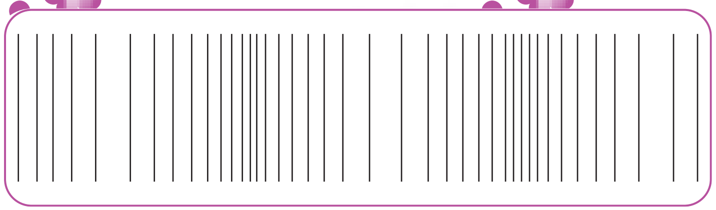
Sound Waves:

How can a sound make something move?

Teacher Guide

Wavelength models



Science Literacy

Vibration

GRADE 8

Core Knowledge Science®

Core Knowledge®

This unit is a modified version of a unit that has earned the NGSS Design Badge. The sole instructional modification is the addition of Core Knowledge Science Literacy content. The modification has not been reviewed.

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Core Knowledge®

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BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources	Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to: • the unit's comprehensive materials list • a full unit pacing snapshot • lesson guidance slides • all other recommended resources. **www.coreknowledge.org/cksci-online-resources**
Student Work Pages	All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.
Student Books	All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

How can a sound make something move?

Students begin the sound unit by considering an interesting phenomenon: a truck is playing loud music in a parking lot and the windows of a building across the parking lot visibly shake in response to the music. Students generate questions about three aspects of sound phenomena: 1) What makes sound? 2) How does sound get from the truck to the window? 3) Why does the window shake like it does? Students engage in model-based reasoning, argumentation, and computational and mathematical reasoning to develop models to explain these three aspects of the mystery.

- By investigating factors including loudness and pitch, students develop a model of vibration that captures important ideas about how changes in the frequency and amplitude of the vibrations that can explain these different characteristics of sounds. Students use this model of vibration to answer their initial questions about what causes different sounds.
- By testing various types of materials and using interactive computer models, students figure out how sound travels from one location to another by causing sequences of vibrations through matter. What they figure out helps students answer their initial questions about how sound is traveling from a sound source to our ears.
- By reasoning with the models they have developed, students also figure out how sounds can be absorbed and transmitted. In particular, they figure out how the energy transferred by the sound wave depends on both frequency and amplitude of a sound wave, and is more affected by its amplitude than the frequency. What students figure out helps them answer their initial questions about how objects that are not touching a sound source can shake in response to sound.

Focal Disciplinary Core Ideas (DCIs): PS4.A

Focal Science and Engineering Practices (SEPs): Developing and Using Models, Using Mathematics and Computational Thinking, Engaging in Argument from Evidence

Focal Crosscutting Concepts (CCCs): Patterns; Scale, Proportion, and Quantity

Building Toward NGSS 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.

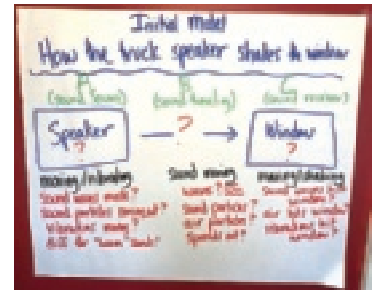
MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

UNIT STORYLINE

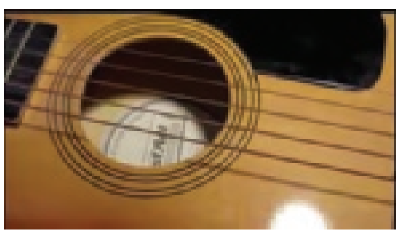
How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES | VIDEOS OR IMAGES | DATA SETS | READINGS | COMPUTER INTERACTIVES

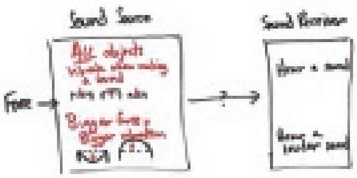
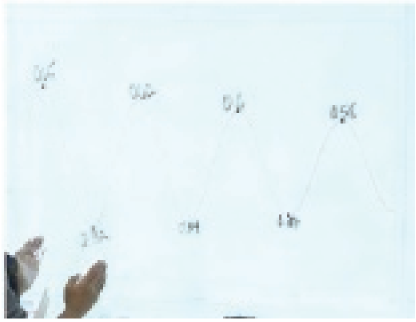
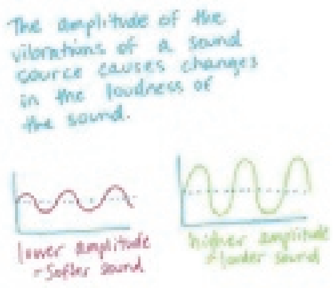
How can a sound make something move?

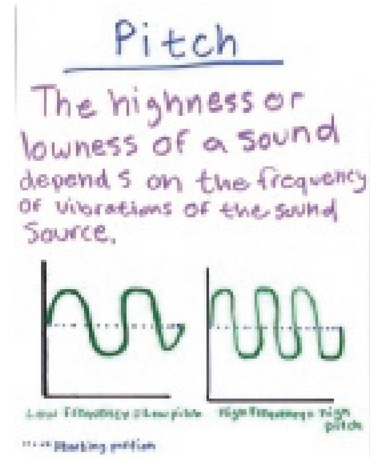
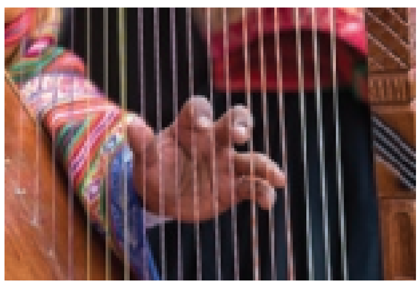
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **3 days** **How does a sound source make something like this happen?** Anchoring Phenomenon	 *Loud music from a truck makes a window in the parking lot move. A speaker moved when it produced sound.*	We observe a perplexing phenomenon: Sound from a truck appears to make a window move from the parking lot. We note observations of this phenomenon as well as of a speaker in the classroom. Our observations, models, and other sound-related phenomena lead us to add a broad set of questions about sound to our DQB and to list ideas for investigations to pursue. We figure out these concepts: • A speaker making sounds can be detected from a distance and can even cause things like a nearby window to move. • The speaker moves back and forth when it is making sound. • Students agree that the sound source, how sound travels, and how sounds are received are important parts of explaining how sounds can make things move.	

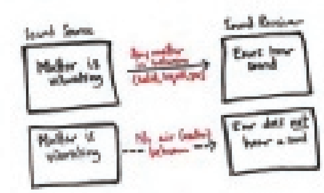
⇩ **Navigation to Next Lesson:** After seeing how the speaker moves when it makes sounds, we wonder if other sound-makers show similar patterns. We decide to bring in other sound-makers to look for patterns in what each does when making sounds.

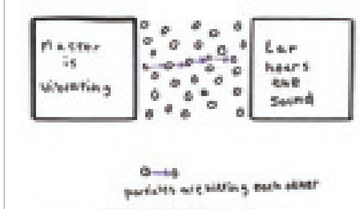
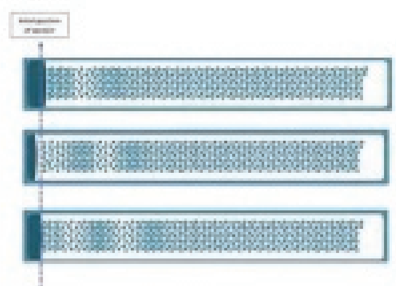
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 2 **2 days** **What is happening when speakers and other music makers make sounds?** Investigation	 *Musical instruments and speakers vibrate (move back and forth) when a force is applied.*	When an instrument vibrates (makes sounds) it includes the following actions: • A force is applied to a part of an object; that part bends or deforms and changes shape. Energy is transferred to the object. • When the force is removed, that part of the object springs back and overshoots its starting position. • That part of the object then repeatedly bends back and forth for a bit (we call this vibration) before stopping. When it stops vibrating, it stops making sounds	

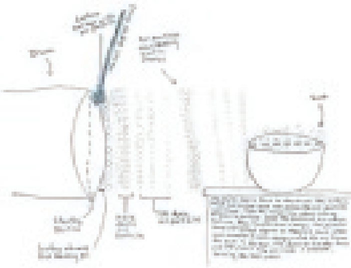
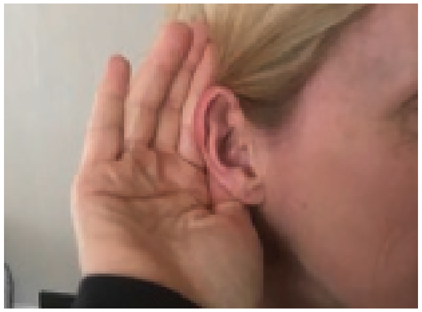
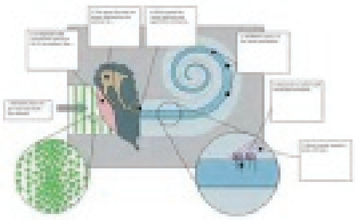
⇩ **Navigation to Next Lesson:** We figured out that instruments and speakers are vibrating (bending back and forth). This made us wonder whether all objects, even something solid like a table, are bending back and forth (vibrating) when they make sounds.

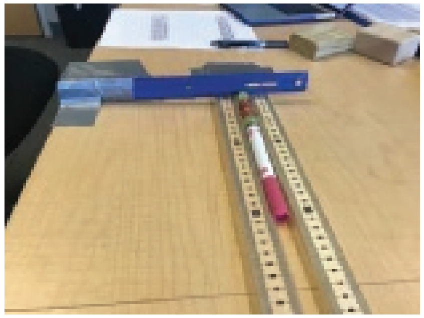
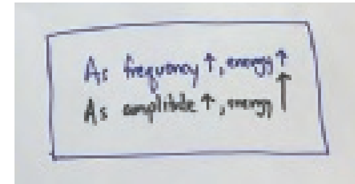
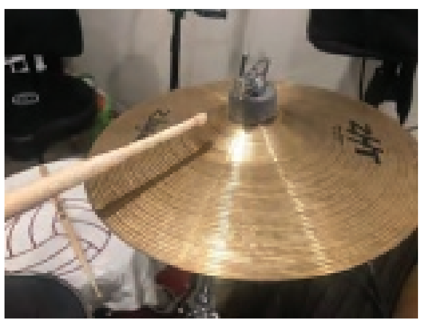
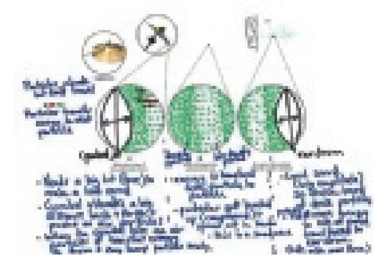
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 3 **2 days** **Do all objects vibrate when they make sounds?** **Problematizing, Investigation**	 *A laser directed at a mirror on a drum, table, and speaker lets us better see the vibrations that happen when those objects make sounds.*	All objects move back and forth (vibrate) when making sounds. Objects vibrate further back and forth (deform more) when a greater force is applied, creating louder sounds.	
Navigation to Next Lesson: What do we mean by "more" vibrations? Is there a way we can more clearly see how a solid object vibrates more?			
LESSON 4 **2 days** **How do the vibrations of the sound source compare for louder versus softer sounds?** **Investigation**		We deform (push) a stick to represent how sound makers move differently for louder or softer sounds. We notice that motion graphs of louder sounds have higher amplitude, and softer sounds have lower amplitude, but the number of vibrations of the stick per second (we called this frequency) didn't change whether we deformed the stick more or less.	
Navigation to Next Lesson: We know that pitch is another way sounds are different, and musical instruments have shorter or longer parts that create different pitches, so now we want to make our stick longer or shorter to see how it moves differently to make those different sounds.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 5 **1 day** **How do the vibrations from a sound source compare for higher-pitch versus lower-pitch sounds?** Investigation	 *A shorter stick vibrates faster than the longer stick, and the graph of the motion of the speaker also shows faster vibrations for higher pitch.*	We use mathematical representations of Position versus Time graphs generated from a tool used to scale up the vibrations of an object to describe wave patterns and support scientific conclusions about how objects move when they make higher-pitch and lower-pitch sounds. We figure out these ideas: • Shorter-length bars produce higher-pitch sounds when struck. • Shorter-length bars vibrate more frequently than longer-length bars when struck. • Sound sources that produce higher-pitch notes vibrate more frequently.	
⇩ **Navigation to Next Lesson:** We figured out that a shorter stick vibrates faster than a longer one and the speaker vibrates faster for higher-pitch sounds. This made us wonder if we can put our ideas about frequency and amplitude together to see if we can explain how any object can make so many different sounds.			
LESSON 6 **2 days** **How can any object make so many different sounds?** Putting Pieces Together	 *A video and graphs of the motion of a harp making sounds are used to model and argue for the different sounds being made.*	We apply our understanding to explain different sounds coming from different objects, complete a summative mid-unit assessment, and return to our DQB.	
⇩ **Navigation to Next Lesson:** We have answered many of our questions about what is happening at the sound source when it makes different sounds, but we still have many questions about how that sound is actually traveling and what happens at the receiver.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 **1 day** **What is actually moving from the sound source to the window?** Problematizing, Investigation	 *By placing a sound maker in a sealed container, we observe that we can still hear sounds coming from inside and that the mass of the container does not change before and after sounds are played.*	We test the idea that the air from the sound source is traveling to the window or our ears by placing a sound source in an airtight container and testing whether we can still hear it. We also record the mass of the container before and after the sound is produced. We use the understandings we gain from these investigations to revisit our initial models to analyze our earlier claims for what's traveling between the speaker and the window in the anchoring video. We figure out these ideas: • Air that is near the sound source is not moving all the way from the sound source to our ears (or window) when sounds are produced. • We still aren't sure what is moving between the sound source and our ears, but our evidence suggests that nothing made of matter is traveling between these two points.	
⇩ **Navigation to Next Lesson:** After seeing evidence that air doesn't move from the sound source to the receiver, we wonder if air is even necessary for sound to travel.			
LESSON 8 **1 day** **Do we need air to hear sound?** Investigation	 *When a sound source is placed in a solid container with liquid or gas inside, we hear sounds coming from inside. When it is placed in a container with no matter inside, we do not hear any sounds coming from inside.*	We test, through two investigations, whether air is even needed to hear sound. One investigation provides evidence that sound moves through any type of matter, while the other investigation provides evidence that sound can't move across empty space that has no matter in it (a vacuum). Sound can travel through all different kinds of matter (solids, liquids, and gases), not just air. Sound cannot travel through an empty space with no matter; sound needs matter to travel.	
⇩ **Navigation to Next Lesson:** We know that sound needs matter to travel, but we don't know yet how to represent sound going through matter. We decide we need to make models to see how matter allows sounds to travel to our ears.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 **1 day** **How can we model sound traveling through a solid, liquid, or gas?** Investigation	 *We use our bodies to simulate a sound source hitting a particle, causing it to collide into the particle next to it, transferring energy to the next particle and so on.*	We recall that models of all states of matter have particles, empty space, and motion. We simulate what happens in the surrounding matter as a vibrating object is interacting with it. This model suggests that motion (or energy) might be transferred through the medium from one end to another through particle collisions. We figure out these concepts: • Solids, liquids, and gases are made of particles moving through empty space, with different spacing in each state of matter. • Particles can collide with other particles in a gas and bump into neighboring particles in a solid or a liquid. • If a push is transferred into the particles at one place in the medium (any state of matter that sound travels through), it might result in a series of collisions among neighboring bands of particles across the medium.	
⇩ **Navigation to Next Lesson:** We figured out that particles collide into one another as sound moves through a medium. This made us wonder if we could better see the interactions among particles by using a computer simulation that shows more particles, repeated vibrations of particles, and vibrations of different amplitude and frequencies.			
LESSON 10 **2 days** **What exactly is traveling across the medium?** Investigation	 *Vibrations of a sound source cause particle bands to push against the particles next to them, creating dark and light bands where there are areas of densely and loosely packed particles.*	We manipulate a computer simulation by changing either the pitch or loudness of the sound produced to see how the motion of the particles in the medium is affected. We figure out these ideas: • When an object moves back and forth, it produces bands of compressed and expanded particles that move through the medium (bands of compression travel, but particles do not). • The density of particle compression gets greater when the amplitude of vibration at the sound source increases. • The distance between compression bands appears to change when we change the frequency of vibration. • Collisions between the particles in the medium result in compression bands moving away from a sound source. • Collisions transfer energy across the medium.	
⇩ **Navigation to Next Lesson:** We figured out that vibrating objects produce bands of compressed particles in the medium in which the sound is traveling. The particles do not travel from the sound source to the sound detector but collide with the particles next to them, transferring energy through the medium. This makes us wonder if we can use our model to explain other sound phenomena.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 **2 days** **How does sound make matter around us move?** Putting Pieces Together	 *Salt on plastic wrap stretched over a bowl jumps up and down when a drum nearby is hit.*	We develop a model to explain a new phenomenon: salt jumping on plastic wrap when a drum is hit. We develop a checklist that includes the key ideas we have developed about how sounds are caused and how sound can cause other things to move. Then, we apply that checklist to revising the model that explains why a window near the parking lot moved when a truck speaker was blasting music.	
⇩ **Navigation to Next Lesson:** We have a good idea about how sound travels, but we still have a lot of questions about how we actually hear things and what is happening at the sound receiver. We've heard that there's a body part called the eardrum, so we wonder how that might fit in with what we already know about sound.			
LESSON 12 **1 day** **What goes on in people's ears so they can detect certain sounds?** Investigation	 *An otoscope video of an eardrum examination, an animated diagram, and a reading show the structures in the ear canal and vibrations entering the inner ear.*	In order to find answers to their questions about how our ears detect sounds, students read an interview with experts and watch several videos and animations about the structures of the ear and how hearing loss can occur. They synthesize that information to annotate a model showing how energy is transferred through the parts of the ear to the nerve cells that send signals to the brain.	
⇩ **Navigation to Next Lesson:** Since we've learned that both loud sounds (high-amplitude waves) and high-pitched sounds (high-frequency waves) can damage our ears, we want to know which is worse. So, we want to investigate which type of sound wave (higher amplitude or higher frequency) transfers more energy.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 13 **2 days** **What transfers more energy, waves of bigger amplitude or waves of greater frequency?** Investigation	 *A ruler (representing a vibrating object) pushes marbles (representing nearby particles) with greater energy when we increase the amplitude or frequency of the ruler's vibrations. Increasing amplitude has a proportionally greater effect on energy transfer than increasing frequency.*	We conduct two investigations to measure "What transfers more energy, waves of bigger amplitude or waves of greater frequency?" First, we change how many times a marker representing the sound detector is hit by marbles in a given time period (the frequency) and measure the total distance the marker moved (the amount of energy transferred to the detector). Next, we change the force acting upon the marbles (changing the amplitude) and measure how this changes the distance the marker moves. We figure out these ideas: • Waves with bigger amplitude transfer more energy than waves with less amplitude. • Waves with higher frequency transfer more energy than waves with less frequency. • Proportional increases in amplitude have a bigger effect on the energy transferred than increases in frequency.	
⇩ **Navigation to Next Lesson:** In this lesson, we figured out that when the frequency of a vibration doubles, the energy transferred doubles, but when the amplitude of the vibration doubles, the energy transferred quadruples. We've figured out so much! Now we are ready to revisit our DQB to show what we have learned by answering many of our questions.			
LESSON 14 **2 days** **How can we explain our anchoring phenomenon, and which of our questions can we now answer?** Putting Pieces Together	 *Hitting a cymbal loudly can damage a musician's ears.*	We revisit the Driving Question Board and discuss all of our questions that we have now answered. Then we demonstrate our understanding by individually taking an assessment. Finally, we reflect on our experiences in the unit.	
LESSONS 1–14 **24 days total**			

TEACHER BACKGROUND KNOWLEDGE

What are the Disciplinary Core Ideas (DCIs) in the context of the phenomenon?

"Disciplinary Core Ideas" are reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. See the **Online Resources Guide** for a link to this resource. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

In this unit, students will develop ideas related to how sounds are produced, how they travel through media, and how they affect objects at a distance. Their investigations are motivated by trying to account for a perplexing anchoring phenomenon—a truck is playing loud music in a parking lot and the windows of a building across the parking lot visibly shake in response to the music. They will make observations of sound sources to revisit the K-5 idea that objects vibrate when they make sounds. They will figure out that patterns of differences in those vibrations are tied to differences in characteristics of the sounds being made. They will gather data on *how* objects vibrate when making different sounds to characterize how vibrating objects' motion is tied to the loudness and pitch of the sounds they make. Students will also conduct experiments to support the idea that sound needs matter to travel through, and they will use models and simulations to explain how sound travels through matter at the particle level.

This unit builds towards the following NGSS Performance Expectations (PEs):

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.

This unit helps develop the following elements of Disciplinary Core Ideas (DCIs):

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)
- A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

What should my students know from earlier grades and earlier middle school units?

Disciplinary Core Ideas

In 1st grade, students develop the idea that sound can make matter vibrate, and vibrating matter can make sound. (1-PS-4-1)

In 5th grade, students develop the idea that air is made of matter, and therefore has mass. These understandings, and a model of air as made of particles too small to be seen, are foundational for students making sense of the phenomena in this unit.

However, our pilots of this unit have revealed that most middle school students have not fully developed these relevant K-5 ideas for explaining sound-related phenomena. There are two sets of ideas that we rarely see in students' initial models:

- Back and forth motion of matter (vibration) is occurring at the sound source (grade 1 DCI).
- The medium that sound is moving through (e.g., air) is made of particles (grade 5 DCI).

Because students typically do not use these ideas in their initial models, several lessons (Lessons 2, 3, and 9) are designed to help students develop and use these ideas, which are essential components on which to build the middle school level DCIs. These lessons are designed to push students to develop a mechanism for what *causes* vibrations in matter related to some other important physical science ideas, and how that moving matter can then move particles of air. That mechanism, the elasticity of solids, is at the heart of understanding how sounds can be produced, why they travel and how they are sensed/detected, and is then built upon in later lessons.

Additionally, this unit builds on disciplinary core ideas that students should have developed in several previous units. In particular, these ideas are elicited, used in new contexts, and in many cases extended through these new uses:

- **PS1.A: Structure and Properties of Matter:** Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (Developed in 6.2 Thermal Energy and used in 7.1 Chemical Reactions) In the Sound Waves Unit, a particle model for matter surfaces in Lesson 9 and is used throughout Lessons 10 to 14. In each case, students are constructing and using models of matter that include understandings from PS1.A. This particle model allows students to model how energy is transferred through a substance by collisions between the particles that make up the substance.
- **PS3.B: Conservation of Energy and Energy Transfer:** When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5) (Started in 6.2 Thermal Energy and continued in 8.1 Contact Forces) In the Sound Waves Unit, students reason that energy transfer from something like a drumstick to a drum means that the drumstick has less energy after colliding with the drum, leveraging a concept from PS3.B. Lessons 2 and 3 also target this DCI area as students analyze data and develop models using the idea that in order to get an object to start moving or vibrating, energy has to be transferred to that object.
- **PS3.A: Definitions of Energy:** Motion energy is properly called kinetic energy and moving objects have energy. (Developed in 8.1 Contact Forces) In Lessons 2 and 3 of the Sound Waves Unit, motion energy (like that of the drumstick) is called out as “kinetic energy” (PS3.A) and students model how this energy can be transferred between objects through collisions, like the drumstick hitting the drum.
- **PS2.A: Forces and Motion:** The idea that solids are elastic (i.e., that they change shape in response to a force being applied to them) is established in Lesson 2 and reinforced in Lesson 3 of the Sound Waves Unit. This idea from PS2.A, which is also addressed in the Contact Forces unit, is expanded in Lesson 4 to include the understanding that a greater force being applied on that solid causes a greater change in shape. Students use these understandings to explain the difference between how objects vibrate when making a louder versus a softer sound, and connect this louder sound with a stronger force being applied to the object. (Developed in 8.1 Contact Forces)
- **PS3.C: Relationship Between Energy and Forces:** When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (Developed in 6.2 Thermal Energy and 8.1 Contact Forces) Lessons 2, 3, 10, and 11 of the Sound Waves Unit leverage the idea that when two objects collide, each one exerts a force on the other that can cause energy to be transferred between the objects. In Lessons 2 and 3, students leverage this idea from PS3.C to model an object exerting a force on a sound-maker in order to transfer energy to the sound-maker to make it move (vibrate). In Lessons 10 and 11, students model how collisions between particles allow for the transfer of energy across a medium.

Science and Engineering Practices

One of our focal practices in this unit is Developing and Using Models. We expect that students have already had experience with the following elements of this practice from the 3-5 grade band:

- Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.
- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.
- Develop and/or use models to describe and/or predict phenomena.
- Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

In earlier middle school units, students have already:

- Developed, used, and revised models to describe, test, and predict more abstract phenomena. For example, they developed models for unobservable mechanisms (i.e., representing particle motion in regard to thermal energy).

In this unit, students will build off these prior experiences with models by:

- Developing and using models to describe, test, and predict unobservable mechanisms (such as participle motion with directionality).
- Using models to describe, test, and predict phenomena at unobservable scales (ie the speed of vibrations).

Another focal practice in this unit is Engaging in Argument from Evidence. We expect that students have already had experience with the following elements of this practice from the 3-5 grade band:

- Compare and refine arguments based on an evaluation of the evidence presented.

- Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.
- Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
- Construct and/or support an argument with evidence, data, and/or a model.
- Use data to evaluate claims about cause and effect.
- Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

In earlier middle school units, students have already:

- Built an understanding that a convincing argument supports or refutes a claim based on empirical evidence and scientific reasoning.
- Constructed arguments with more teacher or peer support to construct arguments at various stages of their work.

In this unit, students will:

- Construct arguments that are more summative in scope, requiring higher-level thinking about the evidence and reasoning elements.
- Develop their arguments with some teacher scaffolding at the beginning of the unit.
- Develop their arguments independently later in the unit.
- Compare and critique arguments.
- Respectfully provide and receive critiques.

This unit also frequently engages students in the practice of Using Mathematics and Computational Thinking. We expect that students have already had experience with the following elements of this practice from the 3-5 grade band:

- Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success.
- Organize simple data sets to reveal patterns that suggest relationships.
- Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.

In earlier middle school units, students have already:

- Used tables of data to find and compare patterns in rates of change.
- Created graphs of data collected from investigations to gather evidence to answer lesson questions.
- Analyzed graphical representations of data to identify positive and negative relationships between variables in an investigation.

In this unit, students will:

- Analyze and compare patterns in graphical and tabular representations of data using concepts like shape, proportion, and rate of change.
- Calculate unit rates from graphical and tabular representations of data.
- Discuss and use mathematical methods of finding the average of data sets, including calculating mean and median as a way to combine results from different groups in order to improve the accuracy of the class's data.
- Decide how to account for or discard outliers in the class's data in order to best represent what each group found in their investigations.
- Gather and use numerical data from investigations to represent functions through tables and graphs.
- Use patterns in tabular and graphical representations of data to identify proportional and non-proportional relationships.

Crosscutting Concepts

This unit focuses on the Crosscutting Concept of Patterns. We expect that students have already had experience with the following elements of this concept from the 3-5 grade band:

- Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena and designed products.
- Patterns of change can be used to make predictions.
- Patterns can be used as evidence to support an explanation.

In earlier middle school units, students:

- Used charts to identify patterns in data to identify cause and effect relationships.

In this unit, students:

- Begin by using patterns to identify cause and effect relationships about sound.
- Use charts and graphs to find patterns in data from their sound investigations.
- Identify patterns in rates of change as they discover that energy is transferred differently for increases in frequency versus amplitude of vibrations.

- Create graphs from investigation data after analyzing it, then look to see if their patterns agree with what they saw in their raw data.

Another focal Crosscutting Concept in this unit is Scale, Proportion, and Quantity. We expect that students have already had experience with the following elements of this concept from the 3-5 grade band:

- Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

In earlier middle school units, students:

- Build an understanding that sometimes things happen as a result of something we cannot see happening.
- Have experience with proportional relationships, such as the relationship between the speed of an object and the force being applied to it, which they investigated in regard to contact forces, and the populations in ecosystems increasing or decreasing proportionally.

In this unit, students:

- Extend their understanding of phenomena happening at scales we cannot see by using a variety of tools to model and collect data about the vibrations that occur when objects make sounds, and how those sounds transfer energy across media.
- Use proportional relationships to gather information from numerical data and graphs of how the energy transferred by a vibration changes with the frequency vs. the amplitude of the vibration, furthering their understanding of this concept.

What are some common ideas students might have?

Students may come to this unit with prior knowledge and experiences that can be leveraged to your advantage. Some of these ideas include the following:

- Things that make sound vibrate. (In particular, students may have had experiences in which they noticed that instruments and/or speakers vibrate as they make sound. If they do realize this, they are unlikely to claim that all objects that make sound vibrate, such as the sound of footsteps on a floor.)
- Sound can make things move, shake, or vibrate.
- Sound can travel through the air, through water, and even through some solids like walls, doors, and windows.
- Sound has a speed. (They may have heard about airplanes that can travel faster than the speed of sound.)
- Sounds travel out in all different directions.
- Sound travels through “sound waves,” which we can represent with wavy lines or curves. However students are unlikely to know *why* we call these waves, or what kinds of things are happening in the sound as the line goes up and down.

Remember not to assume from words or representations in students’ models that they have an understanding of how sound works on a deep, mechanistic level. It is highly unlikely at the beginning of the unit that students are thinking of the “sound waves” as emergent phenomena that are a result of many particles of matter interacting with each other in a repeating pattern. It is far more likely that they heard about sound being a wave, or read about it, or have seen an icon on their stereos or phones that is a wave-like representation. It’s important to keep pushing students to define what these waves are, how they travel, and what physically is traveling from the speaker to the window and hitting the window to make it vibrate.

- Many students, in their initial models, show something physical traveling from the speaker to the window to make the window shake. Some show physical waves, other show particles. Some students think that sound is a separate state of matter (particle or fluid) that has to move in between air particles.
- Students will likely have seen or felt speakers vibrate when music is played. They may not have connected the idea that the speaker changes loudness and pitch by changing its vibrations.
- Students may think that only things that produce sound are naturally springy or bendy, like musical instruments.
- We have also seen evidence that some students remain committed to a science idea commonly developed in prior grades: solids keep their shape (as opposed to liquids taking the shape of their container). So they may resist accepting the claim that things like a table, the floor, or the wall deform, spring back, and overshoot (very slightly). Students need a line of evidence to help them make sense of and accept this idea, which is what the laser and mirror investigation in Lesson 3 provides.
- Students may think that the reason we can hear through water is because water has air in it. While much water (e.g., in fish tanks and ponds) has dissolved gas in it, we want to convince students that sound can travel through a liquid via collisions of the particles of the liquid as it does through air.

- Students will likely have had experiences with or heard about sounds damaging hearing or have had their ears ring with particular sounds. They may not yet have connected these phenomena to what is happening in terms of the energy of the particles in a compression wave.

What modifications will I need to make if this unit is taught out of sequence?

If students haven't developed lines of evidence from previous grades (PS1 in grade 5) that air is matter and therefore air has mass, you may need to conduct additional investigations first to establish these ideas (e.g., massing a soda bottle before and after opening it; massing a volleyball before and after adding air).

If students haven't developed lines of evidence from previous grades (PS1A in MS) that (a) solids, liquids, and gases are made of particles; (b) the spacing between those particles is different for a solid and liquid versus a gas; and (c) that the particles in liquid or gas are moving, you will need to establish these ideas first. The unit rests on explaining sound as the collision of particles that transfers energy—so students need to see matter as composed of particles and see how those particles can move, even in solids.

The idea that moving objects have energy and that this energy can be transferred through collisions needs to be developed prior to this unit.

What are prerequisite math concepts necessary for the unit?

This unit calls upon understandings from all three grade levels in middle school CCSS. Later lessons, in particular, ask students to apply skills and understandings from grade 8 CCSS. Since this unit falls at the beginning of the 8th grade year of the Sequence, it's important to identify which math concepts and skills students may need extra support in applying as these concepts are fundamental to students engaging in Science and Engineering Practices like analyzing and interpreting data as well as using mathematical and computational thinking.

Mathematical concepts and skills from middle school CCSS are used in the following lessons:

- In Lesson 4, students collect and analyze data in the form of distance vs. time graphs showing the motion of a vibrating stick over time. Students characterize the shape of these graphs as wave patterns, and describe differences in properties like the vertical distance between peaks and troughs of waves when looking at graphs for louder vs. softer sounds. They will also connect the properties of these functions to the physical differences they represent using the axes of the graph to inform what the graph represents. This data analysis calls on the ability to describe the relationship between two quantities using a graph (CCSS.MATH.8.F.B.5) as well as the ability to compare two functions expressed graphically in order to determine key properties about each function (CCSS.MATH.8.F.A.2).
- In Lesson 5, students are expected to exercise these same skills and understandings to interpret differences between graphs of distance vs. time for a stick simulating higher- and lower-pitched sounds. In addition, students define the frequency as the amount of vibrations the stick goes through in a second. They calculate this frequency by finding the unit rate (vibrations per second) using the overall number of vibrations and the total time passed (CCSS.MATH.6.RP.A.2).
- In Lesson 5 and 6, students work independently to interpret graphs of time vs. distance to describe sounds in terms of pitch and loudness using qualitative properties of the functions shown on each graph (CCSS.MATH.8.F.A.2). Depending on the math understandings that students display in Lessons 4 and 5, students might need support in reading and interpreting these graphs. It may help some students to go over the axes of the graph as a class to draw attention to what the graph is showing, and students may benefit from probing questions like, "What differences do you notice between these graphs? How do those differences compare to what we saw in the graphs we made with the motion detector?"
- In Lesson 13, students discuss and use mathematical methods of finding the average of data sets, including calculating mean and median as a way to combine results from different groups in order to improve the accuracy of the class's data. They also work together as a class to decide how to account for or discard outliers in the class's data in order to best represent what each group found in their investigations (CCSS.MATH.6.SP.B.5). Depending on their experience using these concepts in math classes, students may need reminders of how mean and median are calculated. You can support students in recalling these procedures by taking a sample data set (either from the investigation or a random example set) and working together as a class to describe how students could find the mean and median of the set. By doing this with the class or with small groups that could use this extra practice, you can support students with mathematical methods needed to analyze the data the class has collected to draw conclusions about the lesson question.

- Later in Lesson 13, students gather data describing how the energy of a vibration changes with changes to the frequency and amplitude of the vibration. They then use this data to describe and graph functions that represent the relationships between energy and frequency and energy and amplitude. From their numerical data and the graphs they create, students will see that there is a proportional relationship between frequency and energy transferred; when we increase the frequency of the vibrations, the energy transferred increases in proportion (CCSS.MATH.7.RP.A.2). While frequency and energy have a linear relationship, amplitude and energy have a nonlinear relationship where increasing amplitude causes much greater increases in energy compared to increasing frequency. Some students may recognize the pattern on the amplitude vs. energy graph as exponential, where increasing amplitude causes a much greater increase in energy than in a linear relationship like that between frequency and energy (CCSS.MATH.8.F.A.3).
- By the end of Lesson 13, Students are expected to use these qualitative properties of the graphs for frequency vs. energy and amplitude vs. energy to conclude that the energy vs. amplitude function has a greater rate of change than does the energy vs. frequency function (CCSS.MATH.8.F.A.2). Depending on students' experience with linear and nonlinear functions, students may identify these differences in different ways. Some students may only be able to state that the amplitude vs. energy graph is steeper or increases more quickly, and they may need support in connecting this observation to the idea that increasing amplitude causes a greater increase in energy compared to frequency. Further, some students may benefit from using the data tables they generate in their investigations to find numerical patterns to support their observations of the two graphs. In this numerical data, for example, they might notice that doubling the frequency doubles the energy but doubling the amplitude makes the energy increase by 4 times. These numerical patterns may be helpful to call out and emphasize for students who are still developing their skills at reading and analyzing graphs.

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy routing integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things, and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form, and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and well-constructed paragraph.

Put Yourself in This Scene

Literacy Objective

✓ Initiate thinking about the need to evaluate text.

Literacy Activity

- Read a brief scenario to pique interest, launch discussion, and begin to frame expectations.

Instructional Resources

Student Reader

Preface

Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigation

The reading of the Preface is appropriate during your first week of unit instruction, while students are investigating Lessons 1 and 2 in class. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS

Crosscutting Concept: Cause and Effect

CCSS

English Language Arts
RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization. No Core Vocabulary terms are highlighted in the text of the Preface.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

media	**oppose**	**science literacy**
social media	**support**	**wind turbine**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the Science Literacy Student Reader and discuss the Preface. If you are performing Science Literacy as a structured, weekly routine, you might plan an introduction like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the Preface reading.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know that for the Science Literacy routine, they will read independently and then complete a short writing assignment. The reading selections relate to topics they will be exploring in their Sound Waves unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have unoccupied class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface about the wind turbine scenario is written at approximately Lexile 1100–1200, which leans toward the high end of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion. (Friday)

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Student Reader

Preface

Pages 2–4 **Suggested prompts**	**Sample student responses**
How would you summarize the "scene" referred to in the title?	*It's an imagined scenario in which I read two social media posts after school.*

Pages 2–4 **Suggested prompts**	**Sample student responses**
What's the topic of the social media posts?	*a proposed plan for wind turbines to be installed nearby in the community*
Where does the scenario have you imagine that you live?	*in a community near the ocean*
How are the posts alike or different?	*One is opposed to the offshore wind turbine project, and the other supports it.*
What reasons does the writer of the first post give for opposing the wind turbine project? What claims does the writer make?	*The turbines will disrupt squid fishers.* *The turbine blades will kill thousands of migratory birds.* *Noise from the turbines will be a nuisance.* *Pressure waves from the rotating turbine blades might cause headaches, fatigue, depression, and insomnia.* *Dredging the seafloor to anchor the turbine towers will destroy the habitats of sponges, seagrass, lobsters, crabs, and fish.* *Construction noise from the turbine installation will disturb migrations of whales and dolphins.* *Cables from the turbines might cause electromagnetic disturbances in the surrounding natural habitat.* *Electrical output will only power a limited number of homes.* *Unsightliness of turbines will make home values go down.*
What reasons does the writer of the second post give for supporting the wind turbine project? What claims does the writer make?	*Most people who oppose the turbines only care about the view from their summer homes.* *The project benefits both the local community and the world.* *The turbines will be so far offshore as to be barely visible.* *The sounds from the turbines will be inaudible both because of distance and because the sounds they make are of a range imperceptible to human hearing.* *Claims of negative health effects are not substantiated by science and are only made by opponents of the project.* *The habitat disruption is minor by comparison with that of the fossil fuel industry.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 2–4 **Suggested prompts**	**Sample student responses**
What does the claim that the wind turbine project is a "net positive" for the community mean?	*that the positive aspects of it outnumber or outweigh the negative aspects*
Does the supporter of the project acknowledge any drawbacks? Does the opposition to the project acknowledge any benefits?	*The supporter implies that there are drawbacks but says that the benefits far outweigh the drawbacks.* *The opposition does not really acknowledge any benefits.*

Page 5 **Suggested prompts**	**Sample student responses**
What does your imaginary mother reveal and point out in the scenario?	*that the wind turbine project had already been previously approved by the town* *that elected officials slowed the project down but different elected officials will start moving the project forward again* *that some of the information in one or both of the posts is probably not accurate*
Does the reading passage tell you which social media post to believe or which side to take in the argument for or against the wind turbine project?	*no*
The scenario sets up the opportunity to think about what skills?	*the ability to tell good information from bad information*
What does the internet have to do with science literacy?	*The internet enables us to see a huge amount of information, and the information is not all accurate, so we have to be able to sort it out.*
Why is scientific literacy important?	*because a lot of the information we have to deal with is untrue or misleading* *because understanding science helps each person individually and helps each individual be a better member of the community*

KEY IDEA—Point out that, without an investigation into the sources of information in the claims made by the writers of the two social media posts, there isn't really a way to make an informed decision about which side to take on such an issue. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more knowledge to apply to the scenario, and they will circle back to the topic of sound and disturbances from wind turbines at the end of the unit.

LESSON 1

How does a sound source make something like this happen?

Previous Lesson

There is no previous lesson.

This Lesson

Anchoring Phenomenon

3 DAYS

We are introduced to an anchoring phenomenon, which will be referred to throughout the unit. We observe a window in a building moving, and it seems to be caused by sound blasting from a truck in the parking lot. We agree that a speaker inside the truck is making these sounds. We observe a speaker up close to see what it's doing when it makes sound. We use the observations from these phenomena to think about other sound-related phenomena, which in turn leads us to form a broader set of questions on our Driving Question Board (DQB). Then we brainstorm ways for the class to investigate these questions.

Next Lesson

We will observe various musical instruments and a speaker when they are making sounds and connect what we discover to what we observe when we analyze slow-motion videos of similar objects. We will co-construct a model to represent the shape changes observed in these objects over time, and we will apply this model to another instrument.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Develop a model to explain how a sound source (cause) can make another object move (effect).

Ask questions about patterns in observations that can be investigated to figure out how sound travels and causes movement in other objects.

What Students Will Figure Out

A speaker making sounds can be detected from a distance and can even cause things like a nearby window to move. The speaker moves back and forth when it is making sound. Students agree that the sound source, how sound travels, and how sounds are received are important parts of explaining how sounds can be detected from a distance.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**MAKE OBSERVATIONS OF A VIDEO OF A TRUCK PLAYING LOUD MUSIC** Show the truck video while students record noticings and wonderings. Have students share some of what they notice and wonder with a partner.	A-B	chart paper, markers, computer and projector, truck video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
2	7 min	**BUILD CLASS RECORD OF OBSERVATIONS OF VIDEO OF TRUCK SPEAKER AND WINDOW** Students share out noticings and wonderings in a whole-group discussion. These are recorded on chart paper.	C	chart paper, markers
3	15 min	**MAKE OBSERVATIONS OF SPEAKER MAKING SOUNDS** Students observe a speaker, like the one in the truck from the video, up close. They make noticings and wonderings of how the speaker is able to make a nearby "window" move.	D	Speaker Examination
4	15 min	**MAKE INITIAL MODELS OF HOW THE SPEAKER MAKES THE WINDOW MOVE** Students individually create initial models.	E	*Initial Model Diagram*
				End of day 1
5	15 min	**SHARE AND COMPARE MODELS OF HOW THE SPEAKER MAKES THE WINDOW MOVE** Pull students together to share similarities and differences in their models and keep track of their comments on the chart paper as they record them in their science notebooks.	F-G	*Initial Model Diagram,* chart paper, markers
6	15 min	**BUILD INITIAL CLASS CONSENSUS MODEL OF HOW THE SPEAKER MAKES THE WINDOW MOVE** Convene in a Scientists Circle to construct a class consensus model for the truck-window phenomenon using their models and their observations of the video and the speaker.	H	*Initial Model Diagram,* chart paper, markers
7	10 min	**BRAINSTORM RELATED SOUND PHENOMENA** Brainstorm examples of other times that students have observed a sound being made, a sound traveling, or a sound being received like in the truck video.	I-J	chart paper, markers

Part	Duration	Summary	Slide	Materials
8	5 min	**DEVELOP INITIAL SOUND-RELATED QUESTIONS** Students record in their notebooks at least two questions that they think we could figure out to learn more about what's happening in the truck video.	K	
				End of day 2
9	7 min	**DISCUSS QUESTIONS TO POST ON DRIVING QUESTION BOARD** Provide question stems to help students work on their questions from last time to prepare to post them on the Driving Question Board.	L	sticky notes
10	23 min	**POST QUESTIONS TO DRIVING QUESTION BOARD** Gather in a circle to construct the Driving Question Board around the three parts of the consensus model.	M	sticky notes, chart paper, markers
11	10 min	**BRAINSTORM IDEAS FOR INVESTIGATING OUR QUESTIONS** Create an Initial Ideas for Investigation poster and record the students' thoughts on how we can figure out the answers to our initial questions as we move forward.	N	chart paper, markers
12	5 min	**NAVIGATION** Look back at our list of questions and the investigations to see where we should start.	O	
				End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Speaker Examination materials			• speaker • mini amplifier • 12V DC power adaptor • RCA to 3.5 mm audio cable • 2 alligator clip wires • music source • plastic wrap • bowl
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Initial Model Diagram* • sticky notes		• chart paper • markers • computer and projector • truck video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • sticky notes

Materials preparation (10 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Online Resources

Test the truck video to make sure it plays. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Determine where to set up the Driving Question Board so that students can gather around it, ideally in a Scientists Circle. Gather notecards or sticky notes and markers.

Prepare chart paper with titles (i.e., Notice and Wonder, Related Phenomena, Ideas for Investigations) ahead of time, if desired.

Day 1: Speaker examination.

- Group size: Whole class
- Setup:

1. Gather the speaker, mini amplifier, 12V DC power adaptor, RCA to 3.5 mm audio cable, two alligator clip wires, and whatever the students will use to play music (e.g., computer, phone, iPod/iPad, mp3 player).

2. Be sure the amplifier is turned off and the volume dial is all the way down (zero).

3. Find the two metal tabs on one side of the speaker. Attach one end of each alligator wire (different colors for each tab) to make a wide "bite" around each of these metal tabs.

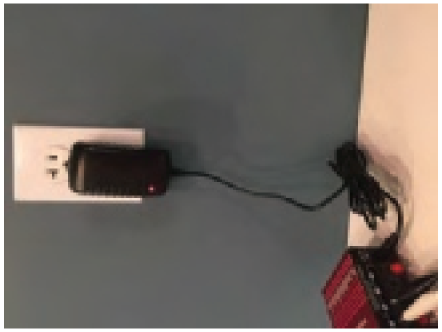
4. Use the other end of each alligator clip to "bite" into two of the tabbed sockets on the back of the amp. You'll have one part of the "jaw" in the socket and one part on the top of the black plastic box for that socket.

5. Choose to use both of either the "R" (black and red tabs) OR "L" sockets—do not use two of the same color. You'll have two sockets left open (also a red and a black).

6. Connect the double ends of the audio cable into the round sockets at the back of the amp labeled "L" and "R."

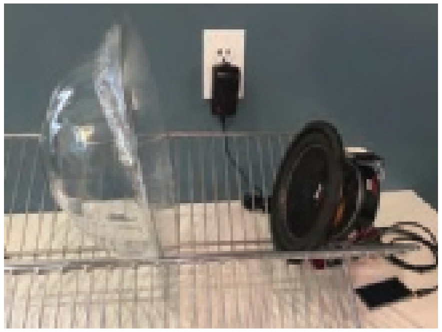
7. Connect the other (single) end of the audio cable into the headphones jack of your music player.

8. Finally, plug the power adaptor into the back of the amp where it says “DC 12V” and then plug it into a standard wall outlet.



9. Confirm that the amplifier’s volume dial is all the way down to zero, then turn on the amp’s power. You should see the outside ring of the volume knob light up. Start music playing from the music source, and then turn up the volume dial to confirm you can hear it. Students can adjust the volume further (up to your discretion; it can get very loud) and adjust the treble/bass knobs as desired during their investigations.

10. Use plastic wrap to create a model of the window. Depending on your situation and where you’re able to set up the speaker, you might put plastic wrap on the top of a bowl that can be held near the speaker.



11. Another option is to put plastic wrap between two legs of a chair or desk near your speaker setup.

- Notes for during the lab: Make sure you have a place where all students can gather around and see.
- Safety: The volume can get very loud. Use caution if students are adjusting the volume.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

This lesson elicits students' initial ideas about how sounds can cause things far away to move. In this lesson students are introduced to the anchoring phenomenon—a video of a truck playing music causes a window nearby to vibrate. This leads students to start wondering about other sound-related phenomena, which in turn leads to a wealth of new questions, such as, (1) What causes different sounds? (2) What is traveling from a sound source to our ears? (3) How are sounds received? By the end of the unit students will be able to answer these questions in terms of how patterns of differences in vibrations are tied to differences in characteristics of the sounds being made and how sound travels through matter.

We hope to foreground competing explanations in this lesson to motivate ideas for investigations that correspond to the investigations students will do in the first learning set of the unit.

Where We Are NOT Going

Students may come to this unit with prior knowledge and experiences that can be leveraged. Remember not to let words or representations in students' models signal a false understanding of how sound works on a deep, mechanistic level. It is unlikely at this point in the unit that students are thinking of the sound waves as an emergent phenomenon that are a result of how particles of matter interact with each other. It is far more likely that they heard or read about sound being a wave or have seen a wave-like icon on their stereos or phones that represents sound. It's important to keep pushing students to define what these waves are and how they travel and what physically is traveling from the speaker to the window and hitting the window to make it vibrate. Asking specific questions, like the following, can lead students to consider gaps in their models that the class can investigate:

- *How could we gather evidence for the model you've made?*
- *How could we test or detect these kinds of waves? Could we see them if we zoomed in far enough?*
- *What are these waves made of? How are they created?*
- *Are these waves something physical? Are they made of matter? Where does the matter to make them come from?*
- *Why is it a wave and not something else?*
- *What's making the window move?*
- *How do these waves get picked up by our ears so we can understand the sounds being made?*

Students may have questions and experiences with hearing that are evoked by all this discussion of sound phenomena. While this unit does not delve deeply into how sounds are received and processed by our ears and brains, it's still productive for students to bring up these ideas in this lesson. We will address what's happening in our ears later in the unit, and what's happening in our ears might provide ideas about mechanisms at work across other phenomena related to how we detect sounds.

LEARNING PLAN FOR LESSON 1

1. Make observations of a video of a truck playing loud music.

8 MIN

Materials: science notebook, chart paper, markers, computer and projector, truck video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Show the truck video. Tell students that you recently saw a video that showed some strange patterns, and you'd like to share it with them. Show **slide A**. Then ask students to create a T-chart in their science notebooks to record what they notice and wonder about in the video the class will be watching together.

Notice	Wonder
I notice ...	I wonder ...

Science Notebook

If students have not yet set up and organized their science notebooks, you can include additional time to do so now. Have students organize their notebooks using a format that will be easy for them and you to maintain across the year. Here are some helpful tips for keeping the notebooks organized:

- Number pages so students can easily refer to their work (models, data sets, and so forth) during collaborative discussions.
- Maintain and update a table of contents throughout the unit. Reserve at least 4 pages (2 pages front and back) for the table of contents for a single unit. The table of contents can be at the front of the notebook for all units within or at the beginning of each new unit within the notebook.
- Give each page a recognizable title that can be added to the table of contents.
- After the table of contents, reserving the next 20 pages (10 pages front and back) for their Progress Tracker for the unit. This is the place where students will individually reflect on their progress and also add key consensus modeling work completed by the class.

For more information on science notebook management, refer to that section of the *Teacher Handbook*.

Play the truck video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) It is helpful to show the video in two sections and to pause after each section to allow students to record noticings and wonderings:

Section 1: Skip the titles and begin the video at 12 seconds and stop the video at 26 seconds (i.e., you will show only from time point 00:12 to 00:26.)

Section 2: Skip the titles and begin the video at 12 seconds and play it to the end.

Watch the whole video (from 00:12) a second time and allow students time to record further observations and questions. Allow students to watch the video multiple times or stop the video at key moments if doing so will help them draw out key noticings and wonderings.

Tell students, *Now we are going to share the noticings and wonderings we've made of the video. We are going to start by sharing these observations with a partner before we build a list as a whole class.*

Students share noticings and wonderings in pairs. Once students have had enough time to closely observe this phenomenon, instruct them to share their noticings and wonderings with a partner**.** Show **slide B**. Questions on the slide can be used to frame their discussions.

While students are discussing their observations and questions, walk around the room and listen to their discussions. Where needed, use questions to help students think about the explanations for their observations or the justifications for their ideas.

Suggested prompts	Sample student responses
What did you see happening in the video? What patterns did you notice?	*The truck was shaking while it was playing music, and the window was shaking, too.*
What did you notice when the music played? Did anything else visibly vibrate?	*The mirror on the truck and the window were vibrating.*
Where did it seem these sounds were coming from?	*I think they were coming from a speaker inside the truck.*
Did all the objects vibrate in the same way?	*The mirrors on the truck vibrated more than the window in the building. I also saw the driver's shirt vibrating.*
Were there instances in which the music did not cause the window to vibrate?	*Sometimes the window would vibrate and then stop vibrating.*
Did you notice anything different about the sounds when the glass was or was not vibrating?	*When it was louder, it vibrated more.* *When the bass played, it vibrated.*
What was different about the music that might have caused the vibrations to stop?	*Wait—but the driver didn't change the volume; it was loud the whole time.*
Does the loudness (volume) of the music matter?	*I noticed that when the bass played, it shook more.*

Additional Guidance

Students will likely refer to loudness as volume. They will be familiar with adjusting the volume of radios, TVs, and so forth, and they will see the volume knob on the amp used later in the lesson. Encourage the students (and remind yourself) to refer to "loudness" of sounds throughout this unit instead of volume to avoid confusion about multiple meanings (specifically that volume is the amount of space an object takes up).

2. Build class record of observations of video of truck speaker and window. 7 MIN

Materials: science notebook, chart paper, markers

Tell students, *We've been sharing with our partners, but it would help to build a list of everyone's noticings and wonderings that includes ideas from all of our partner discussions.*

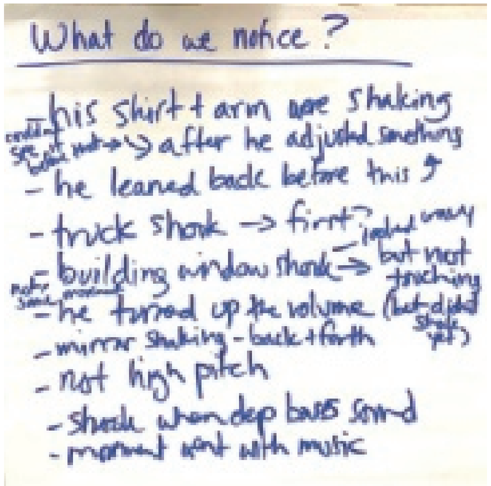
Facilitate a whole-class discussion. Show **slide C.** Ask students to share their noticings and wonderings of the phenomenon they observed in the video. Publicly record these ideas (e.g., using chart paper, the board, or a digital document). For each observation, ask the entire class if other student pairs also had a similar observation. Press students to provide justification for their ideas and begin to explain their observations. The goal is for students to use evidence from the video to support their ideas.*

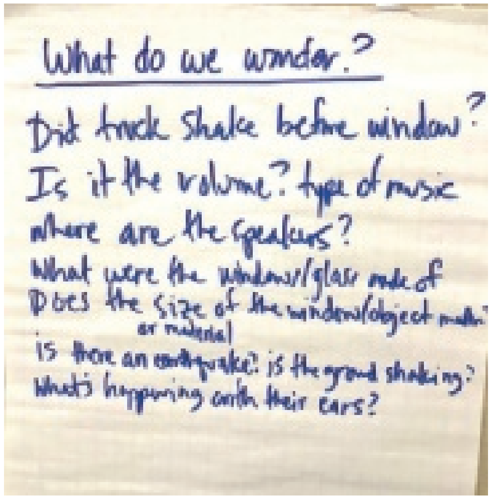
Supporting Students in Making Connections in ELA

Today's activities rely on students communicating and articulating their thinking. One tool that may support classroom discussion is the *Communicating in Scientific Ways* sentence starters. This one-page document can be blown up and printed as a class poster, printed on 8.5×11 paper and posted near students' desks, and/or scaled down and taped into students' notebooks. To support student discussion and writing, reference the sentences starters on the poster and encourage students to use those sentence starters to help them communicate. These sentence starters can be especially useful for helping students engage in scientific talk, particularly students who may feel reluctant to contribute. They can also help students write about their observations, analyses, and explanations.

Rewatch portions of the video as needed. If students do not mention some of the aspects of the phenomenon that are important to notice, such as differences in the sound that led vibrations to start or stop, use the more general questions to prompt them to notice a particular aspect of the phenomenon.

As students provide their initial explanations, it is natural for questions or ideas for investigations to come up. Record these questions and ideas on the Initial Ideas for Investigation charts, respectively.





These pictures show one class's lists of noticings and wonderings of the phenomenon. This is not meant to be a comprehensive list of observations; rather, it's an example of what could be done.

Motivate investigating this phenomenon. Once the class has had some time to build the lists of noticings and wonderings, end the discussion by pointing out that students have identified a lot of patterns that they can't yet explain and that the class has a lot of questions that need to be investigated to better understand what's causing the phenomenon in the video.

*Strategies for this Initial Ideas Discussion

This discussion should be a fluid moment for students to share their observations and consider their initial explanations and questions. The discussion should be grounded in what students notice and find interesting rather than focused on a set question to frame the discussion. Consequently, the emphasis should be on eliciting and recording students' ideas and questions so the class can use these to build on as they move towards explaining the patterns they observed in the video.

With these priorities in mind, we do want students to begin transitioning to thinking about what's happening to cause the patterns they noticed in the video. Supporting students in being specific and thoughtful about what they observed (and what questions those observations make them ask) will help drive the class towards a need to investigate what's happening on a deeper level.

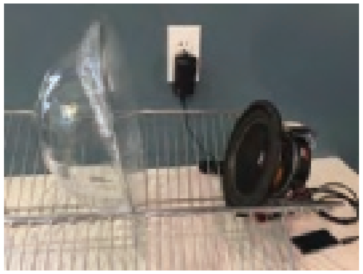
3. Make observations of speaker making sounds.

15 MIN

Materials: Speaker Examination, science notebook

Tell students, *Our observations have led us to the idea that a speaker inside the truck is doing something to make the window move. We had some ideas and questions about what the speaker was doing, and I thought it might be helpful if we could observe something like what's happening in the video up close.*

Introduce students to the speaker apparatus. The speaker device you set up is a way to recreate what happened in the truck video. Show it to students and prompt them to identify how this setup models what they saw in the video.



Suggested prompts	Sample student responses
What does this setup have that's similar to what you saw in the video?	*It has a speaker that can make sounds, like the one in the truck.* *It has something like a window.* *There's space in between the window and the speaker.*
How is this setup different from what you saw in the video?	*The speaker's by itself, not in a truck.* *The window isn't made of the same stuff.* *The speaker and the window are closer together than they were in the video.*
How could observing this model help us understand what's happening in the video?	*We could get a better look at how the speaker is working.* *We could touch stuff or look at it up close, which we couldn't do with the video.* *We could see what happens if we change part of the setup.*

Students make noticings and wonderings of the speaker apparatus. Show **slide D**. Ask students to create a table in their science notebooks to record their noticings and wonderings of the speaker apparatus.

Notice	Wonder
I notice ...	I wonder ...

Tell students, *As we're making observations of this scaled-down version of what we saw in the video, let's keep a couple of our questions in mind. We want to make noticings and wonderings about (1) what the speaker is doing when it's making sounds and (2) what is happening while the speaker is making sounds that might help us understand what's causing the patterns we see in the video.*

Have students gather around the speaker with their notebooks to make their observations. Allow small groups of students to take turns coming closer to the setup to look at each element of the apparatus up close, especially the speaker. Have them record in their notebooks the noticings they make.

Additional Guidance

Students will look closely at what the speaker is doing along with instruments in the next lesson so you do not need to spend extra time here. This examination of the speaker here is to help students make observations about a part of the truck video phenomenon that they mention but cannot see: the speaker.

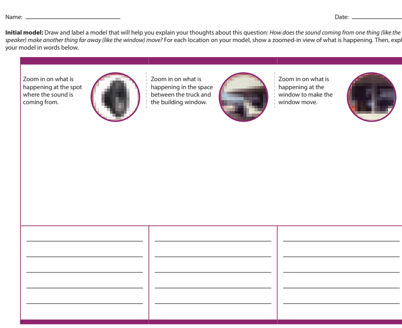
As students are making noticings, ask questions to prompt them to consider what's happening to cause what they notice and how it connects to what they saw in the video.

Suggested prompts	Sample student responses
What do you see happening when you look up closer?	*You can see the speaker vibrating.*
Did you notice any patterns in how the speaker was moving?	*It was moving more when the sound was louder.* *I could see it boom when there was a drum or beat sound.* *It was kind of hard to tell. I think it felt different, but I couldn't really see it because it was moving too fast.*
*Are there other things we could do to help us make clearer noticings or answer some of our wonderings? (**teacher note:** You will not do these additional investigations here in this lesson but will have a chance to look closer in lesson 2—ask students to keep these ideas in mind for ideas for investigations)*	*We could put stuff on the speaker to see how it moves for different sounds.* *We could zoom in on the speaker.* *We could take a slo-mo video of the speaker to see how it's moving.*

Navigate students towards making initial models. Once students have had some time to make their observations, point out that we've figured out more about what's happening in the video, but we still have a lot of questions to answer. Emphasize that now is a good time to shift from noticing to trying to explain what's causing the patterns that we observed.

4. Make initial models of how the speaker makes the window move. 15 MIN

Materials: science notebook, *Initial Model Diagram*



Tell students, *We've made a lot of noticings of what's happening in this phenomenon of a car's speaker making a faraway window move. We seem to agree on what's happening in the video, but it sounds like we have some different ideas about how the speaker is making the window move.*

Help students develop their initial models. Show **slide E**. Pass out *Initial Model Diagram* to students (one per student). Ask students to develop their initial models. Remind students that everyone heard the music and saw the window shaking, but we may have different explanations for why a sound coming from one thing could make another thing far away move.

Ask students to draw on their handouts how they might explain the question, "How does the sound coming from one thing (like the speaker) make another thing far away (like the window) move?" Cue them to show what is happening in each of the three places indicated. Emphasize to students that on their models they should be showing what's happening at a zoomed-in scale at three places: at the surface of the speaker, in the air between the speaker and the window, and at the surface of the window. There might be points where students need to show something they can't see. Remind students that they can use pictures, symbols, and labels to represent components they can't see.

Also, direct students to use the lines below each model to write a short caption explaining what's happening in their model. This will support their explanation and make their thinking clearer to people who might not understand their drawing alone.

While students are drawing their models, walk around the room and quietly ask probing questions if there are no labels on the models.

Suggested prompts

- *What did you draw in the space between the sound and the air? Can you label that?*
- *Where is the sound coming from in your model? Can you label that?*
- *How are you showing the sound moving to the window? Can you label that?*
- *What do these lines represent? Can you label that?*
- *What do you think is happening at the window to make it move? How can you show that?*

When finished, ask students to tape *Initial Model Diagram* into their notebooks.

Wrap up. Summarize for them what happened during the class and what will happen in the next class.

Say, *Today we saw a really interesting phenomenon about music in a truck shaking a window. We made some observations about that, we have some questions about that, and we started thinking about how that happens. But we aren't done! Tomorrow we will take a look at some of the similarities and differences in our models.*

Be sure to have students turn in their notebooks so you can glance through their models before the next class day. You will want to select some different models to share with the whole class.

Additional Guidance

Select models that are very different from one another. A diversity of ideas in the models will help open up new possibilities in student thinking. We often see questions that end up on the Driving Question Board that come from new ideas raised in discussion about these models.

End of day 1

5. Share and compare models of how the speaker makes the window move. 15 MIN

Materials: science notebook, *Initial Model Diagram,* chart paper, markers

Choose a norm to work on today. Display **slide F**. As students begin class today, direct them to look over the classroom norms again. Ask students to choose a norm to practice in class today. Then give students a minute to turn and talk with a partner to share the norm they selected.

Additional Guidance

Based on the work done in the previous unit, evaluate how well your students did with the classroom norms guiding their work. If students did well with some norms, celebrate that now. If students need additional work on other norms, focus their attention to those norms. Spend a few minutes discussing the norms again. Have students share (1) what the norm would look like if everyone was following it and (2) what it would sound like. Then tell students that the class will practice these norms today as they work on their consensus model.

Remind students of their previous work. Say, *Last class, we observed a new phenomenon: We saw a speaker in a truck making a window shake in a parking lot. We also got a chance to observe a speaker like the one in the truck up close to see what it was doing when it made sounds. We had some different initial models for how the speaker is making the window move. We're going to start today by sharing some of our ideas.*

Students compare models with a partner.* Have students create a T-chart with similarities and differences in their notebook. Show **slide G**. Ask students to get out the initial models they created in the last class and compare them with a partner. Instruct students that each partner should have a minute or two to explain the thinking behind their models. While students are sharing and comparing models, they should record any similarities, differences, or questions they see between their models in a table like the one below.

Similarities between our models	Differences & questions in our models

While students are sharing, go around and prompt students to explain what they drew and wrote on their models. Emphasize that at this point it's key for each student to make their thinking visible so the class can see what ideas everyone agrees on and where there are still questions to figure out.

Say, *I really appreciate how you all have shared and analyzed models with a partner. It would also be helpful for all of us to analyze a few of our class's different models together. Does anyone feel like their partner's model would be good for all of us to take a look at?*

A few students share their models with the class. Select three or four students with different models to come up and show their models to the class and explain the elements of their models.*

When a student is done presenting, ask a few students who were listening to say how their peer's model was similar to or different from theirs. Keep track of these similarities and differences on chart paper. Also encourage students to ask clarifying questions of the students presenting.*

Suggested prompts	Sample student responses
What is similar between your model and your peer's model?	*The sound definitely comes from the truck somehow (the speakers, the radio).* *Sound traveled from the truck to the window somehow.* *The window responded to the sound (sound pushed the window) somehow.*

*Supporting Students in Engaging in Developing and Using Models

Emphasize to students that they will use models for explaining why and how phenomena occur as they do. Models need to be "applied" to be useful in explaining something, and models are most helpful when they can help us explain a lot of similar phenomena. Because students have developed their initial models, they may not be able to explain many parts of the phenomenon with confidence, and that is OK. Models are supposed to change as our knowledge grows; therefore, students will continue to revise and edit their model over the course of the unit.

*Strategies for This Initial Ideas Discussion

The purpose of this discussion is simply to get the students to articulate parts of the model that may be in their heads but not on paper. Don't evaluate whether the elements should or shouldn't be there. Just help them talk out loud about everything that is in the model, and if they say something that isn't clearly shown in the model, push them to say where in the model it appears or what they would change or add to the model to show that idea.

*Attending to Equity

This is an important opportunity to emphasize that each individual has contributions to make to

Suggested prompts	Sample student responses
What is different between your model and your peer's model?	*We noticed differences in how the sound was produced. What does a speaker or a radio do to make sound?* *We noticed differences in how people represented how the sound travels or what the sound was.* *We noticed differences in how sound is actually making the window shake.*

their community of learners. It is through differences in thinking that the class will grow their knowledge together. Throughout this unit, students will be asked to be open to sharing knowledge products that depict their current thinking and to be open to learning from classmates who share their knowledge too.

6. Build initial class consensus model of how the speaker makes the window move.

15 MIN

Materials: science notebook, *Initial Model Diagram,* chart paper, markers

Show **slide H.** Say, *There are a lot of similarities and differences in our ideas about how the speaker is making the window move in the video. Let's come together and make a consensus model of what we agree on in our explanation and where we disagree or have questions.**

Convene in a Scientists Circle to construct an initial class consensus model.* Have students come together in a Scientists Circle with their initial models and the list of similarities and differences they recorded in their notebooks.

Additional Guidance

You will form a Scientists Circle in many future lessons as well. Setting up the norms and logistics for forming, equitably participating in, and breaking down that space is important to do if this is your first time forming such a space. Having students sit in a circle so they can see and face one another can help build a sense of shared mission and a community of learners working together. Returning to this Scientists Circle throughout the course of the unit to take stock of what the class has figured out and where students need to go next will be an important tool in helping the class take on greater agency in steering the direction of their learning. This circle will also help build a sense of pride in their work. You may want to inform students that professional scientists also collaborate with one another to brainstorm, discuss, and review their work.

Key Ideas

Purpose of this discussion: Develop an initial class consensus model to capture the ideas we agree and disagree on or are more uncertain about to explain how we can hear sounds from a distance and to help us realize that, while we have agreement on some common elements, we have many questions.

Listen for these ideas:

Areas of agreement

- The speaker is moving back and forth when it makes sounds.

***Attending to Equity**
Emphasize to students that when they work together to build consensus, everyone's ideas matter. Consensus does not necessarily mean that everyone must agree on everything. Rather, consensus is needed to identify areas of common ground between ideas that may appear to differ. That way we have a better sense of where we all agree and where we do not agree.

***Strategies for This Consensus Discussion**
It is again important to accept all student responses and to encourage students to share their ideas. Further, emphasize that it is important to highlight areas of disagreement and help students clearly explicate their thinking in these areas. Accept and probe the different ideas that students propose but do not privilege "correct" ideas over others. Make sure to use student language when writing on the consensus model.

- Sound is traveling between the speaker and the window.
- Something is causing the window to move back and forth.

Possible areas of disagreement or controversy

- **What is happening at the sound source:** How does it make louder sounds? Different pitch sounds? Where does the sound come from? What is coming out of the speaker?
- **How sound is traveling and what sound is:** Is it sound waves, vibrations, particles of sound, or notes going to the window from the speaker? What are sound waves? What is the sound that's traveling? Does it spread out or get less as you move further away?
- **What is happening at the receiver:** Is something (vibrations, waves, particles) hitting the window? How are vibrations from the speaker making the window move?

Say: *After making noticings of the truck video and of the speaker in class making sounds, we have some ideas of what the speaker is doing when it's making sounds and causing the window to shake from a distance. We need to figure out what parts of our explanation we agree on and what parts we need to investigate to make a full and complete model for how the speaker making sounds is causing the window to move.*

Draw and discuss the three parts of the model that all students had. Start co-constructing this model by identifying the three basic parts of the model that were part of every student's initial model. Title this model "Initial Model for How the Speaker Made the Window Shake". Draw in a box for a sound source and label it "speaker". Draw in another box and label it "window". Last, draw an arrow from the speaker to the window.

Discuss what is happening at the speaker or sound source.

Suggested prompts	Sample student responses	Follow-up questions
Let's start with the sound source. What did we seem to agree on there?	*Many of us had the speaker vibrating and moving back and forth.*	*Is this something everyone showed?* *How did different people show that? Did we all show it the same way?*
What are some differences in how you showed what was happening when the speaker moved?	*I showed wavy lines coming off of the speaker when it moved.* *I showed little dots coming off of the speaker.*	*So are you saying that waves are coming off of the speaker?* *Can you say more about that?*
I noticed differences in how some people showed what was coming out of the speaker.	*I showed darker lines right next to the speaker and then they get lighter as they spread out.* *These darker lines show the louder boom sounds.*	*How is that different from what ____ is showing?* *Hmm, that's interesting. Did anyone else show what the speaker is doing when it makes different sounds?*

Summarize what the class agreed upon and move on to the next part of the model. Say, *So it sounds like we have agreement that the speaker is moving, but we have some questions about what the sound coming out is and how it* *makes different sounds*. At this point your model will have question marks at the sound source (we may know what the speaker is doing, but we aren't sure how it's making sounds).

Discuss what is happening when the sound travels.

Suggested prompts	Sample student responses	Follow-up questions
How did we think the sound was getting to the window?	*A lot of us thought there were sound waves going to the window from the speaker.* *Sounds are going through the air to the window.*	*Is this something everyone showed?* *Did we all show it the same way?* *Can you show us how you represented or talked about these waves?*
What are some differences in how you showed what was traveling?	*I showed vibrations traveling because I know that sounds come from vibrations.* *I showed these wavy lines, and they get more spread out as you go.* *I showed like little particles or dust moving.* *I drew like half circle lines like on a speaker.*	*What do you mean when you say the word ____?* *Who thinks they understand what ___ is saying and can say it in their own words?* *Hmmm ... so I'm hearing some people talk about waves and some people talking about little bits of stuff moving, do I have that right?*

Summarize what the class agreed upon and then move to the next part of the model. Say, *So we agree that the sound is traveling somehow, but we have some disagreement about what is actually traveling and how it can actually move.* At this point your model will have question marks on the arrow between the sound source and our ears (we aren't sure how to show sound moving).

Discuss what is happening at the window or receiver.

Suggested prompts	Sample student responses	Follow-up questions
What did we think was happening at the window to make it shake, like we saw in the video?	*Sounds could be hitting the window to make it shake.* *Vibrations from the speaker are making the window move.*	*Can you say more about what you think is hitting the window?* *What do others think?*
What were some differences you saw in how we explained what is happening at the window?	*I showed the sound waves hitting the window and bouncing back.* *I showed the air hitting the window.* *I think the vibrations might be coming through the ground and making the window shake.*	*Who can explain what ____ means when she says that?* *Who feels like their idea is not quite represented here?* *Are there other explanations that we might want to consider?*

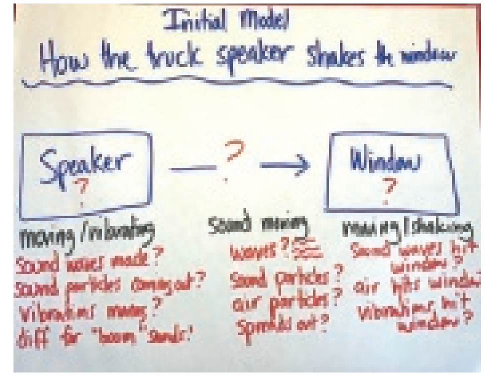
Summarize what the class agreed upon. Say, *So it seems we have some questions about how those vibrations could make the window move. Is something hitting it? If so, what?* At this point your consensus model should represent the ideas the class agreed on with question marks on the areas where students had a lot of different ideas and weren't in consensus yet.

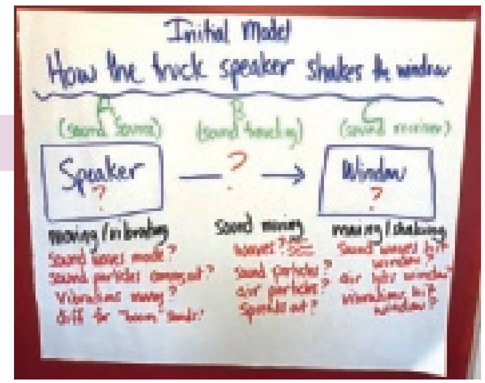
Say, *We have some parts that we agree on, but it definitely looks like we have a lot that still needs to be figured out in our model. In general, though, we agree that there are three things happening in our model. A sound is being made by the speaker, the sound is traveling and the sound is doing something to the window to make it shake.*

Label these three parts (the speaker, the arrow in the middle, and the window) on the class's consensus model as "A", "B", and "C", respectively.

Say, *Since we said the sound is coming from the speaker, let's label the speaker (part A) as the "sound source". Then, we can label the arrow in between (part B) as "sound traveling". Lastly, since the sound is reaching the window, let's call the window (part C) the "sound receiver".*

Add these descriptive labels to the consensus model near the labeled parts A, B, and C.





Additional Guidance

Use color coding and letter coding to foreground the three parts of the model (A, B, and C), as you will be referring to these parts in the Model Trackers across the later lessons in the unit.

Color coding is a useful way to quickly reference the part of the model we are referring to, but letter coding as well helps ensure accessibility for any student who may be colorblind.

You will eventually place this Initial Class Consensus Model poster near the Driving Question Board.

7. Brainstorm related sound phenomena. 10 MIN

Materials: science notebook, chart paper, markers

Say, *We agreed that we still have a lot of questions about how the speaker is making the window move. One strategy that we can use to help figure out how something works is to consider other times when we've seen something similar. Many times, figuring out how one thing works helps to explain a bunch of other related phenomena.*

Students brainstorm some related phenomena. Write each of these four questions on separate chart paper and hang them in the room so they are visible to students.

- When or where have you seen before a time where an object making sounds (the sound source) caused something to move or shake, like the window in the video?
- When or where have you seen sounds being made before? What was making those sounds?

- When or where have you experienced a sound being received before? What objects have you seen receiving sounds besides the window in the video?
- Have you ever experienced a sound going over a distance, like in the video?

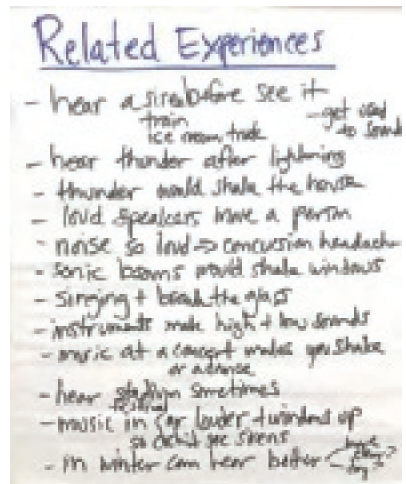
Project **slide I.** Prompt students to add a "Related phenomena" section to their notebook and take a few minutes to jot down a list of similar experiences or phenomena they've observed that might help the class investigate what's happening in the truck video.*

Students share related phenomena. Show **slide J.** When students are finished brainstorming, have them go around to each poster and write one of their responses somewhere on the poster in a list below the question. Alternatively, you could ask them to write their ideas on sticky notes and post those on the posters.

After giving students a few minutes to record their related phenomena, lead a brief discussion to highlight common responses as well as unique phenomena that were recorded on each of the four posters. Keep these posters up or bring them all together in one place so students can use them to brainstorm questions.

Alternate Activity

This method of sharing their related phenomena allows students to move around the room. Alternatively, you could stay in a Scientists Circle after the initial consensus model development and have students brainstorm and then share their related phenomena while seated there.



***Attending to Equity**
When brainstorming related phenomena, students can leverage lived experiences that are personally and culturally meaningful to them in order to generate an expanded sphere of phenomena that the class will work together to explain. Including this routine in Lesson 1 allows students to share the understanding and perspective they bring to the classroom with their classmates and promotes engagement since the class's work will be leveraged to explain something meaningful to each student. It's important to note that this routine encourages students to surface phenomena that are familiar to them, and that these phenomena may be personally or culturally significant to students. The phenomena that students brainstorm and connect to the truck video are fundamentally linked to those students' cultural, racial, and socioeconomic contexts. Encourage students to draw connections to their lived experience to generate a list of related phenomena that's inclusive of all students and that provides all students with inroads to engage with this new topic of study.

8. Develop initial sound-related questions. 5 MIN

Materials: science notebook

Say, *Between making our initial model and all these related phenomena, there are a lot of questions that we could investigate that will help us figure out parts of our model for how a sound from one object could make something else move.*

Students record questions in their notebooks. Show **slide K**. Ask students to take the last few minutes of class to record at least 2 questions that the class could investigate to figure out more about what's happening in the phenomena the class has brainstormed so far. Remind students that it's OK if these questions aren't fully formed or if they aren't sure how to phrase them; the class will work on them next time to get them ready to post on the Driving Question Board.

Emphasize to students that these questions could be about their noticings and wonderings, their initial models, the class's consensus model, or their list of related phenomena. If students are stuck when brainstorming questions, direct them to these places in their notebook or around the classroom.

Home Learning Opportunity

Based on your group of students, instead of taking class time to capture questions, you can assign this for home learning.

Wrap up day 2. Remind students that they have come a long way in a couple of classes. They have seen an interesting phenomenon, they have come to some agreement on what they think they know, and they also have some questions to pursue about this phenomenon. In the next class or so, they will be coming up with concrete questions they will pursue as a class for this unit.

End of day 2

9. Discuss questions to post on driving question board. 7 MIN

Materials: science notebook, sticky notes

Prepare for the Driving Question Board (DQB). Find a place where all students can gather around the DQB. Place the Initial Class Consensus Model poster in the center of the Driving Question Board.

Return to the questions students generated earlier and develop new questions. Say, *Last class, we brainstormed a lot of questions about the truck video, the speaker, and other similar phenomena. Today, we're going to post our sound-related questions to our Driving Question Board and begin thinking about how we're going to investigate to figure out what's happening when sounds make something from a distance move.*

Ask students to look back at the questions they jotted down last time on their notebooks.

Project **slide L**. Instruct students to use the question starters on the slide to draft two questions to contribute to the class Driving Question Board. These questions can be ones they brainstormed last class, perhaps revised based on

***Attending to Equity**
Asking questions in everyday language allows students to share their thinking or experiences, even if they do not have the appropriate scientific vocabulary yet. This is helpful for emergent multilingual students because, by not requiring scientific words at the onset, you do not limit their participation in classroom discourse. These sentence

the suggested question starters, or they can be new sound-related questions. Ask students to write their questions in marker on index card-sized sticky notes (or index cards), one per note. They should write their questions so they are big and bold—we want to be able to see the questions, and they need to be large enough to view when we come in the classroom door. Remind students that it is part of our mission to try to answer these questions.*

starters can help students transform freely brainstormed questions into a format that can be investigated in future lessons. This works to ensure student engagement through investigative questions within the scope of the classroom.

10. Post questions to driving question board.

Materials: science notebook, sticky notes, chart paper, markers

Gather in a Scientists Circle. Show **slide M.** Instruct students that when they have their sticky notes or index cards filled out, they need to bring them along with chairs and notebooks to meet in a Scientists Circle around the DQB.*

Explain to students how you will create the DQB:

- The first student comes up to the DQB with one of his or her sticky note or index card questions, faces the class, and remains standing.
- The student reads his or her question and then posts it on the DQB near the section of the model it is most related to. (*Note: If you feel you need to review the parts of the Initial Class Consensus Model, pose questions such as these:* Does it belong in part A of our model, because it is mostly about the sound source? Or part B, because it is related to what is traveling from the sound source to our ears, a sensor, or some other detector? Or part C, because it is related to the window, hearing, senses, or detectors of sound? If you think your question goes in between two categories such as both A and B or both B and C, you may put it somewhere in between. And if you aren't sure, then you will place your card toward the bottom of the model.)
- Students who are listening should raise their hand if one of their questions relates to the question that was just read aloud.
- The student who read their question selects the next student.
- The second student reads his or her question and posts it on the DQB near the section of the model to which it is most related. The student also says what other question on the board it relates to and why or how. The student selects the next student.
- This process continues until everyone has had a chance to post a question.

After creating the DQB, propose a suggested driving question for the entire board. Suggest that we might have a broader question that our model and DQB are seeking to answer: How can a sound make something move?

***Attending to Equity**
A Driving Question Board provides a public representation of the class's joint mission. Students can share their questions and wondering with one another, and the visual representation offers another modality for students to access science in the classroom.

Additional Guidance

Helpful teacher notes

- If a student forgets to explain why or how his or her question is linked to someone else's question, press that student to try to talk through his or her own thinking. This is a key way to emphasize the importance of listening to and building off each other's ideas and to help scaffold student thinking.

- Don’t worry if some questions are raised that are not part of topics in this unit. Over time students will get better and better at forming testable questions in the scope of the driving question. This type of activity gives them practice at doing that.
- If students can’t figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.
- If a question is similar to (or the same as) another one, have the student place it on top of the question that is similar so other students can visually see how many of the questions are the same or related. Emphasize that this provides us with evidence of where many people are thinking about similar things.

11. Brainstorm ideas for investigating our questions.

10 MIN

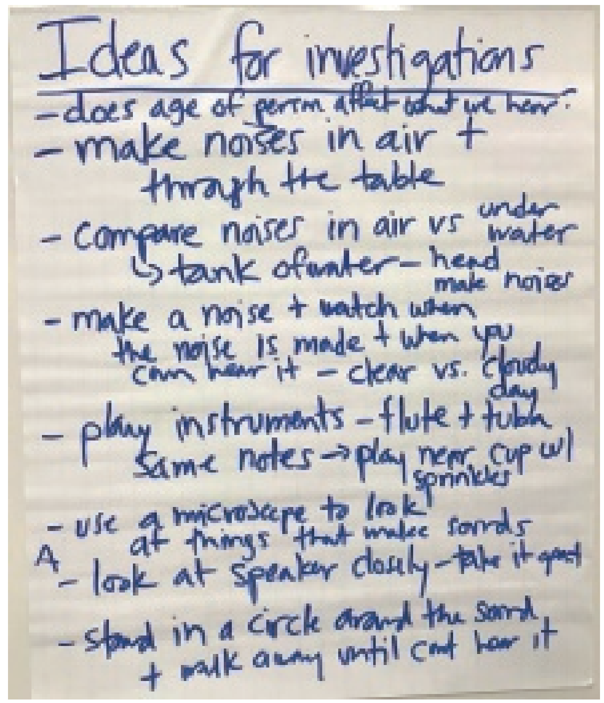
Materials: science notebook, chart paper, markers

Students individually brainstorm ideas for investigations. Project **slide N.** Instruct students to identify questions from the DQB or their notebooks that they think will be important for the class to answer in order to explain the phenomena the class has brainstormed.

Have students work for a couple of minutes on developing their own ideas for investigations that can help answer one or more of these questions and record these in their notebooks.

Share ideas for investigations. Title a piece of chart paper “Ideas for Investigations” and place it near the DQB. Ask students to share their ideas with the whole group, recording a list of ideas for investigations that will remain public throughout the unit.

To ensure all students share ideas, say, *To make sure we have everyone’s ideas up here, I will pass this marker to a person in the circle. The student with the marker should share one idea he or she has. I will write it up here and number it. That student should pass the marker to a neighbor. The second student then shares an idea. If the idea is on the chart already, the student should say which idea is similar and how it is similar. I will then put another tally mark next to that idea.**



In this way, the marker is passed all around the circle and all students have a chance to have their thinking represented on this list. Offer to students that if they have additional ideas that don’t end up on the list, they can raise their hand after we have heard once from everyone in the class (after the marker makes it all the way around the circle).

Emphasize to students that the list is what we want to do that we think might help us answer our questions and that we may not do all these things, but we will do similar-type investigations. The class can add to this list and our DQB as we go through the unit.

***Attending to Equity**
Using the marker (or other object) strategy for passing around from student to student allows for equitable sharing across all students and gives them an opportunity to piggyback on another student’s idea. Try to provide time for a second pass through the class because often students will have additional ideas come up as they are listening to other students. If time is short, revisit this activity at the start of Lesson 2.

12. Navigation

5 MIN

Materials: None

Show slide O. Tell students that we now have initial models, ideas for investigations, and a lot of questions. Suggest to students that we look back at our list of questions and the investigations to see where we should start.

Say, *It looks like we have questions about all three parts of our model for how sound from one object can make another object move. To explain this phenomenon, we're going to have to investigate all three of these parts. Since we already investigated the sound source by making observations of the speaker, it seems like that part of our model is a good place to start.*

Suggested prompts	Sample student responses
Why might it be helpful to start by investigating the sound source?	*We should start with investigating the sound source because that's where the sound comes from to make something like the window move.* *After we understand how the sound source works, we can figure out how the sound travels and how it makes stuff move.* *Maybe investigating the sound source will help us see how the sound starts to travel. That could help us with other parts of the model, too.*
We began investigating how sound sources make sounds by making observations of the speaker. What other investigations could we do to better understand how sounds get made?	*We could make observations of other sound sources to see what they do when they make sounds.* *We could watch videos of sounds being made to see if the same things happen that we saw when we observed the speaker.*
Why is it important to check out other sound sources besides the speaker?	*The speaker is just one sound source. We don't know if all sound sources work the same.* *If we had more than one sound source, we could be more sure about the observations we make about how sounds are produced.*
What kinds of sound sources would we want to check out? How could we observe what's happening with them when they make sounds?	*We could check out things that make sounds, like instruments. Maybe we could borrow some from the music room or from our classmates.** *We could look up close at the different sound-makers to see what they do when they make sounds.* *Maybe we could get a zoomed-in video or a slow-motion video to get a better idea of what's happening when sounds are being made.*

Wrap up the lesson. Remind students that they have come a long way in a few classes. They have seen an interesting phenomenon, come to some agreement on what they think they know, generated questions, and posed some ideas of what to investigate and where to go next.

***Attending to Equity**
At the end of this lesson, students agree that the class needs to investigate some other sound-makers. If students are interested and able, you may consider having some students bring in instruments that they are familiar with to allow the class to closely examine. Having students bring in instruments that are meaningful to them is one way to encourage students to engage with the work the class is doing. Often, students bring in instruments that they have experienced at home or in their community, and this can provide insight for the class into the cultural connections that people make with different modes of music and different instruments. If your students are unable to bring in instruments from home or music class, try to select a couple example instruments that may be culturally relevant for the students in your class. Being mindful about including these instruments will help students to forge connections between phenomena in class and experiences that are personally or culturally meaningful to them.

ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.8.1.C: Pose questions that connect the ideas of several speakers and respond to others' questions and comments with relevant evidence, observations, and ideas.

When the class is building the DQB, if a student forgets to explain why or how his or her question is linked to someone else's question, press that student to try to talk through his or her own thinking. This is a key way to emphasize the importance of listening to and building off each other's ideas and to help scaffold student thinking.

Don't worry if some questions are raised that are not part of topics in this unit. Over time students will get better and better at forming testable questions in the scope of the driving question. This type of activity gives them practice at doing that.

If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

LESSON 2

What is happening when speakers and other music makers make sounds?

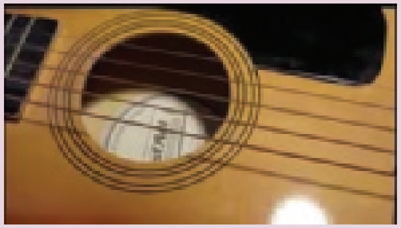
Previous Lesson

We launched our unit by observing a perplexing phenomenon: Sound from a truck appears to make a nearby window move. We made observations of this phenomenon as well as of a speaker. Our observations, models, and other sound-related phenomena led us to add a broad set of questions about sound to our DQB.

This Lesson

Investigation

2 DAYS



We examine what the speaker and musical instruments are doing when music is played and look for patterns. We then look closely at slow-motion videos of similar objects to notice how the objects bend and change shape. We use the patterns we notice to create a class model of what these music makers are doing when they vibrate and then try to apply it to other music makers.

Next Lesson

We will observe various musical instruments and a speaker when they are making sounds and connect what we discover to what we observe when we analyze slow-motion videos of similar objects. We will co-construct a model to represent the shape changes observed in these objects over time, and we will apply this model to another instrument.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Analyze and interpret data to identify patterns in the data that provide evidence of the relationship between a force (cause) on an instrument and the motion/vibration (effect) of the instrument.

Develop a model to describe how a force applied to an instrument causes its shape to change, leading it to repeatedly deform above and below its initial position (effect) as it vibrates and use that model to predict what a force will do to another instrument.

What Students Will Figure Out

- The speaker and instruments moving back and forth in different patterns seems to be related to the type of sound they produce.
- When an instrument vibrates (makes sounds), it includes the following actions:

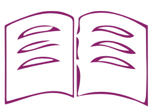
- *A force is applied to a part of an object; that part bends or deforms and changes shape. Energy is transferred to the object.*
- *When the force is removed, that part of the object springs back and overshoots its starting position.*
- *That part of the object then repeatedly bends back and forth for a bit (we call this vibration) before stopping. When it stops vibrating, it stops making sounds.*

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Recall ideas for investigating the sound source and discuss ideas for how instruments and speakers make different sounds.	A	
2	20 min	**OBSERVE INSTRUMENTS AND A SPEAKER** Make observations of the speaker and different instruments in small groups and share out patterns in a whole-group discussion.	B-D	*Instrument and Speaker Stations*, Observing Instruments and Speakers
3	10 min	**OBSERVE SLOW-MOTION SPEAKER AND INSTRUMENTS VIDEOS** Observe slow-motion videos of a speaker, a guitar, and a drum.	E-I	
4	10 min	**ANALYZING OUR INSTRUMENT AND SPEAKER DATA** Analyze the data from the instrument and slow-motion videos individually first, then share with a partner, and finally discuss patterns as a whole group in a Building Understandings Discussion.	J-K	
				End of day 1
5	12 min	**CO-CONSTRUCTING A CONSENSUS MODEL OF AN INSTRUMENT MAKING SOUND** Lead students in co-constructing a consensus model for how parts of instruments change shape back and forth after being struck or plucked.	L	*How do instruments move when making sounds (vibrating)?*
6	10 min	**APPLY INSTRUMENT MODEL INDIVIDUALLY** Work individually to model what is happening when a different instrument vibrates and makes sound.	M	
7	8 min	**GIVE AND RECEIVE FEEDBACK ON THEIR INSTRUMENT MODEL** Students share their models with a partner and give and receive feedback.	N	*How do instruments move when making sounds (vibrating)?, Peer Feedback Guidelines, Self Assessment*
8	8 min	**ADD TO PROGRESS TRACKER** Work together to summarize what we have figured out is happening when an instrument makes sounds and add to our Progress Tracker.	O	

Part	Duration	Summary	Slide	Materials
9	8 min	**APPLY MODEL TO OTHER OBJECTS AND NAVIGATION** Students extend the model to other sound-making objects and predict whether they would see similar vibrations in all objects that make sounds.	P	*How do insects make sounds?*
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 2, students are ready to read Student Reader Collection 1 and then respond to the writing exercise.		Student Reader Collection 1: *Musical Instruments*

Lesson 2 · Materials List

	per student	per group	per class
Observing Instruments and Speakers materials			• drum and drumstick • xylophone and mallet • guitar (and/or other stringed instruments) • 2 tuning forks of different sizes • speaker and amp and wires from Lesson 1
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *How do instruments move when making sounds (vibrating)?* • *Peer Feedback Guidelines* • *Self Assessment* • *How do insects make sounds?*		• *Instrument and Speaker Stations*

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the videos to make sure they play (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**):

- Slow motion guitar strings video
- Slow motion snare drum video
- Speaker in slow motion video
- Tuning fork vibrating in slow motion video

Online Resources

Cut *Progress Tracker* in half so that each student gets 1 progress tracker sheet.

Review *Reference: Peer Feedback Guidelines*.

Day 1: Observing Instruments and Speakers

- Group size: Create 5-6 stations for groups of 4-5 students.
- Setup
  - *Gather a guitar and/or other stringed instruments, a drum and drumstick, 2 tuning forks of different sizes, and a xylophone and mallet.*
  - *Gather the speaker, amp, and sound source from the Speaker Examination in Lesson 1.*
  - *Arrange the items in stations around the room. Place a copy of Instrument and Speaker Stations face down at each station.*

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

A big building block of the science developed in this lesson is that a sound is first generated by some kind of force or impact to an object in the system. The force applied by using a mallet to push on a xylophone tine or a pick to pull a guitar string is needed to start a sound. Students may just call this force a "push" or "pull" or "impact" at this point, and this language is fine; what's important is the conceptual understanding of energy input into the system. Something has to be done (push, pull, impact, force) to the object to make the sounds.

In addition, even though "vibration is a back-and-forth movement" is a piece of a first-grade Disciplinary Core Idea (DCI), the cause of vibrations and the nuances of the type of motion are a deeper dive into a causal mechanism of how sound waves are generated and able to propagate within a medium. Students have experiences with stringed instruments and trampolines that they will draw on. They may be surprised, however, to see metal or wood deforming and may need to carefully analyze images in the slow-motion videos in order to see the shape changes occurring in each object. The idea that an object changes shape (is deformed with the force applied) by bending beyond its original shape and continuing in a back-and-forth motion before retaining its original shape is not a trivial idea. This sets the foundation for how sound travels, which we will get to in future lessons.

Where We Are NOT Going

In future lessons we will get to the idea that because the object making the sound initially deforms in the direction the force is traveling, the particles of the medium get compressed and then expand, bumping into their neighbors, and thus the resulting compressions and decompressions result in a sound wave. Without noting the deformation beyond the original starting position, it's difficult to explain why the particles of air or other media are affected by an object vibrating. This deepening definition of vibration also sets up an understanding that will be developed in grades 9-12 regarding the intermolecular forces that are at play.

Although this intermolecular understanding is beyond this grade band, one can see the learning progression of the definition of vibration. In high school physics classes and beyond, this mechanism will also help account for normal forces on objects at rest on the ground.

LEARNING PLAN FOR LESSON 2

1. Navigation

3 MIN

Materials: None

Discuss where we left off. In order to continue to generalize out to other sound sources, help students connect to the questions and investigations they generated about sound sources in the previous lesson. Pull out the list of ideas for investigation to reference as you talk with students.

Say: *In the last class, we had a bunch of interesting questions we wanted to answer about the sound source. We noticed that the speaker was moving, but we have some questions about what exactly is happening with the speaker (the sound maker) and with sound makers in general. How can all those different sounds be made?*

What were some of the ideas for investigation we had around the sound sources?

Listen for ideas such as looking closer at instruments and other things that make sound, watching slow-motion videos, and looking closer at and slowing down the speaker.

Additional Guidance

To effectively support coherence for students and to honor their ideas and contributions to the storyline, return often to their initial ideas from the DQB and their suggestions for investigations. Mark the question we are investigating next or the investigation we will do next with a sticky note that has a star or check mark on it. Emphasize to students that these ideas came from them.

Discuss ideas about how sound sources make sounds. Project **slide A**. Ask students to discuss the ideas on the slide and then share out a few ideas.

Suggested prompts	Sample student responses
How do you think sound sources like instruments and speakers make all those different sounds?	*They move and vibrate.* *Different instruments have different shapes or are made of different materials.* *You have to hit or do something to it.* *I don't really get how you can get all those different notes.*
What would you expect to see if you looked closely at these sound sources while they are making sounds?	*I think I would see parts moving and I would feel the instrument and speaker buzzing or vibrating.* *I think some instruments would move but others wouldn't—it would depend on the instrument.*

2. Observe instruments and a speaker.

20 MIN

Materials: Observing Instruments and Speakers, science notebook, *Instrument and Speaker Stations*

Set up notebooks. After having students share predictions, point out that there are instruments and the speakers we used in the last lesson placed at stations around the room that we can use to investigate these questions further. Project **slide B**. Ask students to create an observation table in their notebooks to record observations of each sound source (instrument or speaker).

Sound source	Observations

Prep students for the activity. Have students divide into small groups. Tell them that once you are done giving directions, they will move with their group from station to station and make observations. Remind students that instruments (especially those like the guitar) are fragile, so they should use special care in handling them.

Take a minute before beginning to demonstrate what you expect students to do at each station and how to transition between stations on your signal:

1. Students make a new row in their observation tables for each instrument station and record the name of the instrument in the left column of their tables.
2. Students carefully pluck or strike the instrument or play the speaker at each station so as to make sounds.
3. Students then make observations about how the speaker or instrument looks and feels while being played or struck as well as while it's making sounds (i.e., Did anything on the instrument move?).
4. Students record their observations in the right column of their tables.

Project **slide C**. Discuss some of the observations that might be helpful. Ask students what different sounds might be useful to note (e.g., loud and soft; high and low pitch). Ask students if they have additional ideas for what data to collect as they move through the stations. Answer questions and clarify the activity until all students understand what you expect them to do. Turn face up the copy of *Instrument and Speaker Stations* at each station.

Students make observations at stations. Assign each group to its first station. Give students 3 minutes at each station and then tell them to switch. After students have written their observations for each station, ask them to return to their seats to share observations.

Additional Guidance

If you have had students bring in instruments to class (or if students in your class have experiences with particular instruments), you may ask students to briefly introduce each instrument and demonstrate how it's meant to be handled and played. It's important to note that the instruments that students select may be culturally or personally meaningful to them. Giving students time to explain their connection to a specific instrument may help them (or other students) engage with the work the class is doing, and may provide insight for the class about the cultural connections that people make with different modes of music and different instruments.

Share out patterns with the whole group. Project **slide D**. Ask students to share out a few patterns they noticed. This can be a brief discussion. This share out also provides a chance to problematize the need to slow the objects down to see what is really happening.

Additional Guidance

Observations about what causes the object to make different sounds (loudness and pitch) can be leveraged in Lessons 4 and 5 when students examine vibrations for low and high loudness and pitch. Try to capture some of those ideas when students share their observations about patterns and probe them as they are working in their small groups.

Suggested prompts	Sample student responses	Follow-up questions
How does the object look and feel while it is being struck?	*It bent back when we plucked the strings.* *I couldn't see anything change with the xylophone.* *The drum moved down a bit.*	*So, it bent? Could we see that with all of the instruments?* *How could we test whether the objects are changing, even though it might look like they are not?*
Did you notice any patterns for how the objects look and feel while they are making sound?	*They all vibrate.* *They keep moving and eventually stop.*	*Can you say more about what you mean when you say vibrate?* *Could you see or feel that with all of the instruments? What about the speaker?*
What patterns did you notice in how they make different sounds?	*If you hit it harder it was louder.* *The thicker strings on the guitar are lower.* *If you make the strings shorter, they are higher.* *I could feel a boom when there was a drum or beat sound with the speaker.* *It felt like the speaker moved more when it was louder.*	*Can you give an example of where you saw that?* *Could you still see or feel it moving if you hit or plucked it softly?*

Additional Guidance

Many students will start using the word *vibrating* to describe what the instruments are doing when making sounds. Only at the end of the lesson will the class come to a consensus that this word means something more than just what we feel. By the end of the lesson, students will start to use the words *vibrating* or *vibration* to describe the way the position and shape of the object is changing over time that can account for what we feel when the object is making sounds.

3. Observe slow-motion speaker and instruments videos. 10 MIN

Materials: None

Motivate the use of slow-motion videos. Walk over to the Ideas for Investigations list (it is likely that students suggested using slow-motion video). Remind students of their initial ideas for investigating what was happening with the speaker to cause the window to move and the observations they made earlier about how the instruments were moving to motivate the need to look for patterns in videos at a different scale.

Suggested prompts	Sample student responses
It seems like we are seeing some patterns, but some are hard to see or feel. *Why is it hard to see the patterns of what is going on with the instruments when they make sound?**	*They move too fast, so it's hard to see.* *The movement is too small for us to see.*
What else could we do to see more about these sound sources?	*Slow it down or zoom in on it.* *Make a slo-mo video.*
How would observing at a different scale help? *What would looking at a video in slo mo show us that we couldn't see with just our eyes?*	*If we slow it down we could see if there is anything that is happening too fast for just our eyes.* *We could see if there is some movement happening too small for us to see.* *Maybe there are parts of the drum that are moving that we can't see.* *Maybe we can see if things like the xylophone are really moving.* *We could see if all of the drum or just the middle is moving.*

Set up notebooks. Project **slide E**. Tell students that you have videos for the drum, guitar, and speaker. Have students create a new row for each video in their observation tables in their science notebook.

Additional Guidance

We have included videos for a speaker, a guitar, and a drum to show a range of objects. You can add other videos depending on student interest. However, we recommend using the drum because of the simplicity for modeling (fixed sides and a middle surface) and the guitar because it can help make connections to pitch later in the unit. You can show the videos in any order.

Observe slow-motion videos of the speaker and instruments. Use **slides F-I** to show the videos. After each video, give students a chance to record and share out some of their observations. As students view the videos, they should record their observations in the right column of their tables. Tell them to be as detailed and accurate as they can when writing their observations of these instruments in the videos. For the speaker video, play it once without sound

***Supporting Students in Developing and Using Scale, Proportion, and Quantity**
Help students think about what they could change to see more about what is happening with the objects. Posing questions about what the limits are of our instrument observations can help them think about how changing the scale (in this case a slower scale) will help them see more.

(muted) and again with the sound on so that students can match their visual observations with auditory ones. You will likely want to play all the videos more than once. It is helpful to hear from students a few of their observations between each video. Listen for student responses such as these:

- *The speaker moved back and forth but wasn't moving the whole time.*
- *Sometimes the speaker moved a lot, sometimes not as much.*
- *It would get started moving by a drum sound and then keep shaking for a bit afterward.*
- *The speaker looked like it rippled like a wave when it moved.*
- *The strings moved back and forth but not always in sync.*
- *The thicker strings moved further than the skinny strings.*
- *The skinny strings moved faster.*
- *They moved and eventually slowed down.*
- *It looked like it rippled.*
- *It bounced up and down like a trampoline.*
- *When the stick hit it sort of spread out.*

4. Analyzing Our Instrument and Speaker Data

10 MIN

Materials: None

Analyze data individually in notebooks. Project **slide J** and have students use the observations they made in the observation table from the previous step to respond to the following questions:

- What patterns or similarities did you notice in how the different objects you observed moved while they were making sounds?
- What patterns did you notice among the instruments and the speaker?

When students have responded to these questions, they can share their ideas with a partner.

Building Understandings Discussion. Project **slide K**. After students have shared with a partner, ask a few students to describe some of the patterns they identified in how parts of different instruments moved and changed as they were making sounds.*

***Strategies for this Building Understandings Discussion**
Encourage students to use evidence to support what they are saying by asking them to come to the front of the class to point out what they noticed on the slow-motion videos.

Key Ideas

Purpose: Identify patterns in how the surfaces of different instruments moved and changed as they were making sounds. This will lead the class to look more closely at what is really happening when an object vibrates and makes sound.

Listen for these ideas from students:

- As the object was struck or plucked or turned on (a force was applied), it started to change shape and bend (deform).

- In all cases the object didn't directly return to its original shape; it overshot its starting position and changed shape in the other direction.
- The object repeatedly changed shape back and forth around its starting shape or position.

Suggested prompts	Sample student responses	Follow-up questions
What was similar about the motion of different instruments while they made sounds?	*You had to hit it or apply a force to get it started.* *Parts of the instruments started to move / change shape / bend back and forth / vibrate or deform.*	*Is there always a force?* *Can you show us what you mean when you say bend or deform?* *So, it's kind of like they bend or change shape?*
What was different?	*Some bent back and forth in an up-and- down direction; in others it moved in a left- and-right direction.* *Some parts didn't seem to move or they were tied down (e.g., the edge of the drum face, the ends of the guitar string).*	
What type of shape changes did we see in objects when they were struck or plucked?	*When we struck or plucked the surface, it went down away from its original position.*	*Can you show us what you mean?* *Did you see that in all of the instruments and the speaker?*
How did the shape of objects keep changing after we were done striking or plucking them?	*It didn't directly return to its original shape; it overshot its starting position and changed shape in the other direction.*	*Should we watch the video again and see if that happened?* *Note: The changing of an object's shape is a key idea to draw out. You may need to show the video again to help students notice this.*

Summarize that all of this shape changing is what the object is doing when we say we feel these objects vibrating. Tell students that when scientists say something is vibrating, they mean that it is moving back and forth repeatedly. Emphasize that understanding why and how an object vibrates will help us better understand how that object creates sounds that we can hear from a distance.

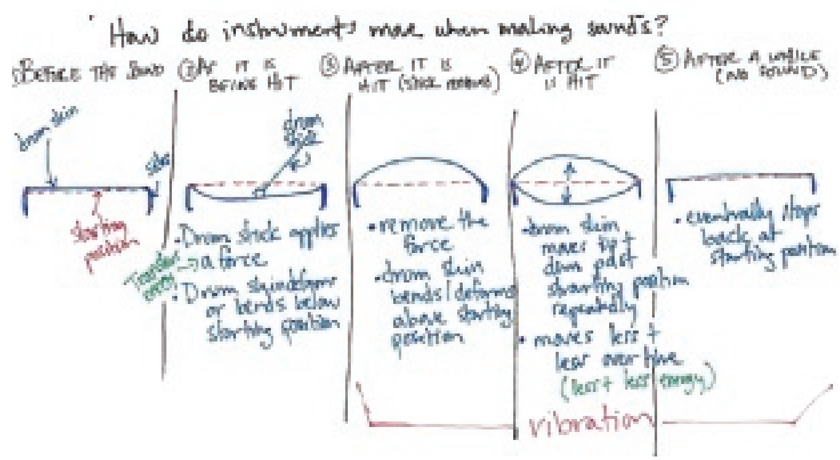
End of day 1

5. Co-constructing a Consensus Model of an Instrument Making Sound 12 MIN

Materials: *How do instruments move when making sounds (vibrating)?*

Navigate from day 1. Say, *In the last class, we all felt the instruments vibrating as we played them in class. When we saw the video clips, we also observed the vibrations of the speaker, the drum, the tuning fork, and the strings on the guitar.*

We need to figure out what caused the vibrations. Project **slide L**. Pass out *How do instruments move when making sounds (vibrating)?*. Students will use these sheets to create two models to represent the chain of cause and effect that connects the ideas shown in the image. The first model will be constructed together as a class; the second is an individual formative assessment.

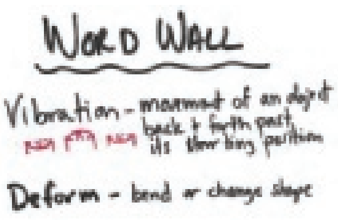


Co-Construct a Model. Tell students that we will use this table to show how one object, the drum, moves while it is vibrating. Say, *Let's try to draw out a representation of how it was moving and why it was moving the way it was*. Each box, or step, in the table, from left to right, will represent how the shape of the drum changes over time as it is making sounds. Ask students to title this table with a question: "How do instruments move when making sounds (vibrating)?"

Give each student a chance to state a response and allow all students to analyze each statement for accuracy, to ask questions, and to suggest any modifications. On a poster or whiteboard, draw the first step (and all subsequent steps in order) that the students report they saw. Under each sketch, include a brief description of what is being drawn. Continue to ask questions until all the observations are drawn and labeled. Have students draw the images and write the text in the table outline on their handout.

Suggested prompts	Sample student responses
What should we show before the sound was made?	*Before the drum was struck, it had an original shape (starting position).*
What did we see happening first to the surface of the drum?	*We hit the drum or applied a force.* *The surface of the drum was not moving until it was hit by the drumstick which caused it to move the other way.*
What caused these changes?	*When a force was applied to a part of the drum (a strike), it bent (or deformed) the object.*
What happened after the force was removed?	*After the force was removed, that part of the drum sprang back (it "wanted" to change shape to return to its original position). As it traveled back, however, it ended up overshooting the original starting position.* *That part of the drum then headed back in the opposite direction and ended up overshooting the original starting position again in the other direction. It kept repeating steps 3 and 4 (this is what we refer to as vibration) until it stopped making sounds.*

Add the word *vibration* to our word wall. This movement back and forth past a starting position is what we now mean when we say *vibration*. Label this on the model and add *vibration* to a word wall. You may also want to add the word *deform*, which is a word that students will have used in the *Broken Things* unit.



Additional Guidance

Not every vocabulary word should be placed on the word wall. A helpful distinction for determining if a word should be added to the word wall is to decide if it's a "word we earn" versus a "word we find out". A "word we earn" is one we work together to understand through investigation and collaborative sensemaking, thus we should celebrate our growing understanding of the word by adding it to the word wall. A "word we find out" may be encountered through text or media and is defined for us. These words are less important to add to our word wall, though such a word may become a "word we earn" if our understanding of the word grows and changes.

An alternative to a word wall is to have students note these words in their science notebook through a personal glossary in which they record the meaning of the word and a vocabulary doodle to represent it.

When developing new vocabulary, strategies that may benefit emergent language learners are to use student-friendly definitions, make connections to cognate words when possible, and include a visual representation of the word. You will develop a visual representation of the word interactions over the course of this lesson.

Connect the movement to energy and contact forces. Help students connect to ideas about transfer of energy. Students should recall from previous work with unit 6.2 (Thermal Energy) that collisions transfer energy and with unit 8.1 (Contact Forces) that collisions apply forces which cause them to transfer energy from one object to another. Guide students to reason about and connect their experiences with contact forces transferring energy from one object to another.

Suggested prompts	Sample student responses
So this seems like another case of where a contact force transferred energy from one object to another. *Which object had kinetic energy before the drum and the mallet made contact? Which did not?*	*The mallet had energy but the drum did not at the start. We know this because the mallet was moving but the drum was not.*
What about after the mallet made contact with the drum?	*After the drum was hit, the surface of the drum now has energy.*
So this back-and-forth movement of the drum is a kind of kinetic energy, which we are thinking came from the mallet when it made contact, that was started by contact forces between the two things. Let's make note of that for now, so later we can think about how we want to represent contact forces between objects and motion energy (kinetic energy) of the objects.	

Additional Guidance

Using words like *bend*, *deform*, *springy*, or *elastic* will help set up the next lesson, which is motivated by the question of whether all objects bend or deform or are springy (up to a point). Use the scientific word *deform* in concert with the phrase "or bend" and use the word *elastic* with the phrase "or springy" in future discussions to help build familiarity with the idea that both terms, in each case, are expressing the same idea.

6. Apply instrument model individually. 10 MIN

Materials: None

Apply the model. Show **slide M**. After modeling what happened to the drum once a force was applied to it, have students apply the model to a different instrument in the next table of their handout. You can collect their models at the end of class in order to give formative feedback using *Rubric for Modeling Motion of an Object Making Sounds*.

7. Give and receive feedback on their instrument model. 8 MIN

Materials: *How do instruments move when making sounds (vibrating)?*, *Peer Feedback Guidelines*, *Self Assessment*

Pair up and compare models. Pass out *Peer Feedback Guidelines* if desired. This can be taped into notebooks. Show **slide N**. Explain how students will give each other feedback. Have students get up and find a partner to share with.

Alternate Activity

You could also have students give and get feedback using sticky notes instead of verbal feedback. Prompts for what to write include the following:

- I wonder about ______. I noticed you ______.
- I appreciate how you ______.
- It would be clearer if you added ________.
- I see you're thinking about ________.
- Do you think you should add ________?

Assessment Opportunity

At the end of this lesson or for home learning is a good opportunity for students to self-assess using *Self Assessment*. Helping students reflect on their progress in giving and receiving feedback will help build their skills in this important area.

8. Add to Progress Tracker.

8 MIN

Materials: None

Additional Guidance

Students work on the three sections of the Progress Tracker after important punchlines in the unit are figured out as a class, usually after the class comes to consensus about something. We suggest not skipping these consensus moments with the Progress Tracker. If these sections are missing, students may have trouble moving forward in their sensemaking.

Gather in a Scientists Circle and set up the Progress Tracker. Tell students that we want to develop a more general model about making sounds that could apply to more objects than just the musical instruments. But we want to first write out the general principles for what all the instruments we modeled share in common in their behavior as a small baby step to this more general model.

Pass out *Progress Tracker*. Show **slide O**. Remind students of how we used the Progress Tracker in the previous unit. Have students turn to this section in their notebooks, which should be 10 pages at the beginning of the notebook section for the new unit.

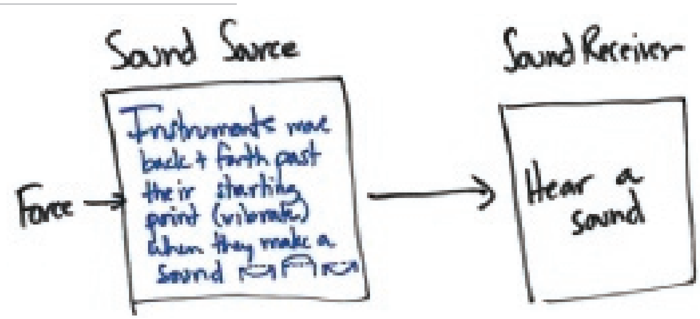
Work together to generalize the model. Ask students to help you summarize in words what we think is happening in **all** of the instruments when they make sounds. Here is one suggested representation. Students can reference the page number in their notebooks where they originally drew the class consensus model for vibration if they do not want to draw the representation again here.

Question	Source of evidence
What is happening when speakers and other music makers make sounds?	Observations and slow-motion videos of a speaker and instruments

What we figured out in words/pictures

- When a force is applied to part of an instrument, it causes it to bend or deform and change shape. Energy is transferred to the object.
- When the force is removed, that part of the object springs back and overshoots its original resting position.
- Then that part of the object repeatedly bends back and forth for a bit until it stops (this is called a vibration), and this is when it stops making sounds.

Have students add these conclusions to their Progress Tracker for this lesson. Make sure to identify the repeated cycle of motion as a vibration now. Emphasize that this motion is more subtle than a simple back-and-forth motion because of things like the shape change and the original-position overshoot that keep happening over and over again for a while after the initial force is removed. You can add these steps to the sound source portion of the initial consensus model.



9. Apply model to other objects and navigation.

8 MIN

Materials: *How do insects make sounds?*

Additional Guidance

If students are already in a Scientists Circle, have them stay there for this initial ideas discussion and navigation.

Make predictions about whether all objects vibrate when they make sounds. Recall with students that we want to be able to explain how more things than just instruments make sounds and that we want to see if the model we've just constructed applies to other objects. Show **slide P**. Ask students to record the following question in their notebooks and take a few minutes to jot down their initial ideas: "Do *all* objects, even ones that aren't musical instruments, vibrate when they make sounds?"

Initial ideas discussion*: After students have had a few minutes to write, ask them to share their predictions with a partner for a minute before going public with their ideas. Prompt students to explore some different examples of objects that can make sounds to see if they believe our model can help explain those phenomena as well.

Key Ideas

Purpose of this discussion: Surface uncertainties about whether *all* objects, even something solid like a table, are bending back and forth (vibrating) when they make sounds. This motivates us to want to investigate this idea.

Common student ideas

- *Tables and floors are too solid to vibrate like the instruments.*
- *Maybe they vibrate just a little bit.*
- *Everything vibrates when it makes sounds, even if we can't see it.*
- *Some things might break instead of vibrating.*
- *It depends on the material.*

Suggested prompts	Sample student responses
Do all objects change shape (vibrate back and forth past their starting point) when they make sounds?	*Tables and floors are too solid to vibrate like the instruments, or maybe they vibrate just a little bit.*
Do all objects, even ones that aren't musical instruments, exhibit this springy behavior when they are pushed or pulled?	*Everything vibrates when it makes sounds, even if we can't see it. Sometimes I can feel the floor or table vibrating if I put my hand on it.*
Would a solid object, like a table or the floor, vibrate when it makes sounds?	*Some things might break instead of vibrating, like a glass table.*

***Strategies for This Initial Ideas Discussion**
During this discussion, use talk moves like revoicing and say more to help clarify the ideas so that others can work with them. The goal is to surface multiple ideas and reasoning, so don't privilege some ideas over others. Draw out the controversy around these competing ideas to help motivate students to figure out a way to further investigate this new question in the next lesson.

Suggested prompts	Sample student responses
So I'm hearing about some things that are hard that might only vibrate a little or might break instead, and then others say that even this table is bending back and forth even though we can't see it.	*We could take a slow-motion video of the table when we hit it or drop something on it.*
What are some ways we could test our initial thinking?	*We need to find a way to look closely at the table to see if it is bending.*

Navigate. Emphasize that we have a new question to explore ("Do all objects vibrate when they make sounds?") to help us come up with a better general model for how objects make sounds. Foreshadow that there are ways that we could test to see if other objects vibrate, even if only a little, while they are making sounds.

Assign home learning. Distribute *How do insects make sounds?*. Tell students that you have a short reading that investigates how insects produce sounds that seems closely related to what we figured out in class. Discussion of these questions in the reading would lead well into the next several lessons.

Alternate Activity

Readings like this one can be saved as in-class work for days when you see only some of the students (e.g., some students are out of class for a band concert) and as home-learning for those students to make up. Or you may want to save them for days when you have a substitute. This reading is most timely and relevant, however, when used before Lesson 4.

ADDITIONAL LESSON 2 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.1: Write arguments to support claims with clear reasons and relevant evidence.

When writing their Claim, Evidence, Reasoning charts, students must state a claim and support their reasoning with evidence from investigations they've conducted so far in this unit. Students may require support to ensure that their reasons are truly clear and connected to their claims. Provide struggling students with a tool to organize their thinking such as a Tree Map. Students can use this tool to organize the structure of their constructed response and ensure that they have clear, connected reasoning and supporting evidence. Encourage students to utilize all the evidence they have collected so far from investigations by referring to class charts and their science notebooks.

SCIENCE LITERACY: READING COLLECTION 1

Musical Instruments

1 **Music Makers**

2 **Anatomy of an Acoustic Guitar**

3 **Analysis of Resonance of Sitka Spruce (*Picea sitchensis*) from Graham Island, British Columbia**

4 **Vintage Vibes for Sale!**

Literacy Objectives

- ✓ Distinguish cause(s) and effect(s) related to how vibrations produced in a set of taut strings result in different sounds projected from an acoustic stringed instrument.
- ✓ Differentiate fact, reasoned judgment, speculation, and opinion.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 1–2.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from the class investigation.
- Prepare a graphic organization of information in response to the reading.

Instructional Resources

Student Reader

Collection 1

Science Literacy Student Reader, Collection 1
"Musical Instruments"

Exercise Page

EP 1

Science Literacy Exercise Page
EP 1

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: How does a sound source make something like this happen?
- Lesson 2: What is happening when speakers and other music makers make sounds?

Standards and Dimensions

NGSS

Science and Engineering Practices: Obtaining, Evaluating, and Communicating Information; Engaging in Argument from Evidence

Crosscutting Concepts: Structure and Function; Cause and Effect; Patterns; Scale, Proportion, and Quantity

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Math

8.EE.B.5: Graph proportional relationships, interpreting the unit rate as the slope of the graph. Compare two different proportional relationships represented in different ways.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, the terms are not intended for isolated drill or memorization.

vibration

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

amplify **density** **elasticity**

frequency **intonation** **pitch** **sustain**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the assignment, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the assignment.

Exercise Page

EP 1

You'll proceed with the next in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then organize information about what they have read into a chart. The reading selection relates to topics they are presently exploring in their Sound Waves unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Students will do a short exercise that involves analyzing two mock advertisements.
- Preview the reading. Share a short summary of what students can expect.
  - *You will read a survey of music instruments with a focus on what makes them produce different sounds with different properties.*
  - *You'll take a closer look at the parts of an acoustic guitar and what they do.*

- *You'll read a more scientific article about a specific type of wood used in acoustic stringed instruments.*
  - *You'll read a couple of advertisements featuring used guitars for sale.*
- Distribute Exercise Page 1. Preview the ad analysis exercise. Share a brief summary of what students will be expected to deliver.
  - *For this assignment you will be expected to evaluate the claims made in two advertisements for used acoustic guitars. You'll complete a T-chart to summarize your analysis.*

Exercise Page

EP 1

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take you approximately 30 minutes to complete in total.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to notice the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.* (There are a variety of styles in this reader collection, and students will see this variety throughout the book.)
  - *Next, "cold read" the selections without yet thinking about the assignments that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the assignments.*
  - *Revisit the reading selections to complete the exercises.*
  - *Jot down any questions you have for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What are some different families of musical instruments described in the first article?	*strings, percussions, woodwinds, and brass*
What is a luthier?	*a maker of stringed instruments, such as guitars*
What is a Sitka spruce?	*It's a type of tree. Its wood is used to make guitars.*

Ask a few brief discussion questions related to the reading that will help students tie the text content back to students' classroom investigations.

Suggested prompts	Sample student responses
What are some different ways that players of musical instruments cause vibrations to occur on or inside of the instruments?	*by striking, plucking, or rubbing a string; by striking a surface; by blowing air through openings in a cavity*

Suggested prompts	Sample student responses
What types of forces are involved?	*pushing, either with the hands or with air forced from the lungs*
How do you think the vibrations a player puts into a musical instrument can vary by the amount of force? What might stronger and weaker forces do to the sounds produced by instruments?	*Stronger force, like plucking, striking, or blowing harder, probably makes bigger vibrations and louder sounds.*

- Refer students to Exercise Page 1. Provide more specific guidance about expectations for students' deliverable due at the end of the week.
  - *The writing expectation for this assignment is to draw a T-chart for comparing and contrasting the claims made in the two advertisements.*
  - *That means calling out claims that seem legitimate and based on sound science as well as the "BS" that suggests one of the ads is less trustworthy.*
  - *Don't worry about understanding all of the terms in the ad. Focus on language you do understand, including terms about sound and what you read in the other selections in this week's collection about how instruments work.*
  - *Also look for language that implies that one seller or the other seller might be less than certain about some claims or details.*
  - *The important criteria for your work are that you draw clear distinctions between the two ads and use those distinctions to determine which of the ads is more compelling and trustworthy. Approach the ads as a would-be buyer but with a skeptical, scientific eye.*
- Explain that a well-organized chart should compare or contrast a specific point or subject from one column to the next. For example, the different manufacturing date details—presence or absence of manufacturer labels and serial number—should be compared or contrasted in one row across both columns in the chart.
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 1

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and the exercise.

Student Reader

Collection 1

Pages 6–13 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Music Makers"?	*It describes how some different families of instruments produce vibrations and sound.*
What is the general purpose of the second selection, "Anatomy of an Acoustic Guitar"?	*It tells about the different parts that make up an acoustic guitar and how they contribute to its sounds.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The second selection gives more details about what the parts of a guitar do and what they are made of.*

Pages 6–13 **Suggested prompts**	**Sample student responses**
*What is the general purpose of the third selection, "Analysis of Resonance of Sitka Spruce (*Picea sitchensis*) from Graham Island, British Columbia?"*	*It describes a study to determine whether or not sound qualities can be measured for a specific type of wood most favored for guitar making.*
What can you take from the third selection to build on what you learned in the second selection?	*Some kinds of wood are more prized than others for the building of guitars.* *But testing the resonance of the most prized Sitka spruce, very old trees with fine wood grain from a very specific place, does not provide any scientific proof that this wood produces superior sound.*
In the third selection, which describes a scientific approach, what are the variables that were tested?	*wood density, grain width, and elasticity*
And what was the variable outcome that was affected?	*the wood's ability to resonate*
What do the results of the paper suggest about how guitar builders and players should evaluate the wood used in the tops of guitars? Can you identify a quote in the paper that summarizes a position about this?	*"(T)onewoods do not need to be cut from old and/or slow-growth trees to produce resonant instruments such as spruce-top guitars. This suggests that the market demand for fine-grain and/or old Sitka spruce is based more on myth or misunderstanding than science."*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and invite confident students to clarify, but summarize with concise explanation.

Point out that, despite the scientific paper in the third selection offering a position in the conclusion of its study, the first three selections are all expository in nature. They tell information without any real effort to persuade the reader.

Proceed with discussion of the last two pages of the collection, the two mock ads for vintage guitars.

Pages 14–15 **Suggested prompts**	**Sample student responses**
What type of text appears on the last two pages of this week's reading selections?	*two advertisements*
What is the general purpose of an advertisement?	*to convince you to buy something*
How are the ads similar, and how do they differ?	*they both promote vintage acoustic guitars for sale, and they both list a bunch of features of the guitars.* *the first one uses a lot more sensational language than the other; the second ad states more verifiable facts.*

Pages 14–15 Suggested prompts	Sample student responses
Let's look at some "soft language" in the ads—words that suggest something good but don't really refer to measurable qualities: *What does* mojo *mean?* *What are "vibes"?* *Is mahogany actually "magical"?*	Mojo *means having a good feeling of confidence in being skilled, capable, or winning.* *Vibes are emotions about something. Feeling "good vibes" in a situation means liking and feeling good about it.* *Mahogany might have many pleasing qualities, but it cannot perform magic.*
In an advertisement, why would you want to flag or ignore terms with no clear meaning?	*because they appeal to your emotions to try to convince you to spend your money and they make claims that can't be proven or disproven*
What hard data or legitimate information can you spot in the ads?	*The Delphi ad provides specific dates, materials, and manufacturing and maintenance details.*
Take a look at the Spot the BS box on page 14. What questionable claims on the page look like bad science?	*the claim that just because this guitar came from the '70s it was probably made from old-growth spruce and therefore produced superior sound (a myth)*
Take a look at the Consider the Source box on page 15. What conclusions can you draw about the two sellers based on the clues in their ads?	*The phrases "appear to" and "pretty sure" suggest the claims of the Diva seller can't be verified. The Delphi seller cites certificates and a serial number as signs of authenticity.*

EXTEND—The internet is full of videos of people playing, showing off, building, rebuilding, and simply talking about vintage guitars, some of which are worth hundreds of thousands of dollars to collectors and players. Students who are curious about the role of tonewoods and the meaning of *resonance* can look for videos on these subjects, but remind students to be skeptical and discerning of videos they encounter. As Exercise 1 should show, it is very easy to make claims on the internet without having to support them.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 1, students should set up a T-chart to compare and contrast the used guitar ads.

- A well-organized chart should compare or contrast a specific point or subject from one column to the next. For example, the different manufacturing date details—presence or absence of manufacturer labels and serial number—should be compared or contrasted in one row across the chart. Likewise, the claims about the spruce tops of the guitars can be compared and contrasted in another row.
- Below the charts, students should identify the more-expensive Delphi guitar as the better buy for a player or collector, because the claims made in the ad are more substantiated by the seller's details and the seller has a better reputation (more reviews, higher average review). The less-expensive Diva is from a less-reputable seller whose listing features a lot of soft, hedging language ("I'm pretty sure" and "at some point") and adjectives and adverbs whose actual meanings in the context of the ad are unclear ("magically" and "mojo").

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 3

Do all objects vibrate when they make sounds?

Previous Lesson

We examined speakers and musical instruments through live observations as well as slow-motion videos. We noticed a pattern and created a model of what these objects are doing when they vibrate and, using our model, tried to explain other things that make music. This led us to wonder if other things bend and deform when they are making sounds.

This Lesson

Problematizing, Investigation

2 DAYS

We investigate whether different solid objects, even ones that don't appear to move, vibrate while making sounds. Since those vibrations are happening on a scale we can't easily see, we set up and use a simple device with a laser and a mirror to "zoom in" on those objects when they're making sounds. This test provides evidence that all solid objects are springy (elastic) to a point and that they do vibrate when they make sounds. Further, we observe how the same object vibrates differently when making different sounds. Students use claim, evidence, reasoning charts to explain their arguments about how solid objects move when they make sounds.

Next Lesson

We will use a motion detector to collect data from a vibrating wooden stick. We will notice wave patterns in that data, called amplitude and frequency. We will conclude that the amplitude of vibration changes when sounds get louder, but the frequency does not change related to loudness.

Building Toward NGSS

MS-PS4-1

What Students Will Do

Engage in argument from evidence to support or refute our predictions about whether all solid objects vibrate (cause) when they make sounds (effect), even when we cannot see them vibrate.

What Students Will Figure Out

All solid objects move back and forth (vibrate) when making sounds. Objects vibrate more (deform further back and forth) when a greater force is applied, creating a louder sound.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	20 min	**NAVIGATION AND PLAN INVESTIGATION TO SEE IF OTHER OBJECTS VIBRATE WHEN THEY MAKE SOUND** Lead students to plan how they can use a laser and mirror device to change the scale of vibrations when a rock is dropped onto a table.	A-C	*How do objects move when they make sounds?*, Laser and Mirror Lab (with Drum and Rocks)
2	15 min	**GATHER DATA USING THE LASER AND THE MIRROR** Observe how the surfaces of two objects, a drum and a table, move when different forces are applied and sounds are made.	D	*How do objects move when they make sounds?*, Laser and Mirror Lab (with Drum and Rocks)
3	10 min	**ARGUE FROM EVIDENCE ABOUT THE MOVEMENT OF OBJECTS WHEN MAKING SOUNDS** Claim that all objects move when making sounds and use evidence and reasoning from today's investigation to support that claim.	E	*How do objects move when they make sounds?*
				End of day 1
4	10 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT HOW OBJECTS MOVE WHEN MAKING SOUNDS** Navigate from partners sharing laser-mirror evidence and reasoning to a whole-class discussion about how all objects move when making sounds.	F	*How do objects move when they make sounds?*
5	10 min	**GATHERING DATA AND DESCRIBING PATTERNS USING THE LASER-MIRROR APPARATUS** Use the laser-mirror apparatus to observe how the surface of the speaker moves while it's making different sounds.	G-I	*How do objects move when they make sounds?*, Laser and Mirror Lab (with Speaker)
6	10 min	**WRITE TO ARGUE FROM EVIDENCE ABOUT THE CONNECTION AMONG FORCE, VIBRATION, AND LOUDNESS** Claim that when more force is applied to an object, it causes bigger vibrations and therefore a louder sound. Use evidence and reasoning from today's investigation to support that claim.	J	*How do objects move when they make sounds?*
7	15 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT DIFFERENT SOUND VIBRATIONS** Come to the conclusion that more force transfers more energy, causing more vibrations and louder sounds, and consider how we could "zoom in" more on that claim next time.	K-M	*How do objects move when they make sounds?*
				End of day 2

Lesson 3 • Materials List

	per student	per group	per class
Laser and Mirror Lab (with Drum and Rocks) materials			• table or desk • drum and drumstick • laser pen • clothespin or binder clip (optional) • lab stand and clamp • mirror or flexible mirror tape • large rock (about 8 cm across) • smaller rock • video camera to record slow motion (optional) • graph paper • masking tape
Laser and Mirror Lab (with Speaker) materials			• table or desk • laser pen • clothespin or binder clip (optional) • lab stand and clamp • mirror • speaker • amplifier • power supply • all speaker setup cables • video camera to record slow motion (optional) • graph paper • masking tape • Feeling the Sound speaker simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *How do objects move when they make sounds?* • science notebook		

Materials preparation (10 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

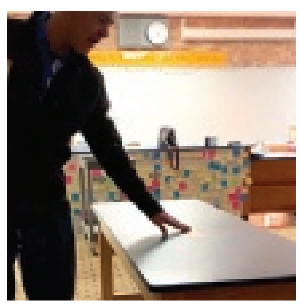
Day 1: Laser and Mirror Lab (with Drum and Rocks)

- Group size: whole class
- Setup
  - *See the photo steps below and watch the lab setup video demonstration of setting up the laser video to see how to build and test the materials for yourself.* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
  - *Gather materials and practice setting up the laser on its stand and directing it onto the mirror so you'll know where best to position it in your classroom. You may choose to disassemble before students come in so you can build it with them during class. Notes for during the lab: Students may suggest dropping objects other than rocks onto the table. If that's OK with you, go for it, just know that they may need to add lines to their data collection table on the handout.*

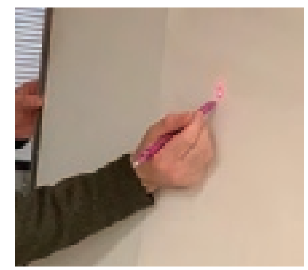
1. Mount a laser penlight onto a lab stand clamp so that it is positioned above a table where it will be pointed to shine on a drum and mirror.

2. You can use a clothespin and masking tape to hold the "On" switch down if needed.

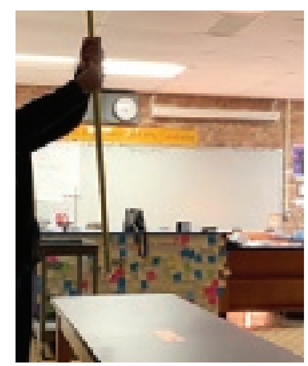
3. Point the laser so that it hits a spot in the middle of the table (and where you will place the drum in this same location, as well). Place a small mirror or flexible mirror tape on that spot on the table. This will cause the laser light to reflect from the table onto a wall or ceiling. To check that the laser is hitting the mirror, move to where you can see a red dot on the mirror surface. If the spot on the wall looks blurry even when it's not moving, check to be sure that the laser is reflecting off a smooth part of the mirror surface. Adjust if needed to avoid curved or bumpy places on the mirror surface.



4. You can set up a piece of chart paper on the wall where the laser reflects and then mark where the laser dot is starting.



5. Practice dropping objects on the table. Use something heavy like a big rock, a hardcover book, or a broomstick; dropping it straight down onto the table provides a concentrated point of impact. See video.



- Safety: Avoid directing the laser (even reflected off the mirror) into anyone's eyes.

Day 2: Laser and Mirror Lab (with Speaker)

- Group size: whole class
- Setup: Keep the laser-mirror device set up from day 1. Also, test the speaker and computer interactives as to make sure they work. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- Notes for during the lab: The speaker's vibrations will be continuous (as long as the sound is playing), so you may see different patterns of "laser blur" depending on the loudness and pitch.
- Safety: Avoid directing the laser (even reflected off the mirror) into anyone's eyes.

Online Resources

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students consider the idea of scale to help them "zoom in" on a solid object when it's making sounds to see if it vibrates. They set up a laser and mirror to more clearly show the motion of a solid object when it's hit (striking a drum, dropping a rock on a table, and increasing the loudness of a speaker).

The laser-mirror device allows students to observe evidence that even solid objects are springy enough to vibrate, even if they previously thought that solids would not move like that (they may have been committed to the idea that solids keep their shape or that they may bend one way but don't spring back past their starting place).

Then, students consider how objects vibrate differently to create louder or softer sounds. They deduce that more force (energy) is necessary to create more vibrations and cause louder sounds.

Where We Are NOT Going

In this lesson, we do not dig any deeper into why these solid objects are springy; we are only looking for evidence that they do move that way. Recognizing that particles in a solid are held together by the forces of mutual attraction and repulsion (which act like springs) is necessary to understand why any medium transmits sound, but that discussion develops in later lessons.

Students may begin to notice earlier on day 1 that the vibrations are different for different sounds (louder or softer); they can certainly note those observations and you can come back to discuss them on day 2.

If students make comments during this lesson about pitch as another way sounds are different, note that. You will return to this idea in the discussion at the end of day 2.

1. Navigation; plan investigation to see if other objects vibrate when they make sound. 20 MIN

Materials: Laser and Mirror Lab (with Drum and Rocks), *How do objects move when they make sounds?*

Navigate from the previous lesson. Recall the patterns we found last time with musical instruments and speakers and remember the other sound makers we wanted to consider today.

Suggested prompts	Sample student responses
What did we discover last time we were together about musical instruments and speakers making sounds?	*When they're making sounds, they move in a certain way: They spring back and forth past the starting point. That's called vibration.*
But then we started thinking about things that aren't designed to make sounds. Remind us of some of those examples.	*footsteps on a floor* *dropping a book on the table or desk* *baseball hitting a bat* *dishes and silverware clinking*

Display **slide A**. After a moment of silent think time, direct the students to turn and talk with a neighbor. Then, invite a few students to share their thoughts.

Suggested prompts	Sample student responses
Would you expect any object that makes sounds to move in the same way we saw musical instruments and a speaker move?	*Yes, any object making sounds will vibrate because that's what sound makers do.*
Why or why not?	*No, I don't think everything can vibrate like an instrument because how could something as stiff and hard as a table/desk/floor be springy enough to move like that?*

Say, *Shall we try it real quick? Here's a rock; drop it on the table. Did we hear a sound? Did we see any vibration? Hmmm … it seems like we need to gather some evidence about what's really going on here. But we can't see it.*

Additional Guidance

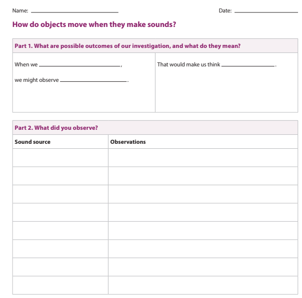
If students suggest taking a slow-motion video of the rock hitting the table, ask why (they may respond with "It's too fast to see the impact, so slowing it down might help us observe what's happening"). Then, go ahead and try it!

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**
Be intentional about naming the concept of changing scales to help us see, and connect back to examples of changing scale that students have already experienced. By explicitly developing their ideas about changing scale, you're giving students information they'll use to more automatically consider this concept in the future.

*** Attending to Equity**
Depending on your students' level of English language proficiency, you may choose to point out and possibly record key terms in various ways. Students may need a direct definition for words like *laser* and *reflect*, and you may choose to add them to a word wall display, including a drawing or image. Also, students can record these words in their personal glossary (if they have one) in their science notebook with a drawing or image and a definition in their own words, possibly using a language other than English, if that's helpful.

Introduce the idea of changing the scale.* Say, *Remember in previous units we have used the idea of scale. Sometimes when we can't observe things at one scale (like a distance or speed), we can change the scale to make them more visible. When we looked at slow-motion videos of instruments, we had changed the scale of the speed so we could really see what was going on. So, I was thinking about what we could do to zoom in on or magnify any vibrations that might be happening on the table. I remember trying to use a laser pointer during a presentation one time. It was so hard for me to hold the dot still when it was up on the screen. I think I was nervous, and the laser was magnifying the shakiness of my hand. So I have a laser pointer we could use. How could we design an investigation that would help us see if the table really does vibrate when it makes sounds?*

Plan the investigation. Display **slide B.** First, work with the class to identify the question you're trying to answer (such as, "Does a solid/stiff/hard/not-intended-for-noise-making object move when it makes sounds?").


Name: ____ Date: ____

How do objects move when they make sounds?

Part 1. What are possible outcomes of our investigation, and what do they mean?	
When we ____, we might observe ____.	That would make us think ____.

Part 2. What did you observe?	
Sound source	Observations

Then, talk through and set up the investigation as you show the class the materials you've brought in. Say, *Let's use this stand to hold the laser so we can aim it where we want, and we'll clamp it so the light stays on. Then, we'll use this mirror to reflect the laser dot onto the wall so we can see it. Now, what will we drop on the table? Should we try different kinds and sizes of objects?**

Students predict possible outcomes. Display **slide C** and distribute the student handout *How do objects move when they make sounds?*. Students complete part 1 ("What are possible outcomes of our investigation, and what do they mean?") with a partner,* then share out their responses.

Suggested prompts	Sample student responses
What are possible outcomes of our investigation, and what do they mean?	*When we drop different-sized rocks on the table, we might observe different sounds (smaller/lighter rock = softer sound, larger/heavier rock = louder sound). That would make us think maybe the vibrations are different.* *When we drop a small rock on the table, we might observe the laser moving a little (short distance or quick duration). That would make us think the table is vibrating a little.* *When we drop a bigger rock on the table, we might observe the laser moving a lot (long distance or for a longer time). That would make us think the table is vibrating a lot.* *When we drop the rock on the table, we might observe the laser not moving at all. That would make us think the table is not vibrating.* *Or, if the laser doesn't move when we drop a rock on the table, it could mean our setup doesn't work. We should test it.*

*** Supporting Students in Developing and Using Cause and Effect**

To be successful at connecting the cause and effect later in the lesson, while students are completing part 1 of the handout, check that they are able to make predictions and say what the outcomes would mean based on the cause-and-effect relationships they observed in the instruments and speaker making sounds. If some students are able to talk or write about the cause-and-effect implications, but others cannot, be sure to elicit multiple examples of what those outcomes might make us think during the share-out discussion. Have the students who are still processing their ideas rephrase and repeat what others have shared.

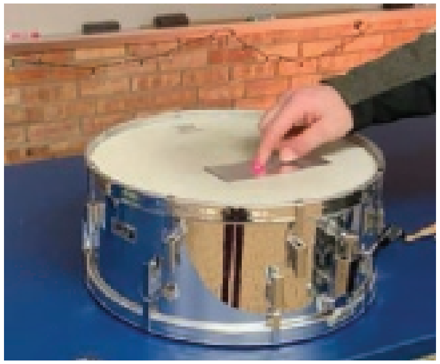
*** Supporting Students in Engaging in Argument from Evidence**

Considering possible outcomes directly connects to the reasoning students will do based on data from this investigation. So, thinking through the possible outcomes is time well spent to prepare students for reasoning later on.

2. Gather data using the laser and the mirror.

15 MIN

Materials: Laser and Mirror Lab (with Drum and Rocks), *How do objects move when they make sounds?*



Test the laser setup using the drum. Say, *I hear you saying we should test the laser setup. Since we already know how a drum vibrates, let's put the mirror onto the drum and see what happens to the laser when we strike it. Based on what you already know about the shape of the drum when it's struck, what do you predict the laser dot will do?*

When you place the mirror on the drum, check to be sure that the laser is reflecting off a smooth part of the mirrored surface. If the laser dot on the wall looks blurry even when it's not moving, adjust the setup to avoid pointing the laser at curved or bumpy places on the mirror surface so the dot is clear.

Display **slide D**. Instruct students to write "drum, soft" as the first sound source in part 2 of their handout, "What did you observe?" Strike the drum softly, and have students record their observations of the laser dot in that row. Repeat if necessary. Then, strike the drum harder (or have a student do so), and have students record their observations of "drum, loud" in the second row of the data table. Repeat if necessary.

Additional Guidance

Some students may argue that it's just the mirror vibrating and not the drum (or later, the table and speaker). If so, ask, *What is making the mirror move?* to help them understand that the energy is being transferred from the strike to the drum to the mirror: The vibrations from the drum are making the mirror move. Highly reflective mirror tape that sticks directly onto the drum and/or table helps make it clearer that the vibrating surface is making the mirror move.

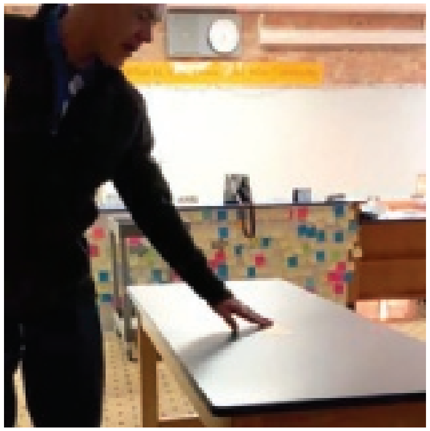
Additional Guidance

Students should observe that the position of the dot moved a lot very quickly. Some students may even see that the dot moves both higher and lower on the wall than in its initial resting position during the time the drum made sounds. To help students see the movement of the laser dot, tape a piece of paper on the wall where the dot is projected when still. Ask a student to mark the initial position of the dot. Then have a student mark the highest and lowest positions that the "laser blur" makes on the paper when the drum is struck. Use a second piece of paper or another color marker to record the movement of the dot when striking the drum harder.

Based on their experience so far with this source of evidence, students may suggest recording a slow-motion video of the laser dot. If students raise this suggestion, allow them to take a slow-motion video and share it with classmates to make more thorough observations of what happens when the drum is struck. Connect this part of the investigation back to the earlier discussions about changing the scale in order to make the phenomenon more observable.

Suggested prompts	Sample student responses
So how will this investigation help us answer our question about whether objects like the table vibrate when they make sounds?	*If we see the laser dot move back and forth, we know the table moved back and forth, so we have evidence that even things that aren't designed to make sounds (stiff, hard, solid things) also vibrate when they make sounds.*

Carry out the investigation. Adjust the laser so it is directed at the mirror placed in the middle of a student table. Direct students to record their observations in two more rows on part 2 of the handout as you (or they) test dropping both of the rocks (one at a time) onto the table with the laser-mirror apparatus. Repeat as needed and use new papers on the wall and/or colors of marker to record the dot's movement in each test. Other rows in part 2 will be used in day 2.



Additional Guidance

Students should see a similar result in the movement of the laser dot when the rock hits the table as they saw with the drum, but its duration and spread will be much shorter. This motion provides us with evidence that even the table is vibrating when it makes sounds.

3. Argue from evidence about the movement of objects when making sounds.

10 MIN

Materials: *How do objects move when they make sounds?*

Make a claim from evidence.* Display **slide E.** Students return to their seats and take a few minutes to complete the table in part 3 of *How do objects move when they make sounds?*. Day 2 will begin with a discussion of these claims and evidence.

Additional Guidance

If students are struggling with reasoning on part 3 of the handout, suggest that they include references to the laser and vibrations. You might also provide more sentence starters or fill in the blanks, such as these below (with possible responses in parentheses):

When we strike the drum, it __ (makes sounds) __, we see it __ (vibrate) __, and we see the laser __ (move up and down) __.

When the rock hits the table, the table __ (makes sounds) __, we don't see it __ (vibrate) __, but we do see the laser (move up and down) __.

Therefore, the table is __ (vibrating when it makes sounds) __ like the drum __ (vibrates when it makes sounds) __, even though we can't see it.

*** Supporting Students in Engaging in Argument from Evidence**
In this lesson, students fill out a table to support their argument about a claim based on evidence and may have some guidance about their reasoning. In future lessons, this table structure can be gradually removed as students become more independent in writing a claim based on evidence and reasoning.

Assessment Opportunity

Collect the handouts as a formative assessment after day 1. Look at part 3 to see if students are able to make a claim.

The claim should state: All objects vibrate when they make sounds. Evidence should include observations of the drum and the rocks on the table. Reasoning needs to make a connection between the sounds and the vibration they can't see that is detected by the laser.

If students have a claim that the table is not vibrating, ask them what evidence they have to support that. Ask them how they can explain the movement of the laser if there is no movement happening from the table. You could lead a class discussion with students arguing for either side.

End of day 1

4. Building Understandings Discussion About How Objects Move When Making Sounds

10 MIN

Materials: *How do objects move when they make sounds?*

Lead a Building Understandings Discussion to connect last class's work to today's. Redistribute the handouts from the previous class. Display **slide F**. Invite students to Stand Up, Hand Up, Pair Up to share their claim, evidence, and reasoning with a few partners before sharing with the class.*

Additional Guidance

"Stand Up, Hand Up, Pair Up" is a partnering strategy designed to get students moving around the room while they chat. As they hold their handouts, direct students to stand up and raise a hand to indicate that they're looking for a partner. When they make eye contact with someone else who has a hand up, they partner up and share their claim, evidence, and reasoning with that person. When both partners have shared, they put hands up again and walk around to find different people to share with. Allow time for students to talk with a few different partners before calling them back together for whole-class discussion.

Key Ideas

Purpose of this discussion: Share claims and reasoning about whether all objects move when making sounds based on evidence from the laser-mirror investigation.

Listen for these ideas:

- All objects vibrate when they make sounds.
- Evidence includes observations of the drum and the rocks on the table.
- Reasoning needs to make a connection between the sounds and the vibration they can't see that is detected by the laser.

*** Strategies for this Building Understandings Discussion**

See if the class can agree on the claims they make related to the original question about whether all objects vibrate when they make sounds. Ask, *What seems to be true about all of our claims?* Also, be sure these claims are supported by evidence. Say, ___ *and* ___ *you made similar claims. Did you have the same evidence?* Or follow up with asking, *What makes you think that?*

Suggested prompts	Sample student responses
What claim can you make based on the results of this investigation to answer the question we had at the start of this lesson?	*Everything must vibrate a little bit when it makes sounds because even the table (something we thought was hard) gave evidence of vibrating.*
How do solid objects move when making sounds?	
What evidence do we have to support the claim that vibrating objects make sounds?	*When we struck a drum with a laser beam (dot) bouncing off a mirror on it, the dot that showed up on the wall moved and shook above and below the point where it started.* *When we dropped a rock onto the table with a laser beam (dot) bouncing off a mirror on it, the dot that showed up on the wall moved and shook above and below the point where it started.*
What is your reasoning to support the claim that all objects vibrate when they make sounds?	*The rock made the table vibrate, which made the mirror vibrate, which made the laser vibrate. We couldn't see the table deform, but the laser showed us that it did.* *The table must be at least a little springy like the drum because it moved when it made sounds. If the table hadn't moved, the laser wouldn't have moved.*

5. Gathering Data and Describing Patterns Using the Laser-Mirror Apparatus

10 MIN

Materials: Laser and Mirror Lab (with Speaker), *How do objects move when they make sounds?*

Explore other patterns we saw in our data. Say, *OK, so we found some good evidence that even stiff, hard, not-meant-to-make-sounds kinds of things vibrate when they make sounds. But what other patterns did you discover in our investigation?* Display **slide G**. After turn and talk time, discuss responses as a group. Navigate by saying, *It sounds like we should put the mirror on our speaker and try the laser with that.*

When you move the mirror to the speaker, check to be sure that the laser is reflecting off a smooth, flat part of the mirror surface. If the laser dot on the wall looks blurry even when it's not moving, adjust the setup to avoid pointing the laser at curved or bumpy places on the mirror surface so the dot is clear. You may choose to use a piece of tape on the back of the mirror to secure it to the center of the speaker, rather than sticking it onto the curved sides.

Test the speaker on the laser-mirror apparatus. Display **slide H**. Say, *Let's try this. I have a way for us to control the sounds our speaker makes. How do you think the laser dot will move when the speaker makes different sounds?* (Accept a few predictions, following up with, *What makes you think that?*)

Online Resources

Use the speaker simulation, *Feeling the Sound* to adjust the loudness and pitch of the sound coming through the speaker. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Display **slide I**. As the speaker makes different sounds, have students record their observations of the laser's motion in the data table in part 2 of their handout (in the rows under the drum and table observations from the last class). For example, students can name the sound sources “speaker soft, low pitch” or “speaker loud, high pitch.”

Additional Guidance

Allow students to make or request changes to the volume or pitch of the sound coming through the speaker so they can see how adjusting each variable changes how the laser dot moves. Encourage students to change just one variable at a time to more clearly show the effect of changing each variable.

6. Write to argue from evidence about the connection among force, vibration, and loudness. 10 MIN

Materials: *How do objects move when they make sounds?*

Make a claim from evidence. Display **slide J.** Students return to their seats and take a few minutes to complete the table in part 4 of their handout.

Key Ideas

The claim should state: When more force is applied to an object, it causes bigger vibrations and therefore a louder sound. Evidence includes observations of the speaker’s wider vibration blur when it was playing a louder sound and/or observations from day 1 that the louder drum strike moved the laser more than the soft one and/or that the larger rock dropped on the table caused the laser to move more than the smaller one. So the reasoning concludes that a bigger force on an object causes the object to move back and forth or vibrate more (or bigger). When that happens more energy is being transferred. This means that louder sounds move more and have more energy than softer sounds.

Assessment Opportunity

If students are struggling to make the claim in part 4, direct them to write their evidence first, and consider offering sentence starters for the evidence section, such as, “When the speaker was ____, we saw the laser move _____. When we hit the drum harder, we saw the laser _____. When we dropped a bigger rock, the laser _____.” Then ask, *So what can we claim about what causes louder sounds?*

If students are struggling with reasoning on part 4 of the handout, remind them of the patterns they noticed when investigating the instruments. You might ask, *If you wanted to make the drum or guitar sound louder, what did you have to do? What* was *the difference in what we could see on the video of the drum or with the laser when the sound* was *softer versus louder? What happened to cause that difference?* Then connect this back to the ”Contact Forces” unit and the relationship between a force that deforms an object and energy; you might ask, *What happens when a force contacts an object? What do you think is happening with the energy when the rock hits the table or the stick hits the drum?*

7. Building Understanding Discussion about Different Sound Vibrations

15 MIN

Materials: science notebook, *How do objects move when they make sounds?*

Use evidence and reasoning to make a claim. Students bring their handouts and science notebooks and gather in a Scientists Circle. Display **slide K**. Ask, *What claim can we make based on the evidence we found today? How does changing the force affect the sound?* Discuss claims and the evidence to support them. If students need support to explain their reasoning, display **slide L** for more prompts to help them arrive at the conclusion that more force transfers more energy, which causes more vibrations and louder sounds.*

Key Ideas

Purpose of discussion: Share and critique claims and reasoning about what causes louder sounds

Look for these ideas:

- When more force is applied to an object, it causes bigger vibrations and therefore louder sounds.
- Evidence includes the following:
  - *observations of the speaker's wider vibration blur when it was playing louder sounds*
  - *observations from day 1 that the louder drum strike moved the laser more than the soft one*
  - *observations from day 1 that the larger rock dropped on the table caused the laser to move more than the smaller one*
- Reasoning concludes that a bigger force on an object causes the object to move back and forth more or vibrate more. When that happens more energy is being transferred. This means that louder sounds move more and have more energy than softer sounds.

Suggested prompts	Sample student responses
What claim can we make based on the evidence we found today?	*Stronger forces (louder speaker, harder drum strike, bigger rock) transfer more energy to an object, causing more vibrations and louder sounds.*
What evidence do we have to support the claim that stronger forces cause louder sounds?	*The laser dot moved more for louder sounds and less for softer sounds.*
What patterns did you see among your observations about the drum, rocks, and speaker?	*When we dropped a larger rock onto the table (that made a louder sound), the laser dot shook more than when we dropped a smaller rock (that wasn't as loud).* *We had to strike the drum with more force to make a louder sound, and that made the laser dot move more than when we struck it lightly (quietly).*
What is your reasoning to support the claim that stronger forces cause louder sounds?	*I know from our "Contact Forces" unit that a stronger force will deform an object more, so its surface moves back and forth more, which causes louder sounds.*

*** Strategies for this Building Understandings Discussion**

It is fine that students just say "more vibrations" (rather than trying to quantify them or even describe how they're bigger or faster). The question of what we mean by "more" will be introduced at the end of this lesson, bringing us into our work for the next lesson.

Suggested prompts	Sample student responses
Why does a stronger force cause louder sounds?	*I know that more force can change an object's motion more, so more force means more deformation which means more motion of that object's surface.*
What did we change to create a louder sound? Does it always work that way?	*We saw the laser move more when a louder sound was made. So that must mean that the louder the sound the more the kinetic energy. To get a louder sound we had to hit the drum or table harder, which transferred more kinetic energy to it, which is why the laser dot moved more than if we had started with less force (and a softer sound).*

Begin navigation to next time's task. Focus the discussion on the idea of the objects moving or vibrating "more" with louder sounds. Ask, *What do we mean by "more" vibration? Is there a way we could understand better how more force makes an object vibrate more?* Invite a few suggestions; students may connect to their work with contact forces and mention that faster motion results from more kinetic energy, or more energy transferred results in more motion. Foreshadow that we can try again to "zoom in" and change the scale of these vibrations so we can really understand how louder sounds and softer sounds are caused.

Assign home learning. Display **slide M.** Tell students that you came across two interesting articles related to using lasers and mirrors to detect vibrations in other objects. Have students turn and talk about this question before leaving, "Could we use a similar setup to detect vibrations in something larger like a bell in a bell tower when it is struck or in the ground during an earthquake?" Then after passing out *Where else are lasers used to detect vibrations?* and assigning it as home learning, tell students that it will help us gather information about some really cool ways that scientists have figured out how to use a similar laser and mirror setup to measure vibrations of some really big things.

Home Learning Opportunity

The readings in *Where else are lasers used to detect vibrations?* provide an opportunity to compare the instrumentation and expected outcomes in both phenomena with the investigations students just conducted in class. You may choose to use class time for these readings or save them for a day when you will be out. Please be aware that the article about Big Ben is Lexile level approximately 1200-1300, which is higher than the expected complexity for eighth grade independent reading. So, you may want to provide students with extra support, such as reading the article aloud to them, or allowing them to read it with a partner. Alternately, this article provides a differentiation opportunity for higher readers who are ready for that challenge themselves. The article about the moon's vibrations is written at approximately Lexile 1100-1200, which is on the high end of the expected text complexity band for middle school.

ADDITIONAL LESSON 3 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.1.B: Support claims with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.

As they work on parts 3 and 4 of the *How do objects move when they make sounds?* handout, students must use relevant evidence from their investigations and logical reasoning to support their claims about how objects move when they make sounds.

CCSS.ELA-LITERACY.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

When students complete *Where else are lasers used to detect vibrations?*, they must compare and contrast what they have learned through their investigations using the laser and mirror with new information about how other scientists have also used lasers to detect an object's motion. Students must write to explain the similarities and differences between what they did in class themselves and what they read about these other investigations. Students also use what they know from their investigations and what they learn in the reading to make predictions about future data.

You may need to support students as they write about their thinking by encouraging them to use precise language that specifies what they observed in class and how that's the same or different from how the Big Ben and Moon investigations used lasers to detect motion, too.

LESSON 4

How do the vibrations of the sound source compare for louder versus softer sounds?

Previous Lesson

We used a simple laser-mirror device to help us see whether all solid objects vibrate when they are making a sound. The results of our investigation provided evidence that all solid objects are elastic (springy) up to a point and that all objects do vibrate when they make sounds. We also noticed that objects vibrate differently when they're making different sounds, and we argued our claims about that based on evidence from our investigations.

This Lesson

Investigation

2 DAYS

We recall that more vibrations (from a more forceful strike or pluck) cause a louder sound, but we want to clarify what we mean by "more" vibrations. So, we use a motion detector to better see those vibrations as plotted on a graph of distance versus time. A long, wooden stick represents part of a vibrating instrument, which we push with more or less force to simulate louder versus softer sounds. We collect and analyze data from this detector apparatus, noticing wave patterns that help us explain more specifically how objects move when they're vibrating. During our analysis, we name two of the wave patterns we notice as "amplitude" and "frequency."

Next Lesson

We will change the length of the wooden stick in order to collect data on how vibrations at the sound source compare for changes in pitch. We will identify patterns in graphs related to the amount of time a vibration takes (its frequency) for sound sources that produce different-pitch sounds.

Building Toward NGSS

MS-PS4-1

What Students Will Do

Use mathematical representations of position versus time graphs generated from a tool used to scale up the vibrations of an object to describe wave patterns and support scientific conclusions about how objects move when they make louder or softer sounds.

What Students Will Figure Out

- The more we deform (push) a stick, the higher the peaks and lower the valleys of the graph of motion.
- We call the distance from the "at rest" position to the peak or valley the *amplitude.*
- Motion graphs of louder sounds have higher amplitude; softer sounds have lower amplitude.
- The number of vibrations of the stick per second (we called this *frequency*) doesn't change whether we deform the stick more or less.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**PROGRESS TRACKER AND NAVIGATION** Introduce the Progress Tracker in science notebooks, and use it to record recent learning. Use questions about how different sounds move differently to transition into today's work.	A, B	student notebook, motion detector
2	8 min	**FAMILIARIZE STUDENTS WITH THE MOTION DETECTOR** Invite a student to walk back and forth in front of the motion detector so students develop an intuition of what the motion detector is graphing.	C	Stick and Motion Detector Lab
3	5 min	**INTRODUCE THE STICK APPARATUS** Discuss and write about how the stick is a tool to help us scale up the vibrations of sound makers by allowing us to track its vibrations with the motion detector.	D, E	Stick and Motion Detector Lab
4	20 min	**MAKE PREDICTIONS AND GATHER DATA** Predict what the motion graphs will look like for each of three conditions: stick at rest, stick pushed lightly, and stick pushed harder. Gather data for each of these conditions, then compare that data to graphs of the motion a speaker makes for louder and softer sounds.	F-I	pencil, colored pencil or pen, Stick and Motion Detector Lab
5	5 min	**RECORD OBSERVATIONS OF GRAPH PATTERNS** Begin to notice patterns about today's data in preparation for a deeper discussion in the next class.	J	
				End of day 1
6	15 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT AMPLITUDE AND FREQUENCY** Describe data patterns and discuss what those patterns mean. Define amplitude and frequency and come back to the stick apparatus to demonstrate understanding of those concepts.	K	optional: *Harp String Graph Handout*
7	5 min	**ADDING TO THE PROGRESS TRACKER** Students work independently to add to Progress Trackers.	L, M	
8	5 min	**EVALUATE THE STICK APPARATUS** Students "take sides" and explain their thinking about the limitations of the stick apparatus as a tool for representing a sound maker.	N	

Part	Duration	Summary	Slide	Materials
9	15 min	**NAVIGATION** Consider other differences in sound and how those could be investigated with our motion detector. Use a xylophone, guitar, and transparent music box to inspire changes to our stick apparatus.	O	optional: *How does the motion detector work?*, xylophone, guitar, transparent music box, or this video of music box being played. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

End of day 2

Lesson 4 • Materials List

	per student	per group	per class
Stick and Motion Detector Lab materials	*L4 Motion Graphs*		• motion detector • software • stick apparatus • speaker simulation Turn It Up! (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
Lesson materials **Student Procedure Guide** **Student Work Pages**	• student notebook • science notebook • pencil • colored pencil or pen • optional: *How does the motion detector work?*		• motion detector • optional: *Harp String Graph Handout* • xylophone • guitar • transparent music box • or this video of a music box being played (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (60 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

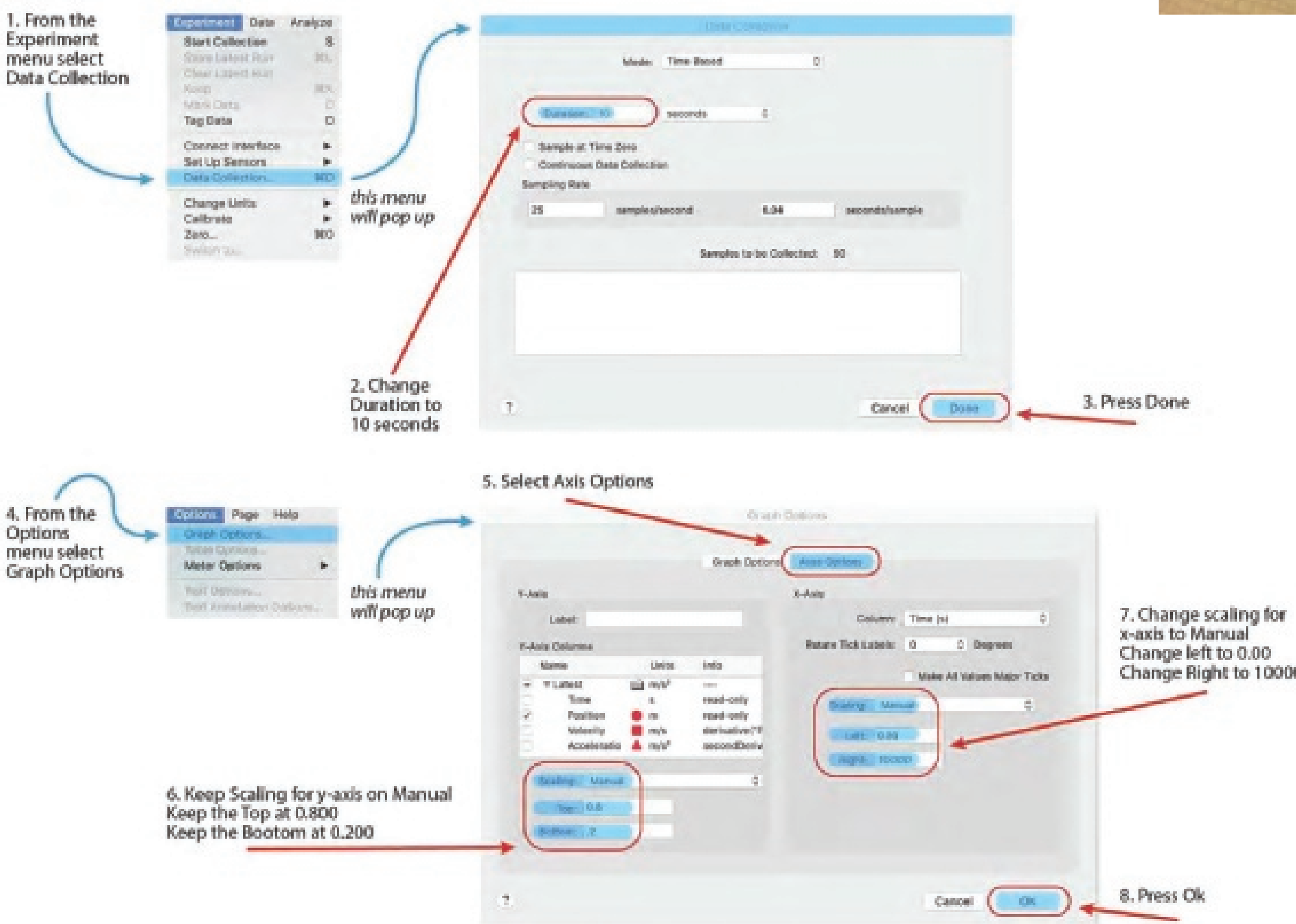
Test the *Turn It Up!* speaker simulation (for Day 2). (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Set up the motion detector and software using the instructions listed here:

1. Download and install the Logger Lite software. (**NOTE: You may need to contact your school's tech department for permission to download and install this program.** See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

2. Plug in the Vernier motion detector to your computer using the USB cable provided or possibly with a USB-USB-C adaptor like this.
3. Open Logger Lite on your computer.
4. Configure the graph settings by following the directions shown below or watching the video for setting up the motion detector. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Note that if you close the program, you will again need to configure the graph settings.



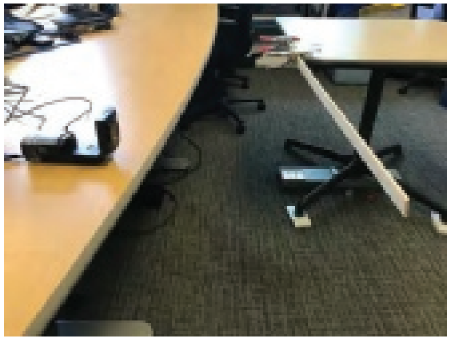
Configuring Logger Lite to collect data

Stick and Motion Detector Lab

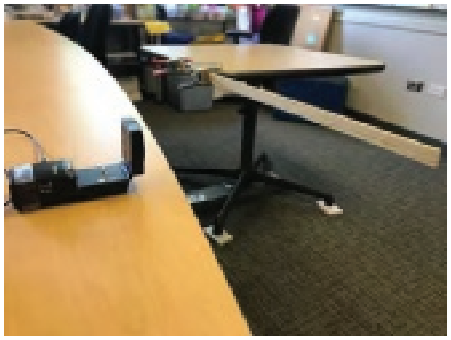
Prepare the stick apparatus and motion detector setup using the instructions below.

1. Hold the stick horizontally, turn it vertically, and clamp it to a horizontal surface so it sticks out like a train crossing gate. You many need to use duct tape as well to keep it secure.

2. Use the full length of the stick by clamping it at one end and placing the other end in front of the motion detector. This will provide the slowest rate of vibration and will allow the motion detector to pick up the movement (it cannot detect vibrations faster than 25 cycles per second). For a smooth graph, the stick should vibrate fewer than 3 cycles per second.



3. Set the motion detector on a surface at the same height as and at a 90-degree angle to the end of the stick so that the circular part of the sensor is facing a spot near the end of the stick. The detector should be a distance of 50 cm from the stick.



Alternate Setup: (Only use this alternate option if the recommended steps above do not work, as the setup above is more useful in helping students think about compression waves traveling through a medium.) If the recommended setup is not possible for you, an alternate option is to clamp the stick to a horizontal, flat surface so it sticks out like a diving board. If you do this, place the motion detector 50 cm below and toward the end of the stick (not at the very end) so that it points straight up at the stick.

Notes for during the lab: Make sure no one is standing behind the stick when it is pulled back. The motion detector might detect a person's body if it's in line with the detector sensor. Have students stand off to the side as the stick is pulled back so they don't interfere with the detector readings.

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will again change the scale of vibrations they want to investigate, this time by using a motion detector to capture the movement of a long stick that represents a sound maker.

Time is represented on the *x*-axis of the graph. That means that any measurement plotted horizontally refers to things like period (the time it takes for one repeated oscillation) or frequency (the number of repeated oscillations per time unit). Distance (toward or away from the motion detector) is recorded on the *y*-axis. Students make several sketches of these graphs throughout the lesson in order to better understand the real-world motion that the graphs represent.

When a bigger force is applied, the stick has more energy to move further back and forth past its starting place. The mathematical representation of the resulting motion in the form of a graph helps us see this motion, and we can attach the scientific term *amplitude* to this idea of distance from its starting point.

In the graphs produced from this vibrating stick, the frequency of vibrations will be constant, regardless of how much the stick is deformed. This is similar to the behavior of a pendulum, whose period and frequency of oscillation are independent of how far you pull it back. It is also independent of its swing length, but it is dependent on the length of the pendulum.

Where We Are NOT Going

The graphs produced by the motion detector have the shape of waves. However, waves include the transfer of energy through space, and these graphs are from an oscillating source but do not show energy transfer across space. So, we do not call the graphs waves, but rather a graph of the motion of the stick.

Time is represented on the *x*-axis of the graph. That means that any measurement plotted horizontally refers only to things like period (the time it takes for one repeated oscillation) or frequency (the number of repeated oscillations per time unit). There is no representation of wavelength yet on this graph. Wavelength is an emergent property of the type of medium that the wave travels through, and it will appear as a characteristic of a pattern of energy and matter in the medium in Lesson 10.

If students refer to the horizontal distance between wave peaks as wavelength, ask them to consider what the variable is on the *x*-axis of the graphs and how we can describe the interval between two points in time. That will help them shift from thinking of that measure as wavelength to thinking of it as the time between two waves (or period).

We begin exploring frequency in this lesson, including defining it and measuring and calculating the number of oscillations in a certain time period. However, frequency will be considered even more in the next lesson.

1. Progress Tracker and Navigation

7 MIN

Materials: student notebook, motion detector

Introduce the Progress Tracker. Display **slide A**. Direct students to draw a 2-column T-chart directly into their science notebooks in the Progress Tracker section that they set up in Lesson 2. The left column is to record the question, and the right column is to record what they figured out.

Tell students, *This is a tool designed to help us keep track of ideas we figure out from each lesson. In the "What I figured out" column, you can draw pictures or write in sentences or make a list or do a combination of these, whatever way is most meaningful for you. Take about three minutes right now to think about what you figured out in our last class from any evidence we have so far. Record your learning in the "What I figured out" side of your Progress Tracker.*

Since there is no defined box or row in a T-chart, students can take up a lot of space or a little space with their response. When students finish recording their ideas for this question, they draw a line after their work to indicate the beginning of the next "row" for the next time the teacher instructs them to write in their tracker.

In the example Progress Tracker row below, the "What I figured out" side has been completed with *possible* student ideas.*

Question	What I figured out
How do solid objects move when they make sounds?	• All objects vibrate when they make sounds. • A bigger force on an object causes the object to move back and forth (or vibrate) more, which makes a louder sound. • Louder sounds have more energy than softer sounds.

Discuss learning from last time. Display **slide B**. Direct students to turn and talk with a neighbor about patterns they saw last time. Then, use the prompts below to briefly review as a class what we discovered about the pattern of "more force transfers more energy, deforming the object more and making more vibrations, which makes louder sounds." Then, move the conversation to today's work.

Suggested prompts	Sample student responses	Follow-up questions
Who can remind us of the pattern we saw last time when objects were making louder sounds?	*We saw the laser vibrate more when sounds were louder.* *More force (harder drum strike, bigger rock on the table, turning up the speaker) made louder sounds.* *More force transfers more energy, which deforms an object more, which makes more vibrations, which makes louder sounds.*	*Can anyone add on?* *Will you rephrase what she/he said in your own words?*

***Attending to Equity**
The example Progress Tracker ideas here serve as teacher guidance for what students might say; however, some students may say more and others may say less. It is important that what the students write or draw in the two-column tracker reflects their own thinking at that particular moment in time. This is an opportunity for students to express their understanding and reasoning in their own way, to be creative and to synthesize their learning in their own words.

Suggested prompts	Sample student responses	Follow-up questions
OK, I hear you saying, "more, more, more," and I agree. But what exactly do we mean by "more" when we're talking about vibrations?	*There's a stronger force starting the vibrations. We had to hit the drum harder (with more muscles) or drop a bigger rock, which would hit the table harder.* *We transferred more energy to the object, so it had more motion … the vibrating object moves more … like faster, makes more back-and-forths in the time it was moving.* *The laser dot moved higher and lower from where it started. We could see that it moved a greater distance on the paper we marked.*	*Tell us more about that.*

***Supporting Students in Developing and Using Scale, Proportion, and Quantity**
Pose questions to help students connect to the fact that the laser we used last time changed the scale of the vibrations so we could see them. Here again we need to change the scale of the motion because it's too fast for us to see to study–interpreting the graph created by the motion detector makes the motion more visible.

Point out the motion detector. Say, *I think we're on the right track here. We have a definite pattern. But we need more evidence that more force makes an object deform more, which makes it vibrate more, which makes louder sounds. I still can't see enough of what's going on—it was all happening so fast with the laser. I want to change the scale again and slow down the whole system so we can see more clearly what's happening differently with those louder or softer sounds. So I have this motion detector, and I'm hoping it will help us "zoom in" again on this motion.**

2. Familiarize students with the motion detector.

8 MIN

Materials: Stick and Motion Detector Lab, science notebook

Introduce the motion detector apparatus. Bring students together around the motion detector apparatus. Point out the motion detector and explain that it helps us measure the motion of objects moving too fast for us to see. Say, *The laser made it easier to see in the moment if vibrations happened, but this detector will show us a graph of how an object is moving over time. We can then take all the time we need to study the graph and investigate the motion it shows, which will make it easier to see quick vibrating movement.*

Demonstrate the motion detector with a student. Switch from displaying slides to showing the Logger Lite motion detector software. Ask for a student volunteer to stand in front of and facing the motion detector sensor, hold a book in front of his or her body, and walk slowly backward away from the motion detector. Students should notice that the graph changed; ask them to describe what they see. At this point, the graph should look like a sloped line moving upward. It might be a little bit wobbly instead of perfectly straight. This is normal due to typical human motion during walking.

Additional Guidance

If you have trouble getting a good graph, be sure to check the data collection rate and the *x*-axis and *y*-axis scales. Refer to step 4 of the materials preparation at the beginning of the lesson.

Suggested prompts	Sample student responses
Why does the graph have the shape it does?	*When someone walks away, the person is getting farther away, so the graph is getting higher.*
By "higher," do you mean this line here is going up? What does that vertical axis tell us anyway?	*It's a measure of the person's distance from the detector.*
OK, so as someone gets farther away, his or her distance from the motion detector gets bigger, so this line goes up to bigger numbers, showing more distance from the detector. Why isn't it just a line going straight up?	*It takes some time for the person to move. So, if the person moves really fast, the line might go straight up, but the person moved slowly, so the line is going up at an angle.*
So what is the horizontal axis telling us?	*It's telling us the time.*
You mean, like, what time it is?	*No—just how much time the person spends walking.*
So, what do you think the graph would look like if the person walked more slowly?	*The slope of the line would be more gradual, not as much movement over time.*
What do you think it would look like if someone moved toward the motion detector instead of away?	*The line would move downward instead of upward because the person's distance away from the detector is getting less and less.*

Additional Guidance

Make sure that students understand that the graph is showing distance away from the motion sensor (*y*-axis) versus the duration of time (*x*-axis).

Test the detector again, but with these changes. Ask another student volunteer to move toward the motion detector apparatus more slowly than the first student had moved away from it. At this point, the graph should start fairly high on the vertical axis and gradually slope downward. Because the student is moving more slowly, the slope of the line should be less than the upward slope was. Discuss how the actual graph compares to their predictions.

Suggested prompts	Sample student responses
Why does the graph have the shape it does?	*The person was moving toward it, so the line is getting closer to 0, which is where the motion detector is.*
Why isn't the graph as steep as before?	*Since the person moved slower, it's taking more time to get to 0. If the person were moving faster, the line would be steeper.*

Sketch these graphs in science notebooks. Direct students to open their notebooks to their next clean page, date it, and write the question for today's lesson at the top: "How do the vibrations of the sound source compare for louder versus softer sounds?" Say, *Remember, today we're looking for the answer to this question, so it's fine that you are probably not sure how to answer it yet.* Display **slide C**. Instruct students to draw sketches of both graphs in their notebooks, being sure to label the horizontal and vertical axes. Next to or under the graphs, they should explain in words what the graph looks like when someone walks away from the motion detector or moves toward it more slowly.

3. Introduce the stick apparatus.

5 MIN

Materials: Stick and Motion Detector Lab, science notebook

Introduce the stick apparatus. Say, *OK, we just saw how the motion detector picked up your movement. It produced graphs that helped us look closer at how you were moving. Now we want to have it make some graphs for the vibration motion that's going on when objects make sounds. We want to study that motion at a larger, slower scale so we can better see those "more" patterns. But we have another issue of scale here. The motion detector picked up your movement well because you are much bigger than our speaker, a tuning fork, or a guitar string. So, if we want the motion detector to show us a clear picture of a sound maker vibrating, we need to enlarge the object that's making the sound. So here's what I came up with.*

Point out the stick apparatus and display **slide D**. Discuss the following questions to help students consider why this tool will help us better see the vibrations.*

Suggested prompts	Sample student responses
How could this stick represent a tuning fork or guitar string?	*We can pull it back and let it go like we would pluck a guitar string or hit a tuning fork.*
How do you think it will move?	*When we apply a force, it will move back and forth like the tuning fork arms or the guitar string.* *It will vibrate like any other matter, but I think it will go slower.*
Retell in your own words why we need to use this long stick as a tool to represent our sound makers.	*We can't see the vibrations of the speaker or instruments well enough to really study how they're different for different sounds. We need to slow them down to see them.*
How will we change the scale of the vibrations by using this stick as a tool?	*We want to use the motion detector to make a graph of how the vibrations are moving, but the motion detector can't see such small movements (like the speaker, guitar string, or tuning fork), so we need to have a bigger sound maker for the motion detector to "watch."*
Will there be a difference between loud and soft sounds? How so?	*If our setup works well, yes, we should see more movement for louder sounds and less movement for softer sounds.*
How would we make that happen? *(Think about how the guitar string or tuning fork or speaker moved differently.)*	*Just like we had to give more energy to the guitar by plucking the string farther or give more energy to the tuning fork by hitting it harder, we will have to pull or push the stick farther to give it more energy. Then it will represent a louder sound.*

Write to consider today's work. After a few students share their ideas, display **slide E**. Direct students to record their own answers to these questions in their science notebooks.

*Supporting Students in Engaging in Developing and Using Models

In middle school, a model is an abstract representation of a phenomenon that is used as a tool to represent how or why something in the world works the way it does. In early grades, the practice of modeling focuses on developing physical replicas that represent concrete events, objects, and systems. However, now students are working with phenomena at scales we can't observe directly (or at all). For this reason, we call the stick apparatus a physical representation that helps students gather data in order to then create a model that explains objects making sounds. To support students in this work, discuss what about the stick apparatus makes it a good representation of a sound maker even though it is not making sounds. For instance, it vibrates back and forth at a rate we can observe directly, which helps us better understand the motion of vibrating objects, even if they move too fast for us to see.

*Supporting Students in Developing and Using Cause and Effect

Questions like, "What scale would help us better see what is happening when an object

4. Make predictions and gather data. 20 MIN

Materials: Stick and Motion Detector Lab, science notebook, pencil, colored pencil or pen

Ready the motion detector and stick apparatus. Place the motion detector so it is exactly 0.5 m away from the stick. Tell students that the distance between the motion detector and the stick is 50 cm, or 0.5 m.

Distribute *L4 Motion Graphs* to each student. Display **slide F.** Instruct students to open their science notebooks to the next blank left and right pages and tape the entire sheet to the left page.

Predict what the graph will look like when the stick is at rest. Direct students to draw in pencil on both graphs (conditions 1 and 2) what they think the graph will look like when the stick is still. Discuss predictions using the prompts below.

Suggested prompts	Sample student responses
What will the shape of the graph be for this stick while it is sitting still?	*It should be a straight line. It should be a flat line.*
Where do you think the line will be? Up here (pointing to top)? Down here (pointing to bottom)?	*The line should be right in the middle at the 0.5-m mark.*
Why do you think that?	*That's where the stick is right now—it's 0.5 m away from the motion detector.* *It's not moving closer or farther away from the detector right now, so it should stay at that spot on the graph.*

Demonstrate the graph of the stick at rest. Press play on the motion detector so it records the stick not moving. Instruct students to compare the actual graph to their predictions and make changes if needed. Also, tell students to draw an arrow pointing to that line on each graph and label it "stick not moving."

Additional Guidance

Be sure that no one is standing behind the stick in view of the motion detector sensor. The motion detector might detect that person's body instead of the stick. When you push the stick in the next steps, stand beside it and out of view of the sensor so that your body doesn't interfere with the motion detector.

Predict what the graph will look like for louder versus softer sounds. Display **slide G**. For the next graph plots, tell students to use a different-colored pencil or pen from what they used for their stationary stick prediction. Direct students to make predictions on both their Condition 1: Light Push and Condition 2: Harder Push graphs using a dashed line. In condition 1, we will push the stick lightly, and in condition 2 we will push the stick harder than that. Students should label these lines "prediction" on both graphs. Switch to projecting the motion detector software.

Test condition 1: Push the stick lightly. Ask the students, *When we push the stick lightly, just a little, what loudness of sound are we trying to represent?* Then, have a student volunteer push the "Collect" button on the computer while

vibrates?" support students' thinking about how the concept of scale helps us understand more about what we can't see clearly. If students struggle to connect the idea of scale to this investigation, explain directly that the stick is a large-scale representation of the guitar string or tuning fork tines. The vibrations of those actual sound makers are too small and too fast to see. The wooden stick is a tool that allows us to study vibrations that are both bigger and slower. We've changed the scale by enlarging the vibrating object so it's easier to study.

you give the stick a light push. Move it between 5 and 8 cm from its resting position. Keep the graph projected on the screen. Have students record the actual graph with a solid line on their Condition 1 graphs in their notebooks. Students should label this line "actual."

Additional Guidance

Students may ask why the vibrating stick doesn't make a sound. You might encourage them to write the following two questions on index cards or sticky notes and add them to the Driving Question Board:

- Why doesn't the vibrating stick make a sound we can hear?
- If all sounds come from vibrating objects, do all vibrating objects make sounds?

Save the graph for later. Take a screenshot of this graph and save it to your desktop to display later (in the conclusion of this lesson and in the next lesson).

Test condition 2: Push the stick a little bit harder. Ask a student volunteer to push the "Collect" button while you give the stick a harder push. Try to deform it about twice as far as the light push (10–16 cm). Keep the graph projected and ask students to record the shape of the graph on the Condition 2 graph in their science notebooks. They should use a solid line and label the line "actual."

Save the graph for later. Take a screenshot of the graph and save it to your desktop to display later.

Online Resources

Look at graphs of a speaker's motion. Switch to the speaker simulation, *Turn It Up!* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Explain to students that this simulation will graph the motion of the speaker while it's making sounds. Start with the loudness turned to a low but still audible volume. Take a screenshot of the graph. Ask students to predict what will happen to the graph when you turn up the loudness. Turn up the loudness and take a screenshot of the graph. The softer sound and louder sound should look similar, but the softer sound will have a wave-like pattern that is not as tall vertically as the louder sound.

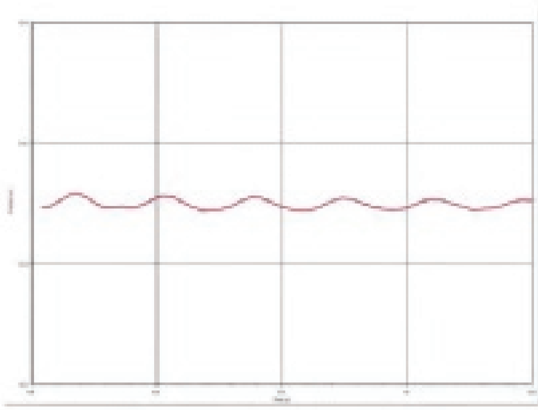
Additional Guidance

This is an opportunity for students to connect the motion of the vibrating stick to the motion of the speaker. The simulation graph is much like the one from our stick, but this time the computer is telling us how far back and forth the speaker is moving when it plays these different sounds. Both the stick and the speaker move back and forth, and the graph of the motion of the speaker looks like the graph of the motion of the stick.

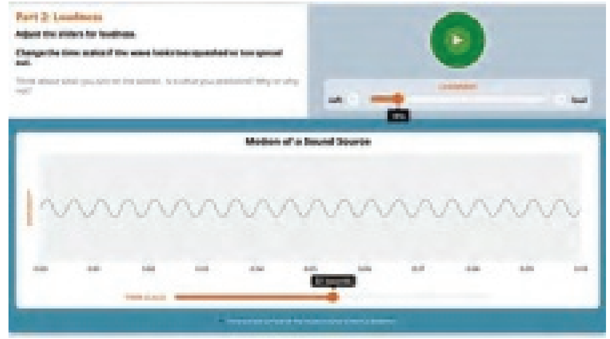
Sketch the speaker graphs. Direct students to sketch the soft sound and loud sound speaker graphs in their notebooks on the right-side page facing the graphs of the stick's motion. Display **slide H** (and then flip back and forth between slides and graphs as needed). Students should title the graph sketches for which sound is which and label the axes. Say, *We will need to look back at these graphs during discussion next time, and I hope making sketches of them is already helping you notice patterns about them.*

Save the graphs for comparison. You should have four screenshots: light push of stick, harder push of stick, soft speaker sound, and louder speaker sound. Move all four images onto **slide I** so that they are stacked with two stick graphs (one above the other) on the left and two speaker graphs (one above the other) on the right. Save this slide to use during the next class's discussion. See the example here.

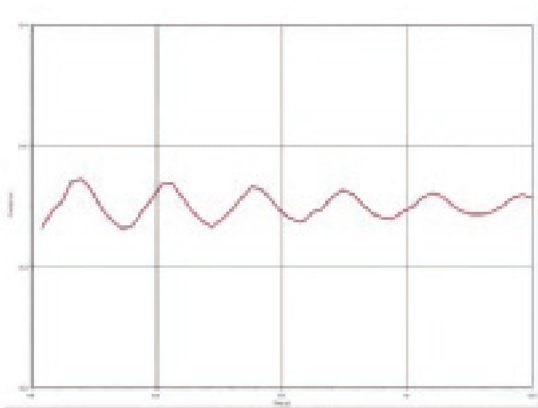
Stick Soft Push



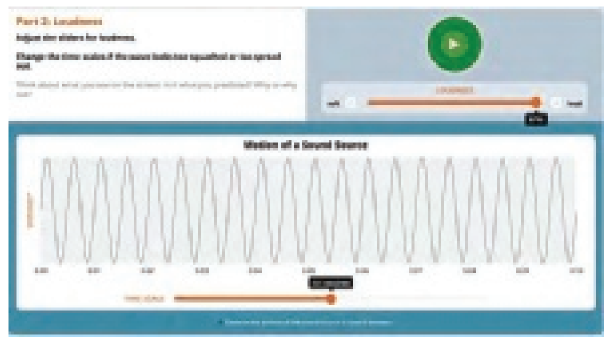
Speaker Soft



Stick Hard Push



Speaker Loud



5. Record observations of graph patterns.

5 MIN

Materials: science notebook

Record observations about the graphs. Display **slide J**. Direct students to look for patterns among the four graphs and describe those patterns in their science notebooks.* They should specifically look for similarities and differences among the graphs. Students should write complete sentences beginning with the phrase, "I notice …" and, when helpful, include arrows pointing to features of the graphs that support their comments.

Notice who could begin the discussion next time. As students write, circulate to identify students who have hit on major points and ask them, *Would you be willing to share that idea with the group when we come back together?* You will want at least one student whose work you can use to discuss amplitude, and at least one student whose work relates well to discussing frequency. Make a note for yourself to remember which students you've selected to begin the discussion in the next class.

Close today's work. Say, *You've made some thoughtful observations about our stick tool and speaker sound graphs. We'll explore those ideas and finish answering our question about the vibration of loud versus soft sounds next time.*

***Supporting Students in Developing and Using Patterns**
Graphs help us analyze data to find patterns. Remind students that they might see patterns in repeating events or relationships. Noticing patterns leads us to ask questions about those relationships.

End of day 1

6. Building Understandings Discussion about Amplitude and Frequency

15 MIN

Materials: science notebook, optional: *Harp String Graph Handout*

Discuss patterns from the graphs, especially about amplitude. Gather in a Scientists Circle. Display **slide I** from last time that shows all four graphs together. Ask the students you previously identified whose noticings related to amplitude to share first so you can focus the discussion on that pattern (and move into frequency next). Make a public record of the ideas. During sharing and discussion, encourage students to add any new ideas they agree with to their own "I noticed" statements in their notebooks. As students describe the patterns they see, invite them to point to the parts on the projected graphs.*

Key Ideas

Purpose of this discussion: Identify patterns in the graphs (including identifying amplitude and frequency) using evidence produced from both the stick and motion detector activity and the speaker simulation. This leads us to add to our model regarding how vibrations relate to loud and soft sounds.

Listen for these ideas:

- Louder sounds have higher peaks and lower valleys.
- The horizontal distance between the peaks stays the same for loud and soft sounds.
- The peaks and valleys get smaller and smaller until the line is flat.

***Supporting Students in Engaging in Developing and Using Models**
Students working to create graphs of the motion of the stick apparatus in this lesson sets them up for planning the changes they will want to make in the next lesson when they predict how they could investigate frequency with the stick apparatus instead of amplitude. In both situations, using the stick to represent a sound source helps students observe phenomena that would otherwise be moving too fast to see. As they anticipate changing a variable (the length of the stick) in the next lesson, they predict how a graph of its motion will change.

Suggested prompts	Sample student responses
We all saw some patterns. What are some of the important features of the graphs or patterns that you noticed?	*There is an S shape or wave shape on all four graphs.*
What do you mean by "wave shape"?	*It's wavy. It goes up and down in a curved line. (Student points to projected graph.)*
Is there a repeating pattern there? Can you show me where the shape starts and where it ends (or begins again)?	*(Pointing at projected graph) I think one starts up at the top, here, and it ends just before it gets to the top again.*
What do we notice about how the shape of the graph changes?	*The spacing between the high and low points gets smaller as time goes on.*
Tell us more about what you mean by "spacing"?	*The distance of spacing between the high and low points (y-axis values) was less in the first graph when the stick was pushed lightly.*
	In both stick graphs, the high and low points get smaller (closer) at the end than when they started.
And do we see anything like that for the speaker?	*Yeah, the up-and-down distance for the graph of the speaker playing soft sounds is smaller than the up-and-down distance for loud sounds.*

Measure and compare the vertical distances on the graph. Invite a student or two up to the projected graphs to actually measure the distances from the "starting position" line of each graph to the tops and bottoms of each wave. Compare the distances on each graph alone. Also contrast the "light push" and "harder push" graphs and the "softer sound" and "louder sound" speaker graphs. Discuss what those patterns mean about the vibrations of loud and soft sounds.*

Suggested prompts	Sample student responses
How do the vertical measurements on each graph compare or contrast with the others?	*The light-push stick graph has a smaller vertical distance to begin with than the harder-push stick graph.*
	For the speaker graphs, the vertical distance stayed the same in each graph.
	But, the louder-sound speaker graph's vertical distance was greater than the softer-sound speaker graph.

***Supporting Students in Engaging in Using Mathematical and Computational Thinking**

This sort of proportional thinking about frequency (vibrations per second) is a theme that will be repeated in future lessons in this unit. Since proportional thinking, unit rate, and equivalent fractions are a focus in the Common Core Mathematical Standards, we integrate it as a focus of this unit starting in this lesson.

Suggested prompts	Sample student responses
What do the vertical patterns on the graphs show us about the vibration of different sounds? *What makes you think that?*	*The vertical distance is greater (higher and lower from the midline starting point) for louder sounds.* *The louder speaker sound had higher and lower vertical distance than the softer speaker sound. Also, the hard-push stick graph had higher and lower vertical distance than the light-push stick graph had.* *We had to push the stick farther to represent a louder sound because more energy makes things move more. It's like when we pluck the guitar string harder or hit a drum harder; we get a louder sound because we gave it more energy.* *The sound makers and our stick tool started from resting, moved one direction, moved back past the starting point, then repeated that movement.*

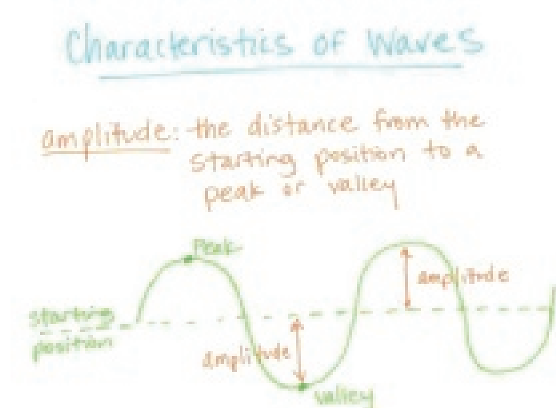
***Attending to Equity**
When recording definitions in their notebooks, students should write in their own words rather than copying a "standard" definition from the teacher. Also, students may write in a language other than English if they choose and include images to accompany their writing. When adding words to the word wall, have several students share out their definitions and ask the class if they agree or disagree with that definition.

Additional Guidance

Students may point out that on the stick graphs, the distance from the starting position to the top or bottom changed as time went on. It was a bigger distance to start and got smaller toward the end. If they do bring this up, you may want to ask them to connect back to the models they drew in Lesson 3 of the drum—it stops vibrating eventually and goes back to its starting position. Students may infer that is what's going on here—the sound is getting quieter and quieter.

Define amplitude. Direct students to record amplitude and its meaning in their notebooks, along with a diagram or drawing to help them remember it.

Say, *Scientists and engineers use a single word to refer to this vertical distance between the midpoint (resting, starting point) and a high point or low point. They refer to that distance as* amplitude. *This is a word you have earned—you understand well what it is. So, let's record it in our science notebooks. Then we will share out and add our agreed-upon definition to our word wall.**



If you haven't already done so, now might also be an appropriate time to name the high points "peaks" and the low points "valleys" just for ease of discussion. Continue to use "high point" with "peak" and "low point" with "valley" to help students remember these terms.

Confirm the connection between higher amplitude and louder sound. Refer to the graphs of the speaker sounds to discuss the meaning of *amplitude*.

Suggested prompts	Sample student responses
What did we hear changing from the speaker when the amplitude of the graph got bigger?	*It gets louder. Bigger amplitude means louder sound.*
The word amplitude *reminds me of the word* amplifier. *Has anyone ever heard of that word? Who knows what an amplifier is?*	*It's a thing in a sound system that makes your sound louder, like what you hook an electric guitar to. You can't hear the electric guitar very well until you connect it to an amplifier.*
How does the amplitude we see on these graphs support what we thought about more energy making louder sounds?	*These graphs prove that the stick or speaker moved a greater distance from where they started when the sound was louder. When we added more energy by pushing more, we saw a higher amplitude because the stick and speaker moved more back and forth.*

Discuss horizontal patterns from the graphs to explore frequency. Ask the students you previously identified whose noticings related to frequency to share next so you can turn the discussion to that pattern. As students continue to describe the patterns they see, invite them to point to the parts on the projected graphs.

Suggested prompts	Sample student responses
So what do you notice about the horizontal distances from top to top (peaks) or bottom to bottom (valleys)?	*They have the same measurement, the whole time, for each device. (Hard-pushed stick matches light-pushed stick, and both loud and soft speaker sounds have the same horizontal distance measurement.)*
What do you think those horizontal distances show us about the vibrations of different sounds?	*Not much! They stay the same no matter how much force we gave the stick or no motter the loudness of the speaker!*
So, what does that distance represent then?	*It shows how much time passes between each "wave" of motion or sound.* *It's how long it takes for one full back-and-forth movement.*
Hmmm … so does this horizontal distance change with louder or softer sounds?	*Seems like no! Since they're the same for the loud and soft sounds (from the same source), it doesn't seem like how fast the waves are happening has anything to do with the loudness.*
So I hear you saying that the horizontal distance shows how often, or how frequently, a wave happens. How could we check that?	*We can count how many high points or low points happen in the time on the graph.*

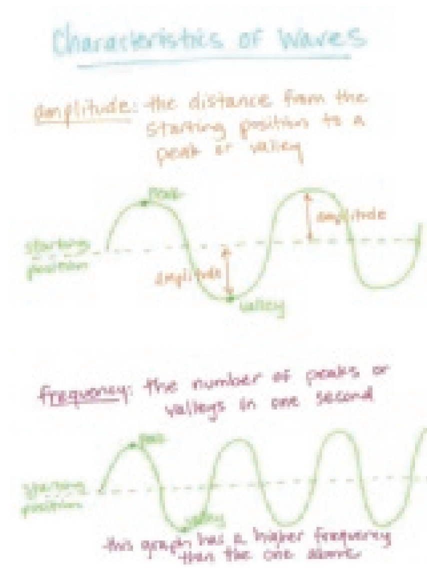
Invite students to measure the space between two high points and/or two low points repeatedly across each graph. After students count how many peaks happen in a given amount of time using the graph, have them calculate how many waves would happen in double or even triple the time.* If they'd like to, students could repeat the stick and motion detector test for that longer time to confirm.

Say, *If scientists or engineers think that the same number of vibrations is occuring in the same amount of time, so that if you double that time you get double the vibrations and if you triple that time you get triple the vibrations, then they say the waves have the same frequency. The frequency is the number of peaks or valleys that you would see in a single second.* Direct students to record this definition in their notebooks, along with a diagram or drawing to help them remember it.*

Additional Guidance

Optional: Have students calculate the frequency (how many peaks or valleys would happen in just one second) of the stick's and/or speaker's motion. Students will also calculate frequency in Lesson 5 when they investigate the connection between frequency and pitch.

Create a chart for "Characteristics of Waves." Draw a sketch of a wave and label the amplitude and frequency. Display this chart for reference throughout the rest of the unit.



Answer our lesson question. Display **slide K**. Discuss the questions and clarify any lingering confusions or disagreements.

Suggested prompts	Sample student responses	Follow-up questions
How does what we discovered from the graphs help us answer our original question, "How do the vibrations of the sound source compare for louder versus softer sounds?"	*The amplitude of the vibrations of the sound source (that we can see by measuring from the midline, or resting position, to the peak or valley of the wave shape) is smaller for soft sounds.* *Greater amplitude in the vibrations of the sound source means louder sounds.* *We noticed that the frequency of the waves on the motion graphs doesn't seem to change—it stays the same for each sound maker no matter the loudness.*	*Show us what evidence you have on a graph.* *Who can add on?* *Who can summarize what we agree (or disagree) about?*
So what is the "more" in the vibration of louder sounds?	*"More" vibration means a greater amplitude–it's moving higher or lower from its starting point for louder sounds.*	
What causes more vibrations and louder sounds then?	*More force or more energy to start with.* *We gave the stick more energy to start with by pushing it farther, so it had more energy to move a greater distance.*	

Assessment Opportunity

This is a great opportunity for students to assess themselves on their engagement in classroom discussions. Use the *Discussion Self Assessment*. This discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day.

7. Adding to the Progress Tracker

5 MIN

Materials: science notebook

Add key ideas to the Progress Tracker. Display **slide L**, or alternately **slide M** if you'd like more scaffolding for your students. Direct students to draw a line underneath the work they did last class in their Progress Tracker. The headings are still the same: "Question" and "What I figured out." Give students about 3 minutes to independently record their findings from this lesson in their Progress Trackers.

Question	What I figured out
How do the vibrations of the sound source compare for louder versus softer sounds?	• Amplitude is the distance from the resting position to a peak or valley. • The more we deform (push) a sound maker, the higher the amplitude of its vibrations. • Louder sounds have higher amplitude than softer sounds. • No matter the push or loudness, the vibrations per second (frequency) didn't change.

Assessment Opportunity

The individual Progress Tracker is a tool to help students reflect on their own learning in response to the question being investigated. Encourage students to use this space to share new connections they have made but also to note where they are still confused. Then, have students leave their science notebooks in the classroom open to today's work so you can quickly scan their Progress Trackers and see what key ideas they understand and note any areas of confusion or uncertainty or questions they still have.

Additional Guidance

The *Harp String Graph Handout* is available to use with this lesson in a variety of ways. If you have time in class, it can be extra practice or an exit ticket for formative assessment. You may also choose to assign it as home learning.

8. Evaluate the stick apparatus.

5 MIN

Materials: None

Play "Taking Sides." Explain that in a moment, you will ask a question and have the students stand on one side of the room or the other depending on their opinion. Neither answer is right or wrong, but students may be asked to defend their opinion with reasons. Display **slide N**. Say, *When I say "move," you will walk to either side of the room. Do you think the stick apparatus was a good tool for scaling up a sound maker? Did it represent a sound maker well? If you think yes, you'll walk over there. If you think no, you'll walk over here. Move.*

Once students have made their choice, invite them to discuss their reasoning with others on "their side." They may then choose a spokesperson (or you choose a volunteer) to share their reasoning with the other side. Discussion across sides is encouraged, as time allows.

Suggested prompts	Sample student responses
Why do you think the stick apparatus is a good representation of a sound maker?	*It helped us see graphs of motion we wouldn't have been able to see otherwise.*
How was the stick a good tool for scaling up the vibrations of a sound maker?	*It moves/vibrates back and forth like a guitar string or tuning fork when you hit it.*
How is the stick similar to sound makers?	*It's flexible like some of the sound makers we looked at, like the drum or the guitar strings.*
	It moves slower than the other sound makers so it's easier to see how it's moving. We can actually see how it's moving with our eyes, and we can definitely see it with a slo-mo video.
	It's bigger than the other sound makers, so it's easier to see what's happening from our seats or without a slo-mo video camera.
	It has one end that moves back and forth, kind of like a big tuning fork.
Why do you think the stick apparatus is not a good representation of a sound maker?	*It does not actually make a sound.*
Why was it not a helpful tool for scaling up the vibrations of a sound maker?	*It moves a lot slower than the sound makers do in the videos.*
How is the stick different from sound makers?	*It's more like a tuning fork and less like the guitar string or the drum–it's not tight at both ends like those sound makers.*

9. Navigation

15 MIN

Materials: optional: *How does the motion detector work?*, xylophone, guitar, transparent music box, or this video of a music box being played. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Discuss where we're going next. Say, *We've seen how vibrations change for loud and soft sounds. The stick apparatus isn't perfect, but it did help us see how that motion is different for the loudness of a sound. But, loudness isn't the only thing that can change about sounds! Let's think about what else we need to investigate about how sound can sound different.* Display **slide O**. Lead a discussion to start planning an investigation about pitch.

Key Ideas

Purpose of this discussion: Plan to use a shorter stick with our motion detector apparatus next time to investigate how the vibrations are different for different pitches.

Listen for these ideas:

- Another way sounds are different (other than loudness) is pitch.
- Instruments that can play different pitches have different lengths of bars or tines.

Suggested prompts	Sample student responses	Follow-up questions
Other than loudness, how else can sounds be different?	*Sounds can be different notes or pitches.* *Sounds can be higher or lower.*	*Tell us more … what do you mean by that?*
Is someone brave enough to sing that for us, to demonstrate how higher or lower pitches sound different?	*(Student sings or hums.)*	*That was great! Thank you!*
I'm not sure we can safely plan an investigation about how your throat vibrates differently to make that sound change. So, let's think of some other objects that make higher or lower pitches … can you think of some?	*String instruments like a guitar, piano, violin, and so forth* *Wind instruments like a flute, recorder, trumpet, trombone, and so forth* *Percussion instruments like xylophones or even chimes*	*Who can add on?*

Explore the xylophone, guitar, and transparent music boxes. Say, *Oh! We still have the xylophone and guitar around that we investigated in Lesson 2. And I have these neat little music boxes, too! Take a minute or two to play them and see what you notice about the different sounds.* Alternately, play this video of a music box being played. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Discuss how we could investigate pitch. Collect the instruments after about 2 minutes of exploration, and invite the students to suggest how we could investigate changes in pitch with our stick apparatus and motion detector.

Suggested prompts	Sample student responses	Follow-up questions
What do you notice about these instruments?	*The xylophone has different-sized bars that make the different notes.* *The music box has bars (sort of) of different lengths, too. They each play a different note.* *For the guitar, you change the length of the strings by turning the keys (to tune it) or pressing the string against the frets. That changes the length of the string that can vibrate when you pluck it.*	*Who can add on?*
I would love to use the motion detector again to be able to see those sound changes close-up, but I think these instrument vibrations would still be too small. How could we use our stick apparatus to represent different-sounding notes instead of loudness? *What would we have to change about the stick system to do that?*	*We could have different sizes of sticks like the different-sized bars on a xylophone or music box or like changing the length of string on the guitar.*	*Do you agree or disagree? Why or why not?*

Say, *That sounds like something we can try next time we're together! I can get a stick that's a different size than the one we already have, like the different sizes of the bars on a xylophone. We can use our motion detector to see if they vibrate differently. Then we'll know how the vibrations compare for sounds of different pitches.*

Additional Guidance

How does the motion detector work? is available to use with this lesson or the next, if you so choose. You may take time to read and discuss this article during class, or leave it with a guest teacher when you are out of the room. You might also choose to assign it as home learning.

ADDITIONAL LESSON 4 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.8.FA.2: Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

In this lesson, students analyze patterns in graphical representations of the stick's motion in order to figure out that a sound maker moves further back and forth (has a greater amplitude) for louder sounds. During this analysis, students identify and describe wave-like properties in the graph of the stick's motion, including a repeating pattern of peaks and valleys in the function of the stick's distance from the detector over time.

Students also compare graphs of the stick's motion for louder and softer sounds with an eye for comparing the properties of the two functions in order to understand what changes about how a sound maker vibrates for sounds of different loudness. During this analysis, they identify that the function for louder sounds has a larger vertical distance between peaks and valleys. They then use this observation to conclude that for louder sounds, the sound maker moves back and forth further.

If students have trouble verbally making comparisons between the graphical representations for loud vs. soft sounds, they may benefit from seeing a projection of the two graphs side by side. Students can then come up and point out differences between the two functions that the class can then use to draw conclusions about how the motion of the stick changes when simulating sounds of different loudness.

Supporting Students in Making Connections in Ela

CCSS.ELA-LITERACY.SL.8.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

In the Building Understandings Discussion, students should be connecting their ideas to their peers' ideas. To support these connections, prompt students to use language such as, "I can connect with _____'s idea because …" or "My idea builds on ____'s idea because …". Post these sentence stems in the classroom as a reference for future discussions.

As you facilitate discussions, push on students' reasoning by asking them to clarify their thinking. Utilize talk moves such as asking, "Can you say more about that?" or revoicing what a student said to ensure you understand them correctly.

CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

In *How does the motion detector work?* students read about the mechanics of a motion detector and learn how motion measurements are recorded in a data table. They utilize this information to read the data table and use it to answer questions about the data. Struggling students may benefit from a scaffolded reading of this text in a small group where the teacher guides students to read each paragraph aloud, drawing connections explicitly and visually to what is listed in the data table.

How do the vibrations from a sound source compare for higher-pitch versus lower-pitch sounds?

Previous Lesson

We used a motion detector to collect and analyze data from a vibrating wooden stick. We noticed wave patterns in the motion of objects that are vibrating and learned they're called amplitude and frequency. We concluded that the amplitude of vibration changes when sounds get louder, but the frequency does not change when sounds get louder.

This Lesson

Investigation

1 DAY

We draw on experiences with instruments to connect with what we notice from playing a song on a small music box. This motivates us to change the length of the wooden stick from the last investigation in order to collect useful data on how vibrations at the sound source compare due to changes in pitch. We collect data with the motion detector to produce graphs that help us notice new patterns of change related to the amount of time a vibration takes (its frequency) for sound sources that produce different pitch sounds (different notes).

Next Lesson

We will use graphs of the position of a sound source that is vibrating to argue for which sounds are being made and apply what we have figured out to revise our initial class consensus model and return to our DQB. We will take an individual assessment, applying what we have learned to explain new phenomena.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Use mathematical representations of position versus time graphs generated from a tool used to scale up the vibrations of an object to describe wave patterns and support scientific conclusions about how objects move when they make higher-pitch and lower-pitch sounds.

What Students Will Figure Out

- The amount of time it takes for one cycle of the motion of a stick to occur is less for shorter sticks. We can see more cycles of the motion of a stick in a unit of time for shorter sticks than for longer sticks.
- The frequency of the vibration of the object changes as the pitch changes, even if the amplitude (loudness) doesn't change.
- Different pitch sounds are produced from differences in the way the sound source vibrates (slower/faster).

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Students revisit musical instruments to consider how various instruments produce different pitches.	A	xylophone, guitar, music box
2	12 min	**GATHER DATA FROM STICKS OF DIFFERENT LENGTHS** Predict what the motion graphs will look like for a shorter stick and a longer stick. Gather data for each of these conditions, then compare that data to graphs of the motion a speaker makes for higher-pitch and lower-pitch sounds.	B, C	*Pitch Graphs*, Different-Length Sticks and Motion Detector
3	10 min	**ANALYZE PATTERNS FROM STICK AND SPEAKER DATA** Students analyze data to identify patterns, noting that the graph of the motion of the short stick has more cycles than the graph of the motion of the long stick.	D	
4	10 min	**BUILDING UNDERSTANDINGS DISCUSSION ABOUT FREQUENCY AND PITCH** Through a class discussion, students make sense of how the graph of the motion of the vibration of a sound source changes as the pitch made by the sound source changes.	E, F	poster paper, markers
5	5 min	**ADD TO OUR PROGRESS TRACKER** Students work independently to add to Progress Trackers.	G	
6	5 min	**EXIT TICKET: ANALYZE FREQUENCY GRAPH** Students complete an exit ticket to answer the question, “How can graphs of vibrations help me understand the sounds produced by a sound source?”	H	*Analyzing Graphs of Sound Source Vibrations*
				End of day 1
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 5, students are ready to read Student Reader Collection 2 and then respond to the writing exercise.		Student Reader Collection 2: *Sounds in Nature*

Lesson 5 • Materials List

	per student	per group	per class
Different-Length Sticks and Motion Detector materials			• 4.5-ft piece of pine trim • 3.5-ft piece of pine trim • C-clamp or spring clamp • computer with Logger Lite installed and configured • Vernier motion detector
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Pitch Graphs* • *Analyzing Graphs of Sound Source Vibrations*		• xylophone • guitar • music box • poster paper • markers

Materials preparation (15 minutes)

Online Resources

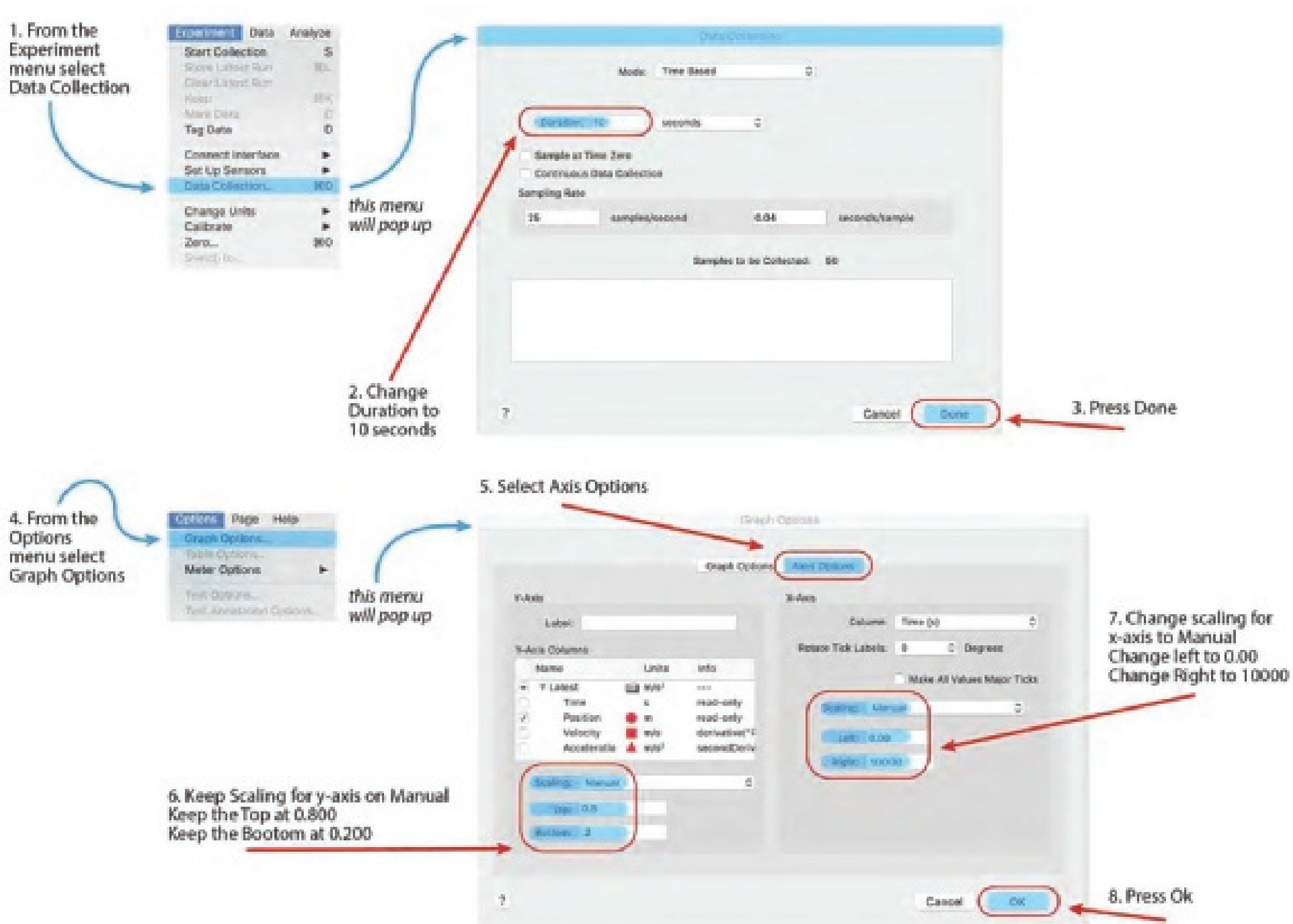
Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

1. Place the xylophone, guitar, and transparent music box (from Lesson 4) at the front of your room so students can see them as they are walking in.
2. Test the music box video to make sure it plays and sound is produced. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3. Test the Hitting the High Notes interactive to make sure the sliders move and different sounds are produced. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Day 1: Different-Length Sticks and Motion Detector

- **Setup:**
  - If you have disconnected the setup from Lesson 4, set up the motion detector and software:
    - Plug in the Vernier motion detector to your computer using the USB cable provided or possibly with a USB-USB-C adaptor like this: .
    - Open Logger Lite on your computer.
    - Configure the graph settings by following the directions shown below or watching the video for setting up the motion detector. Note that if you close the program, you will again need to configure the graph settings. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

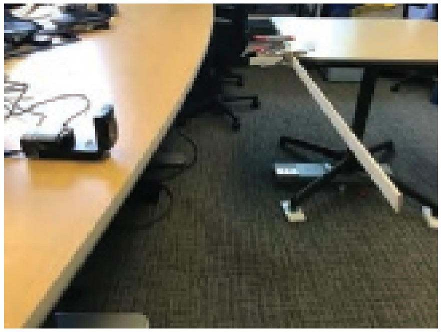


Configuring Logger Lite to collect data

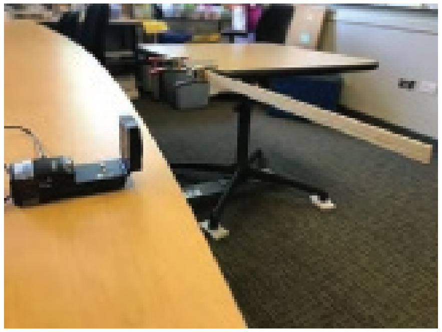
- Gather the stick apparatus from Lesson 4 (4.5-ft piece of pine trim, C-clamp or spring clamp) and a 3.5-ft piece of pine trim.
- Prepare the stick apparatus and motion detector setup using the instructions below.

1. Hold the stick horizontally, turn it vertically, and clamp it to a horizontal surface so it sticks out like a train crossing gate. You many need to use duct tape as well to keep it secure.

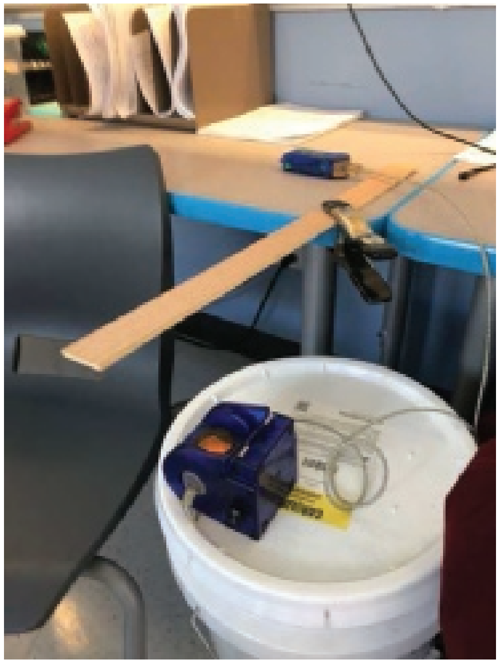
2. Use the full length of the stick by clamping it at one end and placing the other end in front of the motion detector. This will provide the slowest rate of vibration and will allow the motion detector to pick up the movement (it cannot detect vibrations faster than 25 cycles per second). For a smooth graph, the stick should vibrate fewer than 3 cycles per second.



3. Set the motion detector on a surface at the same height as and at a 90-degree angle to the end of the stick so that the circular part of the sensor is facing a spot near the end of the stick. The detector should be a distance of 50 cm from the stick.



Alternate Setup: (Only use this alternate option if the recommended steps above do not work, as the setup above is more useful in helping students think about compression waves traveling through a medium.) If the recommended setup is not possible for you, an alternate option is to clamp the stick to a horizontal, flat surface so it sticks out like a diving board. If you do this, place the motion detector 50 cm below and toward the end of the stick (not at the very end) so that it points straight up at the stick.



- **Notes for during the lab:** Make sure no one is standing behind the stick when it is pulled back. The motion detector might detect a person's body if it's in line with the detector sensor. Have students stand off to the side as the stick is pulled back so they don't interfere with the detector readings.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

This lesson addresses the connections between the pitch of sounds and the frequency of the vibrations for those sounds. In the investigation, students gather and examine data to deepen their understanding of the relationship between the rate of vibrations and the high or low pitch sound produced. For example, when examining the graph of the short stick, students notice the vibrating stick travels more cycles back and forth in the same amount of time, so it must be moving faster. This lesson addresses that this can happen even when the amplitude (which is related to the volume and force applied to make the initial sound) is kept the same.

Where We Are NOT Going

As students explore musical instruments, they should note that objects of shorter length play at higher pitch. On a guitar string, when a player holds a string against a fret, the player is shortening the length of the string that is free to vibrate and thus can play higher-pitch sounds. In the music box and on the xylophone, the shorter tines and shorter bars play higher pitches.

The reason that shorter objects play higher notes is not the focus of the lesson. Instead, the intent is to help students see examples of this important principle, which holds true even for instruments without strings. For example, a piccolo is smaller than a flute, and a piccolo plays much higher pitches than a flute can play.

To reiterate, it is not necessary for students to understand *why* shorter objects play higher notes because it requires better understanding of waves than students are likely to have at this time. In short, every object has its own resonant frequency—a frequency at which it naturally vibrates. Smaller objects and objects under greater tension have higher resonant frequencies than larger objects or objects under lower tension. We advise not going into this detail with students as it requires an understanding that students have not yet developed about wavelength and how frequency depends on the media.

While this lesson touches on the energy differences in high-pitch versus low-pitch sounds, it does not compare the amount of energy in changing the amplitude versus frequency of sounds. This will be addressed in Lesson 14 after looking at the human ear.

1. Navigation

3 MIN

Materials: science notebook, xylophone, guitar, music box

Ask students to turn and talk about their observations of musical instruments from Lesson 4. Present **slide A.** Say, *What patterns did we notice when looking at and playing musical instruments at the end of Lesson 4?*

Walk around the room and listen for responses such as these:

- On all the instruments, smaller things were higher pitch.
- On all the instruments, bigger things (tines, bars, strings) made lower notes or lower pitches.*

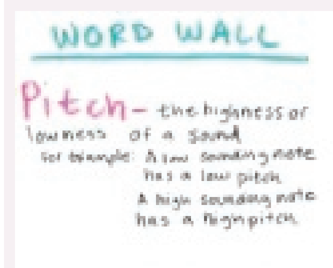
Share ideas to motivate the next investigation. Engage students in a discussion to motivate them for the next part of the lesson. If students reference an instrument, have them go up and use the instrument as they explain their observations.*

Suggested prompts	Sample student responses
What did you discuss that you noticed were patterns across the three instruments?	*We saw that smaller things made higher notes and longer things made lower notes.*
Great! So we figured something out. It seems like smaller things make higher notes, or higher pitches, and longer things make lower notes, or lower pitches. Now let's remember the last class—what were the differences in vibrations for loud and soft sounds?	*They were bigger and smaller waves with different amplitudes.*
Do you think we might see differences in vibrations for high notes and low notes? How did we decide to investigate that?	*Yeah—maybe we should use a shorter stick with the motion detector.*

Next, have students record their ideas in their notebooks for investigating how vibrations are different for higher-pitch and lower-pitch notes. Students should recall that now they want to look at how different notes or pitches can be made using different-sized sticks and the motion detector.

***Attending to Equity**
This is a time when students may again bring up the idea of pitch. Ask students to clarify what they mean when they say *pitch* and then ask other students if they agree or can revoice what that student meant when they said the word *pitch*. Come to a consensus that from now on when we use the word *pitch* we mean the highness or lowness of a note or sound. Add the word *pitch* and the class explanation (using student language) for it to your class word wall.

***Supporting Students in Developing and Using Structure and Function**
You may want to emphasize the relationship between structure and function by introducing the idea that similar structures (smaller bars or tines) tend to have similar functions (produce higher pitches).



2. Gather data from sticks of different lengths.

Materials: Different-Length Sticks and Motion Detector, science notebook, *Pitch Graphs*

Distribute *Pitch Graphs* to students. They should open their science notebooks to the next blank left and right pages and tape the entire sheet on the left page. Present **slide B**.

Describe to students the two conditions for the investigation. Condition 1 will use the long stick from Lesson 4 to represent low pitches or low notes. Condition 2 will use a new, shorter stick to represent higher pitches or high notes. Ask students to use a pencil to draw a dashed line on each graph to indicate their prediction for each condition. They should label the dashed lines "prediction".*

Graph data from the long stick (0.1 m push). Ask for two student volunteers. Student 1 will click "Collect" on the motion detector software. Student 2 will push the stick back 0.1 m and let go. Take a screenshot of the graph that results and save it to your desktop to display later. Ask students to use a solid line to sketch the graph for Condition 1 in their notebooks on the *Pitch Graphs* handout.

*Attending to Equity

To support students of all math abilities in graphing, have them draw the starting position (at 0.5 m) on each graph. Ask students to turn and talk to their partner about each part of the graphs and how it relates to the stick apparatus. Listen for students to identify what the *x*-axis and *y*-axis represent, the scale of the graph, and how the graph is a representation of the sticks' movements.

Alternate Activity

If you have more time, students can take a more active role in setting up the investigation. If you have multiple motion detectors and other investigation materials, students could do this investigation in small groups or at stations where both small and large stick apparatus are set up at the same time. The class can alternate using each apparatus and run the software themselves.

Graph data from the short stick (0.1 m push). Switch the sticks so you are now using the shorter piece of pine trim (3.5 ft instead of 4.5 ft). Ask for two more student volunteers to click "Collect" and push the stick. Take a screenshot of the graph and save it to your desktop for later. Ask students to use a solid line to sketch the graph for Condition 2 in their notebooks on the *Pitch Graphs* handout.

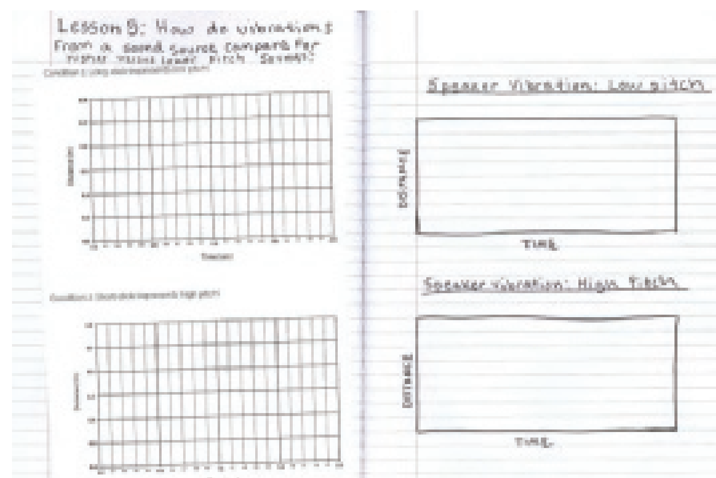
Online Resources

Graph data from the speaker: low pitch and high pitch. Present **slide C** and have students set up the blank right page of their notebooks (across from *Pitch Graphs*) for speaker vibration at different pitches. Have students write "Speaker vibration at different pitches" at the top of the right-hand page that faces the stick graphs. Then have them make a box and label it "Low pitch." Below that have them make another box and label it "High pitch."

Project the Hitting the High Notes interactive. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Play the speaker at low pitch, take a screenshot, and save it to your desktop. Students should make a sketch in their notebooks (inside the first box) of what they see at low pitch.

Now play the speaker at a high pitch, take a screenshot, and save it to your desktop. Students should make a sketch of the second graph in their notebooks in the box labeled "High pitch."



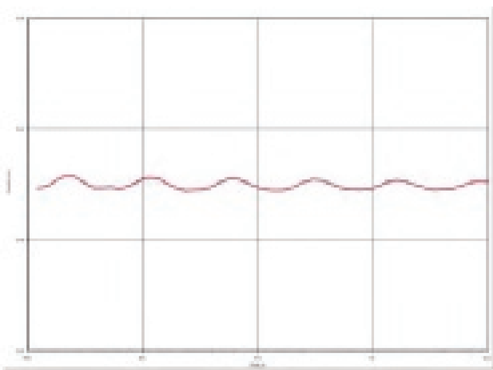
3. Analyze patterns from stick and speaker data.

10 MIN

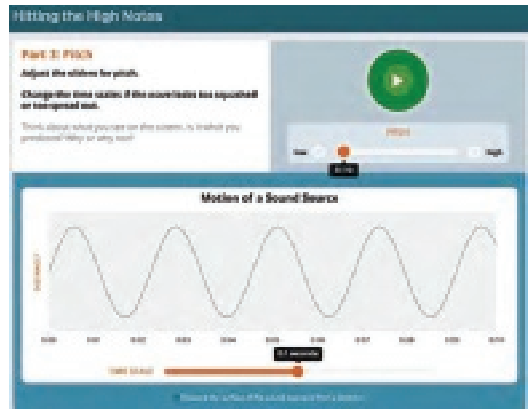
Materials: science notebook

Project all four graphs together. You should have four saved graphs: long stick, short stick, speaker at low pitch, and speaker at high pitch. Drag all four images to a word processing document or **slide D** so they can be stacked. The two stick images should be on the left (long stick on the top, short stick on the bottom), and the two speaker graphs should be on the right (low pitch on the top and high pitch on the bottom). Project **slide D** or the document. Zoom out so students can see all four graphs at the same time as shown below.

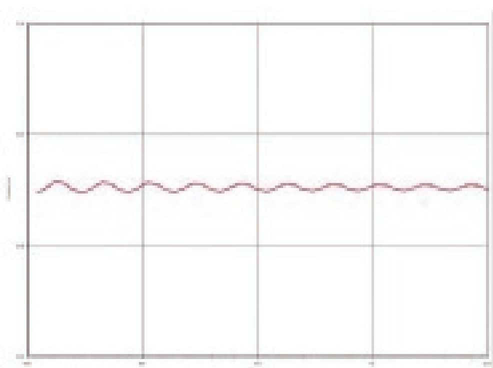
Long stick



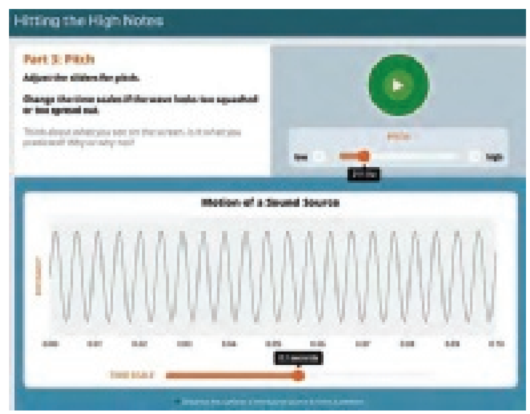
Low pitch



Short stick



High pitch



Say, *We are now going to take some time to analyze the data we collected to look for patterns in the motion of the sticks and the speaker.*

Compare graphs, individually. Ask students to write "What I see" statements in their notebooks describing patterns they see across the four graphs. They should draw an arrow to an important feature and then write one "What I see" comment for each pattern they notice. Remind students to write directly on the graphs.*

Use WIS statements to engage in whole-class discussion. Engage students in a whole-class discussion about the patterns they noticed in the graphs. Be sure to ask students to go up to the projected graphs and point to graph features as they talk.*

Suggested prompts	Sample student responses
How were the vibrations changing for the long stick compared to the short stick?	*There are more up-and-down bumps for the short stick than for the long stick.*
What do you mean by "up-and-down bumps"? Can you point to them on the graph I have projected up here?	*(Student goes to projection and points.)*
And, do we see anything like that for the speaker graph?	*The same thing, the speaker graph for high pitch has more ups and downs in a second than the speaker graph for low pitch.*
What about how tall the graphs are?	*They look like they are the same height.*
Say more about what you mean . . . does it stay the same height all the way?	*No . . . they both get smaller, but they start out about the same, and they get shorter the same.*
Remember in the last class we used the words frequency *and* amplitude*? Can you summarize everything we just said using* frequency *and* amplitude*?*	*It looks like the high-pitch graphs have higher frequency than the low-pitch graphs, but the high-pitch graphs and the low-pitch graphs have the same amplitude.*

As it comes up in discussion, walk over to the word wall and remind students of the terms *amplitude* and *frequency* from the previous lesson. Ask students to recall how we said you could calculate amplitude (and frequency). If you did not calculate frequency in Lesson 4, have a student come up to the projected graphs and count how many peaks and valleys (complete oscillations or vibrations) would happen in just one second on one of the graphs.

Calculate frequency and amplitude. After calculating the frequency of one graph together as a class, have student groups work together to calculate the amplitude and frequency for each graph of the stick. Then ask students to determine which graph has the highest amplitude and which graph has the highest frequency.

Assessment Opportunity

Students will complete an exit ticket later in the lesson where you can provide more detailed and individual feedback. While students are working in their groups, take the opportunity to formatively assess their understanding of frequency and amplitude. Students are calculating the amplitude as a review from Lesson 4 but also to show that it is

***Supporting Students in Engaging in Analyzing and Interpreting Data**

Students will use the Identify and Interpret (I^2) sensemaking strategy to analyze the graphs by making WIS (What I see) and WIM (What it means) observations on their graphs. This strategy helps students break down an information-rich graph into smaller pieces to interpret. If this is the first time using the strategy, consider demonstrating one observation (What I see). You will ask students to share out WIS statements and then afterwards add WIM statements.

***Attending to Equity**

Asking questions in everyday language allows students to share their thinking or experiences, even if they do not have the appropriate scientific vocabulary yet. This is helpful for emergent multilingual students because by not requiring the use of scientific words at the onset, you would not limit their participation in classroom discourse.

frequency that is changing with the length of the stick and not amplitude. Look for students to notice that the changes in amplitude are the same for both the high-pitch and low-pitch graphs but the frequency of vibrations is more for the high-pitch sound and the short stick. To support students in calculating the amplitude and frequency, refer them to the graphs they annotated in Lesson 4 and to the class definitions on the word wall.

After the discussion ask students to add to their graphs any additional "What I see" comments shared by other students. Then have students work in groups to write "What it means" statements next to each of their "What I see" statements. These statements are students' initial explanations of what they think is happening to cause the change in data and will be used to prompt ideas in the whole-class discussion.

4. Building Understandings Discussion about Frequency and Pitch

10 MIN

Materials: science notebook, poster paper, markers

Facilitate a Building Understandings Discussion about the meaning behind the patterns from the stick graphs and speaker simulation. Project **slide E**. Have students bring their science notebooks with them to the Scientists Circle. As a reminder, during a Building Understandings Discussion the role of the teacher is to press students to use evidence to back up their ideas.*

***Attending to Equity**
During a Building Understandings Discussion, students can practice talking with one another as a community of learners. Seat students in a Scientists Circle to promote engagement and student-student discussion. In a Scientists Circle, students gather together in a semicircle around the board so students are facing one another. Engaging in this practice can support all learners in developing academic discourse. They listen to one another's ideas and findings, ask questions about evidence, and come to an agreement about what the class figured out in an investigation.

Key Ideas

Purpose of this discussion: Identify patterns in the graphs using evidence produced from both the stick and motion detector investigation and the speaker simulation. This leads us to add how the frequency of vibrations relates to low-pitch and high-pitch sounds to our initial consensus model.

Listen for these ideas:

- Low-pitched sounds have fewer wiggles, or peaks and valleys, in the same time period as high-pitched sounds.
- The amplitude is the same for low-pitched and high-pitched sounds.
- Frequency is how many complete vibrations happen in one second.

Suggested prompts	Sample student responses	Follow-up questions
Who wants to tell me what patterns they see, and what they think it means, in terms of the actual motion of the stick? You might think back to the last class, walking back and forth in front of the motion detector.	*I remember, when someone walked back and forth in front of the motion detector, the line went up and down. Now when the line goes up and down, it's showing the stick vibrate back and forth in front of the detector.*	*OK, so the up and down of the graph is showing the back and forth movement of the stick?*
So, if that is the case, can you tell me which stick was vibrating back and forth the fastest?	*The short stick was vibrating back and forth the fastest.*	*Let's hear from others. Do you agree or disagree with that idea, and why?* *Does it always work that way?*

Suggested prompts	Sample student responses	Follow-up questions
So, I hear you saying the short stick moved faster, and the detector picked it up. *What other patterns did we see, and what did they mean?*	*For the graph of the speaker, we saw that the higher-pitch sound had a higher frequency of vibrations than the lower-pitch sound, just like the stick, only we couldn't hear the stick.* *When we played the higher notes on the speaker the other day when we were touching it, we could feel it moving faster and faster.*	
And what do you predict would happen to the graph if we used an even longer stick?	*The frequency of vibrations would be less.*	*What's your evidence that might be the case?*
What about the amplitude, did that change?	*No, if you don't change the loudness, the amplitude won't be any bigger, just how close the vibrations are would be smaller.*	*Who can repeat what ________ just said or put it into their own words?*
Who can summarize for me the relationship among three things: length, pitch, and frequency?	*Shorter-length objects vibrate faster. When they vibrate faster, they have a higher frequency of vibration and they make sounds that are higher pitch.*	*Do we agree with ______'s summary?* *Who thinks they understand what _______ just said and can put it in their own words?*
And what can we say about amplitude in these graphs?	*The amplitude goes down the same for both graphs. The number of wiggles doesn't seem to make it get smaller amplitude any faster.*	

Confirm the connection between energy and higher-pitch sounds. Refer back to the graphs of the speaker sounds to discuss the meaning of *frequency*.

Suggested prompts	Sample student responses
What did we hear changing from the speaker when the frequency of the graph got faster?	*It gets higher. Faster frequency means higher sound.*
The word frequency *reminds me of the word* frequent. *Has anyone ever heard of that word? What does* frequent *mean?*	*It is how often you do something.*

Suggested prompts	Sample student responses
How does the frequency we see on these graphs support what we thought about the amount of energy needed to make different sounds?	*These graphs show that the higher sounds have more vibrations that happen in one second, so they would use more energy than lower-pitch sounds that aren't happening as often. Since the amplitude is the same and the stick is moving back and forth the same amount, it is the number of movements that increase for a high-pitch sound.*

Apply ideas to better explain the anchoring phenomenon. Project **slide F.** Ask students to think back to the truck and the stereo. How might they explain how the truck speaker is making so many different sounds (loud, soft, high pitch, and low pitch)? Have students share out a few ideas.

Suggested prompts	Sample student responses	Follow-up questions
How does what we discovered from the graphs and the speaker simulation help us answer our original question, "How might you explain how the speaker in the truck can make so many different sounds (loud, soft, high pitch, and low pitch)?"	*When the high-pitch sound was playing, the graph had lots of peaks and valleys in a short time period, but when the low-pitch sound was playing, the graph had fewer peaks and valleys in the same time period. This means the speaker in the truck would be vibrating at different frequency depending on how low or high pitch the music was playing. This might make the window move at different frequency.*	*Does anyone want to respond to that idea?* *Do you agree or disagree? (And why?)* *Who thinks they could explain why_______ came up with that answer?* *Who can repeat what _____ just said or put it into their own words?*

Additional Guidance

The goal here is to prepare the class for applying the ideas from Lessons 4 and 5 back to explaining more about the truck and the window—specifically, how the speaker produces all the different kinds of sounds we hear. The question on slide F provides students with the opportunity to make these connections. If you are running short on time, add this question to the home-learning assignment, *Analyzing Graphs of Sound Source Vibrations*.

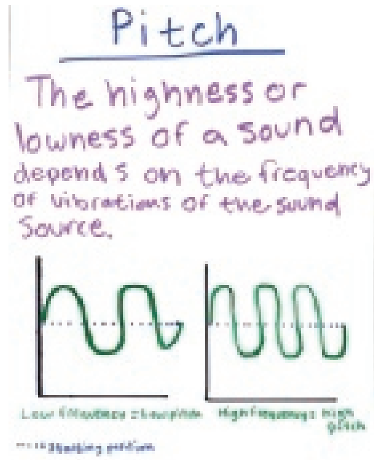
5. Add to our Progress Tracker.

5 MIN

Materials: science notebook

Add key ideas to the Progress Tracker. Display **slide G**, or **slide G Alternate** if you'd like more scaffolding for your students. Direct students to draw a line underneath the work they did last class in their 2-column Progress Tracker. The headings are still the same: "Question" and "What I figured out." Give students about 3 minutes to independently record their findings from this lesson in their Progress Trackers.

Question	What I figured out
How do the vibrations from the sound source compare for higher-pitch vs. lower-pitch sounds?	• Shorter-length bars produce higher-pitch sounds when struck. • Shorter-length bars vibrate more frequently than longer-length bars when struck. • Sound sources that produce higher-pitch notes vibrate more frequently.



Assessment Opportunity

The individual Progress Tracker is a tool to help students reflect on their own learning in response to the question being investigated. Encourage students to use this space to share the many new connections they have made but also to note where they are still confused. Then, have students leave their science notebooks in the classroom open to today's work so you can quickly scan their Progress Trackers and see what key ideas they understand and note any areas of confusion or uncertainty or questions they still have.

6. Exit Ticket: Analyze frequency graph. 5 MIN

Materials: *Analyzing Graphs of Sound Source Vibrations*

Assign students *Analyzing Graphs of Sound Source Vibrations* as an exit ticket. Project **slide H.**

Say, *Now that we have connected our ideas about how different sounds can be produced by changing the amplitude and frequency of the vibrations, we are going to take some time to process our thinking individually. We will share our thinking at the beginning of next class and do more graph analysis practice before putting together all of the pieces we have figured out so far.*

Assessment Opportunity

Collect this exit ticket at the end of class or at the start of the next class. This will give you a day or two before the individual assessment at the end of the next lesson to provide feedback to students to help guide their understanding and revisions before that assessment. This is a key practice opportunity for students to work with the kind of graphs they will see in the assessment.

If you are short on time to give feedback on the exit ticket, consider having students check their work with a partner and/or against a provided answer key (so they can self-correct).

ADDITIONAL LESSON 5 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.8.FA.2: Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

In this lesson, students analyze patterns in graphical representations of the stick's motion in order to figure out that a sound maker moves back and forth more often in a given time (has a greater frequency) for higher-pitched sounds. During this analysis, students identify and describe wave-like properties in the graph of the stick's motion, including a repeating pattern of peaks and valleys in the function of the stick's distance from the detector over time.

Students also compare graphs of the stick's motion for higher-pitched and lower-pitched sounds with an eye for comparing the properties of the two functions in order to understand what changes about how a sound maker vibrates for sounds of different pitch. During this analysis, they identify that the function for higher-pitched sounds has a shorter horizontal distance between peaks and valleys. They then use this observation to conclude that for higher-pitched sounds, the sound maker moves back and forth more often over the same amount of time.

If students have trouble making comparisons between the graphical representations for loud vs. soft sounds, they may benefit from seeing the two graphs displayed side by side. Students can then come up to the projection and point out differences between the two functions that the class can then use to draw conclusions about how the motion of the stick changes when simulating sounds of different pitch.

Supporting Students in Making Connections in Math

CCSS.MATH.6.RP.A.2: Understand the concept of a unit rate a/b associated with a ratio a:b where b does not equal zero, and use rate language in the context of a ratio relationship.

CCSS.MATH.6.RP.A.3: Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.

CCSS.MATH.7.RP.A.1: Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities.

In this lesson, students define and calculate frequency as the number of complete vibrations in one second. Students use graphs of the stick's motion to count the number of times that the stick vibrates and then divide that by the amount of time over which the stick was vibrating. We label this unit rate of how many times the stick vibrates in one second as the frequency of the stick's vibration.

If students struggle to calculate the frequency, refer them to the class's definition for *frequency* on their word wall or in their notebooks. Students may benefit from seeing an example of this calculation starting from a graph of the stick's motion over time as a refresher on how to derive a unit rate from the ratio between the number of vibrations and the time interval over which the stick vibrated.

SCIENCE LITERACY: READING COLLECTION 2

Sounds in Nature

1 **Sound in Air Versus Water**
2 **Whale Sounds**
3 **What Is *Loud*?**
4 **AMAZING Animal Sounds!**
5 **Noise Pollution**

Literacy Objectives

- ✓ Summarize key points related to sounds in nature, particularly those produced by animals.
- ✓ Organize related details about sounds in nature, particularly the frequencies and intensities of the sounds produced by animals.
- ✓ Translate text to visual/graphic representation that summarizes information about animals and sound.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 1–5.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an infographic in response to the reading.

Instructional Resources

Student Reader
Collection 2

Science Literacy Student Reader, Collection 2
"Sounds in Nature"

Exercise Page
EP 2

Science Literacy Exercise Page
EP 2

Prerequisite Investigation

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 3: Do all objects vibrate when they make sound?
- Lesson 4: How do the vibrations of the sound source compare for louder versus softer sounds?
- Lesson 5: How do the vibrations from a sound source compare for higher-pitch versus lower-pitch sounds?

Standards and Dimensions

NGSS

Disciplinary Core Ideas PS4.A: Wave Properties A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

PS2.A: Forces and Motion For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)

Science and Engineering Practice(s): Constructing an Explanation

Crosscutting Concept(s): Cause and Effect; Scale, Proportion, and Quantity; Structure and Function

CCSS

English Language Arts
RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.10 By the end of grade 8, read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently.

Math MP.2: Reason abstractly and quantitatively.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

decibel **frequency**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

hertz	**infrasonic**	**intensity**	**loudness**
solute	**solution**	**solvent**	**ultrasonic**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page

EP 2

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading collection relates to topics they are presently exploring in their Sound Waves unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *You'll read about sound producers in nature, including marine organisms ranging from blue whales to snapping shrimp and terrestrial animals such as bats and elephants.*
  - *You'll also learn how these sounds can be disrupted by other sounds, including some produced by human activities.*

Exercise Page

EP 2

- Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to summarize the intensities and frequencies of sounds produced by animals. You'll generate an infographic to communicate your summary.*
- Distribute Exercise Page 2.
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to notice the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
Does sound travel the same way through water as it does through air?	*no (Sound travels more effectively through water.)*
Can humans hear all whale sounds?	*no (Some are too high or too low in frequency for people to detect.)*
Does noise disturb all birds?	*no (Hummingbirds thrive where noise pollution repels jays.)*

Ask a few brief questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How does frequency relate to how loud a sound is?	*It doesn't really. Frequency determines the high or low pitch of a sound, not how loud it is. Intensity of vibration is related to loudness.*
What do the terms ultrasonic *and* infrasonic *mean?*	Ultrasonic *means the frequency is too high for human ears to perceive.* Infrasonic *means the frequency is too low for human ears to perceive.*

- Refer students to Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The expectation for this assignment is that you will sketch an infographic. Think of an infographic as a small poster (the size of a sheet of notebook paper). It should include sketched pictures and blocks of text to add visual meaning on top of a chart or graph.* (If time permits and you want to display visual examples of infographics for students, a quick Google search [images] yields a wide variety. Be sure students know that their products are expected to be hand-drawn sketches, though.)
  - *Your infographic should summarize the properties of sounds, including frequency and decibel ranges, that are produced by a few different animals.*
  - *Be sure to show data related to different species and the sounds they emit on some kind of graph or other visual that displays one or more axes to show frequency and intensity of sounds.*
  - *An important criterion for your work is that your visual arrangement of information logically relates to the data. Place the animals and data about their sounds in the appropriate places so the comparison and contrast of their sounds is supported visually.*
  - *Focus on the animals that are described in the reading, not other animals you might know about or research on your own time.*
  - *Don't worry about comparing underwater decibels with regular (in air) decibels in the visual.*
  - *You will also write a few sentences to describe what might happen to one of the animals if the sound it emits is disrupted by noise pollution from human activities.*
- Answer any questions students may have relative to the exercise expectations or the reading content.

Exercise Page

EP 2

4. Facilitate discussion. (Friday)

Facilitate class discussion about the readings and writing exercise. Students begin the reading activity by learning how sound travels more easily through water than air and that sound intensity as measured in decibels is greater in water. They then learn about types of whales that emit sounds for a variety of purposes.

Student Reader

Collection 2

Pages 16–19 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Sound in Air Versus Water"?	*It tells how sound travels in both air and water.*
What are the takeaways from that article about decibels and underwater decibels?	*Decibels label how loud something sounds.* *The same sound will be more intense underwater than in air.* *Loudness of sound underwater is expressed in underwater decibels.*
What is the general purpose of the second selection, "Whale Sounds"?	*It describes the variety of sounds that different types of whales make.* *It reveals that whales use sound for a variety of purposes to help with their survival.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*In the first article, we learn that sound travels well in water. In the second article, we discover that whales are adapted to utilize that property in several aspects of their survival.*
Why might whales and other marine organisms use sounds to communicate?	*It's hard to see very far in water. They can be spread far apart in the vast ocean space.*
Why would some marine animals use sound to find or injure prey?	*Every animal has to eat. And any advantage helps.*
Could it be dangerous to be in the water in the path of a sperm whale's clicks?	*possibly, because the sounds are very intense*

The next part of the reading delves into sounds that are outside the human auditory field, or range of frequencies we can perceive.

Pages 20–21 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third selection, "What Is Loud?"?	*It explains that loudness is a matter of perception. Sounds can be very intense but at too high or low frequency, or too brief, for human ears to hear.*
What are the two variables that determine if we can hear a sound?	*frequency and intensity/loudness*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and invite confident students to clarify, but summarize with concise explanation.

Pages 20–21 **Suggested prompts**	**Sample student responses**
What can you take from the third selection to build on what you learned in the second selection?	*Humans and other animals perceive sounds from waves in different frequency ranges.* *There actually could be a lot of sound waves going on around us that we can't hear (ultrasonic and infrasonic).* *Sound waves that we can't technically hear can still have an effect on us.*
Explain the difference between 10 and 20 decibels to show what it means that the decibel scale is logarithmic.	*20 decibels isn't twice as loud as 10 decibels; 20 decibels is 10 times as loud as 10 decibels.*
How do you think the vibrations a player puts into a musical instrument can vary by the amount of force? What might stronger and weaker forces do to the sounds produced by instruments?	*Stronger force, like plucking, striking, or blowing harder, probably makes bigger vibrations and louder sounds.*

The last two sections of the reading look at other animal sounds and noise pollution.

Pages 22–25 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth selection, "AMAZING Animal Sounds!"?	*It tells about some interesting ways that animals in addition to whales make and use sounds—specifically snapping shrimp, elephants, cicadas, and bulldog bats.*
The Connection box on page 23 asked you to revisit an answer to a question from a Connection box in the previous selection. It asks, "(D)o you think there is a connection between an animal's body size (structure) and the loudness of the sounds it can produce (function)?" What can you conclude?	*Both very large and very small animals can make sounds, both loud and soft.* *Some of the sounds can travel long distances. But people can't necessarily hear them.*
What is the main difference between the discussions of sound in the last two selections?	*"AMAZING Animal Sounds!" is about sounds that different animals make.* *"Noise Pollution" is about how sounds that people make affect animals (and plants)."*

EXTEND—Depending on students' prior knowledge, and if it adds value to the discussion by giving students grappling points to tie to:

- Point out what ultrasound and infrasound have in common with ultraviolet and infrared light. (They all represent phenomena outside the range of human perception, whether by ears or eyes.)
- Compare decibels to other scales that are logarithmic rather than linear (e.g., moment magnitude scale in geology).

Pages 22–25 **Suggested prompts**	**Sample student responses**
What are some cause-and-effect claims suggested in the stories about whale strandings and piñon pine trees?	*The first story suggests that noise pollution might be a factor in whales beaching themselves.* *The second story suggests that noise from natural gas air compressors causes a decline in piñon pine trees by keeping away birds that are instrumental in the trees' seed dispersal.*
Take a look at the Consider the Sources box on page 25. What can you tell about the sources, and how does it affect your perception of the article's content?	*The sources are associated with research studies conducted by universities.* *It tends to add credibility to the stories.*

SUPPORT—Logarithmic scales can be difficult for students to comprehend. Use visual aids to show steps on a logarithmic scale in the form of circles or other shapes, including 3-D shapes, that increase by an order of magnitude with each full step on the scale.

Bridge to the writing exercise by asking students to offer ideas about how one of the terrestrial animal's behaviors could be disrupted by noise pollution.

5. Check for understanding.

Evaluate and Provide Feedback

Students are likely to borrow from the figure in the *Loudness and Frequency* section of the reading to set up their infographics. For example, they will most likely draw an axis for frequency on a horizontal axis and another for intensity of sound (loudness) along a vertical axis. They can then use points or bands for each species or specific animal sounds along the axes.

In their sentences, they should identify one of the animals from the reading and specify how noise pollution might disrupt its life.

- Students should identify one of the animals that uses sound to communicate with other members of its species or to hunt prey via echolocation.
- The example of the snapping shrimp would not be a good choice, because it's unclear how noise pollution would interfere with its use of its specialized claw to produce cavitation bubbles that stun or kill nearby prey.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 6

How can any object make so many different sounds?

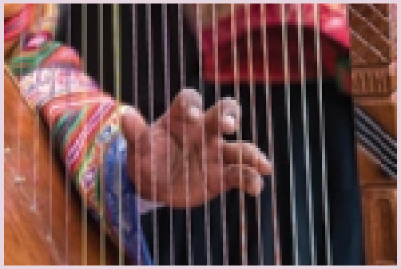
Previous Lesson

We changed the length of the wooden stick in order to collect data on how vibrations at the sound source compare due to changes in pitch. We produced graphs and identified new patterns of change related to the amount of time a vibration takes (its frequency) for sound sources that produce different pitch sounds (different notes).

This Lesson

Putting Pieces Together

2 DAYS



This lesson marks the end of the first lesson set. Students work in pairs using graphs of the position of a sound source that is vibrating to argue for which sounds are being made. We then apply what we have learned in the first five lessons to revise our initial class consensus model and return to our DQB to see which questions we can now answer. On day 2, students take an individual assessment, applying what we have learned to explain new phenomena.

Next Lesson

Lesson 7 marks the start of Lesson Set 2 of the unit, where we will focus on how sound is traveling. We will investigate the idea from our initial models that air is traveling from the sound source to the window by placing a sound maker in a sealed container and testing whether we can still hear it. This will help us to reason that air isn't moving all the way from the sound maker to our ears.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Use a model to explain how a force applied to an instrument causes the sound source to vibrate (effect) and make a sound even if we cannot see it.

Construct an argument using evidence from graphs to support an explanation for which patterns of frequency and amplitude of a wave are indicators of attributes of sounds that we can hear.

What Students Will Figure Out

We apply our understanding to explain different sounds coming from the xylophone, the truck speaker, and a harp.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Talk with a partner about what we figured out about how vibrations of the sound source compare for higher-pitch vs. lower-pitch sounds.	A	
2	5 min	**REVISIT THE EXIT TICKET FROM LESSON 5** Compare thinking with a partner for the exit ticket from the last lesson.	B	*Analyzing Graphs of Sound Source Vibrations*
3	17 min	**PRACTICE CONNECTING GRAPHICAL REPRESENTATIONS TO SOUNDS MADE** Work in pairs using graphs of the position of a sound source that is vibrating to argue for which sounds are being made. Then share with another pair who had a different sound type (loudness or pitch).	C, D	*Connecting Graphical Representations to the Sounds Made*
4	10 min	**REVISIT AND REVISE OUR CONSENSUS MODEL** Apply what we have learned in the first five lessons to revise our initial class consensus model.	E	chart paper, markers
5	10 min	**REVISIT OUR DQB** Return to the DQB to determine what questions we have answered or made progress on.	F	DQB, markers
				End of day 1
6	30 min	**EMBEDDED SUMMATIVE ASSESSMENT** Students demonstrate their understanding of how vibrating objects produce sounds and how the different types of sounds depend on the amplitude and frequency of vibrations.	G	*Assessment,* harp player video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
				End of day 2

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Analyzing Graphs of Sound Source Vibrations* • *Connecting Graphical Representations to the Sounds Made* • *Assessment* chart paper		• chart paper • markers • DQB • harp player video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (15 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 1: Gather coffee stirrers or similar materials to demonstrate different sounds for the alternate activity.

Day 2: Test the harp player video to make sure it plays and you can hear the sound. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

Students will apply their understanding of these key ideas:

- All objects vibrate when they make sound.
- A force applied to an object causes that object to vibrate, or move back and forth, which makes a sound.
- A larger force causes more and bigger vibrations and a louder sound.
- A graphical representation of a wave helps us to see the vibrations.
- Within a graphical representation, amplitude represents the distance the object moves from its starting point, which is related to the strength of the force applied and the object's loudness.
- Within a graphical representation, frequency represents how often the sound source moves in a certain amount of time and the pitch we hear in the sound.

Where We Are NOT Going

Students will not be developing new concepts in this lesson. This is a chance for students to use and apply what they have been learning to this point.

LEARNING PLAN FOR LESSON 6

1. Navigation — 3 MIN

Materials: science notebook

Navigate. Project **slide A**. Ask students to look back at their Progress Tracker and to turn and talk with a partner about what we figured out last time about how vibrations of the sound source compare for higher-pitch vs. lower-pitch sounds. Ask students to share with the whole class what they discussed. Listen for these ideas:

- Shorter-length bars produce higher-pitch sound when struck.
- Shorter-length bars vibrate more frequently than longer-length bars when struck.
- Sound sources that produce higher-pitch notes vibrate more frequently.

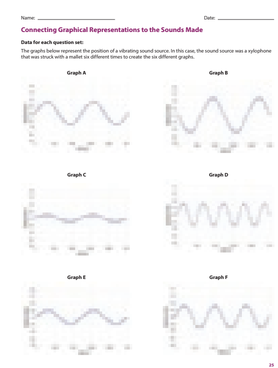
2. Revisit the exit ticket from lesson 5. — 5 MIN

Materials: *Analyzing Graphs of Sound Source Vibrations*

Pair students to compare exit ticket. Project **slide B.** Return *Analyzing Graphs of Sound Source Vibrations.* Ask students to compare their thinking with a partner. After partners have shared, ask for any questions or raise questions that you think the group needs to grapple with based on your review of their exit tickets.

3. Practice connecting graphical representations to sounds made. — 17 MIN

Materials: *Connecting Graphical Representations to the Sounds Made*



Introduce the task. Show **slide C** and pass out *Connecting Graphical Representations to the Sounds Made.*

Say, *Over the past two lessons we have used a stick to represent a scaled-up version of an object, like a guitar string, vibrating when it makes sounds in order to understand what is actually happening when different types of sounds are made. Let's apply what we have figured out to argue for what sounds are being made based on the graphical representations of their movement.*

Explain that there are two question sets: One focuses on loudness, and one focuses on pitch. Students will work with a partner to complete their question set and then share their findings with another pair for feedback and questions.

Pairs work to answer their assigned question set. Give pairs 7-8 minutes to complete their questions. As students are working, listen in on groups to see how they are doing with connecting the graphical representation to the sounds being made. Listen for their use of evidence from the graphs, including the correct use of the terms *amplitude* and *frequency* and how the movement of the object relates to the sound.

Pairs join with another group to share their claims, evidence, and reasoning for their question set. Show **slide D.** As pairs share their claims with another pair encourage them to agree and disagree and ask questions if they don't understand. See the *Key: Connecting Graphical Representations to the Sounds Made* for further information.

Assessment Opportunity

Connecting Graphical Representations to the Sounds Made provides a great opportunity for students to gain further practice in constructing an argument using evidence from graphs to support an explanation for which patterns of frequency and amplitude of a wave are related to sounds that we can hear. This practice contains scaffolding for the elements of their argument and can provide some just-in-time formative information before the independent assessment they take on day 2 of this lesson. If students struggle supporting their claims with evidence, have them look back to the data they collected in Lessons 4, 5, and 6 or their Progress Trackers.

Alternate Activity

You may want to pass out straws or coffee stirrers and have students show what the sound source is doing for the different graphical representations. To do this ask students to hold one end of the coffee stirrer tightly against the side of a table. With their other hand hold the other end of the coffee stirrer and move it back and forth while keeping their hand on both ends the entire time.

4. Revisit and revise our Consensus Model. 10 MIN

Materials: science notebook, chart paper, markers

Gather in a Scientists Circle. Show **slide E.** Have students bring their science notebooks to the circle for a whole-group discussion in order to apply what we have learned to revise our initial class consensus model. Have the initial class consensus model nearby as well as the DQB. You will stay in the circle to look at the DQB after this discussion.

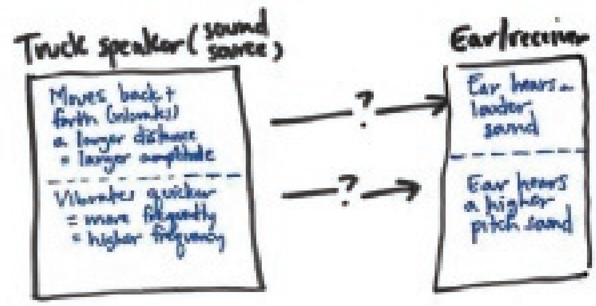
Refer to your initial three-part class consensus model. Celebrate that we have made a lot of progress on the first part of our model.

Say, *How can we revise our model to reflect what we have figured out about what the sound source (including the truck speaker) is doing when it makes different sounds?*

Suggested prompt	Sample student response
What can we now say is happening with the speaker (or any sound source) to make so many different sounds?	*It's vibrating differently for different sounds.* *It moves back and forth a larger distance for louder sounds.* *It moves back and forth quicker or more frequently for higher-pitch sounds.*

Ask students to suggest how we might best capture these ideas on our class consensus model.

Add to the Progress Tracker. Ask students to turn to the Progress Tracker in their notebook and draw a line underneath the work they did in the last class. Give students time to add the revised model to their notebooks.

Question	What I figured out
How can any object make so many different sounds?	

5. Revisit our DQB.

10 MIN

Materials: DQB, markers

Gather around the DQB. Stay in the Scientists Circle or gather around the DQB so that all can see the questions. Project **slide F**.

Additional Guidance

A high-resolution photograph of the Driving Question Board or a typed list of the questions from the Driving Question Board is a useful supplement to provide students for this step.

Say, *Let's revisit our DQB and see which questions we have made progress on, and then next time we can see if there are any questions we need to refine or want to pursue in upcoming lessons.*

One way to note which questions have been answered is by marking them with the following symbols:

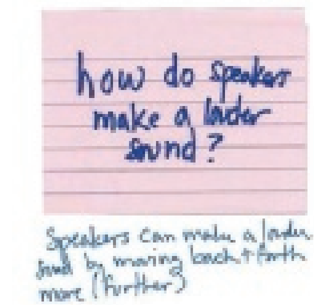
- We did not answer this question or any parts of it yet: **O**
- Our class answered *some parts* of this question, or I think I could answer *some parts* of this question: ✓
- Our class answered this question, or using the ideas we have developed I could now answer this question: ✓+

Additional Guidance

If you have one Driving Question Board for all of your classes you can move the questions so that they are grouped together based on the degree to which they have been answered instead of writing directly on them. Keeping the questions on the board (versus removing ones that we think we have answered) helps keep an important record of the progress we have made. Remind students that even if there are questions that already have check marks indicating questions we would like to pursue further in future lessons, that is OK. It means that we have a joint mission to figure out those phenomena together.

Alternate Activity

You may want to have students write answers to questions we have answered either in pairs or individually. One effective way to do this is to attach the question to a half sheet of paper and then write the answer below. These can then be placed back up on the DQB. This can be a productive activity when you have extra time before or after the assessment or on days when you may be out. There is time built in after the assessment on day 2 of this lesson.



End of day 1

6. Embedded Summative Assessment

30 MIN

Materials: *Assessment*, harp player video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Prepare for the individual assessment. Pass out one copy of *Assessment* to each student.

Show the video of the harp player.* Show **slide G.** Tell students that before they get started, they need to watch a video https://youtu.be/XT968ZJeWhO. (See the **Online Resources Guide** for a link to this item.) They will refer to the video in their answers on the assessment. Show students the video of someone playing a harp. You may want to play the video a couple of times (it's only a few seconds long).

Ask students to complete the assessment.* Have students individually complete *Assessment.*

Return to the DQB questions. Return to the questions that were identified as those we can now answer and have students individually or in pairs work to answer those questions by attaching the question to a half sheet of paper and then writing the answer below. These can then be placed back up on the DQB.

Ask students to identify questions that they are most interested in pursuing next. Have each student share one such question and allow them to add new questions they have or refine an existing question.

***Attending to Equity**
In this assessment, students are leveraging their understandings from across the unit so far to explain how a particular instrument (a harp) makes different kinds of sounds. Though the harp making sounds is a new phenomenon for students, it has similarities to instruments like guitars and violins that students likely have encountered both in class and in their communities. This assessment allows them to forge

Alternate Activity

Once students have completed and turned in the assessment, you may want to assign one of these supplemental resources to work on in class or as home learning.

- *Supplemental Investigation 6A: What Else Besides an Object's Length Affects the Frequency It Vibrates at When Struck or Plucked?*
- *Supplemental Investigation 6B: How Do People Force Their Voice to Make Different Kinds of Sounds?*

Providing students a choice to pick a supplemental investigation or reading to learn more about is one important way to differentiate instruction without compromising coherence of the storyline for the class. When you do this, the key is to make sure the structure of the investigation or information in the reading doesn't give away the punchline of upcoming lessons. Rather, it should extend the application of ideas the class figured out together. Make sure you provide students six wooden coffee stirrers and one rubber band if they want to conduct Supplemental Investigation 6A and provide a deflated balloon if they want to do Supplemental Investigation 6B. Note that the activities in Investigation 6B make a lot of noise.

ADDITIONAL LESSON 6 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.1: Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.8.1.A: Introduce claim(s), acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

On two occasions in this lesson, students are asked to write a claim and support their claim with evidence. Students often struggle to make a clear connection between their evidence and their claim (reasoning). Support students' reasoning by posting sample language such as "This evidence shows _______. I know this because ______." or "I know that _______ is true because I learned ______ when we ______." These sentence stems will help students draw a direct connection between what they learned and the claims they are trying to support.

connections among these similar phenomena and draw from their experiences inside and outside class to model and explain what's happening with the harp while it's making sounds.

*Attending To Equity

This assessment encourages students to demonstrate their understanding of key skills and concepts from the unit so far through a range of modalities: writing to explain, drawing models, and interpreting visual displays of data. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment.

You may consider allowing some students to present their answers verbally with you or another student acting as a scribe to record their thinking on paper. Other students may benefit from using gestures, rather than images, to show how they think a part of the harp moves when it's making sounds. In particular, some students may be better able to represent the movement of a sound source using a manipulative (like a coffee stirrer) rather than through drawing a model on paper. In each case, encouraging students to use multiple modalities to show their thinking creates a clear, accessible, equitable pathway for all students to demonstrate proficiency.

LESSON 7

What is actually moving from the sound source to the window?

Previous Lesson

We used graphs of the position of a sound source that is vibrating to argue for which sounds are being made. We then applied what we learned in the first five lessons to revise our initial class consensus model and return to our DQB. We then took an individual assessment, applying what we learned to explain new phenomena.

This Lesson

Problematizing, Investigation

1 DAY

This lesson marks the beginning of Lesson Set 2 of the unit, where we focus on how sound is traveling. We investigate the idea that the air from the sound source is traveling to the window or our ears by placing a sound source in an airtight container and testing whether we can still hear it. We also record the mass of the container before and after the sound is produced. The results from these investigations provide evidence that no air is moving all the way from near the sound source to our ears (or the window) when sounds are produced.

Next Lesson

We will test whether air is needed to hear sound by investigating how sound moves through any type of matter and whether it can move across empty space with no matter in it (a vacuum). These findings will support the claim that sound needs a medium (gas, liquid, or solid) to travel through.

Building Toward NGSS

MS-PS4-2

What Students Will Do

Respectfully provide and receive critiques in order to revise initial claims about whether air is being moved (cause) all the way from the sound source to our ears when we hear the sounds or when the window moves (effect).

What Students Will Figure Out

By the end of this lesson, students figure out that air that is near the sound source is not moving all the way from the sound source to our ears (or window) when sounds are produced. We still aren't sure what is moving between the sound source and our ears.

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION: REVISIT OUR INITIAL CONSENSUS MODEL AND DRIVING QUESTION BOARD (DQB)** Students gather around the DQB and revisit the class and individual initial consensus models to help them realize that we aren't sure what actually is moving from the sound source to the window.	A, B	Initial Class Consensus Model
2	15 min	**INVESTIGATE A SOUND SOURCE IN A SEALED CONTAINER** Investigate whether air is moving from the sound source to our ears (or the window). Place a cell phone in a sealed container and make it play a sound to find out if students can still hear it.	C-G	*Investigation Plan*
3	7 min	**INVESTIGATE THE MASS OF SOUND SOURCE IN A SEALED CONTAINER** Record the mass of the container and sound source before and after sound is produced to help convince us that the air is not somehow leaking out. Add any claims based on the two investigations.	H	
4	13 min	**REVISITING OUR INITIAL MODELS** Revisit their initial models to analyze the claim they made about what's traveling between the speaker and window in light of the evidence they've just collected.	I-K	sticky notes, *Lesson 7: Exit Ticket*

End of day 1

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Investigation Plan* • sticky notes • *Lesson 7: Exit Ticket*		• Initial Class Consensus Model

Materials preparation (5 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure you have a cell phone that is charged so that it can be used as a sound maker.

Online Resources

If you don't plan on using a cell phone and instead want to use a different sound maker inside the sealed container, make sure you choose one that fits in the container and that you can trigger it to make noise without having to open the container.

Day 1: Sound source inside container investigations

- **Group size:** whole class
- **Setup:** Gather a hard plastic container, an electronic scale, and a phone or other sound source that can be triggered to make a sound from a distance.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

The goal of this lesson is to help students prove that in the anchoring video air is not traveling all the way from the speaker to the window. This links to the larger understanding that what's traveling between the sound source and the sound receiver is not actual matter, as many students might have shown on their initial models. Students will see evidence that no mass is transferred when sounds travel from one location to another, and they will use this evidence to analyze claims they made in their initial models about what's traveling between the speaker and the window.

Students will delve further into what *is* going between the speaker and the window in later lessons. During today's lesson, students are focused on identifying that matter is not going from the sound source to the receiver when sound travels.

Where We Are NOT Going

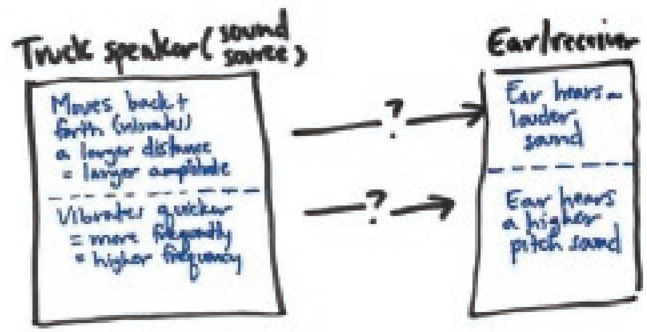
While this lesson clarifies for students what *isn't* traveling between the sound source and the receiver, we aren't yet concerned with students coming to a full understanding of how sound *is* traveling. This question will fuel later investigations and should be emphasized when it comes up so it will loom large in students' minds as they move forward through the unit.

After students prove that there isn't matter moving between the speaker and the window, the question may come up of how to represent sound traveling. Even knowing that they aren't representing matter, students may push that *something* is going from the speaker to the window and may struggle to represent that concept. Encourage multiple representations at this point in the unit, as future lessons will push students to more accurately model what's happening in the space between speaker and window. At this point, it's fine for students to continue to show wavy lines or curves moving between sound source and receiver so long as there is consensus after this lesson that those symbols don't represent matter moving from one location to another.

1. Navigation: Revisit our Initial Consensus Model and Driving Question Board (DQB).

10 MIN

Materials: science notebook, Initial Class Consensus Model



Gather in a Scientists Circle around the DQB. Ask students to bring their notebooks, and display the Initial Class Consensus Model poster. Remind students where we are in our investigation. Project **slide A**.

Say, *We seem to have figured out what is happening at the sound source (the speaker), but we still have a lot of questions about the other two parts of our model. From our initial models and discussion in Lesson 1, we agreed that something is going from the sound source to the window. But we had different ideas of what might be going on in between those two things. That's cool, because it raises a lot of competing ideas of what is happening in this space where we can't see anything happening. This is something we need to investigate further.*

Have students focus on the second part of the model. Ask, *What exactly is going on in between the speaker and the window?* Solicit a few students to read a couple of questions from the DQB that are related to this part of the model.

Ask students to turn and talk with a partner. Project **slide B.** Ask students to look back at their individual initial models that they recorded in their science notebooks and compare with a partner what they thought was happening between the speaker and the window.

Share out ideas about what is moving. Invite a few students to share their ideas about how the sound is traveling.*

Suggested prompts	Sample student responses
What is actually moving from the sound source to the window?	*Maybe the air carries the sound across the parking lot.*
What are some ideas you had on your model or saw on other people's models?	*Maybe the air is being pushed from the sound source to the window.*
	Maybe the vibrating speaker was pushing the air like you do when you wave a fan, and then that air was like wind and it pushed into the window.
	Maybe it isn't like wind, maybe it's more like the air carries the sound to the window and the window then moves when the sound reaches it.

***Strategies for This Initial Ideas Discussion**

The goal of this discussion is to draw out competing ideas about what's traveling between the speaker and the window to make the window move. Students may have a range of ideas of what's traveling between the two places, including sound waves, sound particles, or air. Since we want to dwell on differences in competing ideas, do not expect or push for consensus here. This is a version of the problematizing routine in which you are helping students realize they have a major new question to investigate.

Suggested prompts	Sample student responses
	Maybe sound waves are traveling from the speaker to the window. *Maybe there are particles of sound going from the speaker to the window.*

Accept all student responses. Say, *It seems like we have some different ideas about what's traveling between the speaker and the window to make the window shake. Some of us think there's air actually moving from the speaker to the window, and some of us think there's something else going between the two.*

2. Investigate a sound source in a sealed container.

15 MIN

Materials: *Investigation Plan*

Distribute the handout *Investigation Plan*. Project **slide C.** Have students tape *Investigation Plan* into their notebooks and record the following question in box 1: "Is air moving all the way from the sound source to our ears or the window when sounds are produced?"

Say, *It seems like we need to figure out if air is moving from the sound source to our ears or the window.*

Discuss what we could do to answer our question. Project **slide D.** Show students the container you have and a cell phone (the sound source). Pose the question, *How could we use this container to help us figure out if air is moving all the way from this sound source to our ears?*

Listen for student ideas such as this one:

- Maybe we could block or trap the air around the phone and see if we can still hear a sound.

Students record ideas for Investigation 1. In box 2 for Investigation 1, direct students to sketch and label the plan the class decided to try (i.e., putting the cell phone in a sealed container where the air cannot get out and playing a sound to find out if we can hear it).

With students, brainstorm some possible outcomes. Project **slide E.** Ask, *What are the possible outcomes of our investigation? What could happen?*

Suggested prompts	Sample student responses
So when we put the sound maker in the container and seal it, then play a sound inside, what might we observe?	*Maybe we wouldn't hear the sound coming from inside.*
What are the possible outcomes of this investigation?	*We might still hear it.* *The sound could be muffled.*

Have students record these possible outcomes in box 3.

Connect these possible outcomes to what they would tell us about our question. Have students take a minute with a partner to figure out, for each of the possible outcomes they identified, what that outcome would tell us about our question. Once students have had a moment to think and talk with a partner, ask, *What would each of these outcomes tell us about our question?*

Suggested prompts	Sample student responses
What would it tell us if we could not hear the sound coming from inside the container?	*It would tell us that the air has to go from the sound maker to our ears for us to hear the sound.*
What would it tell us if we can still hear sounds from inside the container once it's sealed?	*That would mean that air doesn't have to go all the way between the sound source and our ears for us to hear sounds.*
What if the sound is muffled? What would that tell us?	*Maybe this means that some air is being blocked and some is still getting through?*

For each potential outcome, have students record in box 4 what each outcome would tell the class about their question.

Conduct the investigation and discuss results. First, turn on the music from a cell phone (or plan to call it from another phone once it is in the container). Then place the cell phone in the container and seal it. Have students jot down in box 5 their observations of what they can hear.

Project **slide F.** Ask students to share their ideas about the results of the investigation. Accept all student ideas.

Suggested prompts	Sample student responses
What did we observe in our investigation?	*When we put the phone in the sealed container, we could still hear sound coming from inside the container.*
What claim can we now make based on these results?	*That would mean that air doesn't have to go all the way between the sound source and our ears for us to hear sounds.*
Is there any evidence that might keep us from making that claim?	*Maybe some air leaked out and did travel. The container could be leaky.*

Have a short, initial ideas discussion about how we could know for sure that air is really being blocked and that no air is getting in or out of the container. Show **slide G.** If students do not suggest weighing the cell phone and container before and after sound is played, ask questions about what students predict would happen to the mass of the container plus the phone in various scenarios.

Additional Guidance

If students haven't developed lines of evidence from previous grades (PS1 in grade 5) that air is matter and therefore air has mass, you may need to conduct these additional investigations first.

A quick demonstration would be to measure the mass of a soda bottle before opening it. Then ask students what will happen when the bottle cap is opened and why. And then remeasure the mass of the bottle and cap after opening it (the mass will decrease because some of the gas escapes upon opening). Another suggestion is to test an inflated volleyball. Measure its mass and then pump it up a little bit and measure its mass again. In both cases, you may need to use a piece of tape to keep the ball on the scale. If so, use the same piece of tape throughout the measuring.

Suggested prompts	Sample student responses
How could we make sure air is really being blocked and that no air is getting in or out?	*We could put our hands up to the outside of the container to feel whether air is leaving.*
	We could weigh the container to see if any air or anything is leaving the container. This would tell us if the container is sealed (a closed system) or not.
So if we were to weigh the container while sounds are coming out, what might we observe?	*If the weight went down, that might mean air is leaving the container.*
What would that tell us?	*If the weight doesn't go down, we'll be more sure that no air is leaving.*

Navigate to Investigation 2. Say something like, *It seems like we need to test this out to make sure that we're correct that no air is getting out.*

3. Investigate the mass of sound source in a sealed container. 7 MIN

Materials: None

Introduce Investigation 2. Gather the phone (or other sound source), the container, and a scale. Remind students that a scale measures something's mass. Discuss possible outcomes of Investigation 2.

Suggested prompts	Sample student responses
What if we put the sealed container and cell phone on a scale? If air leaves the container when sound is being played, how should the mass of the entire system of the sound source plus air plus container afterward compare to the mass of the entire system beforehand?	*If air escapes, the mass should decrease.*
If air enters the sealed container when sound is being played, how should the mass of the entire system of the sound source plus air plus container afterward compare to the mass of the entire system beforehand?	*If air enters, the mass should increase.*

Suggested prompts	Sample student responses
If air doesn't move in or out of the sealed container when sound is being played, how should the mass of the entire system of the sound source plus air plus container afterward compare to the mass of the entire system beforehand?	*If no air moves in or out of the container, the mass shouldn't change.*

Conduct the investigation.

1. Put the cell phone in the container. Measure the mass of the phone and the sealed container on the scale. Record the mass of the phone and container and write the mass on the board.
2. Remove the container and phone from the scale. Call the phone so that it rings. (Or, if using another sound source, trigger it to play a sound.)
3. Once the ringing stops, place the container and phone back on the scale. Record the mass of the phone and container and write the mass on the board.

Additional Guidance

Note: Make sure to measure the mass of the sound source in its sealed container before you play the sound. Then take the container off the scale and play the sound. Then put it back on the scale and get the mass after it plays music or rings. That will ensure that there is no fluctuation in the reading recorded on the scale. If you continuously weigh the sealed sound source while it is playing music, you may see fluctuations in the reading on the scale. This is due to the sound source jumping up and down on the scale as it is vibrating within the container. This is similar to the effect you would see if you were to bounce up and down on a bathroom scale and watch what happens to the weight value displayed.

Students make a claim based on this investigation. Show **slide H.** First, recap with students what they saw in the data they collected in the investigation.

Suggested prompt	Sample student response
How did the mass of the sound source and the container change before and after sounds left the container?	*The mass on the scale didn't change.*

Next, instruct students to take a minute to jot down in their notebooks a claim that they could make after both investigations about whether air is traveling all the way from the sound source to the sound receiver when a sound is being received.

Once students have had a minute to jot down their claim, have them share out what they can conclude from their investigations.

Suggested prompts	Sample student responses
Based on the possible outcomes we discussed before our investigation, what claim can we make about whether air is traveling from the sound source to our ears?	*Air isn't leaving the container.* *Air isn't going all the way from the container to our ears, since the mass of the container didn't change like it would if air was leaving.*

Say, *It sounds like we can go back to our initial models and use our new evidence to revise our initial claims about what's traveling between the sound source (the speaker) and the sound receiver (the window).*

4. Revisit our initial models.

13 MIN

Materials: sticky notes, *Lesson 7: Exit Ticket*

Review their own initial models. Project **slide I.** Ask students to take out the initial models that they started class with and to focus in on what they showed traveling between the speaker and the window.

Instruct students to use their initial model to answer this question on a sticky note that they place on their model: "In your initial model, what claim did you make about what's traveling between the speaker and the window?" (Example claim: "The speaker pushes air all the way to the window, which makes the window shake.")

Partners review each other's initial models. Project **slide J.** After students have had a minute to restate their initial claim, have them exchange their models and sticky notes with a partner. Set a timer for 3 minutes. Instruct students to use the sticky notes near their seat to write feedback for their partner about the part of their model that makes a claim about what's traveling between the speaker and the window. Emphasize to students that the feedback should follow our *Peer Feedback Guidelines.** Have students use the following questions to guide their feedback:

- What claim or claims does your partner's model make about what's traveling between the speaker and the window?
- Do you think that this claim is supported by the evidence we have collected so far in our investigations?
- If not, what changes do you think your partner could make to their claim about what's traveling between the speaker and the window?
- What specific evidence can you connect to your partner's claim to support your feedback?

Revise and reflect upon their initial models. Project **slide K**. Once students have had a few minutes to write feedback on their partner's initial model, have students return the models back to their original authors. Once students have their own initial model back, instruct them to use the feedback their partner provided to complete the questions on *Lesson 7: Exit Ticket*. As students are working, walk around and look at the feedback students provided to their peers to see if they are providing specific and actionable feedback.

- List at least 2 important pieces of feedback that you received from your partner. What could you add or change on your model to address these pieces of feedback?

***Supporting Students in Engaging in Argument from Evidence**

The *Peer Feedback Guidelines* support students' ability to provide productive and respectful critiques about their partner's claims. Depending on your students' familiarity with this resource and skill at providing productive feedback, you may want to spend some time reminding students of the key features and examples of productive feedback.

- After collecting new evidence in our investigations and getting feedback from your partner, do you still support the claim you made in your initial model? If not, what new claim would you make about what's traveling between the speaker and the window?
- What did you see in the evidence we collected today that makes you think your claim from Q2 is correct? How does that evidence support the claim you chose?

After students are finished, you can have a few students share their new claims if there's enough time.

Additional Guidance

Listen for student responses such as the following:

- *No air appeared to escape from the container, but we still could hear a sound.*
- *Yet somehow the sound is still moving to our ears (or to a window).*
- *Air isn't traveling between the speaker and the window.*
- *Something might be traveling between the speaker and the window, but it probably isn't made of matter since the weight of the container didn't change after sounds came from inside.*

Collect these exit tickets from students or have students set them aside to turn in on the way out of the classroom.

Assessment Opportunity

This lesson provides a good opportunity for students to self-assess using the *Peer Feedback Guidelines*.

Do we need air to hear sound?

Previous Lesson

Lesson 7 marked the start of the Lesson Set 2 of the unit. We investigated the idea that the air from the sound source is traveling to the window or our ears by placing a sound source in an airtight container and testing whether we can still hear it. We then reasoned that air is not moving all the way from the sound maker to our ears since no mass left the sealed container while we were hearing sounds from within.

This Lesson

Investigation

1 DAY

We test, through two investigations, whether air is even needed to hear sound. One investigation provides evidence that sound moves through any type of matter, while the other investigation provides evidence that it can't move across empty space that has no matter in it (a vacuum). These findings support the claim that sound needs a medium (gas, liquid, or solid) to travel through.

Next Lesson

We will recall that models of all states of matter include particles, empty space, and motion. We will simulate what happens in matter as a vibrating object interacts with it. This model will suggest that motion (or energy) might be transmitted through the medium from one place to another through particle collisions.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Use evidence from investigations to compare and critique competing claims and argue that air or another medium such as liquid or solid is needed (cause) to hear sound or move the window (effect).

What Students Will Figure Out

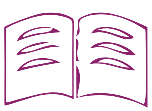
- Sound can travel through all different kinds of matter (solids, liquids, and gases), not just air.
- Sound cannot travel through an empty space with no matter; sound needs matter to travel.

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Students discuss two different claims about whether air is needed for sound to travel, then brainstorm how the class can investigate these two opposing claims.	A, B	chart paper, markers
2	10 min	**INVESTIGATE A SOUND SOURCE WITH AIR REMOVED** Watch a video of a cell phone being played in a jar that is attached to a vacuum pump and observe what happens to the sound as air is removed and as air is added back.	C-F	cell phone in jar video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	10 min	**INVESTIGATE SOUNDS TRAVELING THROUGH OTHER FORMS OF MATTER** Students knock objects together under water and/or put their ears on the sides of a container of water to continue to build the idea that matter is needed for sound to travel.	G-I	fish tank, water, 2 rocks or golf balls
4	10 min	**CONSENSUS DISCUSSION ABOUT WHAT SOUND NEEDS TO TRAVEL AND UPDATE THE PROGRESS TRACKER** Students make claims about what is needed for sound to travel and come to consensus on what they have figured out in order to represent it on their Progress Trackers.	J, L	*Progress Tracker*, index cards
5	5 min	**NAVIGATION** Students discuss how they could figure out how to represent sound moving through matter in a model.	K	

End of day 1

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Progress Tracker*		• chart paper • markers • cell phone in jar video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • fish tank • water • 2 rocks or golf balls • index cards

Materials preparation (5 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Gather chart paper and markers to make the Competing Claims poster.

Check the cell phone video to ensure that it plays and can be viewed by the whole class. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

If you have a vacuum pump, you could do a live demonstration of pumping the air out of the container with a cell phone in it rather than showing the video. If you do this, hang the cell phone inside a bell jar using fishing wire and packing tape so that students are convinced that the phone is more or less "suspended in empty space."

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

This lesson leverages understandings from previous grades (especially PS1 in grade 5) that different media (solids, liquids, and gases) are made of matter and therefore have mass. These understandings, and a model for matter as made of particles too small to be seen, are foundational for students making sense of the investigations in this lesson.

In this lesson, students come to understand that sound can move through different types of matter (solids, liquids, and gases) but cannot move through a space without matter. This leads students to conclude that sound needs matter to travel. Students also begin using a new word (*medium*) to describe the substances made of matter that sounds can travel through.

Students use the understanding from prior grade bands that gases, liquids, and solids are all media (plural of *medium*) made of matter. The investigations in this lesson help students to understand that sound can travel through all these different types of matter, but that it cannot travel through an empty space that is devoid of matter (we call this empty space a vacuum).

Where We Are NOT Going

Students may think that the reason we can hear sounds through other types of matter is because there's air in them, too, like how there are bubbles dissolved in water. While much water (like in fish tanks or ponds) has air dissolved in it, we want students to identify that sound can travel through a liquid, regardless of whether there is air dissolved in it. It is not in the scope of this unit to delve into the exact composition of different kinds of media.

For the purposes of this lesson, students will not yet be exploring the differences among different states or types of matter. This lesson leverages the pattern that the substances that sound can travel through (i.e., air, water, and solids like glass or plastic) are all made of matter. Future lessons will provide students with opportunities to explore how sound moves through these different media, including how each looks different on a zoomed-in scale. To this end, in this lesson students will differentiate between media and spaces without matter (like the vacuum created in the vacuum pump video) in order to construct a causal relationship between taking away the matter in a space and the sound not being able to travel from the sound source to our ears.

LEARNING PLAN FOR LESSON 8

1. Navigation

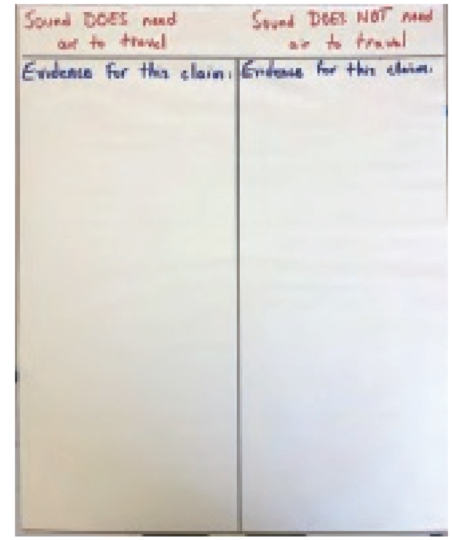
10 MIN

Materials: science notebook, chart paper, markers

Ask students to talk with a partner about these two questions. Show **slide A.**

- If the air from near the sound source isn't moving all the way to our ears or the window, then what is moving?
- Is the air inside the container even needed for sound to travel to our ears?

After talking with a partner, have students write down the following lesson question in their notebook: "Do we need air to hear sound?"



Present students with two competing claims. Display **slide B.** Introduce to students that there are two competing claims that could answer this question: Either sound needs air to travel to our ears, or it doesn't. On a piece of chart paper, create a 2-column chart with these two competing claims labeled over the columns: "Sound needs air to travel" and "Sound doesn't need air to travel".

Emphasize that we are going to use this chart to keep track of what evidence we have to support each of these claims. Ask students to share any evidence we have from prior investigations that could support either of the two claims.

Suggested prompts	Sample student responses
Do we have any evidence from our investigations so far to support the idea that sound needs air to travel?	*There was air between all the sound makers and our ears in our experiments so far.* *Some of us have heard that sounds can't travel in space because there's no air.*
How about the other argument? Do we have any evidence to support the idea that sound doesn't need air to travel?	*Some of us have heard sounds underwater, and there's not any air there.* *We figured out last time that air isn't going all the way from the sound source to our ears since none of it was leaving the container.*

Brainstorm ways to investigate this new question. Focus on the competing evidence that we have so far. Tell students that we need to try to think of some ways we could investigate this question further.

Suggested prompts	Sample student responses
How could we tell if the air inside the container is needed for us to hear the sounds?	*We could replace the air with something else, like water.* *Could we take the air out somehow, then see if we can still hear the sounds?* *Maybe we could put the phone someplace with no air to see if we could still hear it.*

Emphasize to students that we have a new question that we need to answer and some ideas of how we could answer this question.

Additional Guidance

Questions such as, "Why can you hear underwater?" or "Can you hear in space?" or "Why can't you hear the Sun sizzling if it is so hot?" are typical of the type of questions that are often on the Driving Question Board (DQB) connected to this lesson. Ask students how the questions we are trying to answer in this class could connect to those posted questions and ideas for investigations.

2. Investigate a sound source with air removed.

10 MIN

Online Resources

Materials: science notebook, cell phone in jar video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Plan the investigation in science notebooks. Display **slide C.** Explain to students that instead of taping an Investigation Plan table into their notebooks this time around, they will be responsible for recording the investigation plans themselves. Direct students to write the investigation question, "Can we hear sounds coming from a container with no air inside?", at the top of their next clean science notebook page.

Tell students, *I have a video that shows a special piece of equipment that can help us investigate one of your ideas: taking the air out of the container to see if we can still hear sounds coming from inside.*

Show slide D. Play the Vacuum Pump video up to **1:35.** This part of the video explains what the setup includes and how the vacuum pump works. Then show **slide E** and have students set up a T-chart in their notebooks to record the possible outcomes of this investigation and what each outcome would tell them about the question of whether we can hear sounds without air.

Additional Guidance

In this lesson, more responsibility for recording investigation plans and notes is released to the students. If you notice students struggling to keep accurate records, you may choose to give them an *Investigation Plan* handout instead.

Discuss the possible outcomes students considered. Come to a consensus as a class that if air is needed for sound to travel, we shouldn't hear any sounds coming from the container once all the air is removed.

Finish showing the video from where it was paused. While they watch and in the moments following, invite students to record their observations in their science notebooks and then make a claim based on that evidence.

Discuss claims and evidence. Show **slide F.** Once students have had a minute or two to record, ask students to share their observations as well as the claims they made based on the evidence they saw in the video. Lastly, prompt students to revisit the Competing Claims poster we created earlier in the lesson to see if there's any new evidence for either claim that they want to add.

Suggested prompts	Sample student responses
What did we observe from the video?	*The sound got quieter when air was removed.*
	You couldn't hear anything once all the air was gone from inside.
What claim can we make from the evidence we got from this video? What can we say about the two arguments we started with?	*This is evidence that sound does need air to travel, since we couldn't hear it once all the air was removed.*
	This should go on the poster as evidence for "Sound needs air to travel".

Add this new evidence to the Competing Claims poster under "Sound needs air to travel". Once students have settled on the big takeaway from this first investigation, remind them that they had another idea of how they could test to see if air, in particular, was required for sound to travel.

3. Investigate sounds traveling through other forms of matter. 10 MIN

Materials: science notebook, fish tank, water, 2 rocks or golf balls

Navigate to the next investigation. Say, *So in the video, the vacuum pump sucked out all the air from the container, leaving behind an empty space with no matter at all. And we agree that we couldn't hear sounds coming from inside the container once all the air was removed. But we also had this question about whether sound could travel if there was something in the container besides air.*

Suggested prompts	Sample student responses
We found that the sound couldn't travel through the container to our ears when we removed all the matter inside, including the air.	*We could fill the container with something else, like another type of gas or a liquid.*
Is there something we could replace the air with so that we could test whether the sound can travel to our ears?	*We could fill the container with water instead of air.*

Say, *It sounds like we have one more investigation we want to try. We still want more evidence to support our claims and answer our original question.*

Plan the investigation in science notebooks. Show **slide G.** Direct students to write the investigation question, "Will sound still travel through something other than air?", at the top of their next clean science notebook page.

Introduce the next investigation. Bring students over to a fish tank or container filled with water. Hold up the two rocks or golf balls, and ask a student to demonstrate that a sound could be heard when they are knocked together in the air.

Suggested prompts	Sample student responses
These two objects make a sound when they are knocked together in the air.	*We could knock them together under the water.*
How could we use these objects to test if sounds travel through something besides air, such as water?	*If we heard the rocks making noise when they were in the water, it would mean that sound could travel through the water.* *We could put our ears in the water or up against the container to see if we hear the rocks knocking together with water instead of air in between.**

***Attending to Equity**
Students will likely suggest banging the materials together while they are held under water. They may suggest putting their ears under water. If they do, you could ask a volunteer to try this, or you could ask them for ideas of other places we could put our ears that would still let us hear whether the sound is traveling through the water. Allowing students choice in how they test their ideas promotes student agency, respects students' ideas, and promotes equity.

Show slide H. Have students set up a T-chart in their notebooks to record the possible outcomes of this investigation and what each outcome would tell them about the question of whether sound can travel through substances other than air.

Discuss the possible outcomes students considered. Come to a consensus as a class that if we can hear sounds coming from the rocks knocking together under water, it would mean that sound can also travel through water and not only through the air.

Conduct the investigation. Show **slide I.** Have a student gently lower the rocks or golf balls into the tank of water while holding onto them. Direct the student to knock the rocks or golf balls together. Repeat this if some students ask to observe it again or if they would like to put their ears against the tank this time. While students are making observations, instruct them to record in their notebooks what they observe as well as what it tells them about our investigation question.

Once students have had some time to observe and record, have students gather together to share how they think this new evidence connects to the question the class is investigating. Since you will be convening in a Scientists Circle for the Consensus Discussion, you could move to the circle now for this discussion as well.

Suggested prompts	Sample student responses
What claim can we make from the evidence we gathered through our last investigation?	*We could hear sounds coming from inside the container with water, so that means that sound can travel through water.* *This means sounds can travel through other stuff besides air, so maybe sound doesn't need air to travel.*
What can we say about the two arguments we started with?	*This should go on the poster as evidence for "Sound doesn't need air to travel". The sound does need to have something to travel through, but it's not only air.*

Add this new evidence to the Competing Claims poster under "Sound doesn't need air to travel".

Additional Guidance

Students may think that the reason we can hear through water is because water has air in it. While much water (e.g., in fish tanks and ponds) has dissolved gas in it, we want to convince students that sound can travel through a liquid. Consider using vegetable oil as another liquid if this idea comes up.

4. Consensus Discussion about What Sound Needs to Travel and Update the Progress Tracker 10 MIN

Materials: science notebook, *Progress Tracker,* index cards

Gather students in a Scientists Circle for a Consensus Discussion. * Have students bring their notebooks with them to the circle. Tell students that they will be using the evidence they gathered during the investigations to come to a consensus on the question they started class with: "Does sound need air to travel?"

Key Ideas

Purpose of this discussion: Come to a consensus about what sound needs to travel using evidence from this lesson's investigations.

Listen for these ideas:

- Sound can travel through all different kinds of matter (solid, liquid, gas).
- Sound can't travel through an empty space without matter. It needs a medium to travel through.

Additional Guidance

It is important to use words that the class agrees on to capture the essential ideas outlined here, rather than using the exact wording in this *Teacher Guide.* If you simply fill out the Progress Tracker for students, they will have the perception that they are just taking notes, and the experience will be demotivating. By using their own words, students will sense that their own scientific reasoning really matters (as it does). It is recommended that you include a pictorial representation in the Progress Tracker.

Pass out *Progress Tracker.* Present **slide J.** As students share findings from their investigations, have them add these conclusions to their Progress Trackers. Be sure to push students to use evidence from their investigations (recorded on the Competing Claims poster) to support the key ideas they're adding to their Progress Trackers.

***Attending to Equity**
During a Consensus Discussion, students can practice talking with one another as a community of learners. Engaging in this practice can support all learners in developing academic discourse. They listen to one another's ideas and findings, ask questions about evidence, and come to agreement about what the class figured out in an investigation.

Suggested prompts	Sample student responses	Follow-up questions
What evidence did we collect today about whether sound needs air to travel?	*We saw that when you take the air out of a container, you can't hear sounds coming from the inside.* *We could hear sounds coming from inside the container with water instead of air.*	*Do we all agree with that?* *Was there anything else we observed that might help us answer this question?*
What does this evidence tell us about our two arguments about whether sound needs air to travel?	*Sound doesn't need just air to travel, since we could hear the sounds through the water, too.*	*What ideas are we in agreement about?*
	But sound needs something to travel through. It can't travel through an empty space, like in the vacuum chamber.	*Are there still places where we disagree? Can we clarify these?*
It seems like we agree with parts of each argument and disagree with other parts. Is there a different claim we could make about what sound needs to travel?	*If there is nothing in the space that sound would travel through, sound can't travel.* *It seems as if sound needs matter (gas, liquid, or solid) to travel through, but it doesn't have to be air.*	*Why do you think that sound needs matter to travel?* *How do you think sound travels through matter?*

Additional Guidance

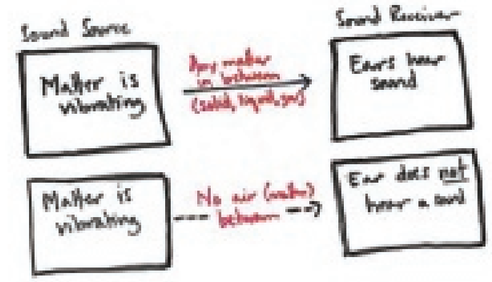
This is an opportunity to introduce students to a new multiple-meaning word that they can use for a substance made of matter that sound can travel through: *medium*. Air, water, and solids like the walls of the container are all media (plural of *medium*) that sounds can travel through. Add this word to the word wall.

Give students a minute or two to finish recording the key findings on their Progress Trackers. Below is a sample of possible language for the Progress Tracker.

Question	Source of evidence
Does sound need air to travel?	• Taking air out of the container and testing if we can still hear sounds from inside • Replacing the air with water and testing if we can still hear sounds from inside

What we figured out in words and pictures

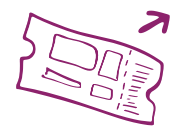
- Sound can travel through all different kinds of matter (solids, liquids, and gases), not just air.
- Sound cannot travel through an empty space with no matter. Sound needs matter to travel.



Problematize how to represent how sound moves through matter. After students have recorded their key findings in their Progress Tracker, pause and say, *It seems like it would really help if we could draw a model of how sound can go through matter but not an empty space.*

Emphasize to students that while they have figured out that sound needs matter to move, they haven't yet described what's happening in the matter that allows sound to travel through from the source to our ears.

Exit Ticket



If time allows, you can proceed to **slide L** for an assessment opportunity that will provide data on students' ability to use evidence from this lesson's investigations to explain whether or not they support the claim that sounds can't travel in outer space because it's a vacuum that contains no matter.

Project **slide L,** and have students answer this assessment question on an index card to collect on their way out of class.

5. Navigation

5 MIN

Materials: None

Plan where the class is going next. Remind students that we need to decide on what questions and investigations to pursue next so we can figure out how to represent how sound moves through matter. Display **slide K**. Invite students to turn and talk about the following questions:

- If we were to draw a model of how sound travels through matter, what would we need to include in that model?
- What do we need to figure out about each of these parts of the model so that we can represent how energy is transferred when sound travels through matter?

Suggested prompts	Sample student responses
If we were to draw a model of how sound travels through matter, what would we need to include in that model?	*We would probably need to show the matter that the sound is moving through.* *We should zoom in to show the particles inside the matter.* *We need to show the sound going through the matter to get from the source to our ears.* *We would need to show the sound being made and then going to our ears.*
What do we need to figure out about each of these parts of the model so that we can represent how sound travels through matter?	*We need to figure out what's happening in the matter when sound is going through.* *We need to agree on what's in the matter for different things, like water or air.*

Tell students that we will pick up in our next class with these questions of how to represent matter and sound going through matter.

ADDITIONAL LESSON 8 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.8.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

As students engage in a Consensus Discussion, the teacher should prompt students to clarify statements so that they are expressing their ideas clearly. One way to support students in this clarification is by asking them to restate their idea in a different way or by asking another student to repeat what a peer said in their own words. Effective engagement in a Consensus Discussion does not necessarily indicate that a student shares a fully formed idea, but rather that they take a risk in sharing their understanding of a situation so that the class can develop a clearer, collective understanding of a concept.

LESSON 9

How can we model sound traveling through a solid, liquid, or gas?

Previous Lesson

We tested whether air is even needed to hear sound. One investigation provided evidence that sound moves through any state of matter. The other investigation provided evidence that it can't move across empty space that has no matter in it (a vacuum). These findings supported the claim that sound needs a medium (gas, liquid, or solid) to travel through.

This Lesson

Investigation

1 DAY

We recall that models of all states of matter have particles, empty space, and motion. We simulate what happens in the surrounding matter as a vibrating object is interacting with it. This model suggests that motion (or energy) might be transferred through the medium from one place to another through particle collisions. This model motivates the need to explore a simulation of this system so that the particle collisions across the medium can be inspected more closely.

Next Lesson

We will run a computational simulation exploring how particle collisions propagate across a medium from a vibrating sound source. Our investigations will help us to develop models for the nature of the wave traveling across the medium, including a particle density model with bands of dense and less-dense batches of matter and the direction of energy transfer across the medium, for different amplitude and frequency sound vibrations of the sound source.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Develop and use a model to describe unobservable parts (particles) of the system and how they would interact with one another in any state of matter to transfer energy from a vibrating sound source through collisions with one another across a medium.

What Students Will Figure Out

- Students recall that solids, liquids, and gases are made of particles moving through empty space, with different spacing in each state of matter.
- Particles can bump into and off one another in a solid, liquid, or gas.
- A vibrating sound source could push particles in the medium it is next to.
- If a push is transferred into the particles in one part of the medium, it might result in a cascading series of collisions among particles across the medium.
- Those particles transfer energy to other particles when they collide or bump into them.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	2 min	**NAVIGATION** Review what we have figured out about sound traveling and the new questions we have.	A	
2	5 min	**MODEL MATTER IN DIFFERENT MEDIA** Students work in pairs to model the particulate nature of the different states of matter from a Lesson 8 investigation.	B	
3	7 min	**SHARE MODELS FOR DIFFERENT STATES OF MATTER** The class comes to consensus on how the particles behave in the different states of matter.	C	chart paper, markers
4	10 min	**SIMULATE PARTICLE MOVEMENT WITH OUR BODIES** Students simulate what happens to particles when a sound source is vibrating against a medium (e.g., water or air) using people as particles of the medium.	D	Large cardboard (11 in by 17 in) labeled "Sound Source"
5	5 min	**PARTICLE MOVEMENT DISCUSSION** Students discuss how the simulation helps them understand the interactions among particles in different states of matter and how we can use these ideas to explain why, in a Lesson 8 investigation, we could not hear anything when the air was removed.	E	chart paper, markers
6	7 min	**MODEL MATTER AROUND A SOUND SOURCE** Students work to draw a model of what is happening to the medium around a sound source when it starts vibrating.	F	*Modeling the Matter around the Sound Source,* clear tape
7	5 min	**SHARE MODELS OF MATTER AROUND A SOUND SOURCE** Students work with a partner to compare their models of matter around the sound source and then discuss areas of agreement and disagreement as a class.	G	*Modeling the Matter around the Sound Source*
8	4 min	**NAVIGATION** Students brainstorm what to include from our discoveries in a computer simulation to use during the next class to help us investigate further how sound travels across a medium.	H	*Self Assessment for Classroom Discussions*

End of day 1

Part	Duration	Summary	Slide	Materials
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 9, students are ready to read Student Reader Collection 3 and then respond to the writing exercise.		Student Reader Collection 3: *Sound and Media*

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Modeling the Matter around the Sound Source* • *Self Assessment for Classroom Discussions*	• clear tape	• chart paper • markers • Large cardboard (11 in by 17 in) labeled "Sound Source"

Materials preparation (5 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Find a large piece of cardboard (11 in by 17 in) and label it "Sound Source."

Online Resources

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

The particulate nature of matter is key in understanding how sound moves across a medium. Sound waves rely on particles and the springy nature of matter to move energy from a source to a detector. Regardless of its state, matter is a necessary component for sound energy to travel. If students haven't developed sources of evidence from previous grades that solids, liquids, and gases are made of particles and that the spacing among those particles is different for a solid versus a liquid versus a gas and that the particles in matter can move, you may need to add supplemental lessons before this one.

Students in 6th and 7th grade have explored the relationship between temperature and the speed of particles. They may have encountered the relationship among temperature, particle motion, and states of matter related to phase changes. If students are familiar with this idea, then it should be included in the particle representations (particles in gases are moving faster than particles in liquids or solids).

Where We Are NOT Going

Though students will draw models for the differences in particle spacing for solids, liquids, and gases, students will really only be simulating how particles collide within the spacing of liquids and gases. Simulating collisions in a gas is difficult to visualize because the average distance gas particles travel before they collide (free mean path) is quite large and the difference in density between compressed and decompressed regions of particles is so small that it would be difficult to see in the simulation.

1. Navigation

2 MIN

Materials: science notebook

Review what we figured out in the previous lesson. Project **slide A.** Ask students, *What are some of the big ideas we figured out in the last class that we recorded in the Progress Trackers?*

Suggested prompts	Sample student responses
What were the big ideas about sound that we figured out last lesson?	*Vibrating matter (like an instrument or a speaker) produces sound, and the same piece of matter can be forced to vibrate at different frequencies and amplitudes to produce many different sounds.* *Sound is not matter, but it needs matter (a medium) to move through the space that matter is in—and it can be any type of matter (gases, liquids, or solids).* *When sound moves through matter, the matter doesn't move all the way from the sound source to our ears or a detector.*
What questions did these ideas raised for us?	*This made us wonder why or how vibrations are moving across matter, and why they would move across matter but not across empty space.* *This reminded us that we need to recall what we know about modeling the different states of matter.*

2. Model matter in different media.

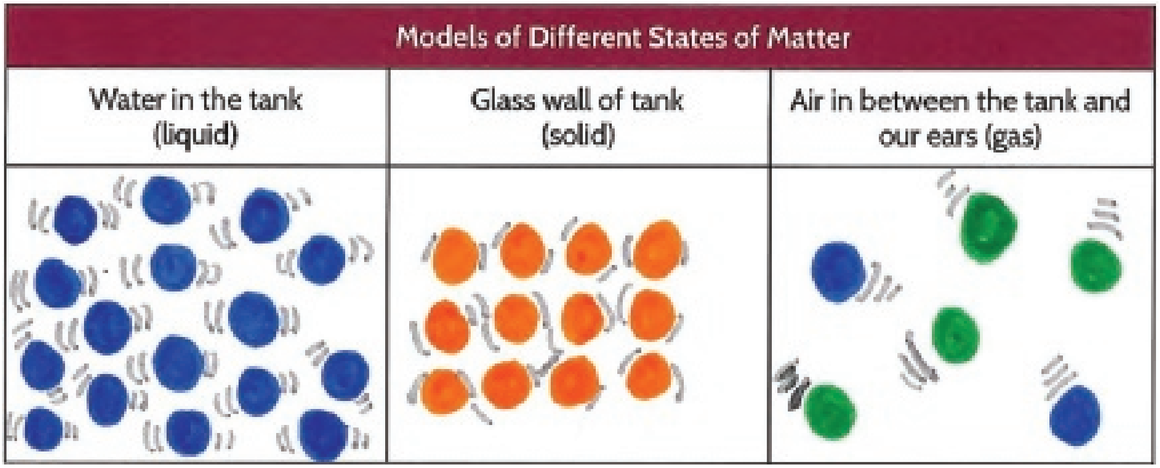
5 MIN

Materials: None

Students complete state-of-matter models in pairs. Project **slide B.** Read through the directions on *Sound and States of Matter* and ask students if they have any questions. Give students time to model what would happen in each part of the scenario.

Say, *We all agree that matter is made of particles. But it's important for us to understand how that idea applies to the different states of matter we are thinking about: gases, liquids, and solids from our investigation in Lesson 8.*

As students are working, listen in on pairs to check if they are representing the particles in the solid close together, in liquid further apart, and in gas even further apart, as seen in this possible representation.



3. Share models for different states of matter.

7 MIN

Materials: chart paper, markers

Pairs of students present their models to the class. Have several partners stand up and describe their models to the class. During sharing, ask students for areas of agreement and disagreement. Present **slide C.** Help the class come to consensus on how the particles behave in the different states of matter. Ask students to explain what they mean by "matter," what we know that all states of matter share in common, and what makes something matter. Record their ideas on chart paper.

Suggested prompts	Sample student responses
Can you explain to me what we mean when we say "matter" in this class?	*Everything that has mass is made of matter.*
	Matter is made of little particles separated by some amount of empty space.
	Everything is made of little particles—even air.
	Everything is made from small parts, like atoms or molecules.
What did we see that was similar for the different states of matter in all of our models?	*The models of solid, liquid, and gas all had little pieces or particles filling up the space.*
What did we see that was different for the different states of matter in our models?	*There are different amounts of space between the particles of matter—gases have more space between the particles than liquids or solids do.*

Suggested prompts	Sample student responses
Why are we talking about the matter of solids, liquids, and gases?	*We are trying to figure out how sound travels through each of these media.*
What do our models not show that might help us figure out how the sound is traveling through the medium?	*We did not show the particles bumping into or colliding with one another, which we know is happening from our earlier units.*

Say, *So, what I hear you saying is that we need to not only be able to model the different spacing of particles in a medium that sound travels through, but we also need to show how the molecules bump into one another. I wonder if we could try this with our bodies as the particles.*

Additional Guidance

Students have previously explored the particulate nature and behavior of matter. In 6.2 Thermal Energy, students experienced particles moving and colliding differently depending on temperature. In 6.3 Weather students explored the particles in solids, liquids, and gases moving and transferring energy. In 7.1 Chemical Reactions, students saw that matter is made up of pieces that can be rearranged. If students haven't developed sources of evidence from previous grades that solids, liquids, and gases are made of particles and that the spacing among those particles is different for a solid versus a liquid versus a gas and that the particles in matter can move, you may need to add supplemental lessons before this one.

4. Simulate particle movement with our bodies.

10 MIN

Materials: Large cardboard (11 in by 17 in) labeled "Sound Source"

Students simulate sound moving through a medium. Project **slide D**. Ask for some volunteers to line up in the front (with a bit of space between them) to represent particles. Hold up the sound source (a large sheet of cardboard labeled "Sound Source").

Ask students for ideas of how they could represent what is happening as sound moves across the room from the sound source. Reintroduce the idea of what we know the sound source is doing when it produces sounds.

Suggested prompts	Sample student responses
What do we know the sound source is doing when it produces sounds?	*The sound source is vibrating or moving back and forth.*
What would that action do to the particles in the air or the particles in a liquid it is up against (like the golf balls or rocks in the fish tank)?	*It would bump into the particles that are in the medium it is up against.*

Suggested prompts	Sample student responses
Let's imagine this sheet of cardboard is the sound source, and it is vibrating. What would that do to the neighboring particles in the medium?	*The particle would be pushed or hit.* *The particle would move away from the thing that hit it.* *Bump into them and push them into the next particle.*

Tell the students who are representing particles nearest the sound source to prepare to slowly simulate what would happen to them as the sound source vibrates. Have the group of students stand about one foot apart, shoulder to shoulder. Stand about one foot from the first student so you can easily push them gently with the cardboard. Hold the cardboard "Sound Source" sign with one hand on the top and one hand on the bottom of the cardboard and move it back and forth (like a door opening and closing). Ask students what this would do when it touches a particle of the medium.

When the cardboard hits the first student they should move in the opposite direction of the hit. For example, if the teacher is standing to the left of the student and hits from the left the student should move to the right. Have the student who was the first particle hit continue moving until coming up against another "particle." Right before lightly pushing into the next person, have the first student "freeze frame," and then ask the class what will happen when this moving particle hits the next particle. Listen for student responses such as the following:

Suggested prompts	Sample student responses
What would happen when this moving particle hits another particle?	*The next particle would move or fly away from the thing that hit it.* *Maybe the particle that hit it would slow down or stop moving.*

Then ask students to resume the simulation by having the first particle complete a light hit on the next particle so that it starts moving toward the next particle. Repeat this process a few times, repeating the "freeze frame" as many times as necessary for students to grasp the concept.

Suggested prompts	Sample student responses
How were we passing the sound in this model? *What thing in real life does that remind you of?*	*We were bumping into one another.* *That reminds me of when we bump into one another in the hallway.* *That reminds me of when dominoes fall over or when the balls hit each other when you are playing pool.*

Suggested prompts	Sample student responses
What could we call it when the particles are passing a movement along by pushing or hitting one another?	*We could call that bumping or colliding.* *We could call that a collision force between the particles.* *We could call that movement to the next particle a vibration or energy.*
Can you say more about how energy was transferred as the sound traveled?	*When one particle hits the next particle it transfers energy which causes the next particle to move away from the first particle and the sound source.*

Repeat the simulation using a smaller-amplitude vibration at the sound source. Ask students (a) how we would show a smaller-amplitude vibration at the sound source, (b) what effect it would have on particle motion in the medium, and (c) how simulating this effect can help us visualize it. Go ahead and try to repeat the simulation with a smaller amplitude, but note that it might be difficult to get meaningful results.

Ask students why trying to simulate the effects of changing frequency and amplitude of the vibrations at the sound source is tricky when using people. Raise the idea that we might need to use a different way to simulate and visualize how those sorts of changes in the vibrations at the sound source propagate across the medium.

Suggested prompts	Sample student responses	Follow-up questions
Why was it a little tricky for us to simulate the vibrations at the sound source using people?	*People have legs that they can use to keep them in one place.* *Our bodies aren't floating in the space like particles.* *We are in a straight line and we know that particles are all over.*	*Can anyone say more about that?*

5. Particle Movement Discussion

5 MIN

Materials: chart paper, markers

Have students return to their seats and participate in a Think-Pair-Share. Project **slide E.** The class should come to consensus regarding how the simulation we did with people as particles can help us explain the results from our earlier investigation when we removed the air from the container and when we used water in place of air. Record their consensus ideas on chart paper.

Suggested prompts	Sample student responses
What state of matter do you think we were simulating? What is your evidence?	*I think we were simulating a liquid because the particles were not too close together and not too far apart.*
Would we see similar interactions between particles if we simulated sound traveling through a solid or a gas? How would those compare?	*With a gas, the particles would move a greater distance before bumping into another particle than if it was a liquid or a solid.* *With a solid, there still would be particles bumping into one another, but they would be spaced more closely together.* *In any state of matter, particle collisions between neighboring particles would occur.*
How does this model help us understand why we couldn't hear any sound when we sucked the air out of a system?	*What we added to the Progress Tracker for Lesson 8 was that there wouldn't be any particles at all—it would just be empty.* *With no particles, there's nothing to pass the sound from the source to our ears.*

Additional Guidance

Students will likely want to model a gas to make the simulation as similar to the speaker and the truck phenomenon. Simulating collisions in a gas is difficult to visualize because the average distance gas particles travel before they collide is quite large and the difference in density between tightly packed and more loosely packed bands of particles is so small that it would be difficult to see in the simulation. This is a productive conversation to have with students about how models can be useful representations of phenomena even though the model has limitations.

6. Model matter around a sound source.

7 MIN

Materials: *Modeling the Matter around the Sound Source,* science notebook, clear tape

Create individual models of the medium around a sound source. Project **slide F**.

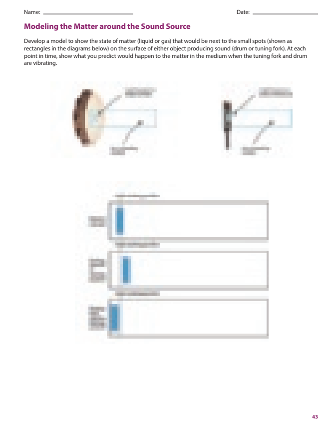
Say, *We are going to use these ideas to develop a model to show what we think is happening to the matter around a sound source that is vibrating.* Remind students of the word *medium* we added to our word wall in the last lesson that means a substance made of matter that sound can travel through.

Distribute *Modeling the Matter around the Sound Source.* Project the handout and point to the top diagram showing the drum and the tuning fork. Ask students to imagine the motion of the small spot on the surface of the drum or the tuning fork after it is struck. Point to the colored rectangles on the drum and on the tuning fork. Have students hold their hands up to show how the surface would move back and forth if they could zoom in very close.

Orient students to the three frames shown below the drum and the tuning fork diagrams. Mention how these close-up frames are similar to how we modeled the instrument motion in past lessons. Explain to students that this time we won't show any shape changes because we are looking at a very small section of the surface of the vibrating sound source in each close-up frame.

Read through the directions on *Modeling the Matter around the Sound Source* and ask students if they have any questions. Give students time to individually model what would happen in each scenario. As students are working, walk around and see how they are representing the movement of the particles.

Have students tape this handout into their notebooks when they finish or collect these to examine more closely and give feedback before the next lesson.



7. Share models of matter around a sound source. 5 MIN

Materials: *Modeling the Matter around the Sound Source*

Compare models. Project **slide G.** Have students share their initial models with a partner or their small group. After they have time to discuss in a small group, convene a whole-class discussion and ask students to share interesting remarks that they heard from their peers or pieces they saw in their peers' models that helped them better understand how sound moves across matter. If students would like to further develop or revise their models, have them use a different color to show how discussing with a partner helped add to their individual thinking.

Review, as a class, ideas about what happens to the matter when the sound source starts vibrating. Ask students to review their ideas that they developed on their ***Modeling the Matter around the Sound Source.***

Say, *What ideas about what happens to the particles when a sound source starts vibrating did you see or hear?*

Suggested prompts	Sample student responses
How did we show the matter around the sound source?	*We showed particles near the sound source.* *The particles get hit by the tuning fork.*
What ideas did we have for what happens to the particles when a sound source starts vibrating?	*Some particles might bump into other particles.* *Maybe some of them "bounce back" after they get hit.*

Use the ideas discussed above to establish the need to develop the students' models further by simulating what types of interactions we think are happening among the particles of matter.

8. Navigation

4 MIN

Materials: science notebook, *Self Assessment for Classroom Discussions*

Say, *Scientists often build computer simulations to help investigate and visualize outcomes in systems that have parts (or particles) in them that are too small to see. Computer simulations are programmed to have the objects and interactions that the user wants or needs. Think about what you would want to see included in such a computer simulation that would help you better understand how sound travels across a medium.*

Show slide H. Ask students to discuss the slide's questions in small groups and to record their ideas in their science notebooks to share out with the whole class during the next lesson.

Home Learning Opportunity

If time is short, students could answer the slide questions for home learning.

Suggested prompts	Sample student responses	Follow-up questions
What sort of things would you want to be able to adjust in that simulation about the motion of the sound source?	*We would want to be able to make sounds that have different amplitudes and different frequency, like the speaker in the truck.*	*If that is the case, how would you want the sound source to move to simulate sounds of different amplitudes and frequencies?*
What sort of particle interactions in the medium would need to be included in the simulation?	*We would need to have enough particles and particles close enough to one another so that they can hit each other to transfer the energy from each vibration.*	*Why would that be important?*
How might running a computer simulation that includes all the things you listed above help us better visualize and understand what exactly is traveling across the medium when a sound is produced from a sound source?	*A computer simulation would help us see the repeated vibrations of a sound source and the medium it travels through. When we used our bodies we could only transfer one vibration.*	*How else would using a computer simulation help deepen our understanding of how sound moves through a medium?*

Tell students we will continue to see how we can model the medium that sound travels through during the next class.

Assessment Opportunity

This is a great opportunity for students to self assess on their engagement in classroom discussions using *Self Assessment for Classroom Discussions*. This discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day.

SCIENCE LITERACY: READING COLLECTION 3

Sound and Media

1 **The Matter Matters**
2 **Breaking the Sound Barrier**
3 **The Acoustic Soundscape**
4 **Using Sound to Measure the World**
5 **Seismic Waves**

Literacy Objectives

✓ Distinguish cause(s) and effect(s) related to sounds traveling through different media that possess different properties.

✓ Organize related details about sound transmission through different media.

✓ Translate visual/graphic representations of information about sound to text.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 1–9.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an expository paragraph in response to the reading.

Instructional Resources

Student Reader

Collection 3

Science Literacy Student Reader, Collection 3
"Sound and Media"

Exercise Page

EP 3

Science Literacy Exercise Page
EP 3

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 6: How can any object make so many sounds?
- Lesson 7: What is actually moving from the sound source to the window?
- Lesson 8: Do we need air to hear sound?
- Lesson 9: How can we model sound traveling through a solid, liquid, or gas?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS4.A Wave Properties: A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

Science and Engineering Practice(s): Analyzing and Interpreting Data

Crosscutting Concept(s): Patterns; Cause and Effect; Scale, Proportion, and Quantity

CCSS

English Language Arts

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently.

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Math

MP.2: Reason abstractly and quantitatively.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

medium

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

acoustic	**acoustic soundscape**	
geosphere	**hydrosphere**	**seismic**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading collection relates to topics they are presently exploring in their Sound Waves unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - How sound moves or whether it moves at all depends on the type of matter it moves through, or the medium. There are general characteristics of solids, liquids, and gases in terms of how sound waves travel through them, and then there are specific properties of certain types of solids, liquids, and gases that further affect sound transmission.
  - Ask for consideration, but don't discuss or answer: *If a tree falls in a forest and no person is there to hear it, does it make a sound?* This question is alluded to in the first section of the reading selection.
- Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this exercise, you'll write a paragraph to summarize data. Your summary will explain how media affect sound transmission.*
- Distribute Exercise Page 3.

Exercise Page

EP 3

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the selection first to see the titles, section headers, graphics, and images to see what the selection is going to be about before fully reading.*
  - *Next, "cold read" the selection without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selection to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

(Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What is one property of a sound wave that is affected by differences in the matter the sound travels through?	*its speed*
What does seismic *mean?*	*It refers to earthquakes or waves traveling through Earth's crust.*
What is the Mach scale, and what does Mach 2 *mean?*	*The Mach scale is used to describe high speeds. Mach 2 is twice the speed of sound (in Earth's atmosphere).*
How can you make a rough determination of how far away a lightning strike occurs?	*by counting the number of seconds between the flash of lightning and the sound of thunder and dividing that number by five*

Ask a few brief discussion questions related to the reading that will help students tie the text content back to students' classroom investigations.

Suggested prompts	Sample student responses
Does sound need air as a medium?	*Not necessarily, but it does require matter. Sound can also travel through liquids and solids.*
What does matter do to transmit sound?	*It vibrates.*
What do the brief collisions of particles in a medium do to the energy in sound waves?	*transfer the energy through or across the medium*

- Refer students to Exercise Page 3. Provide more specific guidance about expectations for students' deliverable due at the end of the week.
    - *The expectation for this exercise is that you will write a paragraph that summarizes how sound waves move through different media.*
    - *That means summarizing the information in the reading, not information you might have acquired in the lessons or from other sources.*
    - *Be sure to pay close attention to the data presented in the reading selections, including those presented in tables and diagrams as well as data embedded in text.*
    - *You will choose from one of four topic sentences already provided. Don't worry about trying to capture all of the information from the reading selections in your summary paragraph. Focus on the key points and the general patterns related to the topic sentence that you choose.*

Exercise Page

EP 3

- *The important criteria for your work are that you accurately summarize what you have learned and organize the facts in a logical way.*

- Remind students that a well-constructed paragraph begins with a topic sentence. Major supports buttress the topic sentence; minor supports buttress the major supports. Major and minor supports are comprised of factual details from the reading. A concluding sentence should essentially paraphrase the topic sentence.
- Answer any questions students may have relative to the exercise expectations or the reading content.

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the readings and writing exercise. Students begin the reading activity by seeing collected data related to how sound waves travel through various media.

Pages 26–31 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "The Matter Matters"?	*It provides data about the speed of sound in different types of matter.*
What does the quantitative data in the selection show?	*Sound moves at different speeds, not just through the different states of matter, but through specifically different types of solids and liquids.*
How can the speed of sound waves vary in a single type of matter?	*Temperature and altitude affect the speed at which sound can travel in air.*
Take a look at the wind diagram on page 27. What is likely to happen to a sound that is being projected toward you if the wind is blowing toward the source of the sound? How do you think it will affect what you hear?	*The sound will be refracted upward.* *I probably would not hear the sound as well or maybe not hear it at all.*
What is the general purpose of the second selection, "Breaking the Sound Barrier"?	*It provides information about objects that can move faster than the speed of sound.*
What is the general purpose of the third selection, "The Acoustic Soundscape"?	*It tells about how objects can affect the sound quality in an environment.*
How does information in the second and third selections build on knowledge you gained from the first selection?	*Sound waves are variable. Several factors affect the speed and direction of sound waves, which, in turn, affect the sound you hear.* *When sound waves encounter a different medium or an area of the same medium that has different properties, they can be absorbed/stopped, they can refract/bend, or they can reflect/bounce.*

Student Reader

Collection 3

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and invite confident students to clarify, but summarize with concise explanation.

CHALLENGE—Students might recognize the equation in the first article, for calculating the speed of sound from the bulk modulus and the density of the medium, as it is similar to the equation that appears in the first reading selection for calculating a tonewood's ability to resonate. Consider putting those equations side by side and discussing their similarities. The term *modulus* means a constant factor or ratio. Bulk modulus and modulus of elasticity are similar.

The last two articles in this week's reading selection reveal a meeting of science and technology—how knowing the speed at which sound travels through various media makes it useful for measurement and subsequently for imaging.

Pages 32–35 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth selection, "Using Sound to Measure the World"?	*It explains how sound can be used to roughly measure how far away a lightning strike happens.* *And, it explains how sonar can measure distances underwater that make it possible to produce images of the seafloor.*
What is the general purpose of the final selection, "Seismic Waves"?	*It explains about waves moving through Earth's crust.*
The information you read in the fifth selection builds on the knowledge you gained from the previous selections. Specifically, how is it possible to use compression waves moving through Earth to determine characteristics of underground features that can't be seen?	*Because sound travels at different speeds through different materials—and because it is possible to transmit sound and receive sound that bounces back—it is therefore possible to tell where the medium that the sound is traveling through changes from one material to another.* *Plotting points to represent where all the changes occur reveals a shape.*

5. Check for understanding.

Evaluate and Provide Feedback

For Science Literacy Exercise 3, students should write a well-constructed paragraph to summarize how sound waves transmit differently through different media. Students' summaries of the reading selection should be organized around the general patterns of how sounds travel through different media, mentioning solids, liquids, and gases. They may also incorporate that sounds can be blocked, absorbed, reflected, and refracted when the medium changes, either in its phase or in some other property, such as temperature and density.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 10

What exactly is traveling across the medium?

Previous Lesson

We recalled that models of all states of matter have particles, empty space, and motion. We simulated what happens in the surrounding matter as a vibrating object is interacting with it. This model suggested that motion (or energy) might be transferred through the medium from one place to another through particle collisions.

This Lesson

Investigation

2 DAYS

We run a computational simulation exploring how particle collisions propagate across a medium from a vibrating sound source. Our investigations help us develop models for the nature of the wave traveling across the medium, including a particle density model with bands of dense and less-dense batches of matter and the direction of energy transfer across the medium, for different amplitude and frequency sound vibrations of the sound source.

Next Lesson

We will consider all we've learned so far and work in small groups to develop a model to explain a new phenomenon: salt jumping on plastic wrap stretched over a bowl when a drum is hit. We will summarize in a checklist the key ideas for explaining this phenomenon, then apply that checklist to revising the model of the truck speaker and window phenomenon.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Apply mathematical concepts to make sense of data generated from a model to test ideas about how changing the frequency and amplitude of the sound source affects the patterns in the wavelengths and compression of particles as energy moves across the system.

What Students Will Figure Out

- When an object moves back and forth, it produces bands of compressed and expanded particles that move through the medium (bands of compression travel, but particles do not).
- The density of particle compression gets greater when the amplitude of vibration at the sound source increases.
- The distance between compression bands appears to change when we change the frequency of vibration.
- Collisions between the particles in the medium result in these compression bands moving away from a sound source.
- The collisions transfer energy across the medium.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION: ADD TO OUR LESSON 9 PROGRESS TRACKER** Students independently add what they have figured out (from Lesson 9) to their Progress Trackers.	A	
2	5 min	**NAVIGATION: SHARING INITIAL IDEAS DISCUSSION** Students look back at their responses to the "Next Steps" questions from the end of Lesson 9. Students volunteer to share their responses.	B	
3	10 min	**MAP REPRESENTATIONS FOR THE VISUALIZING SOUND SIMULATION** Students consider how representations in the simulation map to the real world, and they make predictions about what they think will happen to the particles of the medium.	C-E	*Visualizing Sound Analogy Map*
4	20 min	**INVESTIGATE: GATHER EVIDENCE FROM THE VISUALIZING SOUND IN A MEDIUM SIMULATION** Students use the simulation to investigate what happens to particles in a medium when they are pushed by a vibrating object.	F-J	*Visualizing Sound in a Medium Investigations*, https://openscied.org/sound-in-a-medium/simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
5	10 min	**NAVIGATION: WHAT ARE WE SEEING IN OUR SIMULATION?** Students share what they are seeing and summarize what is happening to particles in the medium.	K	*Visualizing Sound in a Medium Investigations*
				End of day 1
6	3 min	**NAVIGATION: WHAT DID WE SEE IN OUR SIMULATION?** Ask a few students who didn't share their findings in the previous class to share now.	L	*Visualizing Sound in a Medium Investigations*
7	27 min	**MAKE SENSE OF OUR SOUND SIMULATION OBSERVATIONS** Pull students together to discuss findings from the Visualizing Sound in a Medium simulation.	M	*Analyzing Sound in a Medium Simulation Data*
8	8 min	**ADD TO OUR PROGRESS TRACKER**	N	*Progress Tracker*
9	7 min	**NAVIGATION: CAN WE EXPLAIN OTHER THINGS WITH OUR MODEL?** Students start to think about how the simulation lets them explain other things, like being able to hear underwater and how the truck speaker might be able to shake the window.	O, P	
				End of day 2

Lesson 10 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Visualizing Sound Analogy Map* • *Visualizing Sound in a Medium Investigations* • simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Analyzing Sound in a Medium Simulation Data* • *Progress Tracker*		

Materials preparation (15 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the simulation by following the directions in *Visualizing Sound in a Medium Investigations* for loading the simulation in a web browser. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Make sure to test the simulation on student devices. Each group will need two devices (for investigation 2) in order to run two simulations simultaneously, so make sure you have enough devices. Students can either have their own device for investigation 1 and then pair up for investigation 2 or work in pairs on investigation 1 and combine pairs into groups of four for investigation 2.

Lesson 10 • Where We Are Going and NOT Going

We established in the last lesson that the particulate nature of matter is key in understanding how sound moves across a medium. In this lesson students will see the simulated motion of particles of a medium transferring energy across matter.

The simulation is simplified compared to what might be seen in air molecules or water molecules. But the key idea the interactive conveys is accurate. Particles collide with one another, transfer their energy to other particles, and ultimately spring back. If you were to watch a single air molecule, you would see it move back and forth in space as a sound wave passes through.

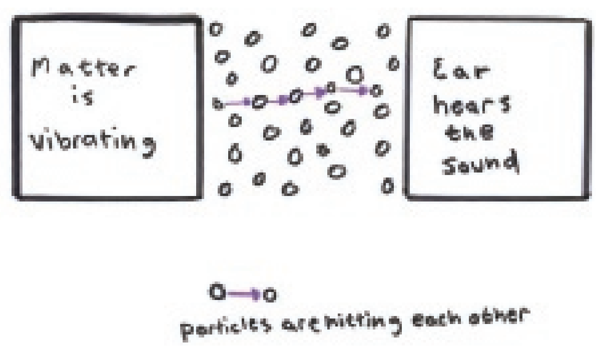
We have addressed several common student ideas already. For example, we have established that sound is not the result of air moving across the room. The task for this lesson is to help students develop a model of what *is* traveling across the room. The simulation is helpful in that regard, but students will typically require a good deal of assistance in making sense of the simulation. Take time to make sure students understand what each part of the simulation represents. And make sure that students have time to grasp the importance of the motion of the particles in the medium.

LEARNING PLAN FOR LESSON 10

1. Navigation: Add to our lesson 9 progress tracker. 5 MIN

Materials: science notebook

Add key ideas to the Progress Tracker. Display **slide A.** Direct students to draw a line underneath the work they did last class in their 2-column Progress Tracker. The headings are still the same: “Question” and “What I Figured Out.” Give students about 3 minutes to independently record their findings from Lesson 9 in their Progress Trackers.

Question	What I figured out
How can we model sound traveling through a solid, liquid, or gas?	• Solids, liquids, and gases are made of particles that are spaced out differently depending on the state of matter. • Particles can collide with other particles in a gas and bump into neighboring particles in a solid or a liquid and transfer energy. • If a push is transferred into the particles at one end of the medium (any state of matter that sound travels through), it might result in a series of collisions between neighboring bands of particles across the medium. 

2. Navigation: Sharing Initial Ideas Discussion 5 MIN

Materials: science notebook

Begin with an Initial Ideas Discussion. Have students look back at their responses to the Navigation questions from the end of Lesson 9. To help connect the use of the simulation to the student questions, ask a few students to read some of the DQB questions around sound traveling. During the discussion, project the Lesson 9 Navigation questions using **slide B**. Ask for some volunteers to share out their responses.

Key Ideas

Purpose for discussion: The purpose of this Initial Ideas Discussion is to make sure that students feel motivated to use the simulation. That is, this discussion helps ensure that students believe that the simulation will help them answer their own questions. It should also make the simulation less abstract and more meaningful for students. Be sure the students are generating ideas regarding what the simulation needs to be useful. They should not just be told why the simulation is useful from the teacher's perspective.

Listen for these ideas:

- Changing the amplitude and frequency of the sound (so being able to change the loudness and pitch of the sound produced)
- Closely spaced particles throughout the medium
- Particle movement and collisions

Say, *Using what we wrote in our Progress Trackers, let's remind ourselves of what we would want in a simulation to help us figure out what is actually traveling across the medium when sound is produced.*

Suggested prompts	Sample student responses
Who can read a few questions from our DQB that are about how sound travels?	*Accept all responses. Questions might include those similar to the examples below:* – *Is sound made of particles?* – *How can we hear something far away?* – *Are there certain molecules that carry sounds to our ears?* – *How does the sound travel through the air?*
At the end of the last lesson, your group brainstormed things you would want to see included in a computer simulation to help us better understand how sound travels across a medium. Let's share some of those. What sort of things would you want to be able to adjust about the motion of the sound source in that simulation?	*We want to be able to adjust the frequency and amplitude of the sound source.*
What kinds of things might we want to see about the particles?	*We want to be able to see particles colliding with each other.*
How might running a computer simulation help us better visualize and understand what exactly is traveling across the medium when a sound is produced from a sound source?	*We could see how all the particles are moving, and we could pause it (like freeze frame) or see it in slow motion.*

3. Map representations for the Visualizing Sound simulation.

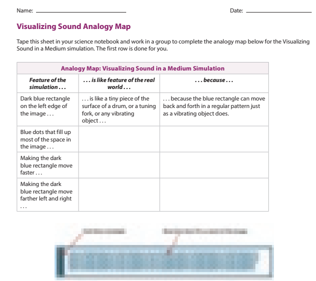
10 MIN

Materials: science notebook, *Visualizing Sound Analogy Map*

Share static images of the simulation representations with the class.

Tell students, *We have a computer simulation available to use, but we need to make sure we understand what the simulation represents and that it does what we want it to do.*

Project **slide C.** Point out to students that we can imagine a tiny piece of any object that is vibrating and the space immediately around it. Make sure to tell them that when they use the simulation, the dark blue rectangle on the left in the simulation will move back and forth just as a tiny piece of any vibrating object would move back and forth.



Name: ______________ Date: ______________

Visualizing Sound Analogy Map

Tape this sheet in your science notebook and work in a group to complete the analogy map below for the Visualizing Sound in a Medium simulation. The first row is done for you.

Analogy Map: Visualizing Sound in a Medium Simulation		
Feature of the simulation . . .	***. . . is like feature of the real world . . .***	***. . . because . . .***
Dark blue rectangle on the left edge of the image . . .	. . . is like a tiny piece of the surface of a drum, or a tuning fork, or any vibrating object . . .	. . . because the blue rectangle can move back and forth in a regular pattern just as a vibrating object does.
Blue dots that fill up most of the space in the image . . .		
Making the dark blue rectangle move faster . . .		
Making the dark blue rectangle move farther left and right . . .		

Project **slide D.** Ask students what is different about this representation. Students can see the same image, but this time there are blue dots in the space next to the vibrating object. Tell students they will explain what these dots represent as they complete the *Visualizing Sound Analogy Map*. Distribute the *Visualizing Sound Analogy Map* to students and ask them to tape it into their science notebooks.*

Students complete the *Visualizing Sound Analogy Map*. Present **slide E.** Walk students through the example in the first row of the handout, then ask students to work in groups to complete the *Visualizing Sound Analogy Map*. Move around the room and listen for evidence that students are making connections between the static images in the simulation and the real world.

Suggested prompts	Sample student responses
What connections are you making between the simulation and the real word?	*It says the dark blue rectangle is like the vibrating object, and the slide showed there was space around the drum and the tuning fork. So these blue dots must be the air.* *The space around could be air or water or whatever the sound is going through.* *The simulation is like the real world because the dots look like particles, and we know that air is made up of particles of gas.*
In the third row, what is it like if we make the dark blue rectangle move faster?	*Changing the speed of the dark blue rectangle would be like changing the frequency of the sound source. Remember when we used the coffee stirrers and made them wiggle faster? That was a higher pitch and higher frequency.*

***Supporting Students in Engaging in Developing and Using Models**

As students complete their analogy maps, they articulate clearly how various elements of the simulation represent elements from the real world, some of which are unobservable, that are part of students' emerging explanation for how sounds travel. In the next several steps of the lesson, students will use this simulation to describe the unobservable mechanisms that allow for the transfer of energy from a sound source across a medium.

Students will also change inputs of the simulation (frequency and amplitude) to collect data on what changes in the model for how energy is transferred across the medium when the sound source is producing sounds of different loudness and pitch. Patterns students notice in these data lead them to describe the amplitude and frequency of sound waves in terms of the physical orientation of particles in the medium as those sound waves are propagating through the medium.

4. Investigate: Gather evidence from the Visualizing Sound in a Medium simulation. 20 MIN

Materials: science notebook, *Visualizing Sound in a Medium Investigations,* simulation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

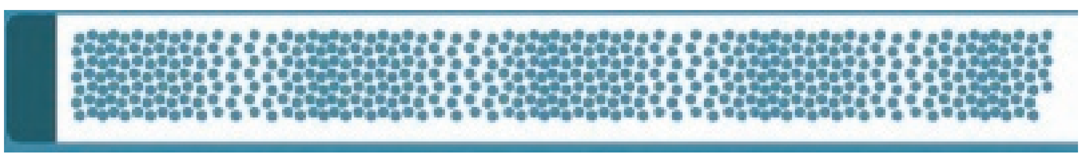
Students make predictions about particle movement. Present **slide F.** Distribute *Visualizing Sound in a Medium Investigations* and ask students to respond in their science notebooks to the questions in part 1, making predictions about what they will see when they run the simulation. If students are struggling, remind them of the activity from the previous class (using our bodies to represent particle collisions moving across the room) and see if they can predict what the dots would do (imagining they are people bumping into one another).

Project **slide G.** If needed, divide students into pairs or small groups, depending on the number of devices you have available to play the simulation. Students will follow directions from *Visualizing Sound in a Medium Investigations* Parts 2 and 3 to complete two investigations. Establish check-in points after various steps to ensure all students successfully complete the simulation.

Setting up the simulation. Move around the room to make sure students don't have trouble linking to the simulation. Check that all student groups are able to play the simulation on *Visualizing Sound in a Medium Investigations.* Encourage students to help one another so that all students can access the simulation.

Begin Investigation 1: What is happening at a spot in space in the medium? Present **slide H** and then **slide I.** Have students follow *Visualizing Sound in a Medium Investigations.* In investigation 1, students work with a single device and record their observations.

Begin Investigation 2: How will the patterns you see moving across the medium change?, working with two screens (two devices) at the same time. Present **slide J.** In investigation 2, students pair up (or two pairs of students join up) to run two different conditions simultaneously. Have students carry out their own procedures, modifying one of the simulations so it is different from the other, as they planned. Ask students to record their observations from *both* computers, noting differences in the patterns, in their notebooks. Students can modify the other variable if they choose (or modify the same variable in a new way).



5. Navigation: What are we seeing in our simulation? 10 MIN

Materials: science notebook, *Visualizing Sound in a Medium Investigations*

Students share patterns they see. Project **slide K.** Ask students from each group to share what variable they changed and what patterns they saw. Listen for student responses such as these:

Suggested prompts	Sample student responses
What variable did your group change first?	*We changed the loudness, or We changed the pitch.*
What patterns did you see when you changed that variable?	*There are bands of compressed and expanded particles traveling through the medium.* *The density of particle packing or compression gets higher when the loudness or amplitude of vibration at the sound source increases.* *The distance between compression bands appears to change when you change pitch, which changes the frequency of vibration.*

Home Learning Opportunity

Ask students to complete the "Making Sense" question on *Visualizing Sound in a Medium Investigations* as an exit ticket or home learning.

End of day 1

6. Navigation: What did we see in our simulation? 3 MIN

Materials: science notebook, *Visualizing Sound in a Medium Investigations*

Students share the patterns they saw in the previous class. Project **slide L**. Ask students who didn't share previously to share now. If everyone has already shared, ask a student or two to summarize the patterns they saw before.

7. Make sense of our sound simulation observations. 27 MIN

Materials: science notebook, *Analyzing Sound in a Medium Simulation Data*

Move to the Scientists Circle. Project **slide M** to show the three different frames of motion of the particles: *Start of the motion, Later,* and *After pausing source.* Pass out a copy of *Analyzing Sound in a Medium Simulation Data* to each student. The class will co-construct a representation of what happens to particles in a medium over time as sound travels through the medium. Have students bring their notebooks with *Analyzing Sound in a Medium Simulation Data* to the Scientists Circle.

Review the features of the simulation. Before discussing each individual image, engage students in a discussion related to the major features of the images.

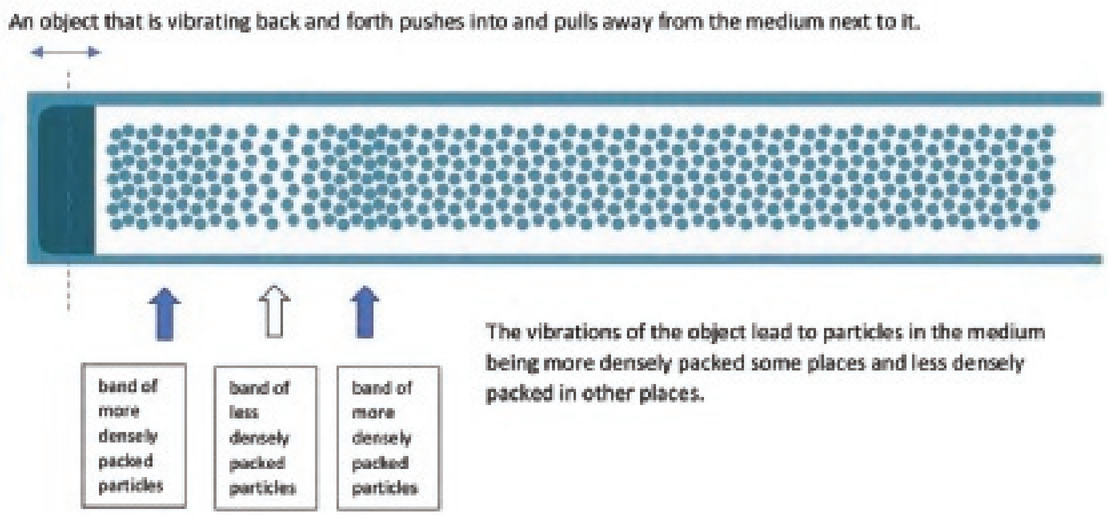
Say, *Before we discuss what is going on in our simulation let's take a minute to recall what each part of the simulation represents.*

Suggested prompts	Sample student responses
Can you remind me of what the different parts of the model represent and what happened when we ran the simulation?	*The dark blue rectangle is the sound source, and the blue dots are the particles that make up the medium that the sound is traveling through.* *We can use arrows to show energy transfer between particles.*
What are these darker bands showing?	*I think the darker bands are just where the particles are closer together. It just looks darker because there is less space between them and the space is a lighter color.*
So, you said the space is a light color and the particles are a dark color. What does that mean for these lighter-colored bands? What do they show?	*I think the lighter bands are just places where the particles are more spread out.*
OK, so we have places where the particles are close together and places where the particles are farther apart. How did they get that way?	*The dark blue rectangle on the end pushed the particles. It moved, it ran into them, and then it pushed them. Then they pushed the ones in front of them and so on.*
How did the particles get spread out again? Why didn't they just stay close together?	*The sound source moved back, so there was room for air to spread out again. And because everything is springy, even air or water, particles will spring back past the point where they came from. The air or water got pushed away from its normal spot, and then it bounced back further from where it started.*
So, the particles were going back and forth? You mean, they didn't just move all the way across?	*No, when we clicked to make one of the dots red, we could see it just went back and forth. It didn't move all the way across.*

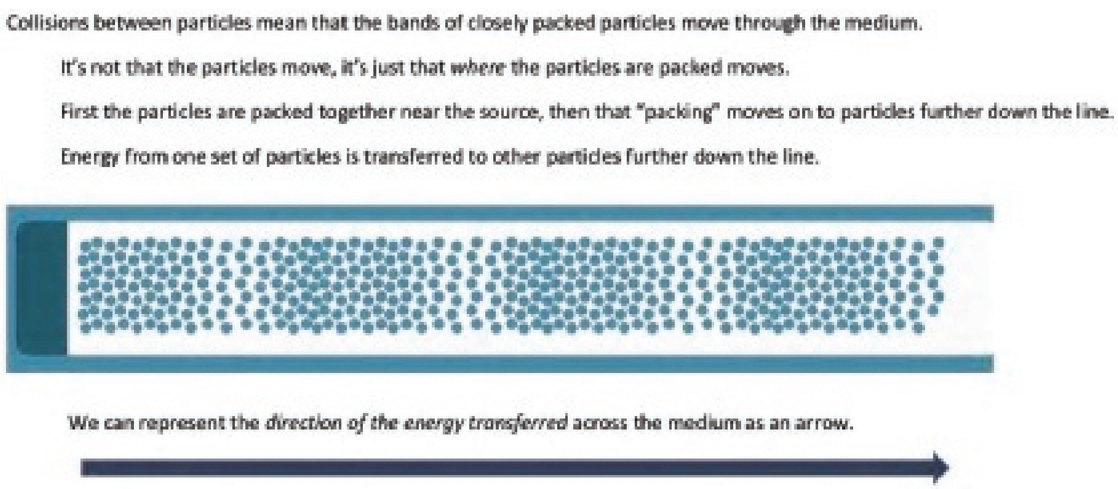
Discuss what is happening in each image. Engage students in a discussion about what is happening in frame 1 (Start of the motion). As you work, ask students to record the class ideas on *Analyzing Sound in a Medium Simulation Data*.

Suggested prompts	Sample student responses
Let's start with this first frame. What is happening with the sound source?	*It's vibrating.* *It's hitting the particles next to it when it vibrates.*
Is it only pushing?	*No, it pulls away from the particles, then it vibrates back past its starting point.*
OK, what do we notice and can label for what is happening to those particles?	*We see sections where the particles are all bunched up and then spread out again.*
Can you show me where you see that? What words can we use to describe those "bunchy and less bunchy" places?	*(Have a student point to different spaced bands of particles in frame 1).* *More dense?* *And less dense?*

Frame 1: Start of the motion



Frame 2: Later (source has been vibrating a while)



Review student language around compression waves. Help students note that the direction of the arrow (showing direction of energy transfer) is also the direction that the *compression wave* moves through the medium. It's clear from comparing the first and second image on your handout that the compression wave (what we call the areas of compressed particles and spread-out particles) has moved to the right (away from the source).

Suggested prompts	Sample student responses
So what is actually moving? What did you notice when you highlighted one dot?	*When we watched one dot we could see that it only moved back and forth–it didn't travel all the way to the sound detector.*
What does that mean for the bands of closely packed or dense particles?	*The bands move?* *The particles don't travel, it's just where the particles are packed that moves.*
Can we try to put into words what is happening after the sound source collides with the particles?	*The particles near the sound source get packed together.* *When they move back past their starting place they leave an area that is spaced out.* *Then they move back again and the "packed" parts move down the line in the medium.*
What do we know happens when one object collides with another?	*Energy is transferred.*
So if individual particles aren't traveling (they just move back and forth), what is happening?	*The energy is transferred from one particle to the next.*
How could we represent that?	
How are these bands different for higher amplitude or louder sounds? What about higher frequency?	*Maybe we could use an arrow?* *Can we add an arrow to show the energy transferred to our model?* *When the sound is louder or has higher amplitude, the bands are thicker but not any farther apart.* *When you have a higher pitched sound with higher frequency, the bands stay the same size but are closer together.*

Recognize that the difference in spacing between the bands is called *wavelength*. Point out that as students mentioned before, the distance between two neighboring compression bands (bands of high density) doesn't change. This might be easiest to see in frame 2. Students might have heard the term *wavelength* before. Here, it is the distance between the two most compressed parts of the medium. Tell students that this distance is another way that scientists describe characteristics of this type of wave. Show that the wavelength can be visualized as the distance from where the particle density is highest at one spot in the medium to the next spot where the particle density is highest.

Ask students to show you how the wavelength measured differently for high versus low frequency sounds and remained constant for loud versus soft sounds.

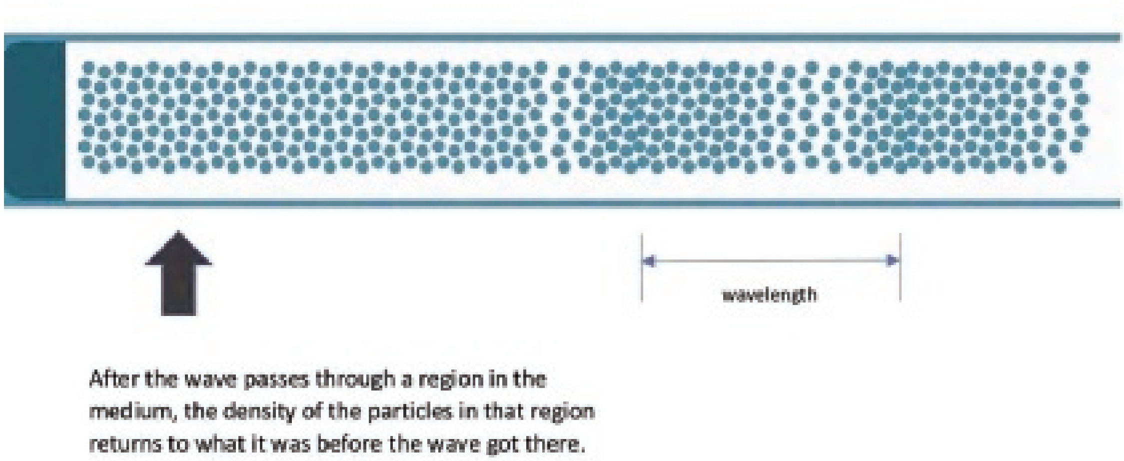
Additional Guidance

Wavelength is an emergent property of two things: the frequency of vibration of the source and the properties of the medium. Different media (e.g., oil and water) will exhibit different wavelengths for a vibrating object placed in them even if the frequency remains constant between the different media.

A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude, and a sound wave needs a medium through which it is transmitted. The *Framework* (NRC, 2012) says: "Sound is a pressure wave in air or any other material medium" (p. 131). Once students have evidence that sound needs a medium to travel through and they understand the compression wave pattern, then we can acknowledge that we can call this a *sound wave* because it has this repeating pattern through a medium.

At this point, come to a class consensus on the ideas of *wavelength* and *sound wave* and add a class definition for each on your class word wall. For example, "A sound wave is a compression wave of particles more densely packed together, and wavelength is how far it is between the compression waves in the medium."

Frame 3: After pausing source



Use frame 3 to help summarize ideas from your discussion. Say, *Let's use frame 3 to help us put all these pieces together.*

Do the bands really move? Emphasize that although it looks like the bands are moving, the movement is actually an optical illusion that comes from particles colliding with each other down the line. This movement shows that all matter is springy (up to a point).

Additional Guidance

Some students may want additional evidence that air is springy. One way to demonstrate the springiness of air is using an air-filled balloon. This object, however, may not convince students that it is the air in the balloon (and not the latex skin) that makes it springy. To address this argument, a glass syringe can provide stronger evidence. Take a glass syringe with air in it and set the plunger halfway into it. Then cover the opening with your finger. When you lightly pull or push on the top of the plunger, it will vibrate up and down for a bit. This doesn't work with plastic syringes due to the high friction between the walls of the syringe and the plunger.

Summarize the results of the analysis. Ask students to volunteer to recap the major points from each frame. You can record the key ideas on chart paper if they are not already recorded.

Suggested prompts	Sample student responses
Who can walk me through the major points we can take away from each frame?	*An object that is vibrating pushes into and pulls away from the medium next to it.* *This leads to a pattern of bands of densely packed particles and less-densely packed particles in the medium.*
How does energy flow in this system?	*Collisions between the particles in the medium result in the appearance of the bands moving away from a sound source.* *We can use little arrows on each side of a particle to show that the particle itself is not moving all the way to the sound.* *We can represent the direction that energy is transferred across the medium using an arrow.* *We can represent the direction that a compression wave moves across the medium using an arrow.*
How does the compression wave differ for loud versus soft and high pitch versus low pitch sounds?	*When the sound is louder (or has higher amplitude) the bands are thicker but not any farther apart.* *When you have a higher pitched sound (with higher frequency) the bands stay the same size but are closer together.*
Can someone explain how the patterns we see in the compression bands correlate to wavelength?	*We measured wavelength (distance between the bands) to be the same no matter what the amplitude or loudness of the sound BUT we found out that the wavelength changes based on the pitch of the sound and the frequency of the vibrations.*
So how would the wavelengths and compression of particles compare if we played a loud low pitch sound versus a loud high pitch sound?	*The loud low pitch sound would have compressed bands of particles that were the same size as the loud high pitch sound BUT the bands would be closer together and have a shorter wavelength for the loud high pitched sound.*

Alternate Activity

Some students may think that the wave that travels through the medium is a transverse wave rather than a longitudinal one. An additional NetLogo model (Sound Waves Through a Medium and Graph) can be used to demonstrate that a transverse wave is only a graphical representation that is an artifact of keeping track of particle density in a region in the medium over time. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

This model will plot a count of the number of particles in a rectangle in a medium as the model runs over time. Use this model if you wish to dig deeper into these different types of patterns in what is seen moving across the medium (a longitudinal wave) vs. what is happening at a single point or in a small region in the medium vs. time.

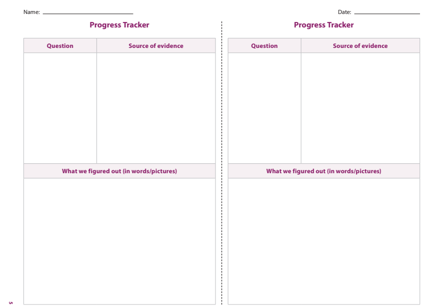
Online Resources

8. Add to our Progress Tracker.

8 MIN

Materials: science notebook, *Progress Tracker*

Students individually add consensus ideas to their Progress Trackers. Project **slide N.** Hand out *Progress Tracker.* Tell students that we have just spent a lot of time building understanding and then coming to consensus on what we think is happening when sound travels through a medium. Now, we are going to individually develop a model or some other representation for how what we figured out helps explain what happens to sound waves as they travel from the sound source to the sound detector.


Name: Date:

Progress Tracker	
Question	Source of evidence
What we figured out (in words/pictures)	

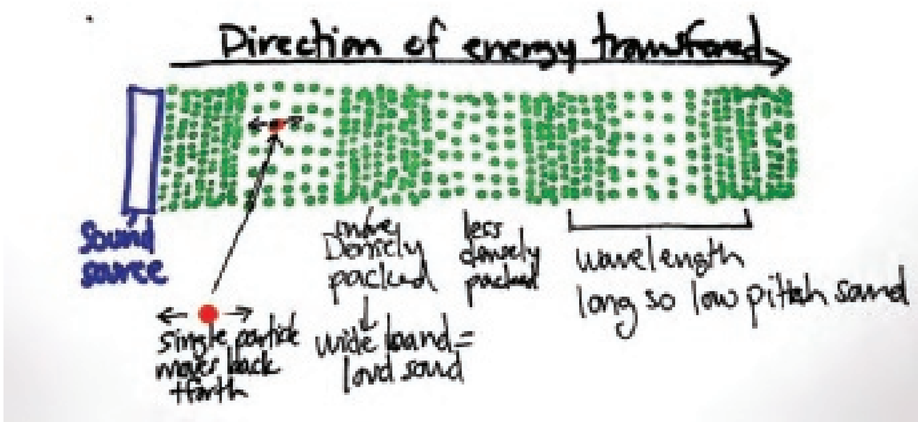
Progress Tracker	
Question	Source of evidence
What we figured out (in words/pictures)	

Have students add to their Progress Tracker along with the lesson question and source of evidence that led to these findings. Here is one representation of what students might write. See the list of ideas on the sample Progress Tracker below to help.

Question	Source of evidence
What exactly is traveling across the medium?	Visualizing Sound in a Medium simulation

What we figured out in words/pictures

- When an object moves back and forth, it produces bands of compressed and expanded particles that move through the medium (bands of compression travel, but particles do not).
- The density of particle compression gets greater when the amplitude of vibration at the sound source increases.
- The distance between compression bands appears to change when we change the frequency of vibration.
- Collisions between the particles in the medium result in compression bands moving away from a sound source.
- Collisions transfer energy across the medium.



9. Navigation: Can we explain other things with our model?

7 MIN

Materials: None

Apply what we learned to the truck speaker and the window. Project **slide O.** Remind students that when doing the practice of modeling, our models (like the ones we have been using) are most useful when we can use them to explain more things. Ask students to walk with you over to where you have your consensus model and DQB hanging in your room.

Say, *Let's take a few minutes to consider whether there are any more questions we can answer from our Driving Question Board or that we would like to refine or revise and if there are any questions we would like to pursue that we have yet to answer.*

Suggested prompts	Sample student responses	Follow-up questions
Are there any other questions we could explain using these ideas?	*We can now better explain what was happening when you hear a sound through water.* *I think we can explain why solid things sound different than hollow things.* *I wonder if we could go back and explain what makes the window shake when the truck speaker is playing.*	*Great idea! Why don't we see if we can apply our models to other phenomena and to the truck speaker and moving window!*
Are there any questions we would like to refine or revise?	*I want to revise my question about why you can hear yourself chew food, but I think I still need more information.*	*Sounds good. Can you say more?*

Suggested prompts	Sample student responses	Follow-up questions
What questions have we yet to answer?	*We still haven't been able to explain why different sounds can damage your ears.* *I still want to know why you can feel some sounds more than others.*	*Seems like we still have some more investigating to do as well as using our models to explain new phenomena!*

Additional Guidance

To support students in refining their questions and pursuing questions they have yet to answer, consider using questions similar to those below:

- What evidence is needed to answer your questions?
- How can we revise the question to make it investigable with available resources in the classroom?
- Explain how those questions will add information necessary for the model to adequately explain the phenomenon.

Let students know that we are going to see if we can use the ideas we have been developing to explain more about what is happening with the truck speaker and the window.

Play the video of the truck speaker and the window one more time, asking students to think about what they learned about sound moving through a medium while they watch the video.

Home Learning Opportunity

Project **slide P**. Assign the final question on the *Analyzing Sound in a Medium Simulation Data* handout to students as home learning. Use the ideas in this lesson to explain how music produced from a speaker in the truck caused the window in a building in the parking lot to move. Make a sketch of what is happening and be sure to include the following in your model: vibrations of the sound source, collisions between particles, energy transfer, and changes that happen in the particle density across the medium.

LESSON 11

How does sound make matter around us move?

Previous Lesson *We ran a computational simulation exploring how particle collisions propagate across a medium from a vibrating sound source. Our investigations helped us develop models for the nature of the wave traveling across the medium.*

This Lesson

Putting Pieces Together

2 DAYS

We take what we've learned from the unit thus far and, in small groups, develop a model to explain a new phenomenon: Salt on plastic wrap stretched over a bowl jumps up and down when a drum is hit. We summarize the key ideas we have developed that are useful for explaining this phenomenon. We write these ideas in a checklist, then apply the checklist to revising the model to explain why the window near the parking lot moved when the truck speaker was blasting music.

Next Lesson *Students will explore their unanswered questions regarding how our ears detect sounds by reading about the structures of the ear and watching videos and animations of those structures. Then they will annotate a model showing how energy is transferred through the ear to the nerve cells that send signals to the brain.*

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Develop and use a model to describe phenomena using unobservable mechanisms for how a sound source could cause vibrations that produce sounds, which cause particles of matter in the surrounding medium to be compressed and expanded, which then collide with neighbors to transfer energy across the medium, which results in movement of an object farther away.

What Students Will Figure Out

By the end of this lesson students figure out that when a sound source transfers energy through collisions to neighboring particles across a medium, those particles can collide with another object, making it vibrate.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Consider how related phenomena could help us answer the general question of how sounds are made and how they can cause other things to move.	A	
2	10 min	**CONSIDER THE PHENOMENON OF BOUNCING SALT** Observe a new phenomenon: Beating a drum can make salt on a nearby surface jump. Connect that phenomenon to our broader question.	B-C	
3	15 min	**DEVELOP GOTTA-HAVE-IT CHECKLIST** Students work in pairs using ideas from their Progress Trackers to create a Gotta-Have-It Checklist for explaining any sound being produced and moving something nearby.	D	*Gotta-Have-It Checklist*
4	15 min	**MODEL THE BOUNCING SALT USING THE GOTTA-HAVE-IT CHECKLIST** Work in small groups using the Gotta-Have-It Checklists to create a model of the drum sound causing the salt to bounce on the plastic covering the bowl.	E	*Gotta-Have-It Checklist*, chart paper (1 sheet per group)
				End of day 1
5	3 min	**FINISH MODELS OF BOUNCING SALT FROM LAST TIME** Groups complete the models they started in the previous class, then they display their models for a gallery walk.	F	*Gotta-Have-It Checklist*, each group's model on chart paper from day 1
6	10 min	**GALLERY WALK TO GIVE FEEDBACK FOR MODELS** Students share their models, give feedback to their classmates on their models, and consider feedback left on their own models.	G-H	sticky notes, *Peer Feedback Guidelines*, *Peer Feedback Self Assessment*, each group's bouncing salt model
7	15 min	**CONSENSUS DISCUSSION ABOUT HOW SOUND CAN MAKE SOMETHING MOVE** Students meet in a Scientists Circle to come to consensus about the key parts necessary in an explanation of how sound can make something move.	I	*Gotta-Have-It Checklist*, example bouncing salt model (chosen by teacher during the gallery walk)
8	15 min	**USE OUR CHECKLIST TO MODEL THE TRUCK SPEAKER AND WINDOW PHENOMENON** Use the Gotta-Have-It Checklist to revise initial models for how the truck speaker makes the window move.	J	*Gotta-Have-It Checklist*, *Revised Model*, *Lesson 11 Modeling Rubric*
				End of day 2

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Gotta-Have-It Checklist* • sticky notes • *Peer Feedback Guidelines* • *Peer Feedback Self Assessment* • science notebooks • *Revised Model*	• chart paper (1 sheet per group) • each group's model on chart paper from day 1	• each group's bouncing salt model • example bouncing salt model (chosen by teacher during the gallery walk) • *Lesson 11 Modeling Rubric*

Materials preparation (10 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If you do not have individual sheets of chart paper for each group, you will need to cut up one poster-sized piece of butcher paper for every 3-4 students.

Day 1: Salt and Drum Demonstration

- **Group size:** whole class
- **Setup**
  - *Stretch plastic wrap very tightly over the top of a large bowl. (The bowl can be any material, but plastic wrap holds tightest by itself to glass. If you use a bowl made of metal or another material, you may need to use tape or a rubber band to hold the plastic wrap tightly across the top.)*
  - *Sprinkle salt on the surface of the plastic wrap.*
  - *Test the drum-bowl demonstration by holding the drum near the bowl and striking it. The salt on the plastic wrap should jump with each beat of the drum.*
- **Notes for during the lab:** You may need to hit the drum quite hard with your hand and relatively close to the bowl to see movement.

Lesson 11 • Where We Are Going and NOT Going

Students can base this lesson's work on the model built in Lesson 3 of the deformation of the drum during vibration. They reason that it is the drum's motion that causes the particles around the drum to get pushed together (compressed).

Students will continue to develop the idea that the energy put into the system by louder sounds results in greater-amplitude vibrations, which results in greater particle density changes. This, in turn, transfers more energy through the wave, which results in a greater amount of energy moving the particles that eventually bump into the plastic wrap in this lesson's investigation.

Help students connect this to the idea that the particles don't move from the sound source to the plastic wrap—only the energy moves. That is the basic definition of a mechanical wave—a repeating pattern of motion where energy moves from point A to point B, but the matter itself does not. It simply moves back and forth.

LEARNING PLAN FOR LESSON 11

1. Navigation

5 MIN

Materials: science notebook

What have we been up to? Project **slide A**. Invite students to quickly flip through their science notebooks and find some of the phenomena we've investigated to this point. Briefly recall what we figured out from investigating those phenomena.

Suggested prompts	Sample student responses
How did we figure out how sounds are made in the first place?	*We hit or plucked instruments so they vibrate, which makes the sounds.* *We watched a speaker vibrate when it makes sounds.* *We dropped a rock on the table and saw that it vibrated, too (we could see the laser on the wall move).*
How did we figure out how different types of sounds are produced?	*We used our stick apparatus and motion detector to look at graphs of how an object moves when it makes sounds.* *We pushed the stick with more or less force, and its graphs had a higher or lower amplitude for louder or softer sounds.* *We used a shorter stick and a longer stick to see how different frequencies cause different pitches of notes.*
How did we figure out what sound needs to travel?	*We could hear a phone ringing inside a container, and we could hear rocks banging underwater, but we could not hear sounds when the phone was in a vacuum with all the air sucked out.* *So, we know sound needs a medium like air or water to move through (the particles get pushed and move back and forth).*

Navigate to today's new phenomena. Say, *We have lots of ideas related to our work of figuring out how the truck's speaker made the window shake. But, as scientists, we want to think bigger and connect the work we've done here in class to the world around us. Today we want to see if we can explain how any sound is caused and how sound can make something else move. So, I have a new phenomenon to show you.*

2. Consider the phenomenon of bouncing salt.

10 MIN

Materials: None

Introduce students to a new phenomenon. Display **slide B**. Gather students around the bowl with plastic wrap stretched across it and some salt on top. Hit the drum nearby with a forceful strike from a drumstick or your hand and invite students to strike the drum, as well. Ask students to describe and discuss what they see happening.

Suggested prompts	Sample student responses
What do you notice happening?	*The salt is jumping every time someone hits the drum. This is weird— the drum isn't even touching the bowl.*
Does the outcome change if you change how hard you hit the drum?	*The harder you hit the drum, the more the salt jumps.*
Do you think this is similar to what is happening in the video of the truck speaker making the window move? Why or why not?	*Yeah, it is kind of similar. The window is like the salt or the plastic wrap, and instead of a speaker there is a drum as a sound source. In both cases, there was some sound making something else nearby move.*

Discuss the task of answering a broader question. Tell students, *OK, now we have lots of phenomena related to our work of figuring out how the truck's speaker made the window shake. And we have this new phenomenon of the bouncing salt to consider. So, we want to put all these separate pieces of evidence together. Can we explain in general how sounds are caused and how they could make anything move? Can we design a model that would explain these broader ideas?* Display **slide C**. Facilitate a discussion to help students consider why designing a broader model would be valuable work (as opposed to only explaining how the speaker makes the window move).

Suggested prompts	Sample student responses
Why would it be helpful to have a model that answers this broader question of how sounds are created and how they can move things? *How would that model help us answer our questions about the truck speaker and the window phenomenon?*	*If we developed a general model that explains how any sounds are caused and how they can make anything move, it should apply to any phenomenon where something far away is moving because of sound that reaches it. The truck speaker and window would just be one case that we could apply our model to.*
Why might we need to consider more than just the truck speakers and the window phenomenon when we start trying to answer this bigger question?	*This question is a general one that applies to more than one example. So, we need multiple examples.*

Suggested prompts	Sample student responses
Who can explain another experience we've had like this, where we needed to use multiple examples to answer a broader question?	*When we wanted to model how instruments move when they are struck or plucked, we had to look at several different instruments, like a drum, a tuning fork, and a guitar string.* *We even investigated a table being hit by a rock to see if it moved like those instruments, so we had several examples of how solid objects vibrate when they make sounds.* *We could compare multiple instruments and other things that make sounds to develop a model for what is similar among all objects that vibrate.*
Could any of the related phenomena we listed at the beginning of our unit connect to a broader model of things that cause sounds or how sound can move things?	*Answers will vary depending on your class list of related phenomena; refer to your class's Related Phenomena poster as needed to generate ideas to consider.*

3. Develop Gotta-Have-It Checklist.

15 MIN

Materials: science notebook, *Gotta-Have-It Checklist*

Explain the task. Tell students, *We are going to make models to explain the bouncing salt phenomenon, but we're also trying to figure out how sounds are caused in general and how they can make things move, more than just the drum bouncing the salt or the truck speaker shaking the window. You have lots of important ideas about this in your Progress Trackers already, but some of them are the most important for explaining the answer to our question. Before we make our bouncing salt models, we need to decide which are the gotta-have-it parts of a model about how sound is caused and how it moves things.*

Distribute the *Gotta-Have-It Checklist* to each student to be taped or glued into their science notebooks. Use **slide D** to preview how to build the checklist in part 1 of the handout. Students will complete only the left column right now. They should leave the right columns blank for now.

Develop the checklist with a partner.* Explain that students are looking for the big ideas that will help explain the general question, "How does a sound source cause sound, and how can that sound then cause something else to move?" Students record their ideas on the *Gotta- Have-It Checklist* in part 1. They do not need to record all the model ideas from the Progress Tracker, only the ones they want to include to answer the question, "How are sounds caused, and how can they make something move?" Students should spend 8-10 minutes working with their partner.

*** Attending to Equity**
Try to take the time to plan partnerships rather than just telling the students, "Everyone find a partner to work with," which can take longer to get organized, leave students feeling excluded, and/or result in unproductive pairings. You could assign specific partners that you've chosen based on who will work well together (i.e., not the highest functioning students with the most in need of help, but those students who will be able to teach and learn from each other as a balanced team). Or, you could randomly choose partners for the students, which at least takes the social pressure off of them.

Alternate Activity

An alternative to doing the Gotta-Have-It Checklist using *Gotta-Have-It Checklist* is to construct the checklist together as a class with a public representation of the ideas the class agrees should be part of the model. If you make a modification to the current activity, keep in mind the following important components to make this activity a productive one:

- The process should be collaborative and involve students arguing from evidence for their ideas.
- There should be a public record, or artifact, of the ideas students agree to include in their models.

Facilitate a brief sharing of ideas. Do not let this discussion take too long or it will take away from students' time to work on the bouncing salt model. Plan to spend 3-5 minutes in discussion. It is fine if students are adding to or removing ideas from their own checklists during this discussion, but we're not trying to come to complete consensus at this point. The example student responses below are not a comprehensive list of all the ideas from the Progress Tracker.

Suggested prompts	Sample student responses
Which ideas did you include on your checklist?	*We do need the idea that the sound source moves back and forth or vibrates past its original starting position for a while.*
Why did you think those were most important?	
What is an example of an idea you had in your Progress Tracker but left off of your Gotta-Have-It Checklist? *Why?*	*We really don't need anything about how other instruments, like the guitar, make sounds for this explanation. We want this explanation to be more general and to apply to all sound makers.*

4. Model the bouncing salt using the Gotta-Have-It Checklist.

15 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, chart paper (1 sheet per group)

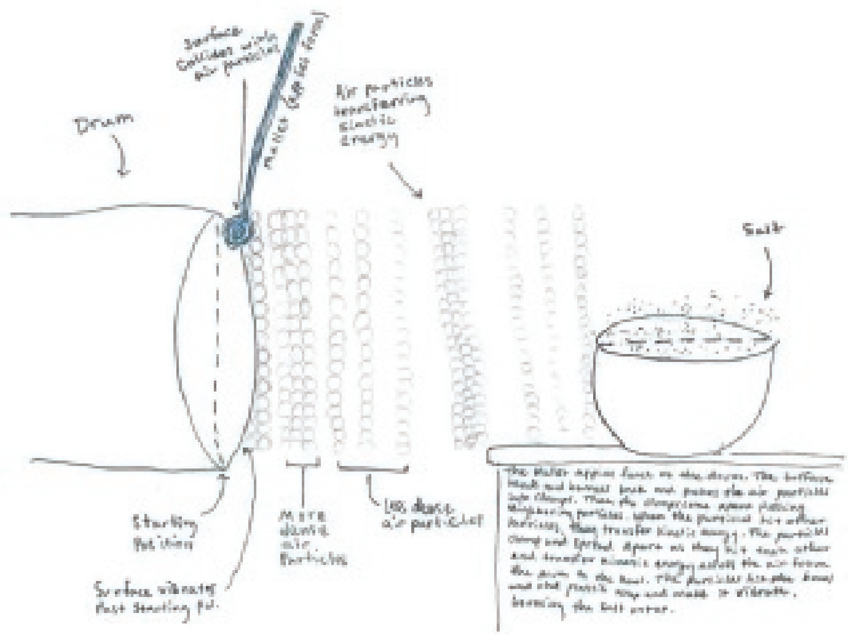
Students work on models in groups. Display **slide E**. Instruct students to work in groups (of no more than four students) to follow the directions in part 2 of the handout *Gotta-Have-It Checklist*. They should use their checklist to create a model to explain the answer to the question, "How did hitting the drum cause it to make a sound, and how did that sound cause the salt to move?" As they use or don't use ideas from the checklist to create their models, have students check off those ideas in the appropriate column on their checklists. At the end of today's class period, ask students to pause in their work and plan to spend a little more time on it next time you meet; it is not expected that they'll be completely finished today.

Additional Guidance

Encourage students to use markers or colored pencils for their models in order to help them communicate their ideas more clearly.

If students need help getting started, direct them back to the model they made in *How do instruments move when making sounds (vibrating)?* from Lesson 2 as a starting point.

Here is an example model for the question, "How did hitting the drum cause it to make a sound, and how did that sound cause the salt to move?"



End of day 1

5. Finish models of bouncing salt from last time.

5 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, each group's model on chart paper from day 1

Student groups finish their models. Display **slide F**. Students gather in the same groups as last time and spend about 5 more minutes completing their models. While students work, take time to circulate around the room and provide feedback as needed. As groups finish, have them post their models on the walls around the room.

Additional Guidance

One way you can provide feedback while you're looking at the students' models is to say something like, *I noticed (x). That made me wonder (y)*, where x and y are things that you want to provide guidance about. For example, *I noticed here that your sound source appears to be still. That made me wonder if you can show how the sound source moves. Would you tell me more about that part?*

6. Gallery walk to Give Feedback for Models

10 MIN

Materials: sticky notes, *Peer Feedback Guidelines*, *Peer Feedback Self Assessment*, each group's bouncing salt model

Students view and give feedback on one another's models. * After students put their models up around the room, invite them to do a short gallery walk to view one another's work. Have students write questions or comments on sticky notes to add to the models as they walk around. Spend about 7 minutes having students review models and give feedback (it will not be enough time for everyone to get to every model, but students should be able to provide useful feedback on a few). Remind students of the peer feedback guidelines (*Peer Feedback Guidelines*) and use **slide G** to provide students with ideas about what to say or write, also listed here:

Your feedback should give ideas for specific changes or additions the group could make to improve their model. For example ...

- The part where you said / showed _______________ is not very clear to me. You could help me understand your thinking better by _________________.
- Your model said / showed ________________. I disagree because _________________. I think you should change ____________________.
- I notice that your model seems to be missing _________________. It would be more complete if you added ____________________.
- You showed / explained ___________________ really well. Please share that with the whole class during discussion.

Choose a model to use during the following Consensus Discussion. During the gallery walk, evaluate the group's models and choose one that clearly incorporates the most pieces of the Gotta-Have-It Checklist. You will use this model to lead the Consensus Discussion after peer feedback is complete.

Review peer feedback. Tell groups to go back to their original models and spend about 3 minutes reviewing the feedback left by their peers. Display **slide H** for reminders about receiving feedback, also listed below. Explain, *We use peer feedback to improve our work, making it more clear, more accurate, and better supported by evidence. When you receive feedback, you should take these steps:*

- *With your group, read your feedback carefully. Ask someone else to help you understand it, if needed.*
- *Decide if you agree or disagree with the feedback and talk with your group about why you agree or disagree.*
- *Revise your work to address the feedback.*

*** Supporting Students in Engaging in Argument from Evidence**

Peer Feedback Guidelines supports students' ability to provide productive and respectful critiques about their models. Depending on your students' familiarity with providing productive feedback, you may want to spend additional time reminding students of the key features and examples of productive feedback. This also provides a good opportunity for students to self assess using *Peer Feedback Self Assessment*.

Additional Guidance

During or after today's work, you may choose to take a photo of each group's model and/or the example model you discussed in class, then print those photos for the students to tape into their science notebooks. A smaller copy there would serve as a good record of the group's work for reference later and might allow you to better manage the wall space you have for displaying multiple models from multiple classes.

7. Consensus Discussion about How Sound Can Make Something Move

15 MIN

Materials: science notebooks, *Gotta-Have-It Checklist*, example bouncing salt model (chosen by teacher during the gallery walk)

Facilitate a Consensus Discussion around key aspects of the model.* Gather in a Scientists Circle with science notebooks and Gotta-Have-It Checklists in hand. Display the student model you selected during the gallery walk where everyone can see it. The goal of this discussion is to put pieces together about what we've figured out throughout our investigations. The class should now be able to explain all parts of a complete model that describes how hitting the drum moves the drum and how that action affects the particles of the air in between the drum and the plastic wrap. As you discuss, work together as a class to record all the Gotta-Have-It Checklist items in a public place, such as on chart paper, in a Google document, or on **slide I.**

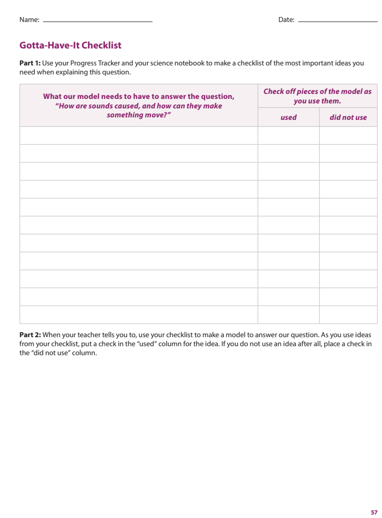
* Strategies for this Consensus Discussion

Remind students that the purpose of the discussion is to come to agreement about this model, trying to resolve lingering questions or disagreement. Students' jobs are to place ideas on the table, clarify other students' perspectives, and evaluate their own ideas and the ideas of others.

Additional Guidance

Consider delegating a student recorder to list the items on the class Gotta-Have-It Checklist, so that you are available to facilitate discussion while referring to the example model.

Be sure to use the wording your students come up with for each Gotta-Have-It Checklist item. *Key for Gotta-Have-It Checklist* is provided just for reference.



Name: ______________ Date: ______________

Gotta-Have-It Checklist

Part 1: Use your Progress Tracker and your science notebook to make a checklist of the most important ideas you need when explaining this question.

What our model needs to have to answer the question, *"How are sounds caused, and how can they make something move?"*	*Check off pieces of the model as you use them.*	
	used	*did not use*

Part 2: When your teacher tells you to, use your checklist to make a model to answer our question. As you use ideas from your checklist, put a check in the "used" column for the idea. If you do not use an idea after all, place a check in the "did not use" column.

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Key Ideas

Purpose of this discussion: Find agreement about the critical pieces of a model explaining how sound is caused, how it travels, and how it can make something else move.

Listen for these ideas:

- The original energy put into the system is from a hand holding a drumstick and pushing it into the drum. That's the same energy that moves the salt.
- Energy is being transferred from the drum to the salt, but the physical matter of the drum and the particles between the drum and the salt do not move along that same path (they do not ultimately change place or position).
- The amount of deformation to the amount of force applied affects the amplitude of vibrations at the sound source. This, in turn, affects the density changes in the particles in the medium, which affects how much energy is transferred across the medium.

Suggested prompts	Sample student responses	Follow-up questions
Take a look at this group's model. What do we need to show first, here at the sound source?	*The force of hitting the drum is first.*	*So how should we list that first step on our Gotta-Have-It Checklist?*
Why does that piece have to be there at the beginning?	*That's where the energy comes from to make the sound.*	
Does it matter how much force we apply to the sound source?	*Yes, a bigger force will make the drum vibrate more.* *Yes, the amount of force makes a louder or softer sound.*	*Why does more force make a louder sound?*
How does the force affect the sound source? Can we see that in this model?	*The object, in this case our drum, vibrates or moves back and forth past its starting position.* *The bigger the force, the larger the amplitude of the vibrations. Larger-amplitude vibrations make louder sounds.*	*Can we see that on our model?* *How should we add that vibration to our checklist?*
OK, let's just check in about something you mentioned last time. When we were talking about phenomena we've investigated already, you mentioned the frequency of the vibrations, too. Why don't we see frequency in this model?	*The pitch of the sound depends on the frequency of the vibrations.* *Since this drum is only making one pitch (playing the same note, no matter how loud or soft), the frequency of the vibrations in this model doesn't change.*	*Would it be important to mention frequency on our checklist, though?* *(Yes, let's add that the pitch of the sound depends on the frequency of the vibrations, because there are other sound sources that can change pitch.)*
Let's look at this model again. What happens around the sound source when it's vibrating?	*The drum disturbs the air particles as it pushes on them.* *The drum is transferring its energy to the air around it.*	*So what can we add to our checklist about those air particles?*
What do we see (or need to see) on this model to show how the sound moves across this space?	*The air particles are moving back and forth and push on other particles.* *They bunch up and spread out.*	*Tell us more about how the particles are moving.*
How did this model (or how could this model) show that energy moving?	*When the particles push on each other, they transfer their energy to each other.* *The particles themselves do not move all the way between the drum and the plastic, though. They go back to their starting position. Just the energy is moving all the way across.*	*Let's make sure we have each of those ideas about how the particles move listed on our checklist.*
How does the sound detector move, then? What does our example model show about the plastic wrap on the bowl and the salt?	*The air particles push into the plastic wrap, so it moves, too.* *The salt bounces because the air particles are bumping and pushing the plastic that's holding the salt.*	*OK, so we need something on our checklist about how and why the detector moves.*
Why doesn't the salt continue to bounce? Why does it stop?	*It stops because the sound stopped.* *The sound source isn't vibrating anymore, so it isn't moving the air anymore.* *The detector will only move for as long as the air particles push on it. When the sound source stops pushing the air, everything goes back to its starting position.*	*Let's make sure we note why it stops on our checklist, too.*

8. Use our checklist to model the truck speaker and window phenomenon. 15 MIN

Materials: science notebook, *Gotta-Have-It Checklist*, *Revised Model*, *Lesson 11 Modeling Rubric*

Direct students to create a new model of the truck speaker and window phenomenon. Say, *Our next step is to take our Gotta-Have-It Checklist and apply it to a model you make explaining how the truck speaker made the window shake. We all agree the items on our list need to be in a model about how sounds are created and how they can move other things, so your model must include everything on this list. This is an important chance for us as a class to see whether the ideas we developed will work well for explaining the truck speaker and window phenomenon. But, it is also an excellent individual assessment for you and me to evaluate your own understanding of the ideas we have developed together so far as a class.*

Display **slide J**. Provide students with *Revised Model* to create a revised model of the truck speaker and window phenomenon. Collect the models when students are finished and assess them using the *Lesson 11 Modeling Rubric*.

Assessment Opportunity

Clearly, this model is a critical assessment of whether students have put together the pieces of this unit so far and are able to explain them in words and pictures. The students have their Gotta-Have-It Checklist to use as a guide for modeling, but you should use the *Lesson 11 Modeling Rubric* to evaluate each student's model and provide timely feedback about what they're doing well and what they may still be missing.

LESSON 12

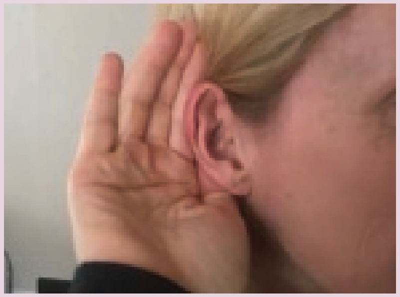
What goes on in people's ears so they can detect certain sounds?

Previous Lesson *We took stock of what we've learned thus far and in small groups developed a model to explain a new phenomenon: salt jumping on plastic wrap stretched over a bowl when a drum is hit. We summarized in a checklist the key ideas necessary for explaining this phenomenon, then applied this checklist when recreating our model and explanation for why the window shook when the truck speaker* was *blasting music.*

This Lesson

Investigation

1 DAY



Students have unanswered questions regarding how our ears detect sounds. So, they read an interview with experts and watch several videos and animations about the structures of the ear and how hearing loss can occur. Then, they synthesize that information to annotate a model showing how energy is transferred through the ear to the nerve cells that send signals to the brain.

Next Lesson *We will conduct an investigation to analyze how changing the amplitude or frequency of an object's vibrations changes the amount of energy transferred by that sound. From this investigation, we will conclude that increasing the vibration's amplitude or frequency increases the energy transferred by the sound. Furthermore, increases in amplitude have a greater effect on the energy transferred by a vibrating object than do increases in frequency.*

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Critically read scientific texts adapted for classroom use to determine the central ideas and obtain scientific information to describe patterns of how the structures in the ear interact with each other to transfer energy from the eardrum to fluid in the cochlea and to a series of sensory cells that move (more or less) in response to vibrations of particular frequencies, which send signals along different nerve cells to the brain.

What Students Will Figure Out

- Vibrations are transmitted from the eardrum to tiny bones in the ear and then to a structure called the cochlea.
- The cochlea contains fluid that transfers vibrations along the basilar membrane, which has different areas that correspond to where different-pitch sounds are detected.
- The vibrations bend hair cells and move their detectors (called stereocilia) more or less depending on the sound.
- Hair cells send signals to nerve cells that relay this information to the brain.
- Hearing loss is caused when one of the structures in the ear is damaged. This damage can be irreversible if the hair cells or their detectors, the stereocilia, are permanently damaged.

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Revisit our consensus model and DQB to determine today's work. Consider having students model their predictions of how the ear works to hear sounds.	A-D	optional: *Model Inside an Ear* if you choose the alternate prediction activity
2	5 min	**VIEW VIDEO OF EAR EXAM** Watch the video of an ear exam, then discuss noticings and wonderings.	E	video of an otoscope ear exam (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	12 min	**READING ABOUT HOW WE HEAR** Read an interview with an ENT and a neurobiologist which includes several links to videos and animations.	F	*Lesson 12 Activity Sheet* in hard copy, computer and headphones, *Information from the Experts* shared digitally
4	15 min	**SYNTHESIZING WHAT WE'VE LEARNED ABOUT THE EAR** Discuss key ideas from the reading and links about how the structures of the ear work to let us hear different sounds. Annotate a diagram to synthesize this information.		*Lesson 12 Activity Sheet*, animation of the ear: http://www.neuroreille.com/promenade/english/ear/fear.htm
5	3 min	**NAVIGATION** Review the questions we still have about hearing loss to motivate the work we'll do next time comparing the energy transfer of higher-amplitude versus higher-frequency vibrations.	G	optional: *Reading: Hearing in Elephants, Dogs, and Humans*
				End of day 1
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 12, students are ready to read Student Reader Collection 4 and then respond to the writing exercise.		Student Reader Collection 4: *Compression Waves*

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• optional: *Model Inside an Ear* if you choose the alternate prediction activity • *Lesson 12 Activity Sheet* in hard copy • computer and headphones • *Information from the Experts* shared digitally • *Lesson 12 Activity Sheet* • science notebook • optional: *Reading: Hearing in Elephants, Dogs, and Humans*		• video of an otoscope ear exam • animation of the ear (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (5 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Be sure the video of an otoscope ear exam plays correctly to show in your classroom. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Post a digital version of *Information from the Experts* for students so that they can click on the links in the reading to access the videos and explore the websites at their own pace while reading independently.

If reading a digital version individually is not an option in your classroom, view these videos and websites together as a class (the same ones are linked in the reading).

- Website showing ear diagrams and animations
- Narrated animation of basilar membrane vibration
- Video that includes a hair cell vibrating
- Website that shows stereocilia that have been permanently damaged from exposure to sound (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

The goal of this lesson is to have students gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain. So, as they read critically and view the various animations and videos independently and together as a class, pause for discussion to help them sift through the key ideas of how the ear works to help us hear sounds. The students represent energy transfer across the structures of the ear, which targets MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

The work students do with ear structure and function in this lesson only begins to address 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. Students read articles and observe animations that they use to show how the ears send sound signals to the brain.

When students wonder about and begin to investigate how hearing loss occurs, highlight those questions to motivate our move into the next lesson about the amount of energy transferred by higher-amplitude versus higher-frequency vibrations.

Where We Are NOT Going

The websites linked in *Information from the Experts* include some specific anatomical terms for the structures of the ear. We focus on the following (which are explained in the reading itself): ear canal, eardrum, inner ear bones, cochlea, basilar membrane, hair cells, and stereocilia. Other more-complex terms are not necessary for students to know and use at this point (unless they are particularly interested in that aspect of science).

LEARNING PLAN FOR LESSON 12

1. Navigation

10 MIN

Materials: optional: *Model Inside an Ear* if you choose the alternate prediction activity

Revisit our consensus model. Display **slide A**. Briefly discuss where we've been and where we want to go next.

Suggested prompts	Sample student responses
When we look at our consensus model and think about the three parts—the source, the medium, and the detector—where have we made the most progress?	*(Answers will vary, but likely will center upon our most recent discoveries.)*
Where do we still have questions on our Driving Question Board? (If any new questions were recently added to the DQB, review those questions, as well.)	*We have questions about how sounds are sensed or detected by people.* *We want to know how our ears work.*

Begin to make predictions about how ears work. Display **slide B**. Ask framing questions to help students consider what might be happening in our ears that allows us to hear sounds.

Suggested prompts	Sample student responses
Looking back at our consensus model, what do you think happens when these kinds of particle compression waves reach our ears?	*I think there is something called an eardrum in our ears. Maybe it vibrates, too.*
What do you picture is going on inside our ears that allows them to detect different sounds?	*I've heard you can damage your eardrum.* *I don't know what is going on inside of ears for sure.*

Alternate Activity

If you would rather have students model on paper what they predict might be happening in our ears to allow us to detect different sounds, you can distribute copies of *Model Inside an Ear*. Display **slide C**. Have students spend about 3 minutes drawing and then take 2 minutes to share out using **slide B** and the prompts listed above.

Discuss possible investigations. Display **slide D**. Say, *So what we're really curious about now is how the detector (in this case, our ears) works. All of our questions are related directly to the structure and function of the ear, so it makes sense to start there. When we look at the ear to try to figure out how that detector helps us hear sounds, what do we want to look at? Where should we start?*

After students turn and talk for a moment, have them share out their ideas.

Suggested prompts	Sample student responses
How could we investigate these questions about our ears?	*Maybe we need to look at the ear to see if it's vibrating when we hear a sound.*
What evidence do we need to support some of our ideas?	*Maybe we should look for a video that shows what happens in our brain when we hear something.* *We should look inside the ear to see what structures are inside.* *We need to look in the ear. We know that there's an eardrum in there, and maybe that's related to how we hear.*

2. View video of ear exam.

5 MIN

Materials: video of an otoscope ear exam (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Introduce the ear exam video. Say, *OK, I'm excited. It seems like you might already know a little bit about what's going on with our ears that lets us hear sound. After our last class I was gathering materials to start trying to answer some of the* *questions we came up with, and I found a video of an examination inside a person's ear. I think that will be a good place to start. Let's watch the video and see where that leads us.* Play the video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Discuss the ear exam video. Display **slide E** and ask students to share their thinking about the video.

Suggested prompts	Sample student responses
What did you notice during this video? *What structures in the ear remind you of anything we've already investigated?*	*I saw the eardrum. The eardrum has to be how we hear sound.* *I think the sound hits the eardrum and that's how we detect sound.* *The eardrum seems like it would work like a drum—a force hits it and it vibrates. But, in our investigations, we used the drum to start the sound, and something else detected it. So I wonder if the drum or eardrum would detect other sounds.*

Say, *Yes, we saw the eardrum in the video when they got inside the ear. We have seen surfaces like that vibrate when bands of particle density change in the medium and when sound waves reach them. But we still haven't answered how that makes us detect or hear a sound. And we can't see anything else in the ear behind the eardrum.*

Suggested prompts	Sample student responses
Where could we get more information about how our ears work? *How could we learn what goes on inside our ears even if we can't look directly behind the eardrum?*	*Maybe we could find a video of the inside, or look on the internet for a diagram.* *We could talk to some doctors to see what they know about our ears.* *We could talk to a scientist who studies the body to see how it works.*

3. Reading about How We Hear

12 MIN

Materials: *Lesson 12 Activity Sheet* in hard copy, computer and headphones, *Information from the Experts* shared digitally

Introduce the reading. Display **slide F**. Say, *I was thinking the same thing, that we would probably need some help from a specialist here. So, I already found an article that might help.*

Distribute *Lesson 12 Activity Sheet*. Explain where students can find the digital version of *Information from the Experts* (available to you as a handout and a reading—the text is the same so use whichever is easier to share). Direct students to read and take notes. Give students about 8 minutes to read *Information from the Experts* and explore the animations and videos while taking notes on *Lesson 12 Activity Sheet*.* *Lesson 12 Activity Sheet—Suggested Responses* is available as a reference for you.

***Attending to Equity**
Students could synthesize the information they gather across this step and the next in several ways. These activities are designed to partially address NGSS MS-LS1-8: "Gather and synthesize information that sensory receptors respond to stimuli by sending messages

4. Synthesizing What We've Learned about the Ear. 15 MIN

Materials: *Lesson 12 Activity Sheet*, science notebook, animation of the ear (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Annotate the ear diagram together. Project http://www.neuroreille.com/promenade/english/ear/fear.htm and work together as a class (or in small groups) to synthesize today's learning by annotating the diagram on *Lesson 12 Activity Sheet*. *Lesson 12 Activity Sheet—Suggested Responses* is available as a reference for you. When finished, have students tape this page into their science notebooks (instead of adding to our Progress Tracker for today's work).*

Key Ideas

Purpose of this discussion: To help students organize the information they gathered from the reading, videos, and animations and synthesize it by explaining on a model how we are able to hear sounds.

Listen for these ideas:

- Vibrations are transmitted from the eardrum to tiny bones in the ear and then to a structure called the cochlea.
- The cochlea contains fluid that transfers vibrations along the basilar membrane, which has different areas that correspond to where different-pitch sounds are detected.
- The vibrations bend hair cells and move their detectors (called stereocilia) more or less depending on the sound.
- Hair cells send signals to nerve cells that relay this information to the brain.
- Hearing loss is caused when one of the structures in the ear is damaged. This damage can be irreversible if the hair cells or their detectors, the stereocilia, are permanently damaged.

Suggested prompts	Sample student responses
Who can help talk us through how energy is transferred through the structures of the ear?	*When the eardrum vibrates, it transfers the vibration to the bones, which vibrate the fluid in the cochlea.*
What structures behind the eardrum touch that membrane? If the eardrum vibrates, what would that do to the structures behind it?	*The vibrations are sensed in different areas of the basilar membrane, which makes the hair cells vibrate, and the stereocilia on each hair cell detect those vibrations.*
After that, where would the energy in these vibrations get transferred to next?	*The information is passed to nerve cells that send signals to the brain.*
How can we hear so many different pitches at the same time?	*There are different areas of the cochlea that detect different pitches. So, we can hear a high-pitched sound at the same time as a low-pitched sound because the basilar membrane has a different area for each sound.*

to the brain . . . ." Feel free to structure this task of gathering and synthesizing in a way that best fits the needs of your students: as individuals, partners, small groups, or a whole class. The remainder of this lesson outlines the option for synthesizing information as a whole class, but you should modify the structures as needed for your class.

***Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

This practice asks students to read "critically," so not only should they be sifting through this information to find the evidence necessary for answering their questions, but they should consider the sources of this evidence. Are the authors or sources of this information reliable and trustworthy? How do we know (or not)?

Suggested prompts	Sample student responses
Which parts of the basilar membrane vibrate in response to lower-frequency vibrations?	*The higher frequencies make the area to the front or bottom of the basilar membrane vibrate.*
Which parts vibrate in response to higher-frequency vibrations?	*The farther inside or back or top of the basilar membrane vibrates in response to lower frequencies.*
What did you learn about hearing loss?	*Hearing loss can be caused when the structures in the inner ear are damaged.* *The ear can be damaged by sounds with a high volume (amplitude) or a high pitch (frequency) over a long period of time.* *Hearing loss can also be caused by old age.*
Considering what we've learned about volume (amplitude) and pitch (frequency) and what we've just read about how our hearing can be damaged, who can share an experience they've had with either an extremely loud sound or an extremely high-pitched sound that hurt or seemed to affect how your ears functioned?	*I was at a concert, and the music was really loud. I couldn't hear as well the next day.* *Whenever the fire alarm in the school goes off, my ears ring afterwards.* *My younger brother just started playing the clarinet, and when he squeaks it, my ears hurt.*

Assessment Opportunity

If you annotate the ear diagram together as a class, you may want to direct students to leave their science notebooks open to that page so you can confirm that everyone recorded the key ideas correctly. If you have students work in pairs or groups to do that synthesis, you will want to circulate during their work or collect it afterward to be sure everyone understood the key ideas correctly. Specifically, you want to make sure that students have noted the energy being transferred through the structures of the ear.

5. Navigation

3 MIN

Materials: optional: *Reading: Hearing in Elephants, Dogs, and Humans*

Wrap up today's work and plan for next time. Display **slide G**. Say, *So we learned from the reading and we know from our own experience that sounds with a great amplitude can cause hearing damage. We also know that sounds with a high frequency can cause hearing damage. That is interesting—sound waves of larger amplitude and waves of higher frequencies can cause more damage than sound waves of smaller amplitude and lower frequencies.*

Suggested prompt	Sample student responses
What new questions do we have about these ideas of frequency and amplitude in regard to our hearing?	*Do high-pitched sounds make your ears ring?* *What does more damage: higher loudness or higher pitch?* *Do only loud sounds make you go deaf, or could high-pitched sounds do that, too?*

Say, *These are very interesting questions, and many of them relate to our DQB. So, when we get together again, let's investigate this idea of greater amplitude or higher frequency doing more damage. Let's think about how we might figure out which transfers more energy–sound waves with greater amplitude or sound waves with greater frequency.*

Additional Guidance

If desired, assign your students *Reading: Hearing in Elephants, Dogs, and Humans* as home learning or as an in-class extension of today's work. It is available as a handout or a reading in the student materials. Be aware that the Lexile level for this article is approximately 1200-1300, which is higher than the level expected for eighth grade independent reading. You may want to provide additional support to your students by reading it aloud to them or having them read with a partner. Or, you could reserve this article for higher-level readers in your class as a differentiation opportunity.

ADDITIONAL LESSON 12 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

Students read an interview from hearing experts as well as a few websites about ear structures to determine how we can hear sounds. They summarize their findings during discussion based on evidence they found in those sources, and they annotate a diagram of ear structures using a few key words that summarize how vibrations move through the ear.

SCIENCE LITERACY: READING COLLECTION 4

Compression Waves

1 **The Loudest Sound on Record**
2 **Compression Wave Action**
3 **Sound Waves Versus Shockwaves**
4 **Sound in 3-D**
5 **The Doppler Effect**

Literacy Objectives

- ✓ Summarize key points related to pressure waves and sound.
- ✓ Distinguish causes and effects related to sound and pressure waves.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 1–12.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an infographic that distinguishes sound waves from shockwaves and a low-amplitude, low-energy sound wave from a high-energy, potentially damaging sound wave.

Instructional Resources

Student Reader
Collection 4

Science Literacy Student Reader, Collection 4
"Compression Waves"

Exercise Page
EP 4

Science Literacy Exercise Page
EP 4

Prerequisite Investigation

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 10: What exactly is travelling across the medium?
- Lesson 11: How does sound make matter around us move?
- Lesson 12: What goes on in people's ears so they can detect certain sounds?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS4.A: A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

Science and Engineering Practices: Constructing Explanations; Using Math and Computational Thinking

Crosscutting Concepts: Patterns; Scale, Proportion, and Quantity; Energy and Matter

CCSS

English Language Arts
RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently.

Math
MP.2 Reason abstractly and quantitatively.

7.RP.A.2 Recognize and represent proportional relationships between quantities.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

longitudinal wave

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

compression	**plane**	**rarefaction**
shockwave	**surface wave**	**transverse wave**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selections relate to topics they are presently exploring in their Sound Waves unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *You will learn about the loudest sound in recorded history, produced by the cataclysmic volcanic eruption of Krakatau in 1883.*
  - *You will also take a closer look at what happens when sound waves become shockwaves.*
  - *And you'll read about how sound waves move through our 3-D world, including how a moving sound source affects what you hear.*
- Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
- *For this assignment you'll generate an infographic that compares and contrasts sound waves and shockwaves as well as low-intensity and high-intensity compression waves.*
- Distribute Exercise Page 4.
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete. (*Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the selection first to see the titles, section headers, graphics, and images to see what the selection is going to be about before fully reading.*
  - *Next, "cold read" the selection without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selection to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

Exercise Page

EP 4

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently.

You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What is notable about the volcanic explosion of Krakatau?	*It produced the loudest sound in recorded history.*
Are compressions and rarefactions parts of transverse waves or longitudinal waves?	*longitudinal*
Can you experience the Doppler effect listening to your TV while sitting in your living room?	*not if you and your television are both stationary* *HOWEVER, you might hear a pretty convincing recording of a sound that changes pitch and simulates the way the Doppler effect sounds in real experience.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
As particles vibrate when a sound wave travels through a medium, what do you call the area where the particles are more closely packed together?	*a compression*
Explain how sound waves transfer energy through a medium without relocating particles.	*The particles in the medium transfer energy through collisions, but they don't relocate relative to one another.*

- Refer students to Exercise Page 4. Provide more specific guidance about expectations for students' deliverable due at the end of the week.
  - *The expectation for this assignment is that you'll sketch summary notes in the form of a small poster (the size of a sheet of notebook paper). Your product should include blocks of text and sketched diagrams to add visual meaning, all arranged in a logical way to show comparisons and contrasts.*
  - *Your notes should summarize what you gather from the reading about compression waves that arrive as sound at one's ears and compression waves that are beyond sound, called shockwaves.*
  - *Your notes should also reveal what makes sound waves more or less energetic and more or less likely to cause physical changes or damages.*
  - *Your summary doesn't require additional research; you should focus on what is in the reading.*
  - *The key criterion for your work is that you identify the properties that differentiate sound waves of different intensities and particularly differentiate them from shockwaves.*
- Answer any questions students may have relative to the exercise expectations or the reading content.

Exercise Page

EP 4

4. Facilitate discussion. (FRIDAY)

Facilitate class discussion about the reading selections and writing exercise. Students begin the reading activity by learning about the volcanic explosion of Krakatau, the loudest sound on historical record. The example provides contrast between mechanical compression waves that generate audible sound and compression waves with such intensity that they disrupt matter (sometimes violently).

Student Reader

Collection 4

Pages 36–41 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "The Loudest Sound on Record"?	*It describes a historical event—the explosion of the Indonesian volcanic island Krakatau.*
Beyond the devastation that occurred on the island itself, what were some of the outcomes of the explosion that were notable elsewhere in the world?	*A tsunami over 100 feet in height swept across nearby islands.* *Dust in the atmosphere changed the color of sunsets far away from the island.* *Sailors about 40 miles away from the explosion experienced hearing loss from the intensity of the sound.* *People thousands of miles away could hear a sound resembling a pair of gunshots.* *Barometers all around the world registered spikes in air pressure over the next three days.*
Address the Connection question on page 37. *"How do you suppose art historians made the connection between the eruption of Krakatau and artworks of the period?"*	*Different artists in wide-ranging locations could see the unusual colors of the sunsets and captured them in their paintings. During the same period, writings such as that of the sea captain of the* Norham Castle *provided written record of the event. Historians can use details such as these like puzzle pieces to reconstruct the story of an event.*
What is the general purpose of the second selection, "Compression Wave Action"?	*It explains how longitudinal waves work.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first selection reveals that the explosion of Krakatau caused sound that could be heard thousands of miles away and inaudible spikes in air pressure that traveled in waves of energy around the entire world. The second selection details how air particles bumping into one another transfer energy in traveling bands called compressions.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and invite confident students to clarify, but summarize with concise explanation.

Pages 36–41 **Suggested prompts**	**Sample student responses**
What does compress *mean, and what is a compression?*	Compress *means to crowd together into closer proximity within smaller space.* *A compression is a band of particles in a medium that are temporarily crowded together more than they are when the medium is undisturbed.*
You can label the same wave as a compression wave, a longitudinal wave, and a mechanical wave. What do those different labels tell you about the wave?	*Calling it a compression wave tells that the energy of the wave travels by compressing particles in the medium together.* *Calling it a longitudinal wave tells that the particles vibrate parallel to the direction of the wave's movement.* *Calling it a mechanical wave tells that the wave's energy is transferred by the collisions of particles in a physical medium, matter.*
What is the general purpose of the third selection, "Sound Waves Versus Shockwaves"?	*It compares and contrasts sound waves and shockwaves.* *It describes the Chelyabinsk meteor explosion.*
What is the same about sound waves and shockwaves, and what is the difference between them?	*Both are mechanical (longitudinal) waves of compressed particles.* *But sound waves do not displace matter; they just cause particles to vibrate in place in the medium, transferring energy through the medium.* *A shockwave is a compression wave with so much energy that it pushes matter beyond vibration, hard enough to actually displace it.*
Besides the Krakatau explosion, what are some other powerful events described in the reading that produced intense infrasonic and audible waves?	*the Chelyabinsk meteor's explosion upon striking Earth's atmosphere* *the Tunguska meteor event* *The asteroid strike, 65 million years ago, in what is now the Yucatan region of Mexico.*

Proceed with discussion of the last two articles in the selection, which relate to sound perceived within three-dimensional space and sound perceived from a moving source.

KEY IDEA—Emphasize that sound waves and shockwaves are both longitudinal waves. Contrast them with transverse waves and surface waves. If you have already covered light in your curriculum, remind students that transverse waves include visible light and other energy waves on the electromagnetic spectrum.

EXTEND—Of the asteroid strike, 65 million years ago, in what is now the Yucatan region of Mexico, students' text states, "The shockwave and other products of the impact of that asteroid wiped out 80 percent of life on Earth, including the dinosaurs." Stimulate curiosity by encouraging students, for extra credit, to do a little research and offer ideas about what "other products of the impact of that asteroid" implies. (It is theorized that, beyond the direct percussions of the shockwaves, debris in the atmosphere globally affected climate enough to produce extended winter conditions that cascaded into food chain collapse, killing nearly 75 percent of Earth's species.)

Pages 42–45 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth reading selection, titled "Sound in 3-D"?	*It explains that, though the pictures created to model waves are two-dimensional on flat paper, sound waves occur in three-dimensional space all around us, in all directions.*
How does the fourth selection help you build knowledge on top of what you learned in the previous selections?	*We know that sound is waves of compressions traveling away from a source. This article emphasizes that the sound is emitted in all directions from the source, not just in a linear direction (which is what the simplified drawings of the compressions and rarefactions in a longitudinal wave might seem to suggest).*
How do multiple speakers in a sound system affect what the playback of an audio recording sounds like?	*They can be placed to make it sound like the sources of sounds are in the space with the listener.*
How do you think you would perceive sound differently if you only had one ear on the very top of your head?	*It would be difficult to tell what direction a sound was coming from.*
What is the general purpose of the final piece in the reading selection that looks like a cartoon.	*It explains the Doppler effect.*
What's it like to experience the Doppler effect?	*Sounds you hear change in pitch as the source making the sound moves toward or away from you.*
Take a look at the picture on page 45. If a sound maker is traveling away from you, is each compression it causes closer to or farther away from the compression it last caused to reach your ears?	*If the sound maker is moving away from me, each compression it causes is farther away from the last compression it caused to reach me.*
And what does that mean related to frequency?	*It's making the frequency decrease (which I perceive as lowering the pitch of the sound).*

The effect of scale on phenomena such as sound can be difficult for students to perceive. Use the example of listeners positioned near a live band and near speakers, in the fourth article of the reading selection, to connect to the relatively flat, 2-D energy of sound on a small scale with the large-scale phenomenon described in the Krakatau story. In a small area, we can perceive sound and manipulate sound as though it's moving in almost straight lines. But when the scale gets larger, sound waves are radiating out in broader directions and also traveling within or across media that give the sound a different shape. For example, Krakatau's pressure waves traveled through the air blanket that is wrapped around Earth. Because of the atmosphere's shape, the waves traveled through that same shape.

SUPPORT—Emphasize that shapes that are simplified, neatened, and rendered in 2-D in a book are often more complex in our 3-D universe, especially if they occur in large scales of space and time. Use visualizations to show how compression waves in the atmosphere can take curve-shaped paths as a result of transmitting through the layer of air that's around the spheroid Earth. These can be compared with tsunami waves that spread out across the oceans in 2004 and 2011.

5. Check for understanding.

Evaluate and Provide Feedback

Students' infographics should feature two illustrations:

- one depicting sound passing through air with rarefactions and compressions that are distinct and labeled but not stark black-and-white, all-or-nothing bands of particles,
- and the other depicting empty rarefactions (vacuums) and very dense compressions.
    - The former is for sound waves, and the latter is for shockwaves.
    - Students should also note that particles in the shockwave can be plowed along in the direction of the wave's transmission, causing permanent relocation of particles as well as change to things that might be struck by those waves.
    - Particles through which sound waves are passing do not relocate.

Infographics should also compare and contrast low-energy and high-energy sound waves.

- Some students might elect to draw graphs of the intensity of these waves, with higher peaks and lower troughs depicting larger amplitudes and therefore greater intensity.
- Others might show variations of the compression-and-rarefaction diagrams that feature more contrast in the band sizes and densities to indicate greater amplitude and energy.

Students will likely connect the high-intensity visual to an event such as Krakatau's eruption in 1883 or a meteor striking Earth's atmosphere or Earth itself.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 13

What transfers more energy, waves of bigger amplitude or waves of greater frequency?

Previous Lesson

Students had unanswered questions regarding how our ears detect sounds. So, they read an interview with experts and watched several videos and animations about the structures of the ear. Then, they synthesized that information to annotate a model that showed how energy is transferred through the ear to the nerve cells that send signals to the brain.

This Lesson

Investigation

2 DAYS

Using a ruler and marbles to represent a vibrating object pushing nearby particles, we conduct an investigation to gather evidence about how the energy transferred by a sound source changes in relationship to the frequency and amplitude of the sound. From patterns in our data, we conclude that vibrations with greater amplitude or frequency transfer more energy. Specifically, we apply our understanding of proportions to argue that increases in amplitude have a greater effect on the energy transferred by a vibrating object than increases in frequency.

Next Lesson

We will revisit the Driving Question Board and discuss all of our questions that we have now answered. Then we will demonstrate our understanding by individually taking an assessment. Finally, we will reflect on our experiences in the unit.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Apply mathematical concepts and processes to find and analyze patterns in numerical data and graphs of how the energy transferred by a vibrating object changes in proportion to changes in the amplitude and/or frequency of the object's vibrations.

What Students Will Figure Out

- Waves with bigger amplitude transfer more energy than waves with less amplitude.
- Waves with higher frequency transfer more energy than waves with less frequency.
- Proportional increases in amplitude have a bigger effect on the energy transferred than increases in frequency.

Lesson 13 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Connect questions from last class about what types of sounds transfer the most energy and navigate towards an investigation that will answer the class's question.	A, B	
2	15 min	**SETTING UP FOR THE ENERGY TRANSFER FOR AMPLITUDE AND FREQUENCY INVESTIGATIONS** Students experience the setup for two investigations to help answer the lesson question: What transfers more energy, waves of bigger amplitude or waves of greater frequency?	C-E	*Analogy Map for Energy Transfer Investigation*
3	20 min	**CONDUCTING THE ENERGY TRANSFER FOR AMPLITUDE AND FREQUENCY INVESTIGATION** Students collect data and reflect on any initial patterns they may notice.	F	*Data Tables for Energy Transfer Investigation*
				End of day 1
4	20 min	**COMPILING AND ANALYZING DATA FROM THE ENERGY TRANSFER FOR AMPLITUDE AND FREQUENCY INVESTIGATION** Students compile the class data, discuss how best to analyze the data, and discuss patterns in their small groups.	G-I	*Energy Transfer Investigation Class Results*
5	10 min	**CONSENSUS DISCUSSION** Students gather in a Scientists Circle to come to consensus about how changing the amplitude and frequency of vibrations changes how much energy is transferred.	J	
6	5 min	**UPDATE PROGRESS TRACKER** Students add their new understandings to their Progress Trackers.	K	*Progress Tracker*
7	10 min	**EMBEDDED SUMMATIVE ASSESSMENT: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?** Students demonstrate their understanding of how changing the frequency or amplitude of a vibration changes the amount of energy transferred by that vibration.	L	*Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?*
				End of day 2

Lesson 13 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Analogy Map for Energy Transfer Investigation* • *Energy Transfer Investigation Class Results* • *Progress Tracker* • *Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?*	• *Data Tables for Energy Transfer Investigation*	

Materials preparation (60 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Check the videos needed for the lesson:

- Frequency vs. energy investigation lab setup
- Amplitude vs. energy investigation lab setup

(See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**)

Online Resources

Energy Transfer for Amplitude and Frequency Investigation

- Group size: 3-4 students
- Setup:

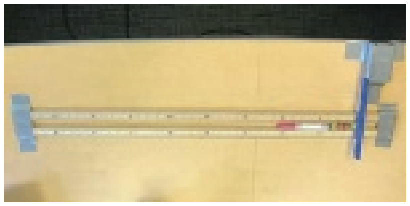
Gather 1 wooden block, 1 plastic ruler, 2 metersticks, duct tape or a C-clamp, 4 marbles, and 1 regular-size smooth marker for each group in your class. The block pictured in following steps measures 1.375 in × 1.375 in × 3.375 in.

Duct tape a plastic ruler to a wooden block so that when you lay the block on a table, the bottom of the plastic ruler is just higher than the thickness of a wooden meterstick. Make sure you can pull back the end of the plastic ruler 4 cm and that it vibrates without the tape coming off the wooden block.

Secure the wooden block to the table so that it doesn't move when you pull back and release the attached ruler. You can do this by taping the block to the table with duct tape or using a C-clamp.

Place 2 wooden metersticks parallel to each other with a 1.9 cm gap between them. Slide them under the loose end of the plastic ruler so that the ruler is lined up over the 10 cm mark on each ruler.

Make sure the marker and marbles can slide between the two metersticks without getting stuck. Adjust the space between the metersticks if needed. Duct tape the ends of each meterstick to the table.



Repeat this process to build one apparatus for every group of 3-4 students.

Watch the videos for the frequency vs. energy investigation and the video for the amplitude vs. energy investigation. Test the two investigations students will do with this apparatus. If for some reason your students cannot conduct the investigation themselves or students are absent, you can show them the videos for each investigation.

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will gather data on how the energy transferred by a vibrating object changes when we change the amplitude or frequency of those vibrations. These data will help students conclude that there is a proportional relationship between energy and frequency, while there is a proportional relationship between energy and the square of the amplitude. The data from students' investigations will come close to (or essentially match) the theoretical relationships between frequency and energy and amplitude and energy.

Students will use methods for calculating mean and median in this lesson, building on understandings outlined in the Common Core Mathematics Standards for grade 6. These methods will be used in the lesson as part of a larger discussion of different groups' results aimed at finding patterns in groups' findings and noting any outliers to the general trends that the class identifies.

From numerical data and graphs constructed through their investigations, students will use their simple mathematical wave models to identify that the energy transfer from waves is directly proportional to the frequency of the wave. *Directly proportional* refers to a linear relationship between energy and frequency where energy increases at a constant rate as frequency increases. Students will identify, for example, that the energy transferred doubles as the frequency doubles. This is an idea outlined in the CCSSM for grade 6.

Students will also identify that the energy transferred by a wave does not increase in proportion with the amplitude of the wave. Through their numerical data and the graphs they construct using that data, students will identify that, for example, if the amplitude is doubled, the energy transferred increases by a factor of 4. The proportional relationship between frequency and energy, as well as the nonproportional relationship between amplitude and energy, are specifically targeted in the evidence statements for PS4-1.

Lastly, in this lesson students use the patterns they identified in their numerical data and graphs to create basic expressions or equations that represent the relationship among amplitude and frequency and the amount of energy transferred. This correlates with an expectation for students in grade 8 under CCSSM that students can "describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing and decreasing, linear or nonlinear)" (p. 55). By analyzing numerical data to find patterns in how energy is related to amplitude and energy (i.e., identifying that as amplitude doubles, energy increases by a factor of 4) as well as by making connections to graphs of simple functions they've seen before, students identify that energy and frequency are in a proportional relationship (like $y = x$) and that energy is proportional to the square of amplitude (like $y = x$). Students may describe that relationship algebraically in terms such as "energy is proportional to frequency" or "energy is proportional to amplitude squared".

Students may have had experiences or heard about how loud or high-pitched sounds can be damaging to people's hearing. Though students may not make the connection yet between this damage and the increased energy transferred by sounds of greater amplitude and frequency, it's important to call out these related phenomena as students will leverage the connection between greater energy transfer and damage in the next lesson.

Where We Are NOT Going

Students may be familiar with more complex methods for statistical analysis of the groups' results from their investigations and may have used these methods in math classes. For the purposes of this lesson, students focus on mean and median as simple measures to identify patterns across data from multiple groups, and the emphasis is on those broad patterns.

Describing nonproportional relationships algebraically (i.e., identifying that there is an exponential relationship between amplitude and energy transferred) is targeted in the CCSSM in grade 8. Younger students or students who have not yet encountered these concepts in their math classes may struggle to use expressions or equations to describe the relationship between energy and frequency or amplitude. For this reason, you may want to treat parts of this lesson as optional in classrooms that are at grade 6 or grade 7. For students at these grade levels, the focus of this lesson should be on identifying that increases in amplitude have a much bigger effect on the energy transferred than do increases in frequency.

Students may also make the connection that waves of highest energy would have increased in both frequency and amplitude. In these investigations, we are separating out those variables and analyzing each variable's relationship with energy. Considering how energy changes (or compares) with changes to both frequency and amplitude fall outside the scope of this unit and, while interesting for students to consider, should be considered extension questions once students have mastered the different relationships between each of these independent variables and the energy transferred by the wave.

1. Navigation

10 MIN

Materials: science notebook

Recall the question the class ended on last lesson.

Say, *Last class, we saw how our ears detect all kinds of different sounds. We agreed that louder sounds or sounds that are really high-pitched can damage people's ears, and we wondered what caused more damage: high-pitched sounds or loud sounds? We said we needed to figure out whether high-pitched sounds or louder sounds transfer more energy.*

Show **slide A**. Ask students to discuss what they think is happening for loud or high-pitched sounds that could cause objects making these types of sounds to transfer a greater amount of energy. Prompt students to ground their explanations in what they've learned about how the sound source and the particles nearby move for sounds of different pitch and loudness.

Suggested prompts	Sample student responses
Why might louder sounds do more damage than quieter sounds? Why would they transfer more energy?	*When a sound source is making a louder sound, it's moving back and forth. It's making a bigger push.* *A bigger push (or going further back and forth) would mean more energy gets transferred.* *In the simulation, we saw that the louder sounds make bigger bands of particles get pushed in the medium. Maybe the bigger bands of particles transfer more energy?*
Why might high-pitched sounds do more damage than low-pitched sounds? Why would they transfer more energy?	*Sound sources move back and forth more times per second for high-pitched sounds. Maybe more vibrations means more pushes and more energy gets transferred?* *The high-pitched sound should push your ears more times. Maybe all those pushes add up to more energy?*

Say, *It sounds like we agree that the increased energy has something to do with changing the amplitude and frequency of the vibration. We agree that increasing either the amplitude or frequency means more energy gets transferred, and more energy means more damage gets done, but we're still not sure whether changing amplitude or frequency would have a bigger impact on the amount of energy transferred.*

Show **slide B**. Have students record the following lesson question at the top of the next blank page in their notebooks: *What transfers more energy, waves of bigger amplitude or waves of greater frequency?*

2. Setting Up for the Energy Transfer for Amplitude and Frequency Investigations

15 MIN

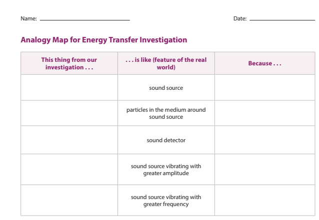
Materials: *Analogy Map for Energy Transfer Investigation*, science notebook

Have students brainstorm how to investigate their question. Show **slide C**. Ask students to brainstorm what we would need in an investigation in order to test this question of which waves, or vibrations, transfer more energy.

Suggested prompts	Sample student responses
What would we need in order to figure out what transfers more energy, waves (or vibrations) of bigger amplitude or vibrations of greater frequency?	*We would need to be able to test waves or vibrations with different frequency and amplitude and compare them with each other.* *We would need to be able to measure how much energy is being made by each vibration so we can compare and see what vibrations transfer the most energy.* *It would be great if we could see close up by the sound source so we could see what's happening when we change the frequency or amplitude of the waves.*

Tell students that there is an apparatus that the class can use to simulate waves, or vibrations, with different frequencies and amplitudes and find out how much energy is transferred in each case.

Distribute *Analogy Map for Energy Transfer Investigation* to students and instruct them to tape this analogy map in their science notebook below the lesson question.


Name: ______________ Date: ______________

Analogy Map for Energy Transfer Investigation

This thing from our investigation . . .	. . . is like (feature of the real world)	Because . . .
	sound source	
	particles in the medium around sound source	
	sound detector	
	sound source vibrating with greater amplitude	
	sound source vibrating with greater frequency	

Introduce the investigation setup. Show **slide D**. Have students bring their notebooks with them to a lab station where you have this apparatus set up. Introduce each part of the setup that students will be using to investigate the lesson question. As the class walks through this introduction, have students complete each row in their analogy map to record how their upcoming investigation simulates a sound source vibrating, the medium around the sound source, and energy being transferred to a nearby object.

Show students the plastic ruler taped to the wooden block. Pluck the end of the ruler and confirm with students that this object vibrates like the sound sources they've observed in earlier lessons. Remind students how they used a similar object, a wooden stick, to represent a sound maker vibrating in Lessons 4 and 5 where they analyzed the stick's movement using a motion detector.

Ask students to add to their analogy map what the ruler taped to the block represents in this investigation.

This thing from our investigation...	... is like (feature of the real world)	because ...
Ruler taped to block	sound source	The ruler vibrates or moves back and forth like a sound source does when it makes sounds.

Tell students that we will pull back the ruler and release it to simulate a sound source producing a vibration. In order to simulate the production of a sound wave, we also need particles surrounding the sound source. Show students the setup of the meterstick track with four marbles, one against the stick as it is pulled back and the other three marbles spaced out a bit, and a marker on the track near the marbles.

Demonstrate the investigation. Pull back and release the ruler so it hits the marbles. Ask students how what they observed in this demonstration compared to what they saw the particles in the medium doing in the Visualizing Sound in a Medium simulation from Lesson 10. Also ask them what in this investigation setup represents the medium and what represents the detector or sensor and guide them through adding to their analogy maps what the marbles and marker represent in this investigation.

Suggested prompts	Sample student responses
How does what we see in the marble particles compare to what we saw the particles doing in the computer simulation?	*There are fewer particles in this investigation than there were in the computer simulation.*
How do the motion and interactions of marble particles in this setup compare to what we saw the microscopic particles in matter doing in the computer simulation?	*There's also just one row of particles instead of many, like in the simulation.* *In both cases, the sound source pushes particles into each other and they push each other in a wave.* *Both show energy going from the sound source and transferring through the medium when the particles in the medium bump into each other.* *In the simulation, the sound source moved back and forth and pushed on the particles in the surrounding medium more than once. In this setup, it just springs back on the marble once.* *In this setup, the particles don't spring all the way back to their original position.* *In this setup, the last particle in the series doesn't have another particle to run into.*
What represents the sound source in this setup? What represents the medium? What represents the detector or sensor?	*The ruler represents the sound source, the marbles represent the medium, and the marker represents the detector or sensor.*

This thing from our investigation ...	... is like (feature of the real world)	because ...
Marbles	particles in the medium around sound source	When the ruler vibrates, it pushes the marbles and makes them vibrate and bump into each other just like the particles did in the computer simulation.
Marker	sound detector	The ruler vibrates and bumps into the marbles and then they bump into the marker, like the particles did to the sound detector in the computer simulation.

Connect energy transfer to the marker's movement. Ask students, *What caused the marker to move when we let go of the ruler?*

Push students to make connections to earlier lessons where they discussed how energy is transferred from the vibrating sound source through particles in the medium to the detector. Help students reason about how the movement of the marker can help us measure how much energy was transferred to it.

Suggested prompts	Sample student responses
What caused the marker to move when I let go of the ruler?	*The ruler pushed the marbles, and the marbles pushed the marker.* *The ruler pushed the first marble, and then it bumped the next one, and so on until the last marble pushed the marker.* *When the ruler pushed the first marble, it transferred energy from each marble to the next one when they bumped into each other. The energy eventually got to the marker when it got bumped by the last marble, and that made it move.*
If we could transfer twice as much energy to the marker, what do you think we would see happen to it compared to what happened to it this time?	*The marker would move twice as far if twice as much energy were transferred to it.*
If we could transfer three times as much energy to the marker, what do you think we would see happen to it compared to what happened to it this time?	*The marker would move three times as far if three times as much energy were transferred to it.*

Emphasize that in order to figure out if twice as much energy is transferred to the marker, we would need to measure the distance that the marker moved each time. This means we need to record where the marker starts and where it stops moving.

Connect this investigation setup to the lesson question.

Say, *So now that we have a way to see how much energy is transferred by vibrations, we should be able to see whether vibrations with greater frequency or amplitude transfer more energy.*

Show **slide E**. Have students turn and talk to discuss the following two questions:

- How will you use this setup to change the amplitude of the vibrations?
- How will you use this setup to change the frequency (number per time period) of the vibrations?

Suggested prompts	Sample student responses
How will you use this setup to change the amplitude of the vibration?	*We could change how far back the ruler moves.* *We could pull the ruler back further (for greater amplitude) or not as far (for lesser amplitude).*
How will you use this setup to change the frequency (number per time period) of the vibration?	*We could make the ruler vibrate more times.* *Since we said the ruler only goes back and forth one time in this simulation, can we pull it back more times?*

Tell students, *One limitation of our setup is that the marble doesn't return all the way back to touch the ruler again as it is vibrating, as particles do in the medium. This means that we can't get more than one compression wave off the ruler after we pull it back. To simulate more than one compression wave, we will have to manually pull the ruler back and reload it multiple times to simulate a repeated series of vibrations going into the medium.*

Demonstrate to students how to represent multiple waves in their investigation. Show students how to simulate more than one compression wave by placing the first marble against the ruler again, pulling back the ruler, and launching it again without moving the marker from where it came to rest the time before. Tell students that in order to simulate the production of three compression waves, we have to repeat it yet another time, allowing the marker to be pushed farther and farther with each wave.

Help students add to the final two rows in their *Analogy Map for Energy Transfer Investigation* to finish setting up their investigation.

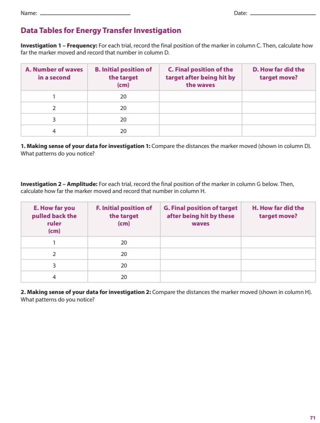
This thing from our investigation ...	... is like (feature of the real world)	because ...
Pulling the ruler further back and letting it go	sound source vibrating with greater amplitude	The ruler (representing the sound source) vibrates further back and forth, which means it has a greater amplitude.

This thing from our investigation ...	... is like (feature of the real world)	because ...
Pulling back the ruler more times	sound source vibrating with greater frequency	The ruler goes through more vibrations over a time period, which means it has a greater frequency.

3. Conducting the Energy Transfer for Amplitude and Frequency Investigation.

20 MIN

Materials: science notebook, *Data Tables for Energy Transfer Investigation*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Data Tables for Energy Transfer Investigation

Investigation 1 – Frequency: For each trial, record the final position of the marker in column C. Then, calculate how far the marker moved and record that number in column D.

A. Number of waves in a second	B. Initial position of the target (cm)	C. Final position of the target after being hit by the waves	D. How far did the target move?
1	20		
2	20		
3	20		
4	20		

1. Making sense of your data for investigation 1: Compare the distances the marker moved (shown in column D). What patterns do you notice?

Investigation 2 – Amplitude: For each trial, record the final position of the marker in column G below. Then, calculate how far the marker moved and record that number in column H.

E. How far you pulled back the ruler (cm)	F. Initial position of the target (cm)	G. Final position of target after being hit by these waves	H. How far did the target move?
1	20		
2	20		
3	20		
4	20		

2. Making sense of your data for investigation 2: Compare the distances the marker moved (shown in column H). What patterns do you notice?

Pass out *Data Tables for Energy Transfer Investigation*, one copy per group. Share the following instructions with students:

- *You will work in groups of three or four. Everyone should wear safety goggles the entire time you are at your stations.*
- *You will need one person to make sure the base of the ruler stays in place and to hold it in place if it is slipping, another person to make sure the first marble is lined up against the ruler as it is pulled back, and a third person to pull the ruler back. If you have a fourth person, they can record data for your group.*
- *When you have collected all your data, you may return to your seats. When you get back to your seats, use Data Tables for Energy Transfer Investigation to answer the Making sense questions 1 and 2 from the handout in your notebooks.*

Safety Precautions

Ensure student safety by making sure each apparatus is tightly secured in place and students wear safety goggles for the duration of the investigation. Marbles can sometimes move off the table.

Have students complete investigations 1 and 2 using the instructions on *Data Tables for Energy Transfer Investigation.* As groups finish collecting data and return to their seats, have students use their data to answer Making sense questions 1 and 2 from *Data Tables for Energy Transfer Investigation,* where they identify patterns in their data, by writing in their science notebooks.

Before students leave, have one student in each group put *Data Tables for Energy Transfer Investigation* in their notebook for the class to use next time.

Assessment Opportunity

After the first day of this lesson, you could collect students' notebooks for a formative assessment of their understanding of some basic patterns in their groups' data. On *Data Tables for Energy Transfer Investigation* in the Making sense of your data sections, look for students' understanding that the energy of a vibration increases when you increase either frequency or amplitude. Also, look for students noticing that increasing amplitude has a much greater impact on the energy transferred by the vibration than does increasing frequency.

End of day 1

4. Compiling and Analyzing Data from the Energy Transfer for Amplitude and Frequency Investigation

20 MIN

Materials: *Energy Transfer Investigation Class Results*

Build a version of *Energy Transfer Investigation Class Results* on chart paper. Hand out a copy of *Energy Transfer Investigation Class Results* to each student to tape into their science notebooks. Tell students that we will use these tables to organize the results of all groups from the investigations we did in the previous class.

Additional Guidance

The advantage of using chart paper is that it generates an artifact to post in the room to refer to in later lessons. Building the tables on chart paper also lends itself to a Scientists Circle as students report out their results.

Ask one or two students from each group to report out the group's numbers as you record them on the chart. Show **slide G.** As values are added to the class's chart, have students record these numbers on *Energy Transfer Investigation Class Results.* Remind students to look for patterns as the numbers are posted, as well as any outliers that might indicate a possible source of error in a particular trial.*

Alternate Activity

Collecting these investigation data is very important for eliciting student engagement and providing a visual and personal experience that students can make connections with later when interpreting data on how energy changes with changes to frequency and amplitude. However, if your class is short on time or materials and cannot do these investigations, videos are available to introduce the investigations. (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**) You may then use *Example Class Data Table for Energy Transfer for Amplitude and Frequency Investigation* to stand in for the class's data. If you choose to do this with your class, the following procedures will still work and students will be able to do the work of interpreting a class set of data to find patterns that help to answer the lesson question.

Say, *We have data from all our different groups now, and there are some similarities and differences across the different groups' data.*

Discuss ways we might describe what a typical value is for each column. Show slide H.

Suggested prompts	Sample student responses
How could we use all our groups' data to find a typical value for each column in our tables?	*We could take an average of all the groups' data so our class answer is in the middle of each groups' answers.* *We could find the mean or the median for each column.*

*** Supporting Students in Engaging in Using Mathematical and Computational Thinking**

On *Example Class Data Table for Energy Transfer for Amplitude and Frequency Investigation,* you can see an example of data tables filled in with values from results from different groups. Your students' data may show greater variation. At this point, record what students report, and the class can work together to decide which (if any) outliers to discard when doing their data analysis.

*** Supporting Students in Engaging in Using Mathematical and Computational Thinking**

Many students are more able to notice patterns in rate of change when they see data plotted on a graph. Constructing these graphs together as a class allows students to collaborate to decide how to set up and label the axes of the graphs to show the relationship they're trying to analyze. This might be a good opportunity to review with students the independent and dependent variables in each investigation and how they can create a graph that shows how changing one variable (like frequency) changes another (like energy).

Suggested prompts	Sample student responses
Are there any values that look like they are extreme outliers, that is, values that are much bigger or smaller than the nearest values? How should we identify those?	*We could put an asterisk next to any numbers that look like they might be outliers.*
How do we think we should deal with these outliers so that we use everyone's data but make sure our class data is as accurate as possible?	*We could decide which numbers are outliers and then not count those for our average.*
(If students need more direction, add: Are there any measures or ways we could more deeply analyze the data we collected to help make sense of the patterns?)	*We need to count all the values so that we're not ignoring some groups' data. The outliers could be the right results or could say something about the investigation.* *If we found the median instead of the mean, we wouldn't have to worry about the outliers throwing off our average.*

Have groups calculate one of these measures of center for each column. Give students a few minutes to work in small groups to calculate either the mean or the median for each column in the data tables.

Once students have had a few minutes to make these calculations, have them report out the average values they found for each column as you record these on the class's data tables.

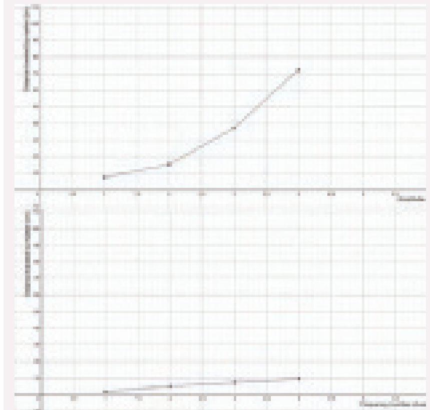
Additional Guidance

One way that students could distribute this work in their groups is to assign each group member a role. One member could double-check all members' calculations to identify where the group agrees and disagrees, one member could report out the group's results for the amplitude vs. energy investigation, and one member could report out the group's results for the frequency vs. energy investigation. This helps ensure that everyone has a role in contributing to this class data consolidation. Alternatively, you could have students add these data directly to the class record as they finish their calculations.

Say, *Now we have tables of data that we collected about how the amount of energy transferred by the vibration changed when we changed the frequency and amplitude. To answer our question about which transfers more energy, waves of bigger amplitude or waves of greater frequency, we're going to have to look for patterns in our data.*

Suggested prompts	Sample student responses	Follow-up questions
Is there a way we could make patterns in our data tables easier to see more visibly?	*We could draw it!* *We could create a graph!*	*Great idea! One thing that often helps with interpreting tables of data like this is to graph the data and look for visible patterns in the graphs we create.*

These graphs can be created by hand on grid paper or on a whiteboard or by using an online graphing calculator, such as a class did that produced the following graphs of their data:



Using grid paper or by projecting an online graphing calculator, use the class data tables to co-construct 2 graphs:

- a graph comparing the distance the ruler is pulled back (the amplitude) to the distance the marker traveled (which is a measure of how much energy was transferred)
- a graph comparing the number of vibrations (the frequency) to the distance the marker traveled.*

As students help to co-construct these graphs, walk through a couple of points on each graph to illustrate to students that they are plotting how the amount of energy transferred changes with changes to either frequency or amplitude. To support students in this, ask them to remind you what you should label each axis on each graph.

Present slide I. Have students answer the following questions in their notebooks to interpret the class's data about how the energy transferred by vibrations changes with changes to the frequency and amplitude of the vibrations:

- What patterns did you notice in how changing the amplitude of the vibration changed the amount of energy transferred?
- What patterns did you notice in how changing the frequency of the vibration changed the amount of energy transferred?
- Using the tables and graphs of our data, which do you think transferred more energy: waves of bigger amplitude or waves of greater frequency? How did you arrive at your claim?

Assessment Opportunity

These questions provide an opportunity for formative assessment of students' understanding of some key patterns about how energy changes with changes to frequency and/or amplitude. Look for students' understanding that the energy of a vibration increases when you increase either frequency or amplitude. Also, look for students noticing that increasing amplitude has a much greater impact on the energy transferred by the vibration than does increasing frequency.

While assessing students' ability to draw these conclusions from patterns in their data, look for students citing specific data or patterns they noticed in their tables and graphs. This could look like students drawing or labeling differences in how energy changes with frequency or amplitude on the graph or students annotating their data tables to point out specific noticings in the numerical data.

These responses can provide insight into the understandings that students will bring to the following Consensus Discussion, and noticing patterns in their ideas on these written responses and in their contributions to discussion will help to identify what questions need to be asked and what key points need to be clarified before the class adds to their Progress Trackers.

To support students who might not be making these connections, prompt them to look back at their data and consider these questions: What happens to the energy when we double the frequency? What happens to the energy when we double the amplitude? What about when we quadruple it? These questions should get students thinking about patterns in the numerical data that will support their understanding of the relationships this lesson targets among the amount of energy transferred, frequency, and amplitude.

* Strategies for This Consensus Discussion

Purpose of this Consensus Discussion: Come to a consensus about key patterns in the data, evident in both the data tables and graphs, about how changing the frequency or amplitude of a vibration changes the amount of energy transferred by the vibration.

Listen for these ideas:

Areas of agreement

- Increasing the frequency of the waves increases the amount of energy transferred.
- Two times as many waves in a time period (doubling the frequency) seems to double the amount of energy transferred; three times as many waves seems to triple the energy transferred.
- Increasing the amplitude of the waves increases the amount of energy transferred.

5. Consensus Discussion

10 MIN

Materials: science notebook

Ask students to bring their notebooks with them to the Scientists Circle for a Consensus Discussion.* Have volunteers share out the patterns that they noticed in their data, and push students to make specific reference to what they saw in the data tables and graphs to support their claims.

Say, *Wow! We have really figured out a lot about how changing the frequency and amplitude can affect the amount of energy transferred when an object vibrates to make a sound. Let's take a few minutes to come to consensus on our areas of agreement and disagreement before we record in our Progress Tracker our current thinking based on evidence.* Show **slide J**.

Suggested prompts	Sample student responses
What patterns did you notice in how changing the amplitude of the vibration changed the amount of energy transferred?	*When we increased the amplitude, the amount of energy transferred went up.* *When the amplitude doubled, the amount of energy went up by about four times.* *The graph for amplitude vs. energy isn't a straight line like the one for frequency vs. energy. It doesn't look like a linear or proportional relationship.* *It looks more like an exponential graph, like the one for $y = x^2$.*
What patterns did you notice in how changing the frequency of the vibration changed the amount of energy transferred?	*When we increased the frequency, the amount of energy transferred went up.* *When the frequency doubled, the amount of energy doubled, too.* *The graph for frequency vs. energy is pretty much a straight line where the energy goes up when the frequency goes up.* *That graph looks like the graph for a line, like $y = x$. It looks like the graph for a proportional relationship.*
Using the tables and graphs of our data, which do you think transferred more energy: waves of bigger amplitude or waves of greater frequency?	*The vibrations with bigger amplitude transferred a lot more energy than the vibrations with greater frequency.* *When we doubled the frequency, the energy doubled, too. When we doubled the amplitude, the energy went up by 4 times. When we doubled the amplitude again, the energy went up by 16 times.*
What evidence did you see in the data tables that helped you make your claim?	*It looks like energy is proportional to frequency but not proportional to amplitude. It looks like energy is related to the amplitude squared.** *The graph for amplitude shows that the energy goes up a lot faster than it does for frequency. The amplitude graph looks more like an exponential relationship where the frequency one looks like a proportional relationship.*

- Doubling or tripling the amplitude has a much bigger effect on increasing the amount of energy transferred than doubling or tripling the frequency.

Possible areas of disagreement/ controversy

- **How changing the amplitude changes the amount of energy transferred:** Students may agree that changing the amplitude has a greater effect on the amount of energy transferred compared to frequency, but they may struggle to identify patterns in how the amount of energy transferred changes with changes to amplitude since this relationship is not proportional.
- **Evidence for proportional relationships:** It's likely that the class's data will show that doubling frequency increases the energy by a factor of a number close to (but not equal to) 2. Students may debate whether the class can use these approximate values to assume that there's a proportional relationship between frequency and energy (or between energy and the square of the amplitude).

6. Update Progress Tracker.

5 MIN

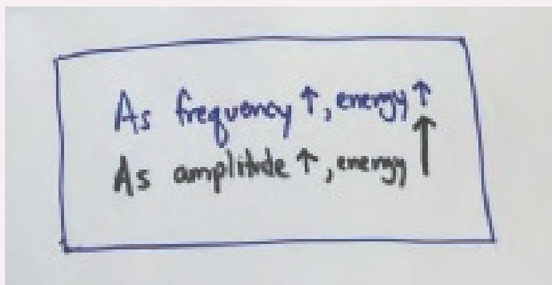
Materials: science notebook, *Progress Tracker*

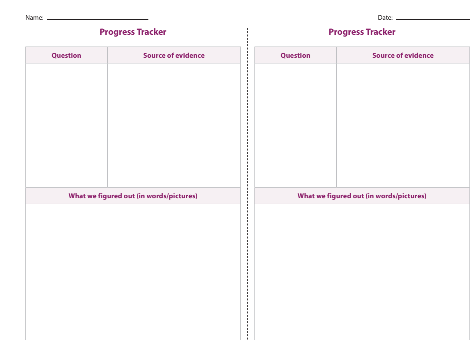
Update the Progress Tracker. Present **slide K**. Hand out *Progress Tracker*. Give students a minute or two to record the key findings on their Progress Trackers. Below is a sample of possible language for the Progress Tracker.

Question	Source of evidence
What transfers more energy, waves of bigger amplitude or waves of greater frequency?	Measuring how far a marker is pushed by vibrations with increasing amplitude and increasing frequency

What we figured out (in words/pictures)

- Increasing the amplitude or the frequency of a vibration increases the amount of energy it can transfer.
- Amplitude increases had a much bigger effect on how much energy is transferred than did frequency increases.
- Doubling the frequency of a vibration doubles the amount of energy transferred. Doubling the amplitude makes the amount of energy increase by 4 times.




Name: Date:

Progress Tracker

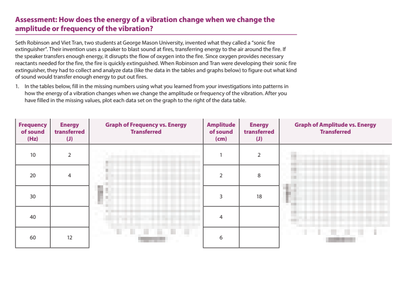
Question	Source of evidence

What we figured out (in words/pictures)

Progress Tracker

Question	Source of evidence

What we figured out (in words/pictures)


Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?

Frequency of sound (Hz)	Energy transferred (J)
10	2
20	4
30	
40	
60	12

Amplitude of sound (cm)	Energy transferred (J)
1	2
2	8
3	18
4	
6	

Graph of Frequency vs. Energy Transferred

Graph of Amplitude vs. Energy Transferred

TEACHER RESOURCES

SOUND WAVES | 284

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Appendix G of the NGSS dictates that by the end of middle school, students should be able to recognize and apply the concept that "scientific relationships can be represented through the use of algebraic expressions and equations" (p. 16).

Depending on the math experiences of your students, in this lesson they may be able to use the data tables and the graphs to describe patterns in terms of algebraic expressions or equations. Students may recognize that the table and graph for energy vs. frequency indicate a linear relationship between the two variables. Likewise, they might recognize that there is a nonproportional, exponential relationship between energy and amplitude. Using these understandings, students can construct basic "word equations" to describe the relationships between these variables in algebraic terms (i.e., "energy is related to the amplitude squared").

7. Embedded Summative Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?

10 MIN

Materials: *Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?*

Introduce the individual assessment. Pass out one copy of *Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?* to each student. Have students read the introductory paragraph individually or out loud as a class.

Present slide L. Have students watch the video of the sonic fire extinguisher in action. Show the video a couple times, if students request to see it again. Review the instructions for each part of the assessment.* Ask students to complete *Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?*.*

Home Learning Opportunity

Some students may need more time than what's left in this class period to thoughtfully complete this assessment. Consider allowing these students to complete the assessment outside of class or providing some time at the beginning of the next class period to finish their work.

*** Supporting Students in Engaging in Using Mathematical and Computational Thinking**

On question 1 of this assessment, students are expected to use patterns in the data provided as well as their investigation data to fill in missing values in tables of frequency and amplitude vs. energy. Students may struggle to identify how they are supposed to know what values belong there since the data are not provided, and they may need support in seeing how they can use the patterns from the provided data as well as from their own investigations to make inferences about what the values should be.

You may consider doing one value from one of the tables as a class to model strategies like looking for patterns in the data tables, revisiting the Progress Tracker, and looking back at the investigation data for this lesson to reason through what values to fill in for question 1. Once students have seen these strategies, they may find it easier to apply them and to show the understandings they've developed through this lesson.

ADDITIONAL LESSON 13 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.8.1: Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.8.1.A: Introduce claim(s), acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

In this assessment, students are asked to write a claim and support their claim with evidence. Students often struggle to make a clear connection between their evidence and their claim (reasoning). Support students' reasoning by posting sample language such as, "This evidence shows _____. I know this because _______." or "I know that _____ is true because I learned _____ when we _____." These sentence stems will help students draw a direct connection between what they learned and the claims they are trying to support.

Supporting Students in Making Connections in Math

CCSS.MATH.6.SP.B.5: Summarize numerical data sets in relation to their context, such as by giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

Students discuss and use mathematical methods of finding the average of data sets, including calculating mean and median as a way to combine results from different groups in order to improve the accuracy of the class's data. They also work together as a class to decide how to account for or discard outliers in the class's data in order to best represent what each group found in their investigations.

Depending on their experience using these concepts in math classes, students may need reminders of how mean and median are calculated. You can support students in recalling these procedures by taking a sample data set (either from the investigation or a random example set) and working together as a class to describe how students could find the mean and median of the set. By doing this with the class or with small groups that could use this extra practice, you can support students with mathematical methods needed to analyze the data the class has collected to draw conclusions about the lesson question.

CCSS.MATH.8.F.B.5: Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). Sketch a graph that exhibits the qualitative features of a function that has been described verbally.

In this lesson, students gather data describing how the energy of a vibration changes with changes to the frequency and amplitude of the vibration. They then use these data to describe and graph functions that represent the relationships between energy and frequency and between energy and amplitude.

*** Attending to Equity**

Offering options for students to express their thinking through multiple modalities provides all students with equitable opportunities to demonstrate their mastery of the key concepts and practices addressed by the assessment.

In this assessment, students express their thinking through writing an argument and by using patterns in numerical data to make mathematical predictions that they then represent using graphs. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment. You may consider allowing some students to present their answers verbally with you or another student acting as a scribe to record their thinking on paper. Other students may benefit from using math manipulatives to do the arithmetic necessary to calculate and graph values in the tables in question 1. Some students may be able to point to and verbally or visually describe properties of the graphs for question 1 and would benefit from being able to convey their answers directly to you or a classmate rather than having to translate their understanding into a written response. In each case, encouraging students to use multiple modalities to show their thinking creates a clear, accessible, equitable pathway for all students to demonstrate proficiency.

When analyzing these data in tabular and graphical forms, students will compare these relationships in order to describe how the energy changes with increases in amplitude vs. frequency. In each case, the energy of the vibration increases with each variable. While frequency and energy have a linear relationship, amplitude and energy have a nonlinear relationship where increasing amplitude causes much greater increases in energy compared to increasing frequency. Some students may recognize the pattern on the amplitude vs. energy graph as exponential relationship, depending on their math experience.

If students struggle to identify the difference in how energy is impacted by changes in amplitude vs. frequency, they may benefit from seeing the two graphs side-by-side to more easily see how properties of the two functions differ. Having students come up to point out these differences on the graphs the class creates using their data from each investigation, like the shape of each function, will help students to understand that increasing amplitude causes a greater increase in energy compared to frequency.

CCSS.MATH.8.F.A.2: Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). For example, given a linear function represented by a table of values and a linear function represented by an algebraic expression, determine which function has the greater rate of change.

Students will use the data they collect in their investigations to construct graphs of how the energy transferred by a vibration changes when we increase the amplitude or frequency of the vibration. From their numerical data and the graphs they create, students will see that there is a proportional relationship between frequency and energy transferred; when we increase the frequency of the vibrations, the energy transferred increases in proportion.

In this lesson, the relationships among energy and frequency and amplitude are represented both by tables of values and by graphs that the class creates. Students use both of these representations to draw the conclusion that energy increases more with increases in amplitude than with increases in frequency, stemming from the observation that the energy vs. amplitude function has a greater rate of change than does the energy vs. frequency function.

Students may notice this pattern and describe it in different ways based on either the data tables or the graphs. Students might notice, for example, that energy doubles when we double frequency, but that energy quadruples when we double amplitude. They also might notice that the curve for energy vs. amplitude is steeper than the one for energy vs. frequency. You can help students label each of these noticings as having to do with the rate of change of the two functions.

LESSON 14

How can we explain our anchoring phenomenon, and which of our questions can we now answer?

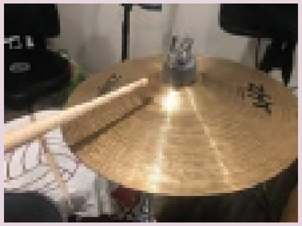
Previous Lesson

We conducted an investigation that led us to conclude that vibrations with greater amplitude or frequency transfer more energy. We graphed how energy changes with amplitude and frequency, which showed that increases in amplitude have a greater effect on the energy transferred by a vibrating object than increases in frequency.

This Lesson

Putting Pieces Together

2 DAYS



We revisit the Driving Question Board and discuss all of our questions that we have now answered. Then we demonstrate our understanding by individually taking an assessment. Finally, we reflect on our experiences in the unit.

Next Lesson

There is no next lesson.

Building Toward NGSS

MS-PS4-1, MS-PS4-2

What Students Will Do

Develop and use a model to explain how loud sounds and the energy transfer associated with high amplitude sound waves cause damage to ear structures.

What Students Will Figure Out

- We can answer many of our Driving Question Board questions!

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	15 min	**NAVIGATION: EVALUATE OUR DQB QUESTIONS** Students evaluate our list of questions in pairs for questions they think we have made progress on. Then students place sticky dots on the questions that they think we have made progress on and move into their Scientists Circle.	A, B	handout of typed-up questions from the DQB, 10 sticky dots
2	30 min	**REVISIT THE DRIVING QUESTION BOARD (DQB) AND REVIEW FEEDBACK FROM LESSON 13 ASSESSMENT** Revisit the DQB with the whole class and take stock of all the questions we've now answered. Review feedback and address questions from the Lesson 13 formative assessment.	C	
				End of day 1
3	35 min	**DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT TASK** Students individually demonstrate understanding on an assessment to explain the phenomenon of hearing loss due to the loudness and pitch of different sounds.	D	*Unit Assessment*
4	10 min	**QUICK WRITE: REFLECT ON OUR EXPERIENCES** Students discuss what was challenging and rewarding about this unit.	E	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 14, students are ready to read Student Reader Collection 5 and then respond to the writing exercise.		Student Reader Collection 5: *Air, Wind, and Sound*

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • handout of typed-up questions from the DQB • 10 sticky dots • *Unit Assessment*		

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Type up or take a high-resolution photograph of all the questions on the DQB.

Display all previous classroom consensus models around the room.

Make sure the Driving Question Board is displayed and space is available for the class to gather in a Scientists Circle.

Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

This lesson is an opportunity for students to demonstrate their mastery of NGSS standards MS-PS4-1 and MS-PS4-2. It provides a final opportunity for students to explain what causes different sounds, how sounds move across a medium, and what happens at the sound receiver. This lesson also highlights how changes in amplitude and frequency affect the amount of energy transferred.

Where We Are NOT Going

This assessment provides an image of the ear and specifically asks students to zoom in on a part of the eardrum, thereby keeping the focus on explaining what is happening with the sound waves and their impact instead of on all the mechanics behind how we hear something.

LEARNING PLAN FOR LESSON 14

1. Navigation: Evaluate our DQB questions. 15 MIN

Materials: science notebook, handout of typed-up questions from the DQB, 10 sticky dots

Have students work in pairs to evaluate what questions the class has answered from the DQB. Project **slide A**. Provide students with a copy of the DQB questions which you created to contain all of the student questions from the DQB, and have students tape it into their science notebook. Have students work with a partner to mark questions they think the class has answered:

- We did not answer this question or any parts of it yet: **O**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓+

Review and share the questions that students think we have answered. Present **slide B** and have students mark on the class DQB with sticky dots the questions that they think we have made progress on.

Then have students move into their Scientists Circle.

*** Attending to Equity**
Revisiting the Driving Question Board is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that 50–75 percent will be at least partially answered), this helps students see that they have done this hard work to answer many of their own questions.

2. Revisit the Driving Question Board (DQB) and review feedback from Lesson 13 Assessment. 30 MIN

Materials: science notebook

Review feedback from Lesson 13 Assessment. Pass back the Lesson 13 Assessment and provide students an opportunity to respond to the feedback and ask questions as needed.

Look for patterns using the sticky dots. In the Scientists Circle, focus on the questions that have the most number of sticky dots.

Discuss as a class the questions the class can now answer. Present **slide C** if needed. Have the class discuss the answers to those questions as a group. If you have space, you might make a Take Aways board that has a record of the answers the class comes up with.

Assessment Opportunity

While students are answering questions from the Driving Question Board, this is an excellent formative assessment opportunity used to address partial understandings and see if any pieces need to be revisited. This is also a good way to help students prepare for the summative assessment.

Alternate Activity

Another option is to have students work on answering their own questions that they posed either individually or in pairs. This could be done similarly to the way they did in Lesson 6 where they attach the question to a sheet of paper and answer in words and/or pictures. A focus on those questions that we have not answered but feel we could now (or partially could) with the ideas we have developed can help students feel like they made progress on their own questions.

Additionally, some teachers start a Wonder board, where questions that have not yet been answered but students are still interested in pursuing are housed. These questions are available for students to pursue independently or as time allows.

End of day 1

3. Demonstrate understanding on an assessment task. 35 MIN

Materials: *Unit Assessment*

Administer *Unit Assessment* to students to work on individually. This will take students about half of a class period to complete.

Assessment Opportunity

If your students are struggling or you think they will need support in creating the model, consider letting them use their Gotta-Have-It Checklists for this assessment task. See *Gotta-Have-It Checklist Key* for an example, but it is best to use the list that your students generated in previous lessons.

4. Quick Write: Reflect on our experiences. 10 MIN

Materials: science notebook

Have students reflect on their experiences with the unit. Project **slide E.** They should begin on their own by answering the questions in their science notebook. Then bring students together for a whole-class discussion.

- What was most challenging in this unit?
- What was most rewarding?
- Think about how you engage in sensemaking discussions with classmates. How would you want to engage in those experiences the next time around?
  - What would you do the same?
  - What would you do differently?

Additional Guidance

This unit asks students to do meaning-making that is very difficult but potentially very rewarding. Taking time to reflect upon the process of this unit can allow students to think about what works well for them as learners.

Consider giving more time to answer these questions if needed.

*** Attending to Equity**

This assessment encourages students to demonstrate their understanding of key skills and concepts from the unit so far through multiple different modalities, including writing to explain and drawing models. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment. You may consider allowing some students to present their answers verbally with you or another student acting as a scribe to record their thinking on paper. Other students may benefit from using gestures rather than images to describe parts of their models. Some students might also benefit from using manipulatives to represent parts of the model and to support a written or verbal explanation of what's happening in each part of the model. In each case, encouraging students to use multiple modalities to show their thinking creates a clear, accessible, equitable pathway for all students to demonstrate proficiency.

SCIENCE LITERACY: READING COLLECTION 5

Air, Wind, and Sound

1 **A Windy Vancouver Vacation**
2 **A Whisper or a Shriek?**
3 **Wind Turbines**
4 **A Survey of Wind Turbine Syndrome Victims**
5 **Wind Turbine Health Impact Study**

Literacy Objectives

- ✓ Distinguish cause(s) and effect(s) related to wind, wind turbine technology, sound and pressure waves, and human health.
- ✓ Argue and support a position on the issue of wind turbine safety.
- ✓ Differentiate fact, reasoned judgment, speculation, and opinion.
- ✓ Describe bias exhibited by a source.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 1–14.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a paragraph in response to the reading to argue for or against the use of wind turbines based on information in the reading selections.

Instructional Resources

Student Reader

Collection 5

Science Literacy Student Reader, Collection 5
"Air, Wind, and Sound"

Exercise Page

EP 5

Science Literacy Exercise Page
EP 5

Prerequisite Investigation

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 13: What transfers more energy, waves of bigger amplitude or waves of greater frequency?
- Lesson 14: How can we explain our anchoring phenomenon, and which of our questions can we now answer?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS4.A Wave Properties: A sound wave needs a medium through which it is transmitted. (MS-PS4-2)

Science and Engineering Practice(s): Analyzing and Interpreting Data; Constructing an Explanation

Crosscutting Concept(s): Cause and Effect; Energy and Matter; Structure and Function

CCSS

English Language Arts

RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

MP.2 Reason abstractly and quantitatively.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

association

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (MONDAY)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Sound Waves unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *You will learn about how wind can produce and affect sound waves in the atmosphere.*
  - *You will also learn about wind, sound, and pressure waves associated with wind turbines that convert mechanical energy to electricity.*
  - *The last two sections of the reading present arguments and information for and against an industrial wind farm in a fictional town.*
- Prime awareness of the terms *causal* and *association*.
- *What is an association that you have with strong winds, particularly the sound of a strong wind?* *(instills worry in me, because my bedroom is under a large tree that sometimes loses branches during strong winds)*
- *What's an example of a causal relationship?* *(wind causes branches to break off a tree)*
- Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this exercise you'll write a public comment that is either for or against the wind farm in the fictional town.*
  - *Pay close attention to the claims made in the last two sections of the reading, and consider the credentials and credibility of the authors.*
- Distribute Exercise Page 5. Review the assignment and clarify your own expectations about how long students' deliverables should be and how much time they should spend on them.
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete. (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)*
  - *A good reading strategy is to scan through the selection first to see the titles, section headers, graphics, and images to see what the selection is going to be about before fully reading.*
  - *Next, "cold read" the selection without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selection to complete the writing exercise.*
  - *Jot down any questions for the mid-week progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

Exercise Page

EP 5

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently.

You may choose to administer a mid-week minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
How does wind affect sound waves?	*It bends (refracts) them either upward or downward.*
How does wind itself produce sound?	*It can create a humming or whistling sound blowing across surfaces.* *It causes materials it moves to make rustling or flapping noises.*
How do wind turbines produce sound waves?	*The mechanical parts inside make sound when they are in motion.* *The motion of the blades through the air makes an audible whooshing sound.* *Wind blowing past the tower can produce a hum.*

Ask a few brief questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How is frequency of sound waves associated with wind turbines?	*Frequency relates to pitch. Mechanical parts inside the turbine emit sounds of an audible tone or pitch. Spinning blades produce broadband sound of no specific pitch.*
How is amplitude of sound waves associated with wind turbines?	*Amplitude relates to intensity of energy transferred by sound waves, which we perceive as loudness. Depending on how close a person is to specific parts of a turbine, the sound intensity could be comparable to a lawn mower or a barely-audible refrigerator.*

- Refer students to Exercise Page 5. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The expectation for this assignment is that you will develop an informed opinion on the subject of the wind farm in the fictional town, and then write a public comment that supports your opinion and cites specific claims, data, and arguments in the related readings.*
  - *That means you need to focus only on arguments and data presented in the readings, not on prior knowledge you have or any information you might acquire from further research.*
  - *The important criteria for your work are that you cite available information data, and that your argument is logical and coherent.*
- Answer any questions students may have relative to the exercise expectations or the reading content.

Exercise Page

EP 5

4. Facilitate discussion. (FRIDAY)

Facilitate class discussion about the reading selections and writing exercise.

Student Reader

Collection 5

Pages 46–50 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "A Windy Vancouver Vacation"?	*It points out some science observations related to a person's social media posts about things they observe on a vacation.*
What are some details from the posts that allow for us to examine the interactions of wind and sound?	*The wind affects how loud the fog horns on passing ships sound at different times of the day.* *The wind prevents people at the shore from hearing the person calling to them from behind. The wind there itself makes a rushing noise and causes the waves to crash on the rocks, producing loud sound.* *The wind whistles through trees.*
Wind can affect other sounds by refracting their sound waves up and away from Earth's surface or bending them down and along Earth's surface. Which tends to focus sound waves and make them easier to hear?	*Sound waves refracted downward, as they are affected by wind blowing toward a listener, are easier to hear.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 46–50 **Suggested prompts**	**Sample student responses**
What is the general purpose of the second selection, "A Whisper or a Shriek?"?	*It tells about how wind and the sounds of wind have historically affected how people feel.*
How can the sounds of or from wind affect people emotionally or psychologically?	*Wind or wind sounds might trigger associations that rouse either positive or negative emotions.* *The annoyance of ceaseless whistling sounds can be bothersome and unpleasant.*
What is the general purpose of the third selection called, "Wind Turbines"?	*It explains how wind turbines work and describes how they make sounds.*
Describe some ways that wind turbines produce sound waves.	*"The mechanical action in the gearbox produces a whirring sound that can have a specific tone."* *"The action of the blades through the air, and the way the tower gets in the way of sound waves coming off the blades, produces a whooshing sound."*

Discuss the two sides of the debate about the fictional wind farm as presented in the reading selection. Emphasize that, in this discussion, students are not being asked to debate the issue, they are being asked to *describe* the debate. For the last four pages of the reading selection, prompt students to identify details that serve as red flags that the content is not trustworthy or as signs that the content could be trusted. Discuss how the three different formats in the last two sections might have made the students think about media and different sources of scientific information differently.

Pages 52–55 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth selection, "A Survey of Wind Turbine Syndrome Victims"?	*The author is trying to convince readers that a wind farm should be shut down because the wind turbines have harmful effects on people.*
How does the title of the selection affect your thinking before you even read the pages?	*The use of the word "victims" gives the impression that people are harmed by wind turbines.* *The use of the label "wind turbine syndrome" in the title sets up the expectation that there is such a thing and that it is a serious condition.*
How does information you read in the third selection called "Wind Turbines" give you background information to help you interpret this selection?	*The third article provides information about how wind turbines work and the sounds they can make without making any claims about effects they may or may not have on people.*

SUPPORT—The reading collection has three different pieces about the fictionalized wind farm. The short news brief is likely to be within the range of students' reading abilities, but the literature review might be challenging, and the self-published report by the lone doctor might come off as scientific and more accessible, causing some students to take its claims at face value or simply to have an easier time following what it says. To help them differentiate and evaluate the different sources of information, draw a table or work with them to develop such a table to record the following: Who are the authors/reporters?; What are their credentials?; What are *their* sources of information?; How did they gather information or arrive at conclusions?; What are some potential or evident biases in their work? As needed, help students complete the table.

Pages 52–55 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fifth selection, "Wind Turbine Health Impact Study"?	*It summarizes findings of a research study about whether or not wind turbines affect human health.*
There are two writing forms in the last reading segment. How are they styled?	*The first part is a professional journal summary and the second part is like a news story sharing what the study found.*
What struck you the most about the anti-wind farm author's site in terms of presentation?	*Clear bias against the wind farm, a website can be written by anyone, and he was the only person named.*
What struck you about the authors of the literature review?	*Multiple people were cited, all with qualifications related to the issue and positions of authority in local institutions.*
What about the news brief that covered the debate? What was its purpose?	*to provide an objective perspective of the issue and present a summary that might help someone whose mind is not made up*
What do you think are some potential negative outcomes for publishing bad information or writing something that seems scientific but actually is misinformation or could be called "junk science?" Do you think these outcomes are the same for everyone, or does it depend?	*People can lose credibility if they're wrong or putting out BS. They can lose their jobs and prestige. But some might be more vulnerable than others. A private citizen who is self-publishing claims without any oversight might not have to answer to anyone, such as an employer. A scientist or physician who works for an institution that depends on its reputation might be more vulnerable, and therefore need to be more careful. If a reporter gets a story really wrong, he or she can lose their job.*

KEY IDEAS—Students should conclude that the survey of wind turbine syndrome victims is neither a proper survey nor anything to do with victims, at least not in any legitimate, scientific sense. Among the problems with that piece are:

- There is a single author who has a medical degree but does not appear to be an expert on sound, wind turbines, or any causal relationships between the two.
- The author is president of an anti-wind farm organization and has clear biases against the farm and its operations.
- The survey he conducted was sent out to more than a thousand people but he received completed surveys from only 137, and all of them self-selected into the survey, which could mean the results are skewed toward people who have strong opinions. A legitimate survey would have more responses and would not allow self-selection on this scale. 119 of the 137 respondents were very or extremely concerned about the wind farm before its construction, which suggests the respondents who opted to respond had an anti-wind farm agenda, like the author.
- The questions in the survey are leading. For example, *How disturbed are you by reports of Wind Turbine Syndrome affecting your friends and neighbors?* implies that there are reports of wind turbine syndrome that are already out there, and that the respondents have heard such reports. Where are those reports? What are they? Are they legitimate? The phrasing of the question on its own would lead people to worry about the wind farms.

- The author's interpretations of his data are misleading and wrong. He writes that "80 percent of Whitman residents are opposed" to the wind farm, but he did not survey enough people to state anything about any percentage of the town's residents. He can only make claims about percentages of the respondents to his survey.

The goal is not necessarily for students to adopt a position in favor of wind farms, but now with a deep understanding of how sound waves transfer energy, for them to recognize the more scientific approach that the authors of the literature review took. That review:

- was conducted by multiple, credentialed, credible scientists and/or physicians.
- reviewed many different scientific reports about wind turbines, noise, and human health.
- produced findings that were less political than Dr. Dauer's and were built on much more careful language.
- took pains to clarify when evidence was insufficient, limited, lacking, and so on.
- pointed out areas of inquiry that could be worthy of further research, including the potential for wind turbine noise to disrupt sleep.
- avoided making sweeping claims.

5. Check for understanding.

Evaluate and Provide Feedback

Students should, based on the readings, likely write in support of the wind farm in their public comments, especially if they focus on the information in the readings and do not stray into other sources of information or other questions surrounding wind power, such as whether it makes practical sense or is cost effective. On the other hand, some students might write compelling negative public comments that are based on bird collision data, the precautionary principle, or purely aesthetic arguments, which are not illegitimate as long as they are straightforward and not based on inaccurate data.

Students should focus on the distinction made in the readings between causal relationships and associations. The literature review and its authors pay close attention to the distinction, whereas Dr. Dauer conflates them and does not seem to realize that what he calls Wind Turbine Syndrome *might* be mostly in emotional association for the people who claim to have it. This is not to say that there are no ill effects of wind turbine noise on humans. Rather, the conviction that there are not as supported by science or facts as Dauer claims.

Structurally, students' positions should be composed in a complete, well-reasoned paragraph. Use the rubric provided on the Exercise Page to supply feedback to each student.

Teacher Resources

Table of Contents

ASSESSMENT SYSTEM OVERVIEW

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial Model: Student Activity Sheet	**Pre-Assessment** The student work in Lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn where students are coming in and what ideas they have that you can build on in this unit. The more ideas in your classroom the better. After students complete the initial model, you can review these models for diversity of ideas. Here all you need to see in common is the speaker, the space/air between the window, and the window. All other ideas and ways of representation are spaces to build on and ways for students to see other ideas in the classroom when they share models. The Driving Question Board is another opportunity for pre-assessment. You can see the types of questions your students are asking and what they are asking about. It is also important that the class comes up with a set of questions to support investigations as you begin the unit. This means you need more open-ended, testable questions that are asking how or why something is happening. If students are struggling to ask how or why questions, guide them through practice turning yes/no questions into how or why questions as a class.
Lesson 2	Student Handout Model Modeling Rubric	**Formative** In Lesson 2 the class constructs a model for vibration of an instrument when it is making sound. Students then apply this to create a model of how an an instrument moves to make sound for a different instrument independently. Use the rubric to assess students' individual models of a different instrument than the class consensus model. If students are struggling to connect all the components and interactions across instruments, facilitate a conversation comparing the class model to a couple of student models and decide as a class if anything needs to be added or changed about the consensus model or the student models. This could be done the day of or after you use the rubric on each model. It could also help the class agree on a set of conventions for modeling force and vibration with respect to sound.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 6	Student Assessment Scoring Guide Modeling Rubric	**Summative+Formative** This lesson is a putting-the-pieces-together lesson. It includes a summative midpoint assessment that can provide formative information for moving forward in the unit. The teacher reference document provides a scoring guide and a modeling rubric specific to this unit. This midpoint assessment is important formatively to make sure the class is on the same page and ready to move forward in the unit. At this point, students should be comfortable with the following claims: • All objects vibrate when they make sound • A force applied to an object causes that object to vibrate/move back and forth which makes a sound • A larger force causes more/bigger vibrations and a louder sound • A graph representation of a wave helps us to see the vibrations • Within a graph representation, amplitude is the distance the object moves from its starting point which is related to the strength of the force applied and the object's loudness • Within a graph representation, frequency represents how often the sound source moves in a certain amount of time and the pitch we hear in the sound Within the lesson, you will also have a discussion about the relationship between force, energy, sound, and the graphical representations of waves. Students should be able to make the connection between a force causing the movement of an object and that movement can be talked about as the force transferring energy to the object causing movement.
Lesson 11	Individual Models	**Formative and Summative** Students first work in small groups to develop a model to explain a new phenomenon: salt jumping on plastic wrap when a drum is hit. They summarize the key ideas for explaining this phenomenon, then individually apply that same checklist to revising the model of the truck speaker and window phenomenon. Use the Lesson 11 rubric to evaluate students' models. If a student struggles to correctly complete a model of the truck speaker and window phenomenon, use what you know about that student to deduce the source of confusion. Is the blank paper too daunting, the level of detail required too complex from scratch? If so, direct those students back to their initial model handout, which included the photos of the speaker, parking lot, and window. They may choose to revise that model by using their Gotta-Have-It Checklist to add details; you may suggest they use a different color pencil or ink for ideas they're adding or changing. If a student's model shows partial understanding, but is missing key pieces, direct him or her back to the science notebook and Progress Tracker and use those resources to help explain each missing piece of the model. If the student has shown the model well enough but lacks words to explain what's going on in the picture, consider asking that student to tell you aloud about the model while you scribe captions to explain that thinking.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 13	Student Assessment	**Formative** This lesson includes a transfer task to give students an opportunity to use data to explain how the energy of a vibration changes when the amplitude or frequency of the vibration changes. Look for students to explain that increasing frequency and amplitude increased the amount of energy transferred but increasing the amplitude with the same proportion had a much greater effect on energy transferred. Students may even notice that the frequency-energy transferred is a linear relationship where amplitude-energy transferred is an exponential relationship. To support students who might not be making these connections, prompt them to look back at their class data and consider: what happens to the energy when we double the frequency? What happens to the energy when we double the amplitude? What about when we quadruple it? These questions should get students thinking about patterns in the numerical data that will support their understanding of the relationships this lesson targets between the amount of energy transferred, frequency, and amplitude.
Lesson 14	Student Assessment Teacher Reference Modeling Rubric	**Summative** This lesson includes a transfer task to give students an opportunity to use the three dimensions to make sense of a different phenomenon. This is meant to be a summative assessment task for the unit and it gives you a grading opportunity. The task includes a teacher reference with a scoring guide. Scoring guides are meant to highlight important ideas students should be including in their responses. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated. If your students are struggling or you think they will need support in creating the model, consider letting them use their Gotta-Have-It Checklists for this assessment task.
Occurs in most lessons	Progress Tracker	**Formative and Student Self Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress Tracker can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative "grade" other than for completion.
Anytime after a discussion	Student Self Assessment Discussion Rubric	**Student Self Assessment** The student self assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try next time to improve such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive.

When	Assessment and Scoring Guidance	Purpose of Assessment
After students complete substantial, meaningful work	Peer Feedback Facilitation: A Guide	There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	Develop a model to explain how a sound source (cause) can make another object move (effect). Ask questions about patterns in observations that can be investigated to figure out how sound travels and causes movement in other objects.	The student work in Lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn where students are coming in and what ideas they have that you can build on in this unit. The more ideas in your classroom the better. After students complete their initial models, you can review these models for diversity of ideas. Here, all you need to see in common is the speaker, the space/air between the speaker and the window, and the window. All other ideas and ways of representation are areas to build on and ways for students to see other ideas in the classroom when they share models. The Driving Question Board is another opportunity for pre-assessment. You can see the types of questions your students are asking and what they are asking about. It is also important that the class comes up with a set of questions to support investigations as you begin the unit. This means you need more open-ended, testable questions that are asking how or why something is happening. If students are struggling to ask how or why questions, guide them through practice turning yes/no questions into how or why questions as a class.
Lesson 2	Analyze and interpret data to identify patterns in the data that provide evidence of the relationship between a force (cause) on an instrument and the motion/vibration (effect) of the instrument. Develop a model to describe how a force applied to an instrument causes its shape to change, leading it to repeatedly deform above and below its initial position (effect) as it vibrates and use that model to predict what a force will do to another instrument.	During part 3 while students are writing individually in their notebooks, walk around and look for students making connections between the force on the instrument and the motion or vibration of the instrument for each case. You want students to use the data to show the relationship between the cause and the effect on the instrument. If students are focused on force or motion but not the relationship between the two, use prompts in the Building Understandings Discussion to bring out ideas that highlight the relationship. If students are struggling to write about patterns across instruments, focus on the similarities and differences prompts in the subsequent discussion. Use *Rubric for Modeling Motion of an Object Making Sounds* to assess students' individual models of a different instrument than the class consensus model. If students are struggling to connect all the components and interactions across instruments, facilitate a conversation comparing the class model to a couple of student models and decide as a class if anything needs to be added or changed about the consensus model or the student models. This could be done the day of or after you use the rubric on each model. It could also help the class agree on a set of conventions for modeling force and vibration with respect to sound.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 3	Engage in argument from evidence to support or refute our predictions about whether all solid objects vibrate (cause) when they make sounds (effect), even when we cannot see them vibrate.	**Argumentation; Cause and Effect** At the end of day 1, look at part 3 of the handout to see if students are able to make a claim. A claim should state as such: All solid objects vibrate when they make sounds. Evidence should include observations of the drum and the rock on the table. Reasoning needs to make a connection between the sound and the vibration they can't see that is detected by the laser. See example in *Teacher Reference*. If students are struggling with the "Reasoning" section, you might provide more sentence starters or fill in the blanks for that part. See *Teacher Reference* for an example. If students have a claim that the table is not vibrating, ask them what evidence they have to support that. Ask them how they can explain the movement of the laser if there is no movement happening from the table. You could lead a class discussion with students arguing for either side. At the end of day 2, collect the handouts as a formative assessment. Look at part 4 to see if students were able to make a claim. The claim should state this idea: When more force is applied to an object, it causes bigger vibrations and therefore louder sounds. Evidence includes observations of the speaker's wider vibration blur when it was playing a louder sound and/or observations from day 1 that the louder drum strike moved the laser more than the soft one and/or that the larger rock dropped on the table caused the laser to move more than the smaller rock. So the reasoning concludes that a bigger force on an object causes the object to move back and forth/vibrate more (or bigger). When that happens more energy is being transferred. This means that louder sounds move more and have more energy than softer sounds. If students' claims, evidence, and/or reasoning don't meet your expectations on this handout, consider looking at their Progress Trackers as well. It may be that they did not put all the pieces together on their own, but after the discussion they understood the content of the lesson. If their Progress Trackers show good understanding of the lesson's key ideas, provide more guidance to these students next time they are using evidence to support a claim. If the Progress Trackers do not show good understanding of this lesson's key ideas, those students should be front-and-center helping lead the investigation in Lesson 4. In addition, if students did not add energy transfer into their reasoning (as mentioned above), plan to revisit the reasoning discussion during the next class.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	Use mathematical representations of position versus time graphs generated from a tool used to scale up the vibrations of an object to describe wave patterns and support scientific conclusions about how objects move when they make louder or softer sounds.	On the Progress Tracker, look for students to explain that the wave patterns on the graphs of louder sounds had higher amplitude (bigger vertical distances) than softer sounds. They should also mention that the frequency (horizontal distances) did not change when the same source was making a louder or softer sound. If students are able to correctly explain the different patterns for louder versus softer sounds but they do not use the terms *amplitude* or *frequency* (or don't use them correctly) to describe them, consider having them complete *Harp String Graph Handout* with a partner or with teacher guidance in a small group to reteach these terms. Be sure they have added those terms to their science notebooks, consider adding them to a word wall display in the classroom, and remind students to refer to either of those word lists as you continue this unit. If a student has not been able to explain at all how motion graphs of louder versus softer sounds are different, consider having that student "play with" the guitar again. What does a guitar player need to do differently to make a loud sound versus a softer one? Then consider printing out the four graphs of the motion of the stick and speaker, holding them near the guitar strings, and pointing out the connection between a longer/farther "pluck" and the higher amplitude on the louder graphs. The softer sounds require a smaller pull away from the starting point, as seen in the graphs with lower amplitude.
Lesson 5	Use mathematical representations of position versus time graphs generated from a tool used to scale up the vibrations of an object to describe wave patterns and support scientific conclusions about how objects move when they make higher-pitch and lower-pitch sounds.	**Using Mathematics and Computational Thinking; Patterns; Scale, Proportion, and Quantity** Students work with their groups to calculate in their science notebooks the amplitude and frequency for each stick. Walk around and look for students to identify amplitude as the distance from at rest to the top of a peak or bottom of a valley. Students should calculate frequency as the number of complete vibrations or oscillations in one second. If you see students who are not able to calculate the amplitude or frequency, refer them to their graphs in Lesson 4 or the word wall. When students are adding to their individual Progress Trackers, in their science notebooks, look for students to connect that the longer the stick, the lower the pitch of the sound and the lower the frequency of vibrations. If students struggle to connect the tone of the pitch to the frequency of vibration replay the video and ask students to find the main difference in the graph of a high pitch and low pitch sound. The last task students will complete in this lesson is *Analyzing Graphs of Sound Source Vibrations,* which will be collected at the end of the lesson. Look at *Key: Analyzing Graphs of Sound Source Vibrations* for an example of student answers. If students struggle to connect the high note on the xylophone to Graph B (highest frequency of vibrations), suggest that students draw a mini xylophone on their paper and then write in which bar would have made each note. Then for each note ask students why they chose that bar. Have students return to Graphs A, B, and C and see if they can now tell which graph represents each pitch (high, middle, and low).

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	Use a model to explain how a force applied to an instrument causes the sound source to vibrate (effect) and make a sound even if we cannot see it. Construct an argument using evidence from graphs to support an explanation for which patterns of frequency and amplitude of a wave are indicators of attributes of sounds that we can hear.	This is a putting-the-pieces-together lesson. It includes a summative midpoint assessment that can provide formative information for moving forward in the unit. The teacher reference document provides a scoring guide and a modeling rubric specific to this assessment. This midpoint assessment is important formatively to make sure the class is on the same page and ready to move forward in the unit. At this point, students should be comfortable with the following claims: • All objects vibrate when they make sound. • A force applied to an object causes that object to vibrate, or move back and forth, which makes a sound. • A larger force causes more and bigger vibrations and a louder sound. • A graphical representation of a wave helps us to see the vibrations. • Within a graphical representation, amplitude is the distance the object moves from its starting point, which is related to the strength of the force applied and the object's loudness. • Within a graphical representation, frequency represents how often the sound source moves in a certain amount of time and the pitch we hear in the sound. Within the lesson, you will also have a discussion about the relationship among force, energy, sound, and the graphical representations of waves. Students should make the connection to the idea of energy transfer where the force that causes the object to move transfers energy to that object.
Lesson 7	Respectfully provide and receive critiques in order to revise initial claims about whether air is being moved (cause) all the way from the sound source to our ears when we hear the sounds or when the window moves (effect).	Look at the feedback students provide on sticky notes to their peers as well as their reflection on that feedback to revise their own initial claims on *Lesson 7: Exit Ticket* to see if students are providing specific and actionable feedback that is related to the science ideas and uses evidence from the investigations conducted in this lesson. If students are struggling with giving specific feedback that uses the evidence, provide sentence starters such as, "I agree/disagree with your claim that __________. The evidence shows __________." If students are struggling with understanding what the feedback from their partner means and how it relates to modifying their own model, encourage them to ask their partner to help them understand it and then ask them if they agree or disagree with the feedback and why. In addition to assessing students' ability to give and take feedback, questions 2 and 3 on *Lesson 7: Exit Ticket* as well as part 5 of *Investigation Plan* serve as a valuable formative assessment of students' understanding that air isn't moving all the way from the speaker to the window. Another key concept to look for is that students connect the fact that since the weight of the container didn't change when sounds were coming from inside, sound isn't made of something physical that travels from one place to another, like a particle. If students aren't displaying these understandings on their activity sheets, you may consider leading students through a Consensus Discussion to connect these key findings from their investigations before continuing on to the next lesson. This lesson also provides a good opportunity for students to self-assess their ability to give and receive feedback using the *Peer Feedback Guidelines*.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	Use evidence from investigations to compare and critique competing claims and argue that air or another medium such as liquid or solid is needed (cause) to hear sound or move the window (effect).	**Argue from Evidence; Cause and Effect** Listen during the discussions after the two investigations for students' use of evidence from their investigations to compare and critique the two claims from the beginning of the lesson about whether sound needs air to travel. Students' contributions in class and the claims and reasoning they record in their notebooks for each investigation can both provide opportunities to assess students' ability to use evidence from investigation to select the best possible claim about what sound needs to travel. For the first investigation, students should connect the evidence to the claim that sound does need air to travel since we couldn't hear it once all the air was removed from the container. For the second investigation, students should connect the evidence to the claim that sound doesn't need air to travel. The sound does have something to travel through, but it's not air. If students are struggling to connect the evidence to the claims that were made at the beginning of class, it may be helpful to frame each claim in terms of what outcome we would expect in each experiment if that claim were true. For example, students can predict that if sound needed air to travel, we shouldn't hear the sounds coming from the container with no air. Making this connection between outcome and inference may help students use evidence from each investigation to support or refute the claims laid out at the beginning of the lesson for what sound needs to travel. To support students in doing this reasoning, it may be helpful to spend extra time after each investigation prompting students to reflect on what they've seen and to consider these questions for each claim, "Would we have seen those phenomena if this claim were true? What would we expect to see if this claim was true?" Doing this will help students to connect the abstract idea in each claim with observations they made in each investigation. Listen during the Consensus Discussion and examine the Progress Trackers at the end of the lesson to see if students are making the claim that matter is needed to hear sound. Look for writing or labels indicating that sound needs a solid, liquid, or gas to move through, and sound cannot move without that matter to travel through. However, it's expected that students will not know yet how to draw that movement of sound in pictures. We will use that struggle as your launch point for the next lesson! If you choose to have students complete the exit ticket question about sound in outer space, you will be able to see how well they can use evidence from today's investigations to support the claim that sound needs some matter (air, in this case) to move through. If you have students who cannot connect today's work with space, consider replaying the vacuum chamber video for them, but pausing to explain that the situation going on inside the jar when the air has been removed is very similar to what we find in outer space.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 9	Develop and use a model to describe unobservable parts (particles) of the system and how they would interact with one another in any state of matter to transfer energy from a vibrating sound source through collisions with one another across a medium.	**Develop and Use Models; Matter and Energy** At the beginning of the lesson students will work in pairs on *Sound and States of Matter* to model the unobservable differences in different states of matter that sound traveled through. The intent is to help students recall differences among the states of matter in terms of spacing of particles. This is meant to be formative to help gauge what ideas students are bringing into the lesson about the particulate nature of matter. Look for students to show that there is generally more space between the particles of gas than there is in liquid and less space between the particles in solid than there is in liquid. Later in the lesson students will get another chance, on *Modeling the Matter around the Sound Source,* to model the particles of matter around a sound source and then in the adjacent medium. This time students will have simulated how particles collide with one another, transferring the energy from the vibration of the sound source, so students should show the particles moving and colliding. If students are not able to show the particle movement in their models, ask them to simulate with their bodies what happened in the simulation by using their hands as particles. If students do not readily talk about what is happening with the particles in terms of collisions and energy transfer, refer them back to their original vibration model in Lesson 2 where they indicated that the energy was transferred to the object when the force was applied.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 10	Apply mathematical concepts to make sense of data generated from a model to test ideas about how changing the frequency and amplitude of the sound source affects the patterns in the wavelengths and compression of particles as energy moves across the system.	**Developing and Using Models; Mathematics and Computational Thinking; Energy and Matter; Patterns** At the start of the lesson students add to their Progress Trackers what they figured out about sound travel from the previous lesson. In their written responses and the models they drew, look for students citing evidence from the simulation they did using their bodies as particles hitting each other and transferring energy across the medium. Students may mention that, in this simulation, their bodies could hit with more force or more frequently for different amplitude and frequency sounds and that this might affect energy transfer from body to body (particle to particle). Look also for students identifying that a true model of energy transfer between particles would include space between particles (a limitation of the particle movement model that students used last lesson). Students will not yet be using mathematics to determine the different wavelengths, but this is a good formative assessment to see if they can take away the necessary understanding from the previous lesson to be able to do so. At the end of day 1 on *Analyzing Sound in a Medium Simulation Data* part 4, step 8 students take their first attempt at making sense of what is happening to the particles in the medium that led to the results they observed. This is a great individual assessment of student thinking immediately after collecting data from the simulation and before a Consensus Discussion. Look for students to notice that the particles in the medium are moving back and forth but not traveling all the way across the medium. Students should notice that the pattern of band spacing changes in width when the amplitude is changed and in distance apart when frequency is changed. Students may represent these patterns through a written response describing the movement of individual particles or the medium as a whole or through gestures or visuals that describe that movement. To support students in seeing these patterns and to lay the initial thinking around using math to determine differences of compression bands in the medium, ask students to refer to how their observations were different when they changed their chosen variable. If students still struggle to see this, you can have them return to their devices (side by side) or pull up the simulation as a class to prompt students to consider how their observations change given different inputs for amplitude and frequency. On day 2, during the Consensus Discussion when students are analyzing the data from the simulation on *Analyzing Sound in a Medium Simulation Data,* students will measure the difference in compression band size. Students will do this as a class, but you can assess them in their ability to recognize these patterns using mathematical concepts at the end of day 2 as they individually add to their Progress Trackers. Look for students to use specific examples and models of the compression band spacing changing to a greater width when the loudness or amplitude is increased and getting closer together when the pitch or frequency is increased. Students may represent these patterns through a written response describing the movement of individual particles or the medium as a whole or through gestures or visuals that describe that movement. If students struggle to recognize these patterns, ask them to think about how the single, highlighted particle was moving and the energy was being transferred by the collisions.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	Develop and use a model to describe phenomena using unobservable mechanisms for how a sound source could cause vibrations that produce sounds, which cause particles of matter in the surrounding medium to be compressed and expanded, which then collide with neighbors to transfer energy across the medium, which results in movement of an object farther away.	**Developing and Using Models; Cause and Effect; Energy and Matter** Use *Lesson 11 Modeling Rubric* to evaluate students' models. If a student struggles to correctly complete a model of the truck speaker and window phenomenon, use what you know about that student to deduce the source of confusion. Is the blank paper too daunting, the level of detail required too complex to complete from scratch? If so, direct those students back to their *Initial Model Diagram* from Lesson 1, which included the photos of the speaker, the parking lot, and the window. They may choose to revise that model by using their Gotta-Have-It Checklist to add details; if so, you may suggest they use a different-color pencil or pen for ideas they're adding or changing. If a student's model shows partial understanding but is missing key pieces, direct him or her back to the science notebook and Progress Tracker to use those resources to help explain each missing piece of the model. If the student has shown the model well enough but lacks words to explain what's going on in the picture, consider asking that student to tell you aloud about the model while you scribe captions to explain that thinking.
Lesson 12	Critically read scientific texts adapted for classroom use to determine the central ideas and obtain scientific information to describe patterns of how the structures in the ear interact with each other to transfer energy from the eardrum to fluid in the cochlea and to a series of sensory cells that move (more or less) in response to vibrations of particular frequencies, which send signals along different nerve cells to the brain.	When you check the students' annotated diagrams at the end of this lesson, be sure they have correctly recorded the key ideas of how the parts of the ear work. Specifically, you're looking for whether students understand that energy is transferred through the structures of the ear. If students were not able to correctly complete the diagram, you have a few options for reteaching. You could direct the student(s) to reread *Information from the Experts*, revisit those links and add to the diagram as they see or hear each part. You could also partner students together (one who is struggling with one who understands well) and have them "test" their hearing using the Online Tone Generator linked in *Reading: Hearing in Elephants, Dogs, and Humans*. As they explore the Tone Generator, direct each partner to explain aloud the path the sound is taking through the ear and how energy is transferred to eventually get a signal to the brain.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 13	Apply mathematical concepts and processes to find and analyze patterns in numerical data and graphs of how the energy transferred by a vibrating object changes in proportion to changes in the amplitude and/or frequency of the object's vibrations.	**Using Mathematics and Computational Thinking; Analyze and Interpreting Data; Patterns; Scale, Proportion, and Quality** Students have several opportunities to develop and revise the way they analyze data and then use mathematical and computational thinking around patterns and scale, proportion, and quantity. First, students collect raw data at the end of day 1 on *Data Tables for Energy Transfer Investigation*. Using their raw data, students will look for patterns in the changes in distance of the marker movement based on the number of waves that hit the marker to help them make sense of how much energy is being transferred for different frequency vibrations (1 wave, 2 waves, 3 waves, and 4 waves per second). Look for students to notice that the more waves in a minute, the farther the marker moved. If students do not see this pattern in the data, ask them to describe what they saw when conducting the investigation, have them watch the Frequency vs. Energy Investigation video (See the **Online Resources Guide** for a link to this item; **www.coreknowledge.org/cksci-online-resources**) or redo 1 wave and 4 waves per second. Ask students, *What was different about the motion of the marker when it was hit by one wave per second versus four waves per second?* Students will repeat this investigation with the same initial proportions but change how far back they pull the ruler to simulate waves of different amplitude (1 cm, 2 cm, 3 cm, and 4 cm). Look for students to notice that the farther they pulled back the ruler, the greater the movement of the marker. If students do not notice this pattern, ask them to compare the final position of the marker after a 1 cm versus a 4 cm hit by the ruler. At the end of day 1, students will record patterns that they notice in the data from each investigation. In these written responses and student discussions within groups, look for students connecting the farther movement of the marker to greater energy transfer. Look for students using patterns from their data to identify that increasing either frequency or amplitude increases energy transferred but that increases in amplitude have a greater impact on energy than do increases in frequency. Another opportunity to formatively assess students analyzing data and using mathematics and computational thinking is at the beginning of day 2 when groups are analyzing data from the energy transfer and amplitude and frequency investigation and they calculate one measure (such as mean or median) for each column in their class results data tables. Look for students using a measure of center and a method of dealing with outliers that provides typical values that match the patterns that students found in their investigations for how changing amplitude or frequency changes the amount of energy transferred. If students struggle to find either the mean or median, you can support students in recalling these procedures by taking a sample data set (either from the investigation or a random example set) and working together as a class or small group to describe how students could find the mean and median of the set. By doing this with the class or small groups that could use this extra practice, you can support students with mathematical methods needed to analyze the data the class has collected to draw conclusions about the lesson question. If students do not readily see the patterns in rates of change here, they will get another chance to think through it when creating graphical representations of their data in the next activity.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		After the class has worked together to create graphical representations of their data, students will individually look for patterns in the relationship of proportionally changing the frequency and amplitude resulting in different amounts of energy being transferred. Look for students to explain that increasing frequency and amplitude increased the amount of energy transferred, but increasing the amplitude with the same proportion as increasing the frequency had a much greater effect on energy transferred. Students may even notice that the frequency-energy transferred is a linear relationship while amplitude-energy transferred is an exponential relationship. To support students who might not be making these connections, prompt them to look back at their data and consider these questions: What happens to the energy when we double the frequency? What happens to the energy when we double the amplitude? What about when we quadruple it? These questions should get students thinking about patterns in the numerical data that will support their understanding of the relationships among the amount of energy transferred, frequency, and amplitude that are targeted in this lesson. At the end of day 2, students engage in a Consensus Discussion about what they can add to their Progress Trackers and have a final opportunity in this lesson to summarize the results from the Energy Transfer for Amplitude and Frequency Investigation. Look once again for students to explain that the greater either the amplitude or frequency, the greater the amount of energy transferred. However, increasing the amplitude by the same proportion as increasing the frequency will transfer much greater energy. Listen during the Consensus Discussion and examine the Progress Trackers at the end of the lesson to discern whether students are able to differentiate between how amplitude and frequency affect energy change. If students are still struggling to connect these ideas during the Consensus Discussion, ask them to explain to a partner what pieces they think they understand from the data. Then have their partner explain the missing pieces to them. Then ask the original student to revoice in their own words what the other student said and to use an example.
Lesson 14	Develop and use a model to explain how loud sounds and the energy transfer associated with high amplitude sound waves cause damage to ear structures.	This lesson includes a transfer task to give students an opportunity to use the three dimensions to make sense of a different phenomenon. This is meant to be a summative assessment task for the unit, and it gives you a grading opportunity. The task includes a teacher reference with a scoring guide. Scoring guides are meant to highlight important ideas students should be including in their responses. If students share these ideas elsewhere in the assessment, it is up to you to decide if that understanding is sufficiently demonstrated. If your students are struggling or you think they will need support in creating the model, consider letting them use their Gotta-Have-It Checklists for this assessment task.

Peer Feedback Guidelines

Teacher Instructions

There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least once, but preferably two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process.

When is a good time to facilitate peer review?

Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work; rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

What are classroom structures I can use for peer review?

Below are three examples of ways to organize peer review in your classroom. You may choose to use all of them depending on your time or material constraints, or you may choose to always use one structure for review, so that your students get familiar with it and better at it over time.

Sticky Note Peer Review: In this protocol—shared on *Tools for Ambitious Science Teaching*—students use sticky notes to leave questions and comments on posted student work. There is time built in for students to respond on the feedback. Use the self-assessment rubrics in this document at the end of the class period for students to reflect on their experience in this feedback session.

Peer Review with Unit Rubrics: Each unit and the curriculum overall, have Science and Engineering Practice (SEP) specific rubrics for teachers to assess student work. You can also use these as a way for students to assess each other's work and give feedback on how to improve. For example, in the Sound unit during Lesson Set 1 students develop models of how objects vibrate to make sound. They can be assessed with this rubric. We suggest having students use the rubric to give specific feedback to each other. You can use this in a gallery walk type setting or have students exchange models.

Group Review: Ask students to get into groups of four. Have students bring their individual model or explanation (or other piece of student work) to the group. Review feedback guidelines as a class, giving examples of good and bad feedback. Then, in pairs, have students provide feedback to the other two pieces of student work. They can use sticky notes or write directly on the work. Make sure to leave individual work time for students to revise their models and complete the self-assessment rubric.

Giving Feedback to Peers

This tool was inspired by the Sticky Note Feedback resource originally developed by Ambitious Science Teaching at: https://ambitiousscienceteaching.org/sticky-note-student-feedback/

Feedback needs to be specific and actionable.

That means, it needs to be related to science ideas and provide your own suggestions for improvement.

Productive examples:

- "Your model shows that the sound source changes position when it is hit. I think you should add detail about how the sound source moves back and forth after it is hit."
- "You said that the drum moves when it makes sound, but the table doesn't move when it makes sound. We disagree and suggest reviewing the observation data from the laser investigation."

Nonproductive examples of feedback that do not help other students improve are:

- "I like your drawing."
- "Your poster is really pretty."
- "I agree with everything you said."

How to Give Feedback:

Your feedback should give ideas for specific changes or additions the person or group can make. Use the sentence starters below if you need help writing feedback.

- The poster said ____________________. We disagree because ____________________. We think you should change ____________________.
- I like how you ____________________. It would be more complete if you added ____________________.
- We agree that ____________________. We think you should add more evidence from the ____________________ investigation.
- We agree/disagree with your claim that ____________________. However, we do not think the ____________________ (evidence) you used matches your claim.

Receiving Feedback from Peers

The purpose of feedback is to get ideas from your peers about things you might improve or change to make your work more clear, more accurate, or better supported by evidence you have collected. It also helps you to communicate your ideas more effectively to others.

When you receive feedback, you should:

- Read it carefully. Ask someone else to help you understand it, if necesssary.
- Decide if you agree or disagree with the feedback and say why you agree or disagree.
- Revise your work to address the feedback.

Self Assessment: Giving Feedback

How well did you give feedback today?

Today, I. . .	YES	NO
Gave feedback that was **specific** and about **science ideas.**		
Shared a suggestion to help improve my peer's work.		
Used evidence from investigations, observations, activities, or readings to support the feedback or suggestions I gave.		

One thing I can do better next time when I give feedback is:

Self Assessment: Receiving Feedback

How well did you receive feedback today?

Today, I. . .	YES	NO
Read the feedback I received carefully.		
Asked follow-up questions to better understand the feedback I received.		
Said or wrote why I agreed or disagreed with the feedback.		
Revised my work based on the feedback.		

What is one piece of feedback you received?

What did you add or change to address this feedback?

Name: ______________________ Date: ______________________

LESSON 2: RUBRIC

Rubric for Modeling Motion of an Object Making Sounds

Use this rubric to provide feedback to students as they explain the components and interactions involved when an object makes sounds.

Components The model clearly represents or describes the system components and must include the following information:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• **original starting position** of the sound source at every point in time (in every frame)				
• the **object that applies an initial force** to the sound source				
• the **shape changes of the sound source (e.g., instrument)** shown at every point in time at and after the initial force is applied with reference to the initial starting point				
Interactions between components The model clearly represents or describes the following information:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• a force applied through contact that causes the shape of the sound source (e.g., instrument) to deform *(cause/effect)*				
• that after the applied force is removed, the sound source (e.g., instrument) deforms back in the opposite direction, extending beyond the starting/original position (*pattern/structure*)				
• the repeated nature of this back-and-forth motion of the shape of the sound source (e.g., instrument) (may identify this back-and-forth motion as a vibration) (*pattern/structure*)				
• that eventually the sound source stops moving back and forth and goes back to its original starting position (*pattern/structure*)				
• that once the sound source goes back to its original starting position, the sounds stop or are no longer heard (*cause/effect*)				

LESSON 3: TEACHER REFERENCE

How do objects move when they make sounds?

Part 1. What are possible outcomes of our investigation, and what do they mean?	
When we ___________, we might observe ____________.	That would make us think ____________.
When we drop different-sized rocks on the table, we might observe different sounds (smaller rock = softer sound, larger rock = louder sound).	That would make us think maybe the vibrations are different.
When we drop a small rock on the table, we might observe the laser moving a little (short distance or quick duration).	That would make us think the table is vibrating a little.
When we drop a bigger rock on the table, we might observe the laser moving a lot (long distance or for a longer time).	That would make us think the table is vibrating a lot.
When we drop the rock on the table, we might observe the laser not moving at all.	That would make us think the table is not vibrating. Or, if the laser doesn't move when we drop a rock on the table, it could mean our setup doesn't work. We should test it.

Part 2. What did you observe?	
Sound source	**Observations**
Drum, soft (day 1)	
Drum, loud (day 1)	
Smaller rock (day 1)	
Larger rock (day 1)	
Speaker loud, high pitch (day 2)	
Speaker loud, low pitch (day 2)	
Speaker soft, high pitch (day 2)	
Speaker soft, low pitch (day 2)	

Part 3. Make a claim from evidence, day 1: How do solid objects move when making sounds?	
Claim: All objects vibrate when they make sounds.	
Evidence to support your claim	**Reasoning:** Why does this evidence support your claim?
Drum When we hit the drum, it made a sound, and the laser moved up and down.	We know the drum vibrates to make sounds because we can see it. The laser moved up and down with the drum vibrations. Note: Any mentions of energy are productive, accurate, and going to be important in day 2.
Rock When the rock hit the table, it made a sound, and the laser moved up and down.	The laser moving is a way for us to see vibrations. When the rock hit the table, it vibrated. Note: Any mentions of energy are productive, accurate, and going to be important in day 2.

Part 4. Make a claim from evidence, day 2: How does changing the force affect the sound?	
Claim: When more force is applied to an object, it causes bigger vibrations and therefore a louder sound.	
Evidence to support your claim	**Reasoning:** Why does this evidence support your claim?
Speaker The speaker had a wider vibration blur when it was turned up louder. **Drum, Rock** The louder drum strike caused the laser to move more than the soft strike. The larger rock dropped on the table caused the laser to move more than the small rock, and it made a louder sound.	A bigger force on an object causes the object to <u>move back and forth or vibrate more (or bigger)</u>. When that happens more <u>energy</u> is being transferred. This means that louder sounds <u>move more and have more energy than softer sounds</u>.

Name: ______________________ Date: ______________________

LESSON 5: ANSWER KEY

Key: Analyzing Graphs of Sound Source Vibrations

Exit Ticket: The graphs to the right represent the position of a sound source that is vibrating. The sound source in each case is a xylophone that was struck with a mallet three different times to create the three different graphs.

1. Based on the three graphs, what can you claim about each instance that sound that was made by hitting a xylophone? Why do you think that?

Graph A: The sound made by the xylophone in Graph a is a middle pitch middle pitch note. I think this because there are a medium number of vibrations in the time period.

Graph B: The xylophone that made the sound in Graph b is the highest pitch sound because it has the most vibrations in the time period.

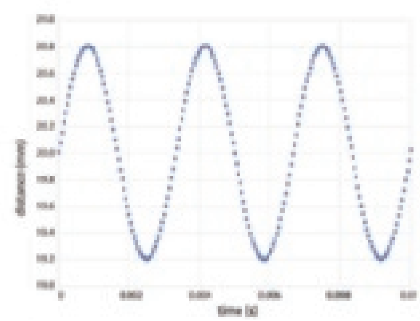
Graph C: The sound made by the xylophone in Graph c is a low pitch note. I think this because there are the least number of vibrations in the time period.

Optional: All three graphs have the same loudness.

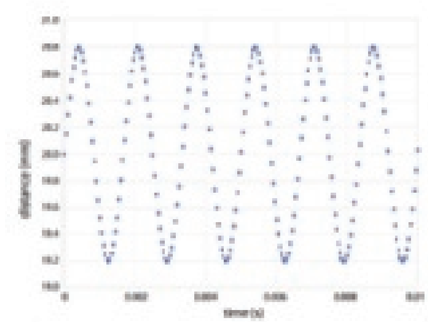
2. Which of the graphs has the highest frequency? Which of the graphs has the lowest frequency? What is your mathematical evidence?

Graph B has the highest frequency. There are 5.5 vibrations in 0.01 seconds. Whereas Graph A has a frequency of 3 vibrations in 0.01 seconds, and Graph C has a frequency of 1.5 vibrations in 0.01 seconds.

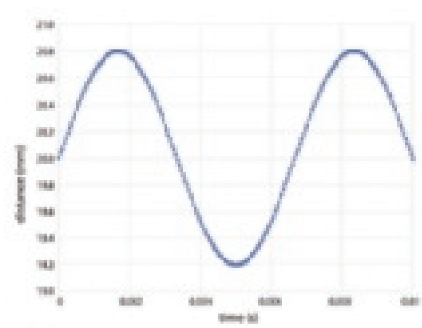
Graph A



Graph B



Graph C



Name: ______________________ Date: ______________________

LESSON 6: RUBRIC

Rubric for Modeling Motion of an Object Making Sounds

Use this rubric to provide feedback to students as they explain the components and interactions involved when an object makes sounds.

Components The model clearly represents or describes the system components and must include the following information:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• the **original starting position** of the sound source **(i.e., the instrument)** at every point in time (in every frame)				
• the **object that applies an initial force** to the sound source				
• the **shape changes of the sound source (e.g., instrument)** shown at every point in time at and after the initial force is applied – with reference to the initial starting point				
Interactions between components The model clearly represents or describes the following information:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• A force applied through contact causes the shape of the sound source (i.e., the instrument) to deform *(cause/effect).*				
• After the applied force is removed, the sound source deforms back in the opposite direction, extending beyond the starting/original position *(pattern/structure).*				
• The nature of the back-and-forth motion of the shape of the sound source is recurrent (may identify this back-and-forth motion as a vibration) *(pattern/structure).*				
• Eventually, the sound source stops moving back and forth and goes back to its original starting position *(pattern/structure).*				
• Once the sound source goes back to its original starting position, the sounds stop or are no longer heard *(cause/effect).*				

LESSON 6: ANSWER KEY

Key: Connecting Graphical Representations to the Sounds Made

Question Set 1

1a. Make two claims:

Which graph represents vibrations that are producing the quietest sound? ___C____

Which graph represents vibrations that are producing the loudest sound? ___B____

1b. What is your **evidence** from the graph (use the words *amplitude* and *frequency*)?

Graph B has the highest amplitude, which means that it has the most movement up and down from its starting place. Graph C has the smallest amplitude, or movement up and down from the starting place. The amplitude is related to the loudness but the frequency is not.

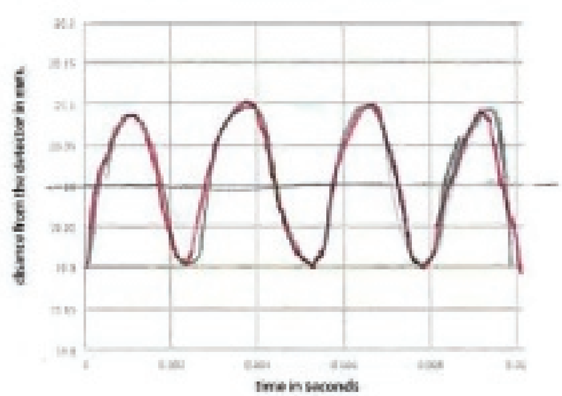
1c. How does the evidence support your claim (reasoning)? How does the movement of the object relate to how loud the sound is?

The loudness is related to the **force** on the instrument so the harder someone hits the xylophone, the more it will move and the louder it will be.

Additional practice:

The graph to the right represents the position of a sound source that is vibrating. The sound source is a guitar string that was plucked. The time frame depicted is 0.01 second.

1d. Draw a new version of **graph G** that represents the vibrations of a sound source from an instrument that is deformed with just as much amplitude as the one above but is vibrating with a frequency that produces four back-and-forth motions (four waves) in 0.01 second.



1e. If a sound source is producing sound with a steady pitch and is vibrating with a frequency of 2 waves per 2 seconds, then how many times would it move back and forth in 10 seconds? 10 times

Question Set 2

2a. Make claims:

- Which graph represents vibrations that are producing the lowest pitch sound? _A, B, C, or E_
- Which graph represents vibrations that are producing the highest pitch sound? _D__
- Which graph represents vibrations that are producing a sound with a pitch that is not the lowest and is not the highest of the three? __F___

2b. What is your **evidence** from the graphs (use the words *amplitude* and *frequency*)?

Graphs A, B, C, or E all have the same frequency which is how many times it moves back and forth in a certain time. Graph D has the highest frequency and therefore the highest pitch. Graph F has a frequency that is in the middle.

2c. How does the evidence support your claim (reasoning)? How does the movement of the object relate to the pitch of the sound?

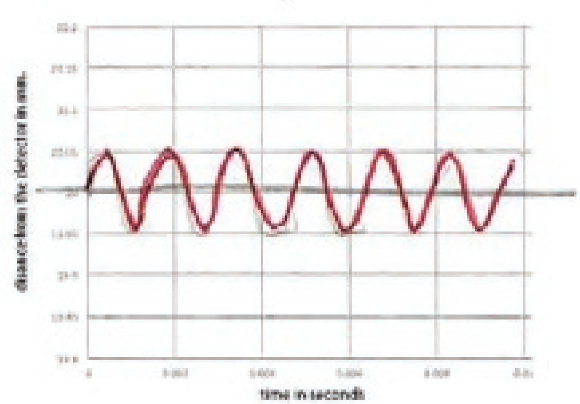
Sounds that are high pitch **vibrate** faster—the xylophone is going back and forth faster in graph D.

Additional practice:

The graph to the right represents the position of a sound source that is vibrating. The sound source is a guitar string that was plucked. The time frame depicted is 0.01 second.

2d. Draw a new version of **graph G** that represents the vibration of a sound source from the same instrument, which is producing a sound at the same frequency but with a smaller amplitude.

Graph G



2e. If a sound source is producing sound with a steady pitch, and is vibrating with a frequency of one wave per 2 seconds, then how many times would it move back and forth in 20 seconds? 10 times

Name: ______________________ Date: ________________

Assessment

A harp, an instrument we have not yet seen, makes sounds like all instruments. Your teacher will play a video showing a harp making different sounds. Answer the questions below to use what we've learned so far about sound sources to model what we see in this video.

1. What parts of the instrument are the sound sources?

2. What would you expect to see these sound sources doing anytime one of them produces a sound? Explain in one sentence.

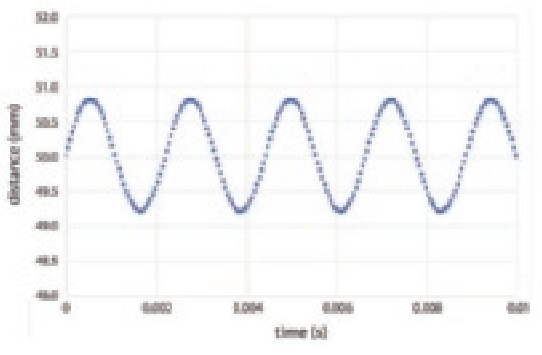
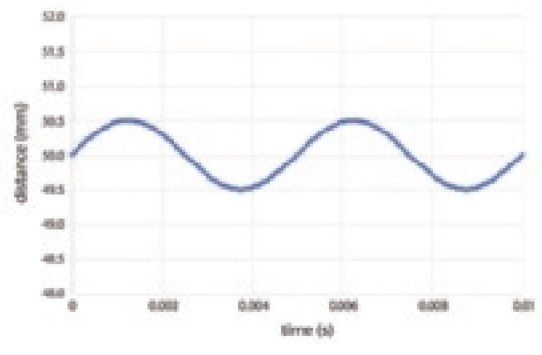
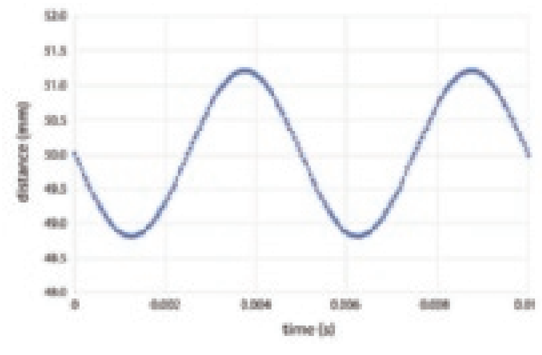
3. What does the musician need to do differently when she interacts with these sound sources in order to get them to produce softer sounds?

4. Draw and label a step-by-step model that shows and describes what the sound source is doing when it makes a sound. Step 1 should show what the sound source looks like before it makes a sound. The middle steps should show what the sound source looks like as it is making a sound. Step 5 should show what the sound source looks like when it stops making a sound.

Step 1	Step 2	Step 3	Step 4	Step 5

5. Now that we have a model of the harp making sounds, we have a problem with some data from the harp.

Sam collected motion detector data from different sounds that the harp made but he forgot to label his graphs and does not know which graph goes with which sound he played.

Graph D	Graph E	Graph B
		

Sam needs to know which graph shows both a high pitch and a high loudness sound. Complete the table below to write an argument for which graph shows the high pitch, high loudness sound.

CLAIM	EVIDENCE FROM GRAPH (use amplitude and frequency)	HOW DOES THIS EVIDENCE SUPPORT YOUR CLAIM	WHY IS IT NOT THE OTHER GRAPHS?

LESSON 6: TEACHER REFERENCE 2

Assessment Key

A harp, an instrument we have not seen yet, makes sounds like all instruments. Your teacher will play a video showing a harp making a sound. Answer the questions below to use what we've learned so far about sound sources to model what we see in this video.

1. What parts of the instrument are the sound sources?

+1 The strings are the part of the instrument that make sound.

2. What would you expect to see these sound sources doing anytime one of them produces a sound? Explain in one sentence.

+1 When a string makes sound, we will see it vibrate back and forth.

3. What does the musician need to do differently when she interacts with these sound sources in order to get them to produce softer sounds?

+1 If the musician wants to make softer sounds, she needs to use less force on the strings OR pull the string back a smaller distance OR don't pull the string back as far before releasing it OR pull it back softer.

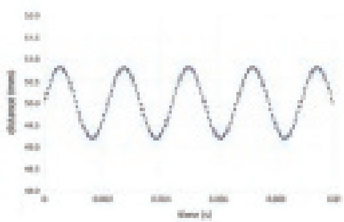
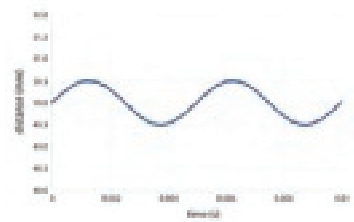
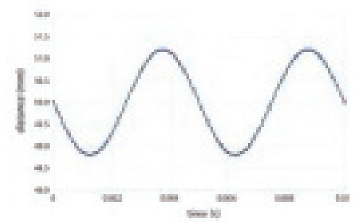
4. Draw and label a step-by-step model that shows and describes what the sound source is doing when it makes a sound. Step 1 should show what the sound source looks like before it makes a sound. The middle steps should show what the sound source looks like as it is making a sound. Step 5 should show what the sound source looks like when it stops making a sound.

Step 1	Step 2	Step 3	Step 4	Step 5

Use the rubric from Lesson 2 to evaluate this model.

5. Now that we have a model of the harp making sounds, we have a problem with some data from the harp.

Sam collected motion detector data from different sounds that the harp made but he forgot to label his graphs and does not know which graph goes with which sound he played.

Graph D	Graph E	Graph B
		

Sam needs to know which graph shows both a high-pitch and a high-loudness sound. Complete the table below to write an argument for which graph shows the high-pitch, high-loudness sound.

CLAIM	EVIDENCE FROM GRAPH (use amplitude and frequency)	HOW DOES THIS EVIDENCE SUPPORT YOUR CLAIM	WHY IS IT NOT THE OTHER GRAPHS?
Graph D shows a high-pitch, high-loudness sound.	You can see high pitch on a motion detector graph or on wave graph in the frequency of the peaks and valleys—that is how close together the peaks and valleys are. In Graph D the peaks and valleys are closer together which means they are more frequent so it has a higher frequency. ———— In Graph D the distance from the starting point is greater so it has a bigger amplitude.	Sounds that are high pitch **vibrate** faster—the harp string is going back and forth faster in Graph D. ———— The loudness is related to the **force** on the instrument so the harder someone plucks the string, the more it will move and the louder it will be.	It is not Graph E because the amplitude of the wave is smaller than the amplitude in Graph D meaning the sound in Graph E was not as loud. In addition, Graph E also has peaks and valleys farther apart than Graph D which means this sound had a lower pitch. Graph B shows a louder sound than Graph D because the amplitude of the wave is higher than Graph D. However, the peaks and valleys are farther apart meaning that this graph was data collected from a lower-pitch sound.

Scoring Guide

A complete argument about loudness and pitch represented in wave data should include all of the following information:

Claim

+1 Graph D shows the sound with the high loudness and high pitch.

Evidence

+1 qualitative description of the loudness because of a larger amplitude

+1 qualitative description of the higher pitch because of a higher frequency (peaks and valleys)

Reasoning

+1 Statement connecting the high pitch to faster vibrations

+1 Statement connecting the high loudness to a force` on the string of the harp

Counter evidence (why is it not the other graphs)

+1 It is not Graph E because the amplitude is smaller and therefore the loudness is lower than Graph D.

+1 It is not Graph E because the frequency is smaller and therefore the pitch is lower than Graph D.

+1 It could be Graph B because the amplitude is the highest and therefore this is the loudest sound in the set of graphs.

+1 It is not Graph B because the frequency is much smaller and therefore the pitch is lower than Graph D.

Key for Gotta-Have-It Checklist

What our model needs to have to answer the question, *"How are sounds caused, and how can they make something move?"*	***Check off pieces of the model as you use them.***	
	used	***did not use***
1. Force is applied to an object.		
2. The object vibrates or moves back and forth past its starting position.		
3. The bigger the force, the larger the amplitude of the vibrations. Larger-amplitude vibrations make louder sounds.		
4. The pitch of the sound depends on the frequency of the vibrations.		
5. The sound source disturbs or pushes the particles in the surrounding medium and transfers energy to those particles.		
6. Particles near the sound source move back and forth, pushing on other particles farther away.		
7. Particles get bunched up and spread out.		
8. When the particles push on each other, they transfer energy across the medium (using arrows, the energy moves from the sound source to the detector), but the particles themselves do not move all the way from the sound source to the detector.		
9. Particles push on the detector repeatedly, which transfers energy to it and also makes it move.		
10. The detector will keep moving until the sound source stops vibrating.		

Name: ______________________ Date: ______________________

LESSON 11: RUBRIC

Modeling Rubric

Component Clearly represents or describes the system components and must include the following:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• the **sound source**				
• the **initial force applied** to the sound source				
• the **particles of the medium** (air) in between the sound source and the detector				
• the **detector** of the sound				
Interactions between components Clearly represents or describes the following:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• The deformation of the sound source causes the particles in the medium to start moving *(cause/effect).*				
• Particles in the medium go back and forth and hit neighbors (show this with some sort of convention for wiggle) *(cause/effect)* but do not travel all the way from the source to the detector.				
• The nature of the back-and-forth motion of the sound source is recurrent (may identify this back-and-forth motion as a vibration) *(pattern/structure).*				
• The particles of the medium push on the detector, causing it to move (cause/effect).				
• Collisions transfer energy across the medium (the energy moves from the sound source to the detector, but the particles do not move all the way from the sound source to the detector) *(energy).*				
• Particles and the sound source go back to their original starting position *(pattern/structure).*				

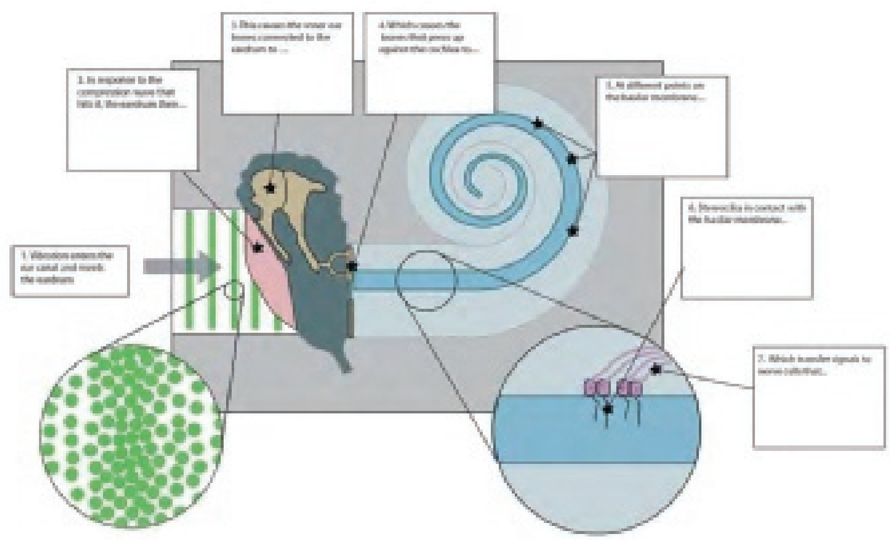
Lesson 12 Activity Sheet—Suggested Responses

Responding to the reading and video and animation links: As you read *Information from the Experts,* use the space below to take notes on anything you found that could help us answer our questions about how the structure and function of the ear allow us to detect different sounds.

Questions we are still trying to answer: • What is happening inside the human ear that allows it to detect different sounds? • What else is happening in the human body that allows it to hear sounds?
Notes from the reading and video and animation links: (Comments and questions will vary.)

Constructing Explanations: Use what you learned from the article and links to show how energy from sounds is transmitted through the inner ear and detected by different sensory cells. Track your findings on the diagram below.

1. Vibration enters the ear canal and meets the eardrum.
2. In response to the compression wave that hits it, the eardrum then... vibrates because the energy has been transferred to it.
3. This causes the inner ear bones connected to the eardrum to... move back and forth because the energy has been transferred to them.
4. Which causes the bones that press up against the cochlea to... transfer energy into that fluid, which transfers the vibrations along the basilar membrane.
5. At different points on the basilar membrane... different pitches cause vibrations in different places, allowing our ears to detect differently pitched sounds.
6. Stereocilia in contact with the basilar membrane.... bend back and forth as the energy is transferred to them.
7. Which transfer signals to nerve cells that... relay those signals to the brain.



Example Class Data Table for Energy Transfer for Amplitude and Frequency Investigation

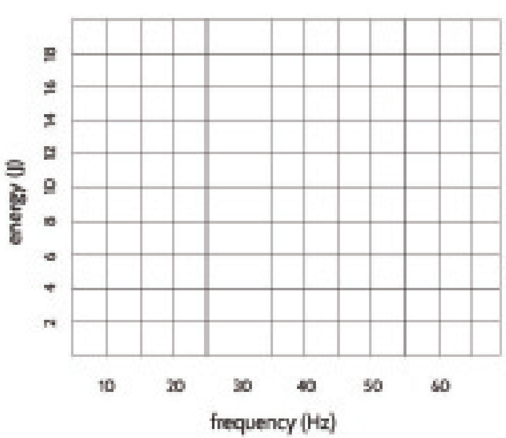
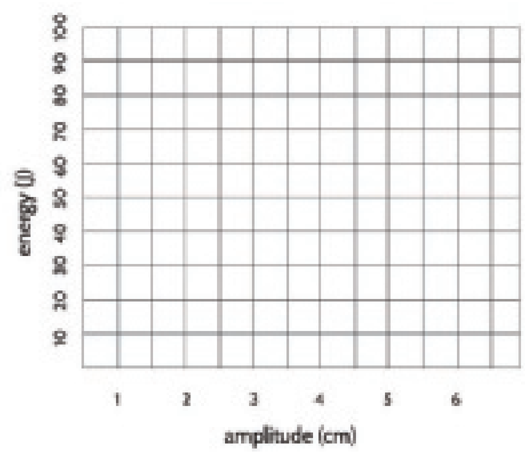
Group	Investigation 1: Frequency versus Energy			
	How far the target moved after 1 wave (cm)	How far the target moved after 2 waves (cm)	How far the target moved after 3 waves (cm)	How far the target moved after 4 waves (cm)
1	3	8	11	14
2	2	4.5	8	9
3	3.5	8	8	12
4	1	3	6	9
5	2	5	9	10
6	2	3	5	7
7	2.5	5	7	10
8	1	4	5	8
9	1	8	11	12
10	3.5	7	9	12

Group	Investigation 2: Amplitude versus Energy			
	How far the target moved after 1 cm (cm)	How far the target moved after 2 cm (cm)	How far the target moved after 3 cm (cm)	How far the target moved after 4 cm (cm)
1	7	13	46	64
2	8	17	36	73
3	7.5	14	36	75
4	5	13	37	67
5	8	18	48	75
6	6	16	32	75
7	7	12	40	68
8	9	16	28	75
9	9	14	33	75
10	8	19	35	75

Assessment: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?

Seth Robinson and Viet Tran, two students at George Mason University, invented what they called a “sonic fire extinguisher”. Their invention uses a speaker to blast sound at fires, transferring energy to the air around the fire. If the speaker transfers enough energy, it disrupts the flow of oxygen into the fire. Since oxygen provides necessary reactants needed for the fire, the fire is quickly extinguished. When Robinson and Tran were developing their sonic fire extinguisher, they had to collect and analyze data (like the data in the tables and graphs below) to figure out what kind of sound would transfer enough energy to put out fires.

1. In the tables below, fill in the missing numbers using what you learned from your investigations into patterns in how the energy of a vibration changes when we change the amplitude or frequency of the vibration. After you have filled in the missing values, plot each data set on the graph to the right of the data table.

Frequency of sound (Hz)	Energy transferred (J)	Graph of Frequency vs. Energy Transferred	Amplitude of sound (cm)	Energy transferred (J)	Graph of Amplitude vs. Energy Transferred
10	2		1	2	
20	4		2	8	
30			3	18	
40			4		
60	12		6		

2. Construct an explanation for how you selected the numbers you put in **each** of the empty boxes in the table.
(Example: "For the energy transferred by a sound with a frequency of 30 Hz, I put __________ because..."
"For the energy transferred by a sound with an amplitude of 4 cm, I put __________ because...")

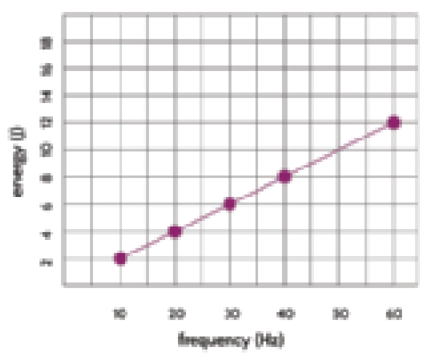
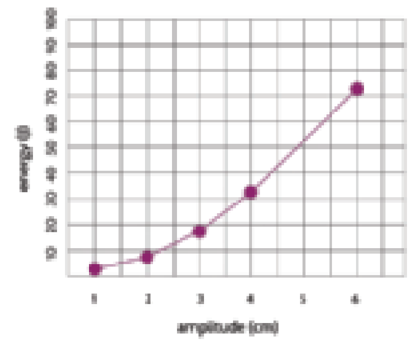
3. Using the evidence from these sets of data, as well as the patterns you saw in the data from your experiments, make a claim in the table below that answers the question: *Which type of sound do you think would be best to transfer enough energy to put out a fire, a louder sound or a higher-pitch sound?* Complete the rest of the table to argue for your claim with evidence.

Claim:	**Evidence:**	**Reasoning:**
Which type of sound do you think would be best to transfer enough energy to put out a fire, a louder sound or a higher-pitch sound?	*Your evidence should include patterns from data tables and graphs you analyzed on this assignment and in your own investigations.*	*"This evidence shows _____. I know this because ____."* *"I know that ____ is true because I learned ____ when we _____."*

Assessment Key: How does the energy of a vibration change when we change the amplitude or frequency of the vibration?

Seth Robinson and Viet Tran, two students at George Mason University, invented what they called a “sonic fire extinguisher”. Their invention uses a speaker to blast sound at fires, transferring energy to the air around the fire. If the speaker transfers enough energy, it disrupts the flow of oxygen into the fire. Since oxygen provides necessary reactants needed for the fire, the fire is quickly extinguished. When Robinson and Tran were developing their sonic fire extinguisher, they had to collect and analyze data (like the data in the tables and graphs below) to figure out what kind of sound would transfer enough energy to put out fires.

1. In the tables below, fill in the missing numbers using what you learned from your investigations into patterns in how the energy of a vibration changes when we change the amplitude or frequency of the vibration. After you have filled in the missing values, plot each data set on the graph to the right of the data table.

Frequency of sound (Hz)	Energy transferred (J)	Graph of Frequency vs. Energy Transferred	Amplitude of sound (cm)	Energy transferred (J)	Graph of Amplitude vs. Energy Transferred
10	2		1	2	
20	4		2	8	
30	6		3	18	
40	8		4	32	
60	12		6	72	

2. Construct an explanation for how you selected the numbers you put in each of the empty boxes in the table.

(Example: "For the energy transferred by a sound with a frequency of 30 Hz, I put ______ because..." "For the energy transferred by a sound with an amplitude of 4 cm, I put _______ because...")

- For the frequency data, I noticed that when the frequency doubled from 10 to 20 Hz, the energy doubled, too. To find the energy transferred by a 40 Hz sound, I doubled the energy for a 20 Hz sound to get 8 J. To find the energy transferred by a 30 Hz sound, I divided the energy for a 60 Hz by 2 to get 6 J.
- For the amplitude data, I noticed that when the amplitude doubled from 1 to 2 cm, the energy went up by 4, which is the square of 2. To find the energy transferred by a sound with an amplitude of 4 cm (4 times the amplitude of 1 cm), I multiplied the energy for a 1 cm sound by 16, which is the square of 4, to get 32 J. To find the energy transferred by a sound with an amplitude of 6 cm (6 times the amplitude of 1 cm), I multiplied the energy for a 1 cm sound by 36, which is the square of 6, to get 72 J.

3. Using the evidence from these sets of data, as well as the patterns you saw in the data from your experiments, make a claim in the table below that answers the question: *Which type of sound do you think would be best to transfer enough energy to put out a fire, a louder sound or a higher-pitch sound?* Complete the rest of the table to argue for your claim with evidence.

Claim	Evidence	Reasoning
Which type of sound do you think would be best to transfer enough energy to put out a fire, a louder sound or a higher-pitch sound? I think the louder sound would transfer more energy than the higher-pitch sound.	*Your evidence should include patterns from data tables and graphs from this assignment or from your own investigations.* In this data and the data from our investigations, when the frequency doubled, the amount of energy doubled, too. When the amplitude doubled, the amount of energy went up by 4 times. The graph for amplitude shows that the energy goes up a lot faster than it does for frequency. The amplitude graph looks more like an exponential relationship where the frequency one looks like a proportional relationship.	*How does your evidence prove that your claim is correct?* When the amplitude is doubled, that makes the amount of energy transferred go up much more than when the frequency is doubled. Doubling the amplitude makes the energy go up by 4 times, which is twice as much of a difference as when we double the frequency. That means that increasing the amplitude of the vibration increases the energy transferred more than increasing the frequency of the vibration. The graph for amplitude vs. energy shows a greater rate of change than the graph for frequency vs. energy. This means that the energy goes up more when we increase the amplitude than it does when we increase the frequency.

LESSON 14: TEACHER REFERENCE

Gotta-Have-It Checklist Key

What ideas our model needs to have to answer the question, *"How does a sound source cause sound and how can that sound then cause something else to move?"*	*Check off pieces of the model as you use them.*	
	used	*did not use*
1. Force is applied to an object.		
2. The object vibrates back and forth past its starting position.		
3. The bigger the force, the bigger the vibrations. Bigger vibrations make louder sounds.		
4. The pitch of the sound depends on the frequency of the vibrations.		
5. The sound source disturbs/pushes the particles in the surrounding medium and transfers energy to those particles.		
6. Particles near the sound source move back and forth, pushing on other particles farther away.		
7. Particles get bunched up and spread out.		
8. When the particles push on each other, they transfer energy across the medium (using arrows - the energy moves from the sound source to the detector) but the particles themselves do not move all the way from the sound source to the detector.		
9. Particles push on the detector repeatedly, which transfers energy to it and also makes it move.		
10. The detector will keep moving until the sound source stops vibrating.		
11. Louder sounds (higher amplitude vibrations) can transfer more energy than softer sounds.		
12. Higher pitch sounds (higher frequency vibrations) can transfer more energy than lower pitch sounds.		
13. Amplitude increases have a much bigger effect on the amount of energy transferred than frequency increases.		

End of Unit Assessment Rubric

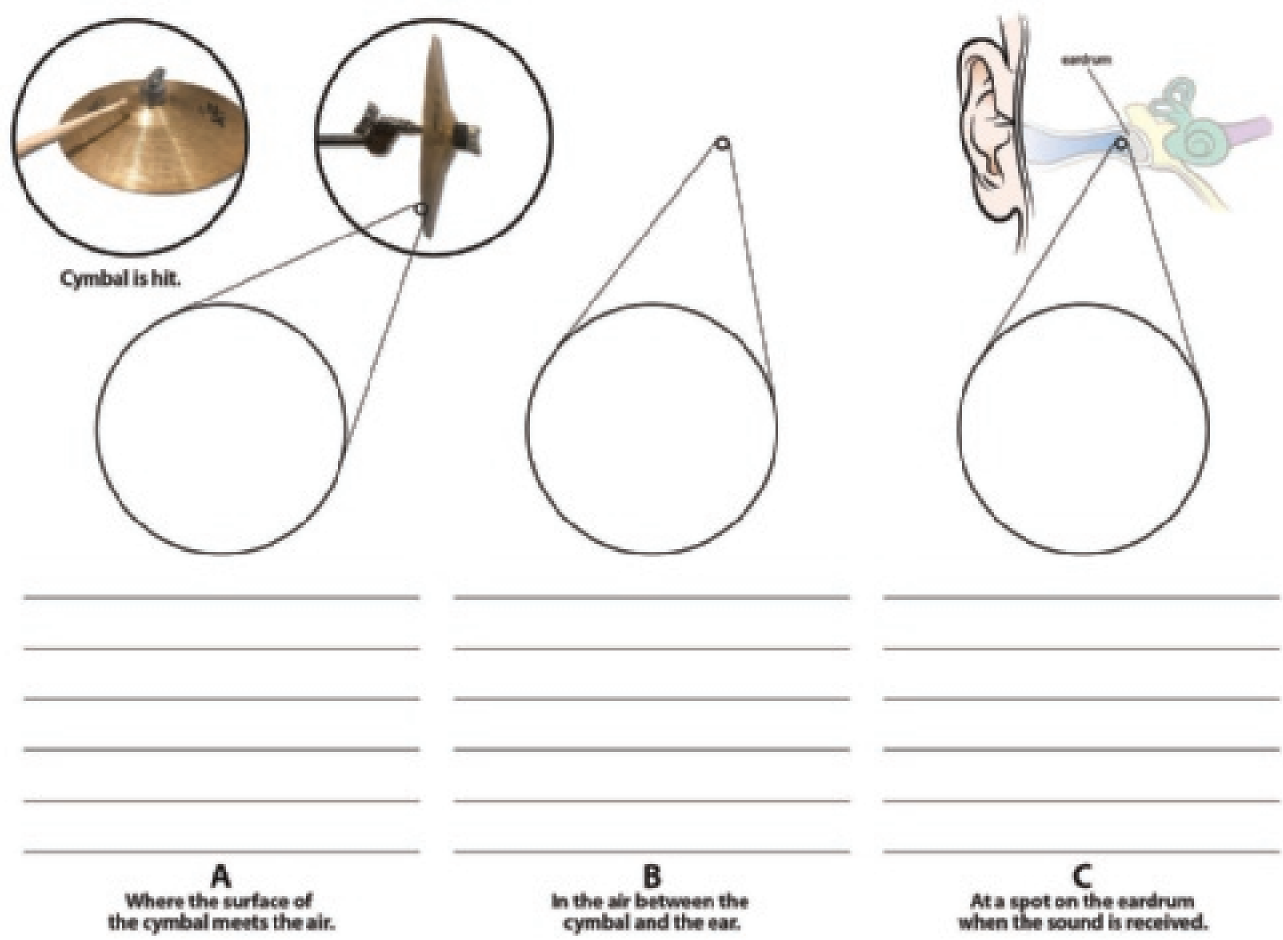
Component Clearly represents or describes the system components and must include:	**Category**			**Feedback**
	Missing	Developing	Mastered	
• the **sound source**.				
• the **initial force applied** to the sound source.				
• the **particles of the medium** (air) in between the sound source and detector.				
• the **detector** of the sound.				
Interactions Between Components Clearly represents or describes the following ideas:	**Category**			**Feedback**
	Missing		Mastered	
• The deformation of the sound source causes the particles in the medium to start moving *(cause/effect).*				
• Particles in the medium go back and forth and hit neighbors (show this with some sort of convention for wiggle) *(cause/effect)* but do not move all the way from the source to the detector.				
• The nature of the back and forth motion of the shape of the sound source is recurrent (may identify this back and forth motion as a vibration) *(pattern/structure).*				
• The particles of the medium push on the "detector," causing it to move *(cause/effect).*				
• Collisions transfer energy across the medium (the energy moves from the sound source to the detector but the particles do not move all the way from the sound source to the detector) *(energy).*				
• Particles and the sound source go back to their original starting position *(pattern/structure).*				

Name: ______________________ Date: ______________________

Unit Assessment

Musicians experience hearing loss more often than non-musicians. Hearing loss is the result of repeated damage to parts of the ear. The New Orleans Musicians' Clinic recommends reducing the loudness of sounds as much as possible to slow hearing loss.

1. Using words and pictures, develop a model by completing circles **A-C** below to show how hitting a cymbal loudly would damage a musician's ears. Make sure your model shows how energy is transferred from the cymbal to the eardrum. Include a key, if needed, to explain what you draw.



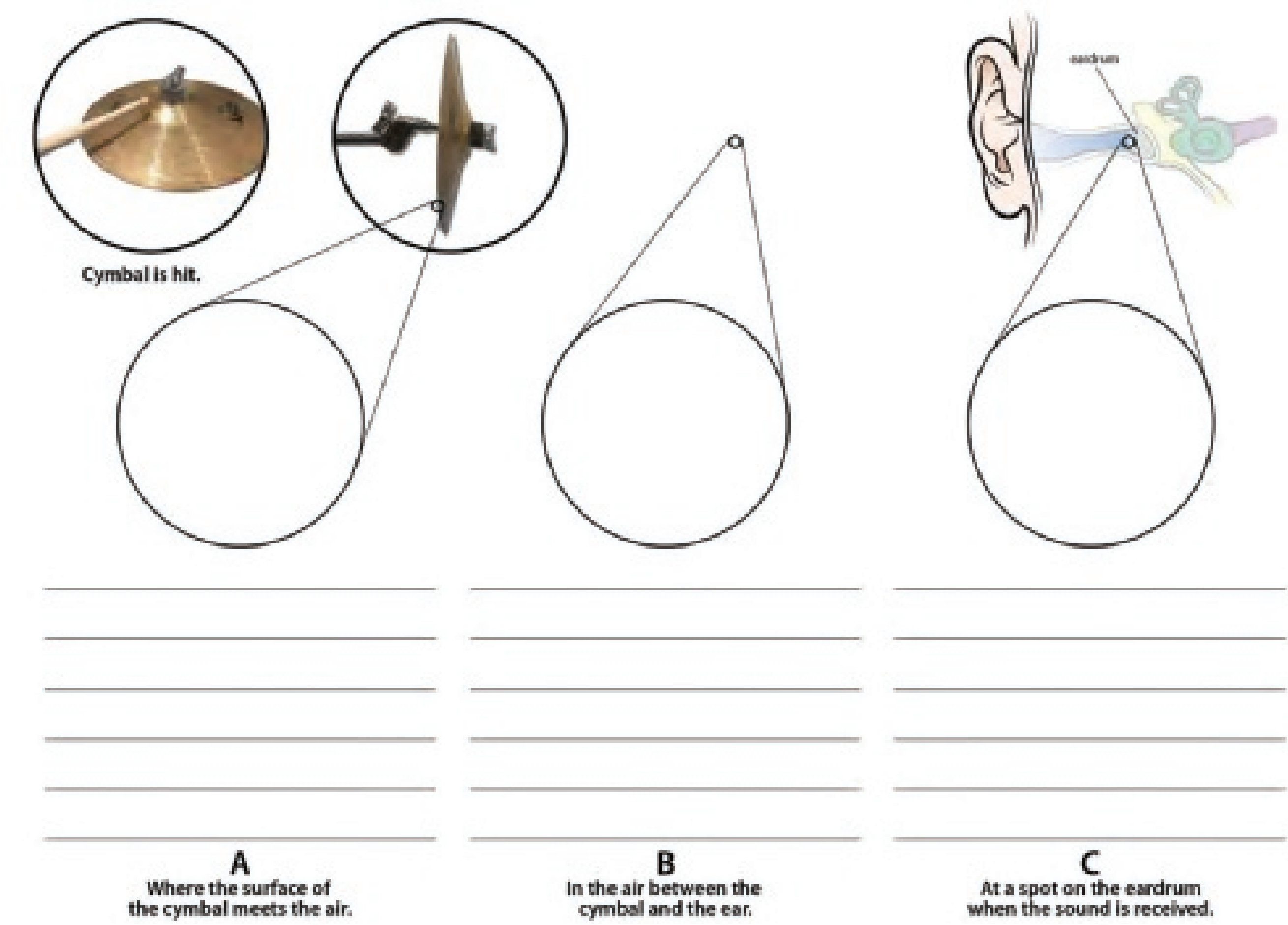
2. The New Orleans Musicians' Clinic recommends avoiding listening to loud sounds for long periods of time to protect your ears. Why do soft sounds do less damage to your ears than loud sounds? Use your model and what you have learned about sound waves and energy to **write an explanation**. Some helpful words to include in your response are *air particles, energy, force*, and *eardrum*.

3. The New Orleans Musicians' Clinic **did not** make any recommendations about low or high pitch sounds. Why are high pitch sounds less damaging to ears than louder sounds? Use your model and what you have learned about sound waves and energy to **write an explanation**. Some helpful words to include in your response are: transfer, energy, eardrum, and air particles.

Unit Assessment Answer Key

Musicians experience hearing loss more often than non-musicians. Hearing loss is the result of repeated damage to the ears. The New Orleans Musicians' Clinic recommends reducing the loudness of sounds as much as possible to slow hearing loss.

1. Using words and pictures, develop a model by completing circles **A-C** below to show how hitting a cymbal loudly would damage a musician's ears. Make sure your model shows how energy is transferred from the cymbal to the eardrum. Include a key, if needed, to explain what you draw.



Use the *Final Modeling Rubric For Sound* to assess this question.

2. The New Orleans Musicians' Clinic recommends avoiding listening to loud sounds for long periods of time to protect your ears. Why do soft sounds do less damage to your ears than loud sounds? Use your model and what you have learned about sound waves and energy to **write an explanation**. Some helpful words to include in your response are air particles, energy, force, and eardrum.

Scoring Guide:

+1 Loud sounds start with a larger force applied on the cymbal than soft sounds.

+1 Loud sounds vibrate back and forth for a larger distance than soft sounds—in the model, this would look like a shorter back and forth movement in circle A.

+1 These vibrations cause the particles in the air to collide with each other as you can see in parts A and B of the model.

+1 The loud sound vibrations cause harder collisions between air particles.

+1 Through these collisions, loud sounds transfer more energy between air particles than soft sounds.

+1 When the air particles transfer energy to the eardrum in the ear, the particles from loud sounds hit the eardrum with more force than the soft particles.

+1 When the eardrum is hit repeatedly by large forces from loud sounds, it causes damage to the structures in the ear that help you hear.

3. The New Orleans Musicians' Clinic **did not** make any recommendations about low or high pitch sounds. Why are high pitch sounds less damaging to ears than louder sounds? Use your model and what you have learned about sound waves and energy to **write an explanation**. Some helpful words to include in your response are: transfer of energy, eardrum, and air particles.

Scoring Guide:

+1 High pitch sounds transfer energy from the cymbal to the air more frequently than sounds of the same loudness at a low pitch.

+1 Assuming you had a loud sound and a softer sound with a high pitch, the air particles with the loud sound would be transferring more energy less often than the high pitch sound which would be transferring less energy more frequently.

+1 When the high pitch air particles transfer energy to the eardrum they are colliding with the eardrum more frequently but with less force.

+1 The force of the collision on the eardrum causes more damage than the frequency of the collisions.

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Editorial Director

Daniel H. Franck

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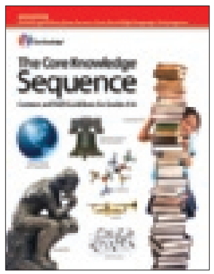

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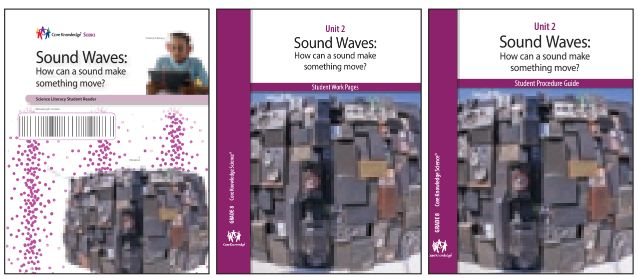

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