	Local store
Plastic wrap		1 roll	Local store
Wax paper		1 roll	Local store
Corkboard		1 pack per class	Cork tiles [Web Link]
Rubber liner		1 roll	Rubber liner [Web Link]
Heavy duty trash bag		1 box	Local store
Cotton washcloth or T-shirt fabric			Local store or thrift shop
Cotton balls		1 bag	Local store
Duct tape		1 roll	Local store
Masking tape		1 roll	Office supply store
Glue		1 large bottle	Office supply store
Paper clips		1 large box	Office supply store
Pipe cleaners		1 large package	Pipe cleaners [Web Link]
Playdoh® or modeling clay		1 large tub	Local store

## Day 7: Design a Quieter Cabin



#### Introduction (10 minutes)

Refer students to the Engineering Design Problem on page 3 in the Design a Quieter Cabin Student Handbook. Review the Day 1 Design Problem on page 14 in this teacher handbook, where students shield a passenger's ears (represented by a decibel meter) from exterior sounds (represented by a sound source 3 feet away). The cabin that surrounds the passenger is a 4-inch length of 4-inch diameter piece of PVC pipe (see Figure 1).

Have students cut a 4-inch diameter circle out of cardboard and cut a hole in the middle to allow for the insertion of the decibel meter (see Figure 2). Use any tape to fasten the cardboard to the PVC pipe (see Figure 3). Have a precut physical example to show students what the finished product should look like.

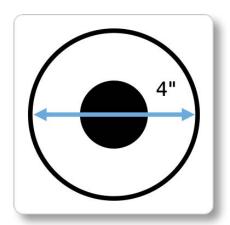
#### **Engineering Design Challenge**

- You have a \$10,000 budget to add materials to the interior of an airplane cabin to make it more resistant to sound.
- All materials must be fastened or laid inside the cabin so they are no more than 1.5 inches away from the container's walls.
- Materials can be placed on the cardboard lid, but the height of the lid should not exceed .5 inches.
- At no point should the material come in direct contact with the decibel meter.
- You must consider the properties, cost, and placement of each material.
- You must justify all design decisions using science ideas developed throughout the module.

At the time of testing, the PVC cabin will be placed in a cap to ensure a uniform base for each team.



▲ Figure 1



▲ Figure 2



▲ Figure 3

Material	Size/Quantity	Cost
Copy Paper	each 8.5" x 11" sheet	\$200.00
Aluminum Foil	each 4" x 6" sheet	\$200.00
Plastic Wrap	each 4" x 6" sheet	\$200.00
Wax Paper	each 4" x 6" sheet	\$200.00
Rubber Liner	each 4" x 6" sheet	\$300.00
Heavy Duty Trash Bag	each 4" x 6" sheet	\$300.00
Cotton Cloth or T-shirt Fabric	each 4" x 6" sheet	\$300.00
Corkboard	each 4" x 6" tile	\$600.00
Cotton Balls	each	\$20.00
Duct Tape	per linear foot	\$1,000.00
Masking Tape	per linear foot	\$700.00
Glue	unlimited	\$500.00
Paper Clips	each	\$50.00
Pipe Cleaners	each	\$200.00
Clay	1 ounce	\$200.00



▲ Interior of Completed Test Cabin



▲ PVC Cabin Placed in Cap

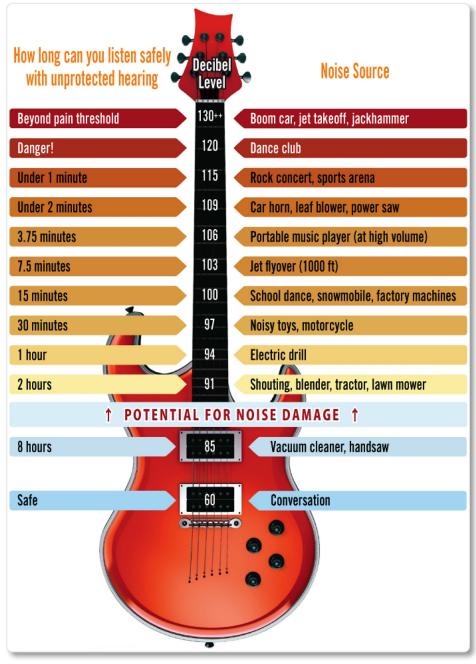


▲ Final Setup



## Investigation: Decibel Levels (10 minutes)

In the design challenge, a *quieter cabin* is measured by measuring the decibels inside the cabin when a sound is played outside the cabin. Share the Decibel Level diagram with students and lead a discussion about what a decibel measures.



▲ Decibel Level Diagram

Source: http://canadianaudiologist.ca/the-hearing-foundation-of-canada-sound-sense



## Design Work: Individual Design and Cost Sheet (10 minutes)

Have students turn to Design a Quieter Cabin: Individual Design on page 10 in their Design a Quieter Cabin Student Handbook. Instruct students to individually sketch their initial designs for their noise resistant cabins.

Students must include approximate measurements, materials, and projected costs. Students must also justify design



### Helpful Tip

Have all the materials laid out on a table for students to view while they create their individual designs and budgets.

decisions using evidence collected throughout the module. Students should cite specific evidence from their Design a Quieter Cabin Student Handbooks or from the Driving Question Board.

Refer to the Materials List or the materials and cost table shown earlier in this lesson for a complete listing of materials available to students for their build. The materials and cost table is also presented as part of the Engineering Design Problem on page 3 in the Design a Quieter Cabin Student Handbook.



### Design Work: Team Design and Cost Sheet (15 minutes)

Have students take turns sharing their individual designs with their teams. Remind students to explain the reasoning behind their designs and materials choices. Students must be able to justify all design decisions with evidence from the module.

After all students share their ideas, each team must decide on a team design. The design could be one team member's design, a compilation of team member designs, or a new design altogether. Once teams decide on a design, each team member sketches their team's design on Design a Quieter Cabin: Team Design (page 11) in their Design a Quieter Cabin Student Handbook. Students must also complete a new cost sheet. Again, all design decisions must be justified using science ideas. Students must also justify design decisions using evidence collected throughout the module. Students should cite specific evidence from their Design a Quieter Cabin Student Handbooks or from the Driving Question Board. Monitor teams and sign off on each team's design and budget once they have come to consensus.



### Lesson Close (5 minutes)

Have design teams share their ideas with a different design team. Instruct students to give kind, specific, and helpful feedback as they share. After sharing and receiving feedback, students should modify their designs.

## Day 8: Design a Quieter Cabin



### Introduction (5 minutes)

Each team should review each other's **Team Design** sketch on page 11 in the **Design a Quieter Cabin Student Handbook**. Challenge teams to incorporate all that they have learned about sound generation, sound travel, and the transfer of energy to either alter their original design and modify their blueprint or stick with their initial team design.



#### Design Work: First Build and Test (20 minutes)

Demonstrate to the class how each team will test their cabin with the sample cabin you created for Day 1 by following the Setting Up the Design Challenge Notes shown below. Each team then uses their design blueprints to construct their first sound proof cabin. Upon build completion, each team participates in a private preliminary test with the teacher. Teams then modify their designs prior to the first formal class test. Teams must sketch their modifications and new budget on the Modification After Private Test page (page 12) inthe Design a Quieter Cabin Student Handbook. Students must back up all modification decisions with science ideas developed throughout the module. Students should cite specific evidence from their Design a Quieter Cabin Student Handbooks or from the Driving Question Board.

#### Setting Up the Design Challenge Notes

- Set up a microphone 3 feet away from a speaker that will be playing audio from this <u>Boeing 777 takeoff video</u> at a loud, but safe volume.
- Note that the jet engine audio generates many different frequencies and some materials do a better job than others at reflecting and/or absorbing different wavelengths, so students should consider using a variety of materials.



Play the segment from 5:05-7:00.

Boeing 777 Takeoff [YouTube Link]



## Design Work: First Class Trial (20 minutes)

Have each team share their design with the class.

- Have students measure the volume of sound at the cabin location, but outside the cabin. Students record this as their Control Reading on page 13 in the Design a Quieter Cabin Student Handbook.
- 2. Have the students insert the decibel meter into their noise-reduced cabin.
- 3. Have students record the volume decibels at 5:05, 5:15, 5:30, 5:45, 6:00, 6:15, 6:30, 6:45 and 7:00 in the First Class Trial table on page 13 in the Design a Quieter Cabin Student Handbook.

4. Have students calculate the average of their 9 data points to measure the effectiveness of their solution and record the average in the First Class Trial table on page 13 in the Design a Quieter Cabin Student Handbook.

5. Have students compare their average to the control recording to see how much their design reduced sound.



## Design Work: First Redesign (5 minutes)

Each team discusses the results of the First Class Trial. Students work together to develop their next team design. Students record their redesign in the Modification after First Class Trial section on page 13 in the Design a Quieter Cabin Student Handbook.

## Day 9: Design a Quieter Cabin



#### Design Work: Redesign and Testing (35 minutes)

The teams construct the second design based on the Modification after First Class Trial blueprint on page 13 in the Design a Quieter Cabin Student Handbook.

Teams test their modification using the same testing system developed in the previous lesson. Teams record their results and calculate their design's average in the Modification Trial table on page 14 in the Design a Quieter Cabin Student Handbook.

Teams continue to modify their design in preparation for the final trial. Teams record their Final Class Trial on page 15 in the Design a Quieter Cabin Student Handbook.



### Design Work: Final Class Trial (15 minutes)

Each team shares their design with the class. Gather the class around the testing station. Run a control sound test before each team runs their final test. Have each team, one at a time, insert the decibel meter into their noise-reduced cabin. Have teams record the volume decibels at 5:05, 5:15, 5:30, 5:45, 6:00, 6:15, 6:30, 6:45 and 7:00 and record their average of the 9 data points in the Final Class Trial table on page 15 in their Design a Quieter Cabin Student Handbook.

Instruct students to comment on the successes and failures of their various designs on page 15 in their Design a Quieter Cabin Student Handbook. Students should ground their discussions in the science ideas developed throughout the module.



#### **Assessment**

Several opportunities for formative assessment exist in this lesson:

- Design a Quieter Cabin Student Handbook entries can be used to monitor student progress during the module. Focus specifically on students design justifications on pages 10–15
- Consider gathering evidence of student progress through small group and whole group discussions.

Use the identified assessment opportunities to monitor student progress on disciplinary core ideas, science and engineering practices, and crosscutting concepts. Provide appropriate supports or extensions when necessary.

Reference Appendix B for suggestions for meeting the needs of all learners.



### **Community Connections**

If time permits, invite movie theater managers or local church choir directors to share how their facilities shield and or magnify sound.



## Suggested Teacher Resources

Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B	
Design a Quieter Cabin Student Handbook	[Resource Link]	
Boeing 777 Takeoff (video)	[YouTube Link]	

## Design a Quieter Cabin

## Day 10: Presentations

Grade Level	Early Middle School (Grade 6)
Lesson Length	One 50-minute session



#### **Lesson Overview**

In this lesson, students share their final products with the class. They draw three iterations of their design on chart paper and explain the evolution of their product along with their average test results from each trial.



### Connecting to the Next Generation Science Standards

On Day 10, students demonstrate understanding of the performance expectations and three dimensions developed throughout the entire module. This lesson serves as a performance assessment in which all of the performance expectations and dimensions are addressed in the final presentation. Refer to the performance expectations, disciplinary core ideas, science and engineering practices, and crosscutting concepts referenced in this module's front matter.



### **Basic Teacher Preparation**

This final lesson gives the teams an opportunity to share what they have learned throughout the module. It also provides the students with an opportunity to learn from each other as well as discuss various approaches to the same solution. As with previous lessons, preparation of materials needs to be done prior to class. Refer to the **Materials List** for necessary components and preparation guidelines.

Consider inviting other classes, parents, past volunteers, or relevant community members to hear students' presentations.

Required Preparation	Links/Additional Information
☐ Gather or purchase the required manner for the lesson	aterials Refer to the Materials List below
☐ Review suggested teacher prepara resources	tion Refer to the Suggested Teacher Resources at the end of this lesson



## **Materials List**

Item	Description/Additional Information	Quantity	Where to Locate/Buy
Large sheets of drawing paper, dry erase board, or blackboard	Each design team draws three iterations of their designs		Available in most schools, or buy at office supply store
Markers or chalk		Set(s) for class to share	Available in most schools, or buy at office supply store

## Day 10: Presentations



#### Design Work: Team Preparation (25 minutes)

Each team draws and labels at least three iterations of their designs. Instruct the students that the drawings must include measurements, dimensions, total cost for the design, and average test results. All drawings must also include justifications and explanations that incorporate science ideas developed throughout the module.

Remind students that the drawings must be detailed enough that another team could build their design from their blueprint. Each team must prepare to discuss the evolution of their design and the reasoning behind their design modifications in front of the class. Teams use their drawings as a reference during their presentations.



### Design Work: Team Presentation (25 minutes)

Each team gives a 2- to 3-minute presentation. Provide 2 minutes for classmates to ask questions as well as provide peer feedback.



#### **Assessment**

Use the final presentation as a summative assessment for the unit. A Presentation Rubric can be found in Appendix C.



## **Community Connections**

Have students ask an adult family member if they give presentations as part of their job. If the family member does give presentations, have students ask them to share ways in which they prepare for a presentation and how they make their presentation engaging. Take a few minutes at the beginning of class to have students share their family member's presentation ideas with the entire class.

Consider inviting community members to the presentations.



## **Suggested Teacher Resources**

Meeting the Needs of All Learners	Design a Quieter Cabin Teacher Handbook, Appendix B
Presentation Rubric	Design a Quieter Cabin Teacher Handbook, Appendix C

## Appendix A

## **Engineering Design Process**

#### Step 1 Identify the Need or Problem

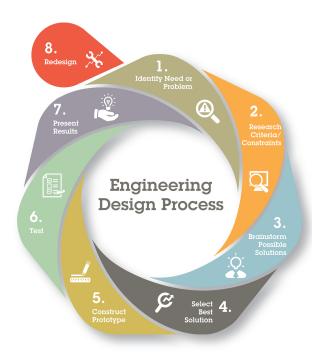
Describe the engineering design challenge to be solved. Include the limits and constraints, customer description, and an explanation of why solving this challenge is important.

#### Step 2 Research Criteria and Constraints

Research how others have solved this or similar problems, and discover what materials have been used. Be sure to thoroughly research the limitations and design requirements for success.

#### Step 3 Brainstorm Possible Solutions

Use your knowledge and creativity to generate as many solutions as possible. During this brainstorming stage, do not reject any ideas.



#### Step 4 Select the Best Solution

Each team member presents their solution ideas to the team. Team members annotate how each solution does or does not meet each design requirement. The team then agrees on a solution, or combination of solutions, that best meets the design requirements.

#### Step 5 Construct a Prototype

Develop an operating version of the solution.

#### Step 6 Test

Test your solution. Annotate the results from each test to share with your team.

#### **Step 7 Present Results**

Present the results from each test to the team.

#### Step 8 Redesign

Determine a redesign to address failure points and/or design improvements. The design process involves multiple iterations and redesigns. Redesign is based on the data from your tests, your team discussions as to the next steps to improve the design, and the engineering design process Steps 1 through 7.

Once your team is confident of a prototype solution, you present the results to the client. The client may:

- Accept your solution as is, or
- Ask for additional constraints and criteria to be included in the solution. At this point, you and your team revisit the engineering design process and resume the iterative redesign cycle.

## Appendix B

## Meeting the Needs of All Learners

Every learner is unique. To meet the needs of all learners in your class, consider the following strategies:

- Provide students with sentence stems for models, arguments, and explanations (see below).
- Use a graphic organizer to help students organize their thinking prior to creating their final presentation (see below).
- Prior to each group discussion, engage students in individual or small group discussions to help them prepare to share their ideas in a larger group.
- Provide students with a vocabulary list using the Glossary.
- Offer additional extension problems or challenges in math or science.
- Provide students with additional time to formulate their ideas prior to sharing with the class.
- Offer opportunities for students to engage in additional investigations to extend learning. This may
  include additional readings, science investigations, or research.

Design Problem:
Colon co. Idago valete dita the Decima Duchlama
Science Ideas related to the Design Problem:
First Draft Design Solution:
Reflection/Modifications Needed:
Second Draft Design Solution:
Reflection/Modifications Needed:
Final Design Solution and Justification:

#### **Sentence Stems**

Contributed by Karl Muench, Collins Middle School, Salem, MA

#### Claim

You frame the question and answer it. This may take a sentence or a paragraph. Examples of claim sentences include the following.

- Analysis (breaking down the elements)
  - o Our analysis looked at the parts and their function in ...
  - o We know from our data that ... is comprised (made of) ..., ... and ...
- Comparison (similarities and differences)
  - o ... (A) and ... (B) are alike in that both ...
  - o However, while ... (A) does this ..., the other, ... (B), does this ...
- Evaluation (testing against a set of rules)
  - o The ... (subject of study) best matched the rule that ...
  - o In the situations involving ..., the ... (subject of study) showed ...
- Problem/solution
  - o ... is a problem, and the best solution is ...
  - o Very often, ... will have a problem with ... The way to fix it is ...
- Cause/Effect
  - o ... causes ... to happen.
  - o ... is created when ...
  - o ... if ... then ...

Give a preview of how you will prove your claim. Follow the above statements with the word *because*.

#### **Evidence**

Include research and results of demonstrations or your own experimentation that support your claim. In science, you need to cite ALL available evidence, even some that may work against your claim. (You can deal with that issue by using reasoning.)

- Analysis
  - o We conducted this experiment ... The results are shown in the following table.
  - o We graphed ... over ... and saw this pattern ...
  - o In most cases, we saw ... Sometimes, however, ... would happen.
  - We found the following analysis of this in our research ... (direct quotes with sources)
- Comparison
  - We compiled the following T-chart showing where these things are alike and unalike.
  - o In this Venn diagram, we can see where these things are similar and different.
  - o In both cases, ... is true. But only for ... is ... true.
  - o We have both things on this graph. You can see here ... where they meet.
- Evaluation
  - We were looking for the following criteria ... The following met those criteria ... The following did not meet those criteria ...
  - o The rule ... applies to the following ... and does not work for ...

o Scientists say ... (quotation with source). We found this applied to ...

#### Problem/Solution

- o These sources ... point to this issue ...
- We tested our prototypes by ... These were the results ...
- o Experts such as ... (sources) say ... is a common problem.
- o ... (source) emphasizes that ... is a problem, with this possible solution ...

#### Cause/Effect

- o Every time ... happened, ... would happen.
- Scientists believe that ... is caused by ... (quote with source)
- o The following graph shows how ... influences ...
- o This chart shows when ... happens (or is present) and what happens next.
- Statistics indicate that ...

#### Reasoning

You need to explain in your own words how your evidence supports your claim. In the case of evidence that contradicts your claim, you must explain why other evidence has more merit or reliability.

#### Analysis

- o The evidence supports our claim because ...
- The graph shows that as ... rises, ... rises/falls at a (steady or increasing) rate. This allows us to predict ...
- o Taking the evidence as a whole shows ...

#### Comparison

- o These things behave similarly when ... but differently when ...
- Considering these similarities and differences indicates ...
- o Looking at the chart of evidence, we see how ... is similar to ..., but different in ...

#### Evaluation

- o If ... is true, we should see ... This is exactly what we see in the case(s) of ...
- o Every time (or almost every time) we tried this ..., this happened ...
- o ... did not meet our criteria as well as ..., eliminating it as an option.

#### Problem/Solution

- As you can see, our test (or research) indicates this solution will solve the problem because ...
- o Our research and testing found ... can best solve this problem by ...
- o We were looking for this ... and found it in ...

#### Cause/Effect

- o The evidence shows that ... causes ... because ...
- o Looking at the data, we see that ... followed ... every time.
- o Our research shows that scientists support that ... causes ... because ...

#### Dealing with contrary evidence

- By looking at all of this, we can see that these data ... are outliers.
- o While some scientists say ..., most scientists agree that ...
- o Some of our results are less reliable because ...

## Appendix C

## **Presentation Rubric**

The **Presentation Rubric** is intended to be used as a guide for the development of the assessment for the final presentations. Teachers should tailor the rubric to fit the module's specific needs and design problem.

# Science and Innovation A Boeing and Teaching Channel Partnership

PRESENTATION RUBRIC

	No Evidence	Beginning	Developing	Advanced
Quality of Design Product  NOTE: This section should be tailored to assess specific module and performance expectations.	Design product fails to address most aspects of the performance task.	Design product addresses some aspects of the performance task.	Design product addresses most aspects of the performance task.	Design product addresses all aspects of the performance task.
	Design product shows no evidence of thoughtful problem solving.	Design product shows little evidence of thoughtful problem solving.	Design product shows some evidence of thoughtful problem solving.	Design product shows clear evidence of thoughtful problem solving, deliberation, and decision making.
	Design product shows evidence of low-quality craftsmanship.	Design product shows evidence of mediocrequality craftsmanship.	Design product shows evidence of mostly high-quality craftsmanship.	Design product shows clear evidence of high-quality craftsmanship.
Explanation of Science Ideas  Science Ideas  Science ideas include science and engineering practices, disciplinary core ideas, and crosscutting concepts.  NOTE: This section should be tailored to assess specific module and performance expectations.	Relevant science ideas are not addressed. Evidence is not cited.	Most relevant science ideas are stated and partially described in relation to the design problem.  Some evidence is cited. Evidence was gathered through science investigations or critical analysis of existing sources.	All relevant science ideas are stated and described in relation to the design problem.  Several lines of evidence are cited. Evidence was gathered through science investigations or critical analysis of existing sources.	All relevant science ideas are clearly stated and described in detail in relation to the design problem.  Multiple lines of evidence are cited. Evidence was gathered through science investigations or critical analysis of existing sources.
Organization	The presentation does not include all of the required components.  The presentation does not have a main idea or presents ideas in an order that does not make sense.	The presentation includes most of the required components.  The presentation moves from one idea to the next, but the main idea may not be clear or some ideas	The presentation includes all of the required components.  The main idea is clearly stated. The presentation moves from one idea to the next in a logical order, emphasizing main	The presentation includes all of the required components and either provides additional information for each component or adds additional components relevant to the presentation.

		may be in the wrong order.	points in a focused, coherent manner.	The main idea is clearly stated. The presentation moves from one idea to the next in a logical order, emphasizing the main points in a focused, coherent manner. (CC 6-8. SL.4)
Presenting Skills	The presenter does not look at the audience and reads notes or slides.  The presenter wears clothing inappropriate for the occasion.  The presenter mumbles or speaks too quickly or slowly.  The presenter speaks too softly to be understood.	The presenter makes infrequent eye contact and reads notes or slides most of the time.  The presenter dresses professionally.  The presenter speaks clearly most of the time, although sometimes too quickly or slowly.  The presenter speaks loudly enough for most of the audience to hear, but may speak in a monotone.	The presenter keeps eye contact with audience most of the time and only glances at notes or slides.  The presenter dresses professionally.  The presenter speaks clearly and not too quickly or slowly. (CC 6-8.SL.4)  The presenter speaks loudly enough for everyone to hear and changes tone to maintain interest. (CC 6-8.SL.4)	The presenter engages the audience by drawing their sustained attention.  The presenter maintains eye contact with the audience most of the time and only glances at notes or slides. (CC 6-8.SL.4)  The presenter dresses professionally.  The presenter speaks clearly and not too quickly or slowly. (CC 6-8.SL.4)  The presenter speaks loudly enough for everyone to hear and changes tone to maintain interest. (CC 6-8.SL.4)

## Glossary

The key terms below are frequently used in the module. Students should develop a strong conceptual understanding of each term throughout the module. Definitions from dictionary.com unless otherwise noted.

compression	The act of condensing, shortening, or abbreviating.
decibel	A unit used to express the intensity of a sound wave.
energy	The ability to do work.*
frequency	The number of cycles per unit time of a wave or oscillation.
hertz	The standard unit of frequency in the International System of Units (SI) equivalent to one cycle per second.
mechanical energy	Energy possessed by an object due to its motion or its stored energy of position. Mechanical energy can be either kinetic energy (energy of motion) or potential energy (stored energy of position).**
medium	The matter through which a wave travels.*
oscillation	An effect expressible as a quantity that repeatedly and regularly fluctuates above and below some mean value, as the pressure of a sound wave or the voltage of an alternating current.
particle	One of the extremely small constituents of matter, such as an atom or nucleus.
vibration	The oscillating, reciprocating, or other periodic motion of a rigid or elastic body or medium forced from a position or state of equilibrium.
wave	A traveling disturbance that moves through space and matter transferring energy from one place to another.***
wave height (amplitude)	The maximum displacement of a wave from its rest position.**
wave length	The length of one complete wave cycle.**

<sup>\*</sup> Definition developed by module authors.

<sup>\*\*</sup> Definition from physicsclassroom.com.

<sup>\*\*\*</sup> Definition from ducksters.com.