Last Updated: 08/20/25

How Science Works

Teacher/Mentor Workbook

8th Grade - Waves

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Welcome to SciTrek!

Thank you for being a part of SciTrek! This lead workbook is designed for teachers and the SciTrek Mentors and Leads who will be guiding students in the classroom. Inside, you'll find a detailed schedule, procedures for each day of the module, and descriptions of key concepts central to the learning activities. Please note, this document is not a complete guide for leading the module and it is important for teachers to attend the SciTrek orientation as well. Please read this before the orientation to help us make the most of our time together.

SciTrek staff support varies from day to day during a Module. On Days 1 and 5 of the Module, you will have 1-3 SciTrek Leads supporting the opening and closure of the program. On days 2 and 4, a team of 8-10 undergraduate Mentors in the classroom, working in small groups with your 8th grade students on science activities and experiments. On day 3, activities will be led without SciTrek staff support but in accordance with the sequence outlined in this workbook, with the aim of promoting independent reinforcement of concepts and practices essential to the Module.

Here's a table summarizing the SciTrek support during this module:

Day	SciTrek Support	Role
Day 1	1-3 SciTrek Leads (senior SciTrek undergraduates or SciTrek staff)	Support in opening the program
Day 2	7-10 Undergraduate Mentors	Assist with small group science activities and experiments
Day 3	None	Teacher leads activities independently, reinforcing key concepts
Day 4	7-10 Undergraduate Mentors	Assist with small group science activities and experiments
Day 5	1-3 SciTrek Leads (senior undergraduates or SciTrek staff)	Support in closing the program

Teachers, we encourage you to work with our staff to tailor the content to fit your unique teaching style and make this module as engaging as possible!

The Waves Module addresses the following NGSS Standards:

NGSS Performance Expectations (PE)

- MS-PS2-3 Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
- MS-PS4-1 Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
- MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

SciTrek Module Learning Objectives:

- Understand how transverse and longitudinal waves move.
- Discover how amplitude affects wave height, and how frequency changes the number of waves.
- Identify crests, troughs, compressions, and rarefactions.
- Draw connections between the size and shape of a wave to its interaction with other waves and materials around it.
- Recognize experimental errors and measurement limits.
- Develop, test, and present their own hypotheses.
- Analyze data, create graphs, and present their findings through oral presentations and group posters.

Important Vocabulary

Wave: a disturbance in a medium that transfers energy from one place to another in a regular and organized way. The basic properties of a wave include amplitude, frequency, and wavelength.

Amplitude: The height of a wave. A larger amplitude means there is more energy present in the wave.

Frequency: The number of wavelengths that travel past a certain point in a given amount of time. Higher frequencies indicate higher amounts of energy but smaller wavelengths, while lower frequencies indicate less energy and have longer wavelengths.

Crest: The highest point of a wave.

Trough: The lowest point of a wave.

Mechanical Wave: A wave that requires a medium to travel, and is caused by the vibration or disturbance of the particles in that medium.

Electromagnetic Wave: A wave that does not require a medium to travel, and can travel in a vacuum. These waves are caused by organized movements in electric or magnetic fields.

Medium: Any matter that a sound wave can propagate through. If there is no medium, mechanical waves cannot exist.

Resonance: The amplification of vibrations when an external force matches an object's natural frequency. An object's natural frequency is determined by its composition, size, structure, weight, shape, and other physical properties.

Wavelength: The length of the wave. The wavelength is described as the length of one repeating unit of a wave, e.g., from one crest to the next.

Hypothesis: A hypothesis is a testable guess or prediction about what will happen based on what you know.

Observation: information gathered using your 5 senses.

Opinion: belief that may or may not be based on facts.

Outliers: Data significantly different from other data in the same experiment.

Day 1

Slinky Science: Unraveling the Secrets of Waves

This session will be led by the teacher *with the support of 1-3 SciTrek staff. Each activity should take 10-15 minutes, but please use your own discretion - you know your class best! Please review ahead of time to ensure the smoothest procedure possible.*

Objective

Students will be introduced to the concept of waves, including key properties like amplitude, frequency, and wavelength. Using a slinky and some other cool equipment, the class will explore how waves carry energy, and become familiar with the physics of transverse waves, longitudinal waves, wave resonance, interference, amplitude, speed, and frequency. They will also start to explore some of the ways that sound waves travel through different media and how to calculate the speed of a wave.

Materials:

- Elastic Cord
- Wave Driver Apparatus
- Sine Wave (Sound) Generator

- **TEACHER-LED: Introduction to SciTrek**
    - Welcome students and introduce SciTrek Leads.
    - Briefly explain the purpose of the SciTrek program and how it will support their learning.
    - Introduce the day's topic: **waves**, their basic properties, how they interact with things around them, and their importance in the real world.

- **TEACHER-LED Activity 1: Introduction to Waves**
    - Ask students to take a moment to discuss with their peers on what the definition of a wave might be. Instruct students to write their definitions in the space provided in their workbooks on page 6.

Key Content

A **wave** is a disturbance in a medium that transfers energy from one place to another in a regular and organized way.

The basic properties of waves include the following:

- **Frequency:** The number of wavelengths that travel past a certain point in a given amount of time.
- **Amplitude:** The height of the wave from the rest position.
- **Wavelength:** The distance between two corresponding points on consecutive waves.

Additional properties include:

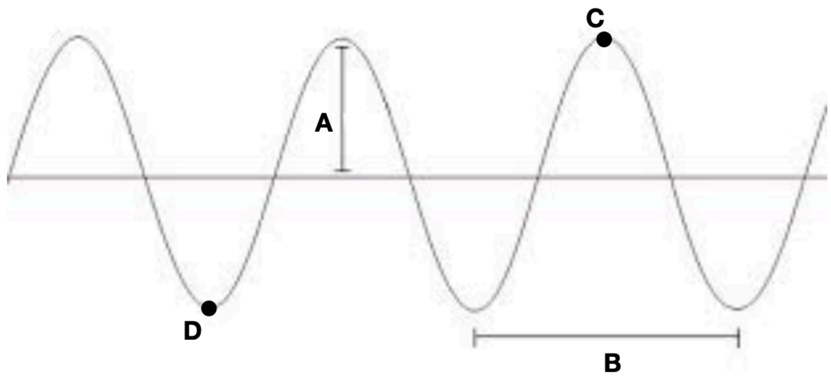
- **Crest:** The highest point of a wave.
- **Trough:** The lowest point of a wave.
- **Energy Transfer:** Emphasize that waves carry energy.

Key Vocabulary

Perpendicular: Two lines are perpendicular if they meet or cross each other at a right angle (90 degrees).
Example: The corner of a piece of paper forms perpendicular lines.

Parallel: Two lines are parallel if they are always the same distance apart and will never meet, no matter how far they extend.You
Example: The edges of a railroad track are parallel.

  - On the board, draw the diagram on the next page and reinforce what each point illustrates: amplitude (a), wavelength (b), crest (c), and trough (d). Ask students to copy the diagram in the designated space in their student workbooks on pg. 7.



- Share the [Introduction to Waves and Measuring Waves] short videos (1.11 sec./video) with students, which will highlight the two types of waves and the different contexts in which they may occur (e.g., ocean waves, sound waves, light waves).
- Ask students to review the video information by filling in the blanks on page 8 in their student workbooks, either during or after the video:
  - **Mechanical Wave:** A wave that requires a medium to travel, and is caused by the vibration or disturbance of the particles in that medium.
    - Fun Fact: The waves formed in the ocean are examples of mechanical waves, caused by the "pulling" motions of the moon, earth, and sun!
  - **Electromagnetic Wave:** A wave that does not require a medium to travel, and may instead do so in a vacuum. These waves are caused by organized movements in an electric or magnetic field.
    - Fun Fact: Electromagnetic waves are at work whenever you listen to music on your car radio, or cook food in a microwave

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- **TEACHER-LED Activity 2: Investigating Waves with Slinkys**

The following demonstrations will be performed by the teacher in front of the class with one or more student volunteer(s) as a large group demonstration. This activity will require

slinkies, open space (hallway or classroom with sufficient room to stretch out the slinky), and student workbooks.

Students will engage in discussion throughout the demonstrations below and complete corresponding activity-related questions in the Student Workbook beginning on Page 9.

Transverse and Longitudinal Waves

- Start by explaining that **a slinky can model different types of mechanical waves**.
  - Remind the students that mechanical waves require a medium to travel, are caused by the vibration or disturbance of the particles in that medium, and involve a transfer of energy from one place to another.
- Tell the students that in today's demonstrations, they will study waves by making observations about energy transfer and various wave properties through the coils of a slinky. They will follow along and answer the questions on pages 9-10 in their workbooks.
- Select a student to assist with the demonstration. Ask the student to stand on one end of the open space, take hold of one end of the slinky, and stand as still as possible. If this is being done in groups, the teacher should demonstrate in front of the class and the groups of students should watch and then try the demonstrations after and with the teacher.
- Stretch the slinky out horizontally along the floor, table(s), or in midair.
- Shake your end of the slinky up and down rapidly in order to create a transverse wave. This movement will make the coils oscillate **perpendicular to the direction of the wave's travel**. Define perpendicular and parallel if necessary:
  - **Perpendicular:** Two lines are perpendicular if they meet or cross each other at a **right angle** (90 degrees).
    <u>Example</u>: The corner of a piece of paper forms perpendicular lines.
  - **Parallel:** Two lines are parallel if they are always the **same distance apart** and will **never meet**, no matter how far they extend.
    <u>Example</u>: The edges of a railroad track are parallel.
- [Activity 2, Q1] Explain to the students that for a **transverse wave**, the displacement of the coils is *perpendicular* to the wave's direction.
- Shake your end of the slinky again, identifying the formation of peaks *(crests)* and valleys *(troughs)* in the movement, just like the diagram they drew previously.

    - [Activity 2, Q2] Ask the students to briefly discuss the following questions: Where did the energy come from to make these waves? Are both ends of the slinky moving in the same way? What does that tell you about where the energy is coming from?
    - [Activity 2, Q3] Now, vary the speed of your shaking to demonstrate how it affects the wave.
        - Show students that increasing the speed results in higher frequency (more waves per second) and shorter wavelengths (distance between crests), and decreasing the speed results in lower frequency and longer wavelengths.
        - Show students that the amplitude (height of crests) increases with higher speed, or more energy, and decreases with less energy.
    - Fun fact: Light waves are transverse waves!

- Select another student to assist with the demonstration. Ask the student to stand on one end of the open space, take hold one end of the slinky, and stand as still as possible.
- Stretch the slinky out horizontally along the floor, table(s), or in midair.
- Pull one end of the slinky quickly towards and away from you (push-pull motion), compressing and stretching the coils along its length to create a longitudinal wave. This movement will make the coils oscillate *parallel* to the direction of the wave's travel.
- [Activity 2, Q3] Explain to the students that for a **longitudinal wave**, the displacement of the coils is **parallel** to the wave's direction.
    - [Activity 2, Q4] Slowly demonstrate **compression** (away from you, coils closer together) and **rarefaction** (towards you, coils farther apart) along the slinky again.
- Now, vary the speed of your push-pull to demonstrate how it affects the wave.
    - Show students that again increasing the speed results in higher frequency (more waves per second).
    - Show students that more forceful push-pulls create higher amplitude (larger compressions and rarefactions) and how the frequency of push-pulls affects the spacing between compressions.

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- **TEACHER-LED Activity 3: Types of Waves**
  - Students will continue their understanding of the difference between transverse and longitudinal waves by working with three materials to produce waves: a slinky, dominoes and a rope.
  - Explain to students that their job is to determine which types of waves can be modeled with each material: transverse, longitudinal, or both. Students will also draw a diagram of each wave model they create.
  - Instruct students to fill in the data table on pg.10-11 as they conduct their experiments.
  - Once the students have completed conducting their experiments, ask a member from each group to share their results.
  - Explain that they should have been able to make both transverse and longitudinal waves with the slinky and rope, but only a longitudinal wave with the dominoes. Explain the reason behind the phenomenon for each medium.

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- **TEACHER-LED Activity 4: Measuring Wave Speed**
  - Students will first learn how to compute the speed of a wave with teacher guidance, and then work in groups to demonstrate independent capability.
  - Using the slinky, create a wave using a slow up-and-down motion. Now, vary the speed of your movement to demonstrate how it affects the wave.
    a. Remind students that increasing the speed results in higher frequency (more waves per second).
    b. Show students that more forceful up and downs create higher amplitude. Remind students that the frequency of the up and down motion affects the spacing between waves.

2. Using a stopwatch timer, ruler and the formula for speed, instruct the students to calculate the speed of the wave.
   a. [Activity 4, Q2] Measure how long it takes for a wavelength to travel from one end of the slinky to the other.
   b. [Activity 4, Q3] Then, have a student measure the distance from one end of the slinky to the other.
   c. [Activity 4, Q5]Students can now calculate wave speed using the formula **speed = distance/time**.

Group Activity:

1. Instruct students to use the formula above to design an experiment to calculate the speed of a wave they create with the rope provided.
2. Ask students to record their calculations in the space on pg. 12, reminding them to label their answers in units!

***HINT- Wave speed is a measurement of how quickly a wave passes a point. As you think about how to complete the activity, consider what units are typically used to measure speed.**

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- **TEACHER-LED Activity 5 (Optional): Interference & Superposition**

Key Content

Interference

Interference happens when two waves meet and combine to make a new wave. There are two types:

1. **Constructive Interference**: When the waves line up (crest to crest or trough to trough), they combine to make a **bigger wave**.
2. **Destructive Interference**: When the waves are opposite (a crest meets a trough), they cancel each other out and make a **smaller wave** or no wave at all.

Superposition

The superposition principle is like adding waves together. When waves overlap, the new wave is the **total of both waves' heights** at each point. This is what causes interference.

Simple Example:

Imagine two people jump on a trampoline at the same time:

- If they both jump **up** together (constructive), they go higher.
- If one jumps **up** while the other jumps **down** (destructive), they cancel each other out, and the trampoline stays flat.

Superposition explains how their jumps combine, and interference is the result of that combination.

- Select another student to assist with the demonstration. Ask the student to stand on one end of the open space, take hold of one end of the slinky, and stand as still as possible.
- Stretch the slinky out horizontally along the floor, table(s), or in midair.
- Instruct the assisting student to help you create waves from both ends of the slinky, simultaneously. Tell the students to closely observe how the waves interact.
- Demonstrate waves at different frequencies interacting. Ask the assisting student to shake their end of the slinky slowly, while you shake your end quickly. Now, both shake quickly. Now, both shake slowly.
  - Tell the class to closely observe how the waves combine to form complex **interference patterns**, which occur when two waves meet.
- [Activity 5, Q1] Explain the concept of **superposition**, where overlapping waves can result in waves adding up to a higher amplitude *(constructive interference)* or waves cancelling each other out *(destructive interference)*. Instruct students to fill in the blanks in their student workbooks with these definitions.
  - Change speeds and instruct the assisting student to do the same.
  - [Activity 5, Q2] Show students one final time how these interactions can create complex wave patterns along the slinky.
- [Activity 5, Q3] Ask students to briefly discuss with their classmates what constructive and destructive interference look like.

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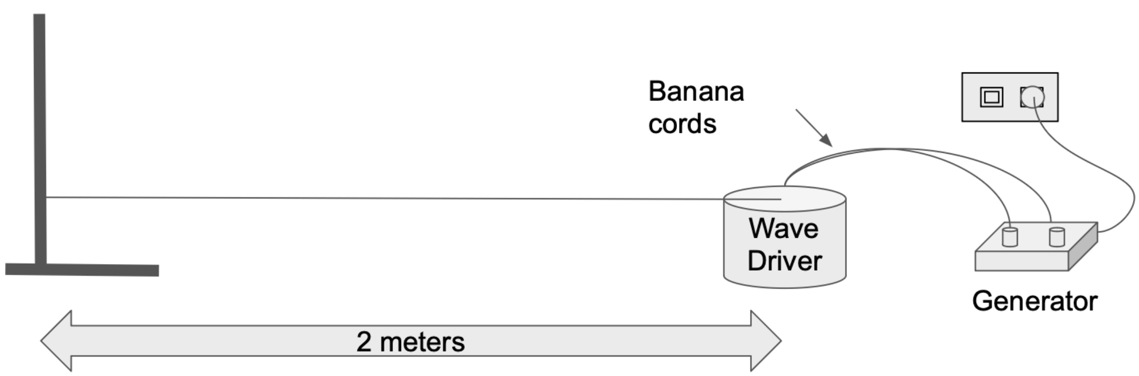
- **TEACHER-LED Activity 6 (Optional) : Standing Waves and Amplification, The Wave Driver**

This activity requires an understanding and practiced use of a wave driver. While a wave driver allows you to observe sound waves and wave interactions on a visual level, it should be noted that the frequency of waves that you can observe using a wave driver are *not* of a frequency that can be heard by human ears. Refer to the following video below to aid your set-up of the wave driver:

  - [Wave Driver Set-Up Procedure]()

Materials Needed:

- Elastic Cord
- Wave Driver Apparatus
- Sine Wave (Sound) Generator
- 2 Banana Cords
- 1 Power Cord
- 1 Ring stands
- Meter stick



  - **Wave Driver Set-Up Procedure**
    Note: The wave driver should be set up ahead of class. Set up can take up to 15 minutes.
    - Plug the power cord into the generator and the wall.
    - Connect the wave driver and generator using the 2 banana cords.
    - Assemble the ring stand.
    - Place the wave driver and ring stand 2 meters apart, using the meter stick for measurement.

        - Tie one end of the elastic cord around the ring stand and insert the other end into the wave driver. Make sure that the height of the cord is level and that the cord is as tight as possible.
        - Turn the amplitude knob all the way to the right.
    - Tell the students that for this final activity, you will be using a wave driver in order to demonstrate wave motion in a controlled environment.

Key Content

A **wave driver** is a device that is used to show what sound waves look like by causing disturbances at various controlled frequencies. It should be noted that, while the wave driver device will be producing physical waves that match the frequency of simultaneous sound waves that it produces, the frequency of the waves that are a good size for making standing waves on the 2-meter string are too low for us to hear.

While wave drivers have been in use since the mid-19th century, they now typically consist of two rods connected by a thin string or wire. When one rod is moved on the end, energy is transmitted to the other rod through the wire.

If you set a wave driver to the correct frequencies - which will depend on the length of your wire or string - you will be able to observe standing waves, which were discussed in depth above.

It should be noted that the wave driver will make sound waves visible, but the frequency of waves that you can easily observe using a wave driver will be at frequencies that are too low to be heard by human ears.

    - Ask students to closely observe how changing the frequency and amplitude affects the wave produced. 13-14
    - [Activity 6, Q1a, 1b] Set the wave driver at a random frequency to demonstrate the movement of the elastic appearing somewhat random, or undefined.
        - Ask the student to record this frequency, and draw the associated wave in their student workbooks.
        - Ask students why there is no standing wave.

- [Activity 6, Q1c] Increase the amplitude on the wave driver, and ask students to observe what happens to the height of the waves.
    - The height of the waves (crests and troughs) should increase.
- [Activity 6, Q1d] Increase the frequency on the wave driver, and ask students to observe any changes in the number of waves they see.
    - The number of waves should increase - they may increase so much that they are difficult to see with the naked eye!
- [Activity 6, Q2] Now, **change the frequency until you find the first harmonic,** or where a standing wave appears with the nodes at each end of the elastic string. Tell the students the exact frequency that the wave driver is set to. Ask them to record this number, and make a drawing of the wave, in the data table provided in their student workbooks.
    - See the Key Content box below for more on harmonics.
- Remind the students that with a standing wave, two waves are moving towards each other that have the same amplitude and frequency. Then, ask for a few "best guesses" on the frequency that will result in the second harmonic.
    - Collect guesses and offer hints until a student answers with the number twice the amount of your first harmonic frequency.
    - Note:
        - The **fundamental frequency** is the first harmonic.
        - The **second harmonic** is **twice** the fundamental frequency.
        - The **third harmonic** is **three times** the fundamental frequency, and so on.
- Set the wave driver to the frequency that will result in the second harmonic. Ask the students to record this frequency, and make their drawings in their student workbooks.
- Then, ask the students to find the frequency that will result in the third harmonic. Set the wave driver to this frequency. Ask the students to record this frequency, and make their drawings in their student workbooks.
- Now, ask the students to find the frequency for the twelfth harmonic. Verify that they have come to the correct answer by multiplying the first harmonic by 12. Then, instruct students to record this frequency, and make their drawings in their student workbooks.
    - [Activity 6, Q3, 4]Instruct the students to discuss with their classmates, and write their answers in their student workbooks:
        - How were you able to find the twelfth harmonic? How did you know that this would work?

            - If the length of the wave driver's string changed, would the frequency to find each harmonic need to be changed too? Why or why not?
    - Reinforce that the reason that the frequencies were so regular and predictable is because the **standing waves were** only produced by periodic waves with certain wavelengths that are **dependent on the length of the string or wire between the two rods**.

Key Content

Harmonic frequencies (a type of standing wave pattern) are whole number multiples of the fundamental frequency, which is otherwise known as the "first harmonic."

The **first harmonic** is the lowest resonant frequency of a vibrating object. When the first harmonic is visible, you will observe a single arc moving up and down in a way that is similar to a jump rope but without full rotations.

Because standing waves are regular, repeating, and predictable, it is easy to find any harmonic of an object once you determine the frequency its first. For example, if you have determined that the first harmonic of an object is 4 hertz, then you can also know that the second harmonic is 8 hertz, and that the 8th harmonic is 32 hertz.

- **TEACHER-LED Wrap-Up and Reflection**
    - Briefly reinforce key concepts: a wave is a disturbance in a medium that transfers energy from one place to another in a regular and organized way, and its basic properties are amplitude, frequency, and wavelength. Making a change to one of these properties will change the way in which a wave interacts with its mediums and any other waves.
    - Think back to our first activity. What type of wave is created when the medium moves up and down?
        - Answer: Transverse wave.
    - Think back to our second activity. What type of wave is created when the medium moves back and forth?
        - Answer: Longitudinal wave.
    - How do you calculate the speed of a wave (what is the formula)?
        - Answer: Speed = Distance / Time.

- Think back to the wave driver activity. How was it possible to predict the frequency which would create the twelfth harmonic, after finding the first harmonic?
    - Ask students to share their general observations and overall thoughts.

End of Day 1

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Day 2
Working with Waves: The Science of Speakers

This session will be facilitated by a team of 7-10 SciTrek undergraduate Mentors and one Lead. The teacher should be prepared to do a session introduction, conclusion, and provide guidance and oversight for students during the session.

Objective

Students will work with their SciTrek Mentors and apply their knowledge from Day 1 to explore how waves interact with media to amplify sound in a real-life example–constructing a speaker!

Materials:

- Small slinkies
- **Basic Speaker Kit**
  - Plastic cup
  - 4 meters of wire
  - (2) 1-inch magnets
  - Alligator clips
  - Aux cord
  - MP3 player
- Tape
- Plastic bin & lid
- Attachable decibel meter

There will be enough SciTrek Mentors and materials for highly-focused instruction, so students will break into sub-groups to ensure each student has the opportunity to participate in speaker construction.

- **TEACHER LED Introduction**
  - Welcome students and provide a quick overview of today's key concepts: A sound wave is just another disturbance travelling through a medium in the form of a vibration, and sound waves might change in noticeable and important ways as they travel through different mediums.
  - Divide students into 4-6 equal groups and introduce them to their SciTrek Mentors, who will be waiting to facilitate the testing of these variables. There

will be multiple groups – the exact number will depend on the number of students in the class – doing the same experiments at once to ensure that students get individual attention.
    - Tell the students that their SciTrek Mentors will guide and assist them with the day's experiments. There will be enough SciTrek Mentors to assist with every small group.

- **Activity 1: Same Waves, Smaller Sea - Slinky Demonstration Review**
    - **Objective:** Observe wave interaction as demonstrated by patterns of movement in the smaller slinkies, visually reviewing concepts from Day 1.
    - **Instructions:** First, review key wave terms: frequency, amplitude, wavelength, crest, and trough.
    - In their small groups with SciTrek mentors, students should use a slinky to demonstrate each of the wave characteristics above. For example, students should create slow waves to demonstrate low frequency and fast waves to demonstrate high frequency, and create waves of varying heights to demonstrate differences in amplitude (pg. 17)
    - [Activity 1, Q1] Ask students to share how they demonstrated each characteristic, providing both a brief definition for that characteristic, as well as describing the actual physical motion that they used to demonstrate it.
    - Now that the students have described their own movements in creating waves with a slinky, ask the students to answer the following question in their student workbooks:
        - [Activity 1, Q2] What causes a wave to come into motion?
            - ***Answer: Energy from an outside force***

- **Activity 2: How Does a Speaker Work?**
    - **Objective:** Learn about the mechanics behind the sound amplification in speakers through the use of a short informative video.
    - **Instructions:** As a class, watch the following short video explaining how speakers work while they answer the questions on pg. 18-20 (answers below)
        - How Speakers Make Sound (about 2.26 minutes)

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Activity 2: How Does a Speaker Work?

Your Mission:
Learn about the mechanics behind the sound amplification in speakers through the use of a short informative video.

Video Questions:

1. Fill in the chart as you watch the video.

Main Speaker Parts	Function	Simple Version Replacement
Diaphragm	• Moves back and forth and creates:	
Voice Coil	• Coil of _______ • An _____________ current runs through the wire.	
Magnet	Creates a _________________ field that interacts with the magnetic field of the voice coil.	

- Instruct students to use the word bank to fill in the blanks, and complete the description of how a speaker works.

  The _***electricity***___ in the wire carries the _***sound***_ information. The _***coil of wire***_ lets the sound information "talk" to the _***magnet***__ so they can work together to make the _***diaphragm***_ vibrate and make the sound from the source louder.

Key Content

Magnets are a key component in how a speaker works because they help convert electrical energy into sound through a process involving both electromagnetism and vibrations. Here's how it works:

1. The Coil and Electromagnetism

- Inside a speaker, there is a coil of wire that is positioned near a magnet.
- When an electric current (from a phone, MP3 player, or audio source) flows through the coil, it creates a magnetic field around the coil. This is the basis of electromagnetism.

2. Interaction Between the Coil and the Magnet

- The magnetic field created by the coil interacts with the magnetic field of the speaker's magnet.
- Depending on the direction of the current flowing through the coil, the magnetic field of the coil will either be attracted to or repelled by the speaker's magnet.

3. Vibration and Sound Production

- As the electric current changes (following the sound wave patterns of the audio signal), the coil is pushed and pulled by the magnet.
- This movement causes the coil, which is attached to the speaker's diaphragm (or cone), to vibrate.
- The vibrating cone pushes and pulls the surrounding air, creating sound waves that travel to your ears.

4. Frequency

- The speed of the coil's vibration determines the frequency (or pitch) of the sound: fast vibrations create high-pitched sounds, and slow vibrations create low-pitched sounds.
- The strength of the electrical signal (and hence the magnetic interactions) determines how far the cone moves, affecting the volume of the sound.

Summary:

Magnets in a speaker work by interacting with the electromagnet (the coil) to create motion. The motion of the coil makes the speaker diaphragm vibrate, which pushes air to produce sound. This system of electric current, magnetic fields, and vibrations is what turns electrical audio signals into audible sound.

SCITREK LED Activity 3: Building a Speaker in the Classroom… With a Box of Scraps!

- **Step 1: Introduction**
  - Ask the students to quickly come up with a group name, which will be shared at the end of class.
  - Tell students that every group will build the same exact speaker today with opportunities to customize and upgrade it on Day 4. Briefly introduce them to all of the components that you will use.
  - **TEACHER** - Show students this quick video of how the speaker will be assembled.
- **Step 2: Position the Magnet**
  - Instruct students to place the magnet inside the coil and hold this at the bottom of the plastic cup, on the outside. The magnet should be centered at the base and have some slight ability to move inside the coil, but should not be too loose.
- **Step 3: Secure the Magnet and Coil**
  - Ask another student to position a second magnet from inside the cup. The second magnet will hold the first magnet and coil in place.
    - If a second magnet is not available, you may use tape to attach the coil and magnet to the bottom of the cup.
  - Ask the students to check that two free ends of wire are hanging down from the coil
- **Step 4: Plug in the Power**
  - Instruct students to use sandpaper to sand down the ends of the wire. You may need to assist them with this.
  - Next, have students use the alligator clips and attach each clip to an end of the wire hanging out from the coil. With the other ends of the alligator clips, attach these to the exposed wires of the auxiliary cord.

        - Use tape to secure these connections, if necessary. Guide students in taking the ends of the wire and connect each to one of the exposed wires from the auxiliary cable or MP3 player.
        - Instruct students to use tape to secure these connections.
    - **Step 5: Testing, 1…2…3…**
        - Ask one student to plug the end of the auxiliary cable into the MP3 player.
            - Instruct students to play one of the following tracks: 440 Hz tone (lower), 1kHz tone (higher), electronic track, guitar track
            - You should hear the vibrations through the cup as sound.
        - Guide students in adjusting the tension of the membrane or magnet placement for better sound quality, if needed.
    - **Step 6: Is This Thing On?**
        - Explain that in order to measure the volume of each speaker design, you will be using a decibel meter. Decibel meters measure sound by calculating the pressure of the sound waves moving towards them through the air.
        - Place the plastic bin on a flat surface.
        - Insert the metal end of the decibel meter through the hole in the plastic bin. This will allow you to take recordings of sound inside the box.
        - Turn on the decibel meter, and ensure the microphone is facing the speaker, at a consistent angle.
    - **Step 7: Record Data**
        - Students will now take baseline decibel readings without any music playing and then for each of the four tracks: 440 Hz tone (lower), 1kHz tone (higher), electronic track, guitar track. (pg. 22-23)
        - Ensure that the entire speaker apparatus is in the box with the lid tightly closed before taking each reading.
        - Instruct students to record these in the Speaker Design and Decibel Readings Data Table, including a description of their materials for this design.

Baseline dB reading (empty box)	dB:

🎤🎤🎤 **Speaker Design and Decibel Reading Data Table** 🎤🎤🎤				
Description of Materials				
Speaker #1 Design Drawing				
Name of Track Played				
Decibel Reading				

Small group experiments are finished. Students should help tidy up and then return to their places, or simply attend to the teacher, who will conduct the wrap-up discussion.

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- **Activity 4: TEACHER LED Wrap-Up AND Reflection**
    - Conclude the lesson with a summary of the key concepts of speaker design that are tied to sound waves and electromagnetism.
        - The flow of electric current through a coil creates a magnetic field.
        - When the coil is positioned near the magnet in the speaker, its magnetic field will interact with the one of the coil.

        - Changing electric currents, such as the variation in sound across an entire track, causes the coil to vibrate against the diaphragm.
        - This movement is the pushing/pulling of surrounding air that causes sound waves to travel to our ears.
    - Walk the students through a discussion of their wrap-up questions, instructing them to write their answers in their student workbooks.
        - [Activity 4, Q1] Explain how a speaker works as though you were discussing with a friend or family member who does not know anything about sound waves.
        - [Activity 4, Q2] Now, imagine you are talking to your teacher or SciTrek mentor who knows about sound waves. Can you explain how the sound of the track was played in the cup? *(Hint: Refer back to the vocabulary discussed at the beginning of Day 2 or your Speaker Design and Decibel Reading Data Table).*
        - [Activity 4, Q3] Think back to when you recorded your decibel readings for each track. Did the decibel meter show the same reading the entire time each track played? If not, why might this be? *(Hint: Think about the readings of the decibel meter for a steady track (1kHz or 440Hz) compared to one with more variation (the guitar or electronic track).*

End of Day 2

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Day 3

Sound-sational! Exploring Sound Waves and Resonance

This session will be independently led by the teacher, without SciTrek staff support.

Students will explore how sound waves travel by engaging in **experiment-based observation and participation in hands-on demonstrations**, using tuning forks to observe how sound moves through different mediums. Additionally, they will explore the processes behind reflection, echoes, amplification, tuning, resonance, and the effects of medium density on a wave's intensity and speed.

Objective

Students will learn about resonance and its connection with sound. Students will further explore how sound waves change depending on the media they interact with, now critically evaluating each medium for its potential use in upgrading their basic speakers. Students will then use these observations and knowledge of how the properties of a medium change waves to create a detailed diagram of the speaker they will build on Day 4.

Materials:

- Ping pong ball
- String/yarn
- Tape
- Tuning forks
- Rubber mallets
- Cup of any kind
- Tin foil
- Rubber band
- Sand
- Larger plastic beakers, ¾ full of water
- Elbow
- Wooden blocks
- Glass jars
- Metal Cups
- Plastic Cups
- Memory foam

TEACHER-LED Activity 1: Resonance Video & Questions

- Show students the Resonance Explained Video and instruct them to fill in the questions on pg 25-26 as the video plays (5:12 min)
    - Feel free to pause the video when need be to discuss the questions and answers
    - Answers can be found below

Video Questions:

1. Resonance has to do with ___***vibrations***____ and __***sound***___.
2. Vibration is a motion that gets _***repeated***__.
3. The _***frequency***___ is how many times the motion occurs per _***second***__.
4. Frequency is measured in ***hertz***__.
5. 10Hz would mean the object's motion occurs __***10***__ times per second.
6. The amplitude is the __***intensity***___ of the vibration.
7. Why does the wine glass make a sound when struck by a pencil?
   The glass makes a sound because the disturbance (pencil) causes it to vibrate.
8. Everytime the glass is hit, it sounds the same. This means that it is vibrating at the exact same __***frequency***__ every time it is hit.
9. This noise is the _***natural***_ frequency of the glass.
10. Every material has its own __***natural frequency***____.
11. Why will the glass vibrate when the speaker plays at 1000Hz but not when it plays at 700Hz? ***The glass will only vibrate when the frequency is equal to its natural frequency, which is 1000Hz.***
12. When an object vibrates due to an external vibration that has a frequency equal to the __***natural***_ frequency of the object, we call that __***resonance***_.
    If the speaker continues to play at 1000Hz, what happens to the intensity or amplitude of the vibrations in the wine glass?***Both intensity and amplitude will increase because 1000Hz is its natural frequency, which means it will resonate.***

TEACHER-LED Activity 2: Resonance Identification Game

- Relate the information from the video to resonance phenomena in musical instruments:
    - You have probably heard, or know firsthand, that after time and use, guitars need to be "tuned" in order to make the right sounds. Tuning is typically tightening the strings to a specific level of tension. The reason that tuning is

necessary is because the characteristic, "correct" sounds that each guitar string makes when you pluck them are examples of resonant frequency, which is dependent on the characteristic tension of the medium – the guitar string– it is moving through.

- The wave patterns created on a guitar struck after being plucked will depend on how it is being moved. How it is being moved will depend on how tight or slack the string is.
- When a guitar is properly tuned and the guitar string is the right amount of thickness, the vibrations along the guitar string are big enough to create a sound and will create the same tone each time.

- Present familiar, real-world examples of resonance to the class and offer the opportunities for students to dissect and explain the processes behind each phenomenon using their new knowledge from Day 1 & Day 2.
- **Instructions:** Review the following points with students:
    - Natural Frequency: The frequency at which an object will tend to naturally vibrate when disturbed, like a playground swing that will naturally swing back and forth.
    - Vibration Matching: When you push or vibrate something at its natural frequency, it will vibrate more strongly.
    - Sound Amplification: Resonance can make sounds louder, such as if you hold the bottom of a struck tuning for something wooden (a desk or resonance box).
- Ask students to gather with their small groups, and direct them to page 26 in their workbooks, where they will see a variety of examples of how sound waves are affected by and affect materials around them.
- One by one, go through the below list of real-world examples of resonance with students. You may go through the list as a class and call on volunteers to dissect each example or you may assign one example of resonance to a table group of students, who will discuss amongst themselves then share their answer with the class.
    - Singer breaking a glass using their voice
        - Answer: The singer's voice matches the glass's natural resonant frequency which causes the glass to vibrate, and then shatter.
    - A ball bouncing higher on a trampoline
        - Answer: If you bounce the ball at the right rhythm, it can bounce much higher due to the trampoline's natural bouncing frequency.
    - A playground see-saw pushing highest when using a certain rhythm

        - Answer: If you time your rocking motion to match the seesaw's natural rhythm, it will go higher.
    - Singing in the shower
        - Answer: The sound of your voice bounces off the walls and creates a bigger, richer sound because the walls are resonating with your voice.
    - The amplified sound created by a properly-tuned guitar
        - Answer: A properly-tuned guitar string makes the whole guitar body vibrate, thus amplifying the sound.
    - Playground swing going higher with synchronized pushes
        - Answer: When a swing receives a push that matches its natural frequency, its amplitude increases and it goes higher and faster.
    - The amplified sound created by a properly-tuned guitar
        - Answer: A properly-tuned guitar string makes the whole guitar body vibrate, thus amplifying the sound.
    - Tuning fork and resonance box
- Ask students to discuss with their small groups, and see if they can think of one more familiar example of resonance. Instruct them to write their answers in their student workbooks.

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TEACHER-LED Activity 3: Sights and Sounds

The following three mini-demonstrations (Steps 1-3) will be demonstrated by the teacher with assistance from student volunteers. SciTrek will provide enough materials for each student small group to perform the demonstration at their own tables, if time permits. Alternatively, teachers may elect to walk around the classroom and replicate the demonstration at each table.

    - Regardless of how students observe the demonstrations (Steps 1-3), instruct students to record observations in their workbooks as each experiment is performed.

1. **Start the Music (pg. 27)**

Materials:

- Ping pong ball

- String/yarn
- Tape
- Tuning fork
- Rubber mallets

- Attach the ping pong ball to a string so that it is suspended and relatively stable. Then, ask a student to hold the string with the attached ball over the silent tuning fork (without having struck it first) so that the ball is lightly touching the prongs.
    - Ask the students to describe this movement of the ball without striking the tuning fork in their student workbooks.
- Now, instruct the students to suspend the ping pong ball again, but this time, striking the tuning fork before placing its prongs lightly back under the ball.
    - The ball should be pushed away by the vibrating prongs and bounce back as a result of the vibrations.
    - Ask the students to describe the movement of the ball after striking the tuning fork in their student workbooks.
- Guide the students in a group discussion about what, exactly, changed in the movement of the ping pong ball and why this change happened. Then, instruct students to write their explanations in their student workbooks.
    - The explanation should center on the **transmission of energy through sound waves.**

2. **Move & Groove (pg. 28)**

Materials:

- String
- Tuning fork
- Rubber mallet

- Instruct two students to each hold one end of the string/yarn between their fingers, keeping the string as taut and still as possible.
- Ask the students to describe the appearance of the string in their student workbooks.
- Strike the tuning fork (either you or another student volunteer may do this) and place it against the taut string.
- Ask students to observe the change in the string, and describe the movement of the string in their student workbooks. They might be able to describe a sensation of vibration or movement in the fingers that held the string, as well.

- Guide the students in a group discussion about what, exactly, changed in the movement of the string and why this change happened. Then, instruct students to write their explanations in their student workbooks.
  - The explanation should center on the **transmission of energy through sound waves**.
- Ask the students to draw a "before" and "after" of the string in their student workbooks.

3. Best for Last Dance (pg. 28-29)

Materials:
- Cup of any kind
- Tin foil
- Rubber band
- Sand
- Tuning fork
- Rubber mallet

- Stretch the tin foil around the opening of the cup until it is wrinkle-free and taut. Secure the tin foil in place using the rubber band.
- Pour a pinch of sand onto the surface of the tin foil.
- Ask the students to describe the appearance of the sand in their student workbooks.
- Now, you or a student volunteer may strike the tuning fork and place the prongs as closely to the middle of the tin foil as possible, without actually touching anything.
  - The sand should be pushed away by the vibrating prongs. It may even jump around and off of the surface.
- Ask the students to describe the movement of the sand and the tin foil in their student workbooks.
- Guide the students in a group discussion about what, exactly, changed in the movement of the sand and why this change happened. Then, instruct students to write their explanations in their student workbooks.
  - The explanation should center on the **transmission of energy through sound waves.**

4. Small Group Discussion
- Guide students in comparing and contrasting the movement of the ping pong ball, the string and the sand after the vibrating tuning fork was introduced.

- Did the ping pong ball, string and sand demonstrate the same pattern of movement? Describe and explain why or why not.
- If you have time watch the two **Cymatics Videos** as a class:
    - Links on teacher slides

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TEACHER-LED Activity 4: Sound Wave Transmission Through Different Media

Objective:

How do the properties of a sound wave - such as tone, clarity and volume - change when transmitted through different mediums? Which materials, densities, and frequencies work best for making a sound wave the loudest?

Materials Needed:

- Tuning fork
- Rubber mallets
- Larger plastic beakers, ¾ full of water
- Wooden blocks
- Glass jars
- Metal Cups
- Plastic Cups
- Memory foam
- Elbow

- **Step 1: Formulating the Hypothesis**
    - Ask students - what is a hypothesis? How are hypotheses usually written?
    - Instruct students to turn to page 29 in their student workbooks and formulate a hypothesis on how the intensity, or volume, of a sound wave relates to the type of medium - gas, liquid, or solid - that it is travelling across.
    - Ask the students to share their hypotheses and explain their reasoning, while reaffirming that their answers were just a "best guess."
    - Guide students through the key content below.

Key Content

The way that a sound wave will travel through a medium, and the volume it reaches as a result, depends on the unique features of that medium. Below, see how these features help and/or hinder sound waves as they travel:

How Heavy or Packed the Material Is (**Density**):

> Helps: Materials that are heavy and tightly packed, like metal, let sound move quickly because the particles are close together.
>
> Hinders: If the material is too tightly packed, it might absorb some of the sound and make it quieter.

How Stretchy or Springy the Material Is (**Elasticity**):

> Helps: Materials that can stretch and bounce back easily, like steel, are great at letting sound travel.
>
> Hinders: If the material doesn't stretch well, like rubber, it absorbs the sound instead of letting it move through.

How the Material Is Built (**Structure**):

> Helps: Materials with neat and organized patterns, like crystals, help sound travel better.

Hinders: If the material is messy or has holes, it can block or scatter the sound.

How Stiff the Material Is (**Rigidity**):

Helps: Stiff materials like glass let sound travel quickly because they don't bend easily.

Hinders: Materials that are too stiff and can break easily might stop the sound by reflecting or scattering it.

If the Material Has Holes (**Porosity**):

Helps: Solid materials without holes, like metal, are better for carrying sound.

Hinders: Materials with lots of tiny holes, like foam, absorb sound and stop it from moving.

How Much the Material Soaks Up Vibration (**Damping**):

Helps: Materials that don't soak up vibrations, like wire, let sound move far.

Hinders: Materials like cork or rubber soak up vibrations and stop the sound from going through.

Edges or Layers in the Material (**Grain Boundaries**):

Helps: Materials without a lot of edges or layers let sound flow smoothly.

Hinders: If the material has lots of layers or cracks, the sound gets blocked or bounces around.

- **Step 2: Testing Sound Through Different Materials**

Instructions:

1. Tell the students that your small group will be conducting a series of trials to test how the sound waves change depending on the media that they travel across. Today, the media that they test will include air, water, wood, metal, glass, memory foam, plastic and skin.

2. Remind the students that in order to create a wave, you must first create a disturbance in a medium where energy is carried from one place to another. In this case, the disturbance will be striking the tuning fork against a rubber mallet.
3. Instruct students to strike the tuning fork and hold it in the air, which will act as the "gas" medium for the wave to travel across. Ask students to look for visible movement in the medium - in this case, air - and quietly study the characteristics (especially intensity, pitch, and clarity) of the sound produced by this first trial.
    - Instruct students to fill out the Intensity and Volume Data Table in their student workbooks (pg. 32).
    - Remind students that they will use this sound to compare all other sounds to.
4. Instruct students to look at their data table on pg. 33 and fill in their hypothesis for all of the materials.
5. Instruct students to fill ¾ of the large plastic beaker with water at room temperature. Instruct students to strike the tuning fork and submerge its base in water, which will act as the "liquid" medium for the wave to travel across. Ask students to look for visible movement in the medium and quietly study the characteristics of the sound produced by this second trial.
    - Instruct students to fill out the Sounds Through Different Media Table on pg.33 in their student workbooks.
6. Instruct students to strike the tuning fork and touch its base to the wood block, which will act as the first "solid" medium for the wave to travel across. Ask students to look for visible movement in the medium and quietly study the characteristics of the sound produced by this second trial.
    - Instruct students to continue to fill out the table in their workbooks
    - Repeat this step for all other solid mediums: metal, glass, tin, memory foam, plastic, and their skin.

Step 3: Small Group Discussion: Understanding Your Data

Students will fill in blanks and answer questions according to the following discussion about speed and density, intensity and density, transition, reflection and echoes (pg. 34).

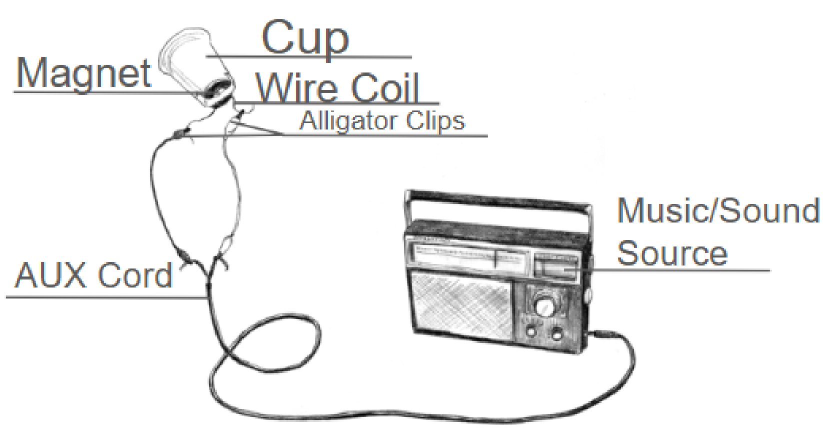
- **Speed & Density:** Ask students if they were able to tell which medium allowed the sound waves to travel fastest. Assure them that it's okay if they weren't able to tell - our ears just aren't sensitive enough!
    - Sound waves travel fastest across dense substances, because the particles of a dense substance will be closer together. It is easier for closer particles to transfer sound energy from one place to the next.

        - Instruct students to use this information to fill in the blanks in their student workbooks, using a "best guess" for the second blank.
        - Tell the students that water, which is much denser than air, allows sound to travel about 4.3 times faster. A solid medium, which is the most dense of the three, will allow for the fastest travel of all.
    - **Intensity & Density:** Unlike with speed, the *intensity* of sound will typically decrease when it passes through denser mediums. This is because with more particles closer together, some of the sound will be absorbed by the medium and less of the sound wave will continue to travel.
        - Ask students to complete their workbook questions for this section. For the final question, they will write down an example of this phenomenon in their student workbooks.
        - This is why thicker walls in a home, or heavy concrete in an industrial building, are used for help with soundproofing. The higher density in the materials used help to absorb sound.
    - **Transition:** Ask the students if they noticed two mediums being "accidentally" tested at once during any of their trials. That's right! You first struck the tuning fork in the air, and then transitioned it to another medium, such as water.
        - When sound waves move from one medium to another, some of the sound energy is transmitted into the new medium, while some of it reflects back into the original medium. This will result in a change to the wave's speed and sound.
        - Instruct students to copy this information into their student workbooks by filling in the blanks.
    - **Reflection & Echoes:** As discussed above, when you transition a sound wave from one medium to another, it is the difference between the densities of those two mediums that creates reflection. The greater the difference between the two media, the more sound is reflected.
        - This reflection can cause echoes, which are most common in environments with hard surfaces that allow sound to travel faster.
        - Ask students to write down an example of this in their student workbooks.
        - Echoes are common in places with a lot of hard surfaces for sound waves to reflect off of, such as bathrooms, indoor pools, canyons, and caves.
    - Ask students - which materials do you think will be most effective for building the best speaker in the class for your Day 4 challenge? Why?

TEACHER-LED Activity 5: Speak Up! Your Design Diagram

Provide students with a reminder of a basic design example for the DIY speakers that they will construct on Day 4, and encourage visualization of their own design through the creation of a labelled diagram.

- **If you feel students would benefit from a reminder of how they built speakers on Day 2, you may show the video below.** Otherwise students may proceed to label an example diagram of the basic speaker from memory on pg. 36 of their student workbooks.
  - DIY Plastic Cup Speaker
  - URL: https://youtu.be/ASEQBidsz6g?si=szm6AfoVEJRB_2jq
- On the board, draw and label the following diagram for students:



- Tell students that in preparation for tomorrow's activities, they will now be sketching a diagram of a new DIY speaker **with changes** they would like to make based on what they learned about sound vibrations and media. They should label each component with its materials and function as they go.
- Encourage creativity, but remind students to also be accurate and realistic when representing their components!

Activity 6: Wrap-Up: What Did You Discover?

- **Group Discussion & Wrap-Up (pg. 36-37)**
    - Recap the key points learned in today's session, reminding students that the media that a sound wave interacts with can drastically affect that sound wave's characteristics, including sound amplification and damping.
    - You may use the following reflection questions for discussion:
        - In what way were you able to "see" sound waves at work today? What did this look like when tested on the ping pong ball? How about on the string/yarn? The sand?
        - How did the sound waves behave when introduced to each of the mediums tested today - air, water, wood, metal, glass, plastic, memory foam, plastic, and your body?
        - Which experiment was your favorite and why?
        - What were some things that could have gone wrong in your experiment? How could you fix them next time?
    - Provide a brief overview of what to expect on Day 4, and encourage students to think about the materials and design they will use to make their group's speaker the loudest in the class.

End of Day 3

Day 4
Sound Off! Let's Build a Speaker

This session will be facilitated by a team of 7-10 SciTrek undergraduate Mentors and one Lead. The teacher should be prepared to do a session introduction, conclusion, and provide guidance and oversight for students during the session.

Objective

Thinking back to previous experiments, demonstrations, key content, and the principles behind speaker construction, students will work to strategically upgrade their speakers from Day 2. They will then test your upgraded speaker and collect evidence of their design choices' effectiveness by measuring the speaker's sound.

Materials:

- **Basic Speaker Kit**
    - Plastic cup
    - 4 meters of wire
    - (2) 1-inch magnets
    - Alligator clips
    - Aux cord
    - MP3 player
- **Speaker Upgrade Kit**
    - Metal cup
    - Paper cup
    - magnets
    - Glass jar
    - Wooden cup
    - Spool of copper wire
- Tape
- Sand paper
- Aluminium foil
- Wire cutters
- Plastic bin & lid
- Attachable decibel meter

- **TEACHER-LED Introduction**
    - **Summarize:** Provide a brief review of what the experiments from Day 3 showed about sound waves and the transfer of energy.
        - A wave's transfer of energy was demonstrated visually using the ping pong ball, string/yarn, sand, and sand.

- Changing the media (air, water, wood, metal, glass, tin, memory foam, plastic, and skin) that a wave travels across affects the volume of the sound produced.
- Explain the goal: Today, you will demonstrate your understanding of everything you've learned about waves over the past few days, in this challenge to build the loudest speaker in the class.
- Tell students that each group will be modifying the basic speaker design from Day 2. They will test 3-4 different speaker designs, change only one component between each design, and take a decibel (volume) measurement for each.
- Tell students that at the end of the experiment, the volume measurement from each group's most successful speaker design will be shared and compared, and one group will be named the winner.

TEACHER-LED Activity 1: Variables

Objective: Students will be able to identify variables in an experiment, and explain why only one variable should be tested at a time. Students will also learn how to stack variables in an experiment.

- Explain variables to the students using the provided slides or your own. Emphasize what a variable is and provide examples (temperature, type of material, etc.), of how and why a variable might be changed throughout an experiment.
- Instruct students to answer the following questions in their workbook on pg. 38.
    1. What is a variable? ***A variable is the factor that is changed in an experiment. We change a variable in order to see if we get some sort of a change in results.***
    2. If you want to test how light intensity affects plant growth, what would be the variable in the experiment? ***The amount of light.***
    3. Why can't you test two variables at one time? ***If you test two at once, you will not be able to identify which change caused the results. The results could be caused by one variable, the other or both. You can stack variables by testing one variable, recording results, and then adding another variable to see how those results are affected.***

SCITREK-LED Activity 2: Can We Build It? Yes We can!

Materials:

- **Basic Speaker Kit**
    - Plastic cup
    - 4 meters of wire
    - (2) 1-inch magnets
    - Alligator clips
    - Aux cord
    - MP3 player
- **Speaker Upgrade Kit**
    - Metal cup
    - Paper cup
    - magnets
    - Glass jar
    - Wooden cup
    - Spool of copper wire
- Tape
- Sand paper
- Aluminium foil
- Wire cutters
- Plastic bin & lid
- Attachable decibel meter

- Instruct students to discuss and formulate their group's hypothesis based on their knowledge of how sound waves interact with different media on pg. 39.
    - **"Based on how sound waves interact with these media, we hypothesize that the following media [...] will be the most effective for sound amplification because…"**
    - This should be discussed within the group with the SciTrek mentors.
- **Create & Track:** Instruct students to build original design and fill in data on pg. 40
- **Redesign and Repeat - Iterate:** Inform students that it is now time to compete to see which small group will build the loudest speaker!
- Refer students to their first Speaker Design Data Table. Guide the group in a quick discussion as to which component they will change in their 1st design.
    - Have students define what a variable is. Remind them that it is important to change just one thing at a time so that they can be sure that any changes in amplification are attributable to *a specific upgrade*.
    - Ask the students to take a baseline reading to have as a comparison for future iterations. Students will first build their (normal) original speaker, take an

initial reading, and record the track and decibel reading in the first data table on pg. 40.
    - Remind students that they will complete multiple iterations, so each group member should take a turn in choosing a component if a decision can't be reached as a group.
    - Upgrades you may make include, but are not limited to, adding/removing magnets, making new coils, changing the material of the cup or choosing a new track.
- Instruct students to complete the Speaker Design Data Table including all available information such as the variable changed, the track played, the decibel reading and an explanation for why the volume went up or down for each iteration. Pg. 41
- Students will now repeat this process for 2-3 more iterations. Be sure that students are actively involved in changing out parts of the speaker. It's okay if the speaker does not work on the first try.
- Students will fill in the last data table with an explanation and drawing of their best speaker design to share with the class. Pg. 42

ORIGINAL SPEAKER DESIGN DATA

Original Speaker Design (no variables)

Track Played	Decibel Reading

NEW **SPEAKER DESIGN TRIALS**

Speaker Design	**Variable** (What changed in this design from the original design)	**Track Played**	**Decibel Reading** (Don't forget units!)	**Possible Explanation**
1				
2				
3				
4				

(Hint: remember to only change one variable at a time! However, you can stack variables once the first variable has been tested and recorded).

MOST SUCCESSFUL SPEAKER DESIGN DATA

Variables including the track	Decibel Reading	Labeled Drawing

TEACHER-LED Activity 3: Measuring Speaker Success

- **Results Are In!**
    - Tell the students that you will now be comparing the highest decibel reading from each group's most successful speaker to see which student group chose the best materials and had the most effective design.
    - Select a student group, and ask for their group name. Then, ask for their highest decibel reading as well as the upgraded materials that made their loudest iteration. Record this information in the Small Group Speakers Data Table below, which should be copied or projected onto the board. Instruct students to fill in their own class data tables on pg. 43.

SMALL GROUP SPEAKERS DATA TABLE:

Group Name	Upgrade(s)	Highest Decibel Reading 🎵🔊

- Once all speakers have been tested, announce the winner for the class challenge to build the loudest speaker.
- Ask the winning student group to report their chosen materials for the building of their winning speaker design, and instruct students to record this list of materials in their student workbooks.
    - Now, ask every other student group to check which materials their own group shared with the winning group. Instruct students to record this list of materials in their student workbooks on pg. 44.

- **Group Discussion & Wrap-Up**: Discuss whether or not it is possible to know exactly which materials are most or least effective for each component of the speaker, using just the information they have from their materials lists, diagrams, and trials. Why or why not? Instruct students to record their answers in their student workbooks. Pg. 44-45
    - Ask each group to choose just one material that they would change on their speaker if given the chance to perform another trial. Tell students to explain their reasoning in their student workbooks.
    - Ask students if there any household items that they might have liked to use in their designs instead, had they been given the chance. Tell students to explain their reasoning with reference to both size and materials, and record their answers in their student workbooks.
    - Conclude by reinforcing the importance of careful experimental design, accurate data collection, and critical analysis of results.
    - Ask students to complete their final reflection question in their student workbooks on pg. 45.

End of Day 4

Day 5

Poster Perfect: Showcasing Your Scientific Journey!

Objective

Students will create a research-style poster that reports on their “Sound Off! Let’s Build a Speaker” experiment, including a title, data table, graph, speaker diagram, results, and conclusion. This activity will help students organize and present their scientific findings in a professional and deliberate format.

SciTrek will provide the poster elements as printed sheets that students can fill out and arrange on their posters, and then decorate.

TEACHER-LED Session Overview

- **Introduction:** Explain the purpose of research posters and how scientists use them to share findings. Briefly review the key components: title, data table, graph, speaker diagram, results, and conclusion.

SCITREK-LED Poster Creation

1. Students will first fill in their workbooks (like a rough draft) with all of the information that will be needed for their posters. Pg. 46-49
2. Then students should fill out their poster templates NEATLY. Tell students that they can divide up the templates if desired, and assign different parts of the poster to each member of their group.
3. Lastly, students will cut out their completed templates, glue them on their posters and decorate the posters.

Step 1: Title - Students use the poster template to write a clear, descriptive title for their project. This should be something catchy but still focussed on the purpose of the experiment. Somebody who reads it should be able to get an idea of what the experiment was about.

Step 2: Data Table- Students will use the data from Day 4 to fill in the results table showing their variables for each speaker design and corresponding decibel readings.

Step 3: *Draw & Diagram*- Have students draw and label a picture of their best speaker design on the template, focusing on the key components listed in the Day 4 Label Key: copper wire coil, magnet, auxiliary cable.

Step 4: Graph Key Results- Students use their data from their original, "normal" speaker and the 4 iterations (Day 4) to design a bar graph showing the 5 different decibel levels. A basic graph template is provided, but they will need to put the correct decibel range on the y-axis. Instruct students how to determine the range and increments of the y-axis. Not all groups have to be the same.

Step 5: Conclusion- Students write a conclusion on the template that interprets their results and explains why they think they got the results they did. They can also discuss any possible sources of error or things that they found difficult.

Step 6: Waves Concepts- Students will fill in three different waves concepts they learned over the last week. You can instruct them to think about all of the activities they completed. They can also use their workbooks to help them remember.

Step 7: Assemble the Poster- Once the rough draft has been completed in their student workbooks, the students will NEATLY fill out the templates for their poster. Student groups should glue the sections onto the posterboard in a clear and logical order. After the components are glued, students can decorate their poster, making it visually appealing while keeping it readable and focused on the scientific content.

TEACHER-LED Poster Presentation

- **Gallery Walk and Peer Feedback**
  Students display their finished posters around the room. Everyone participates in a gallery walk to view each other's work and provide positive feedback and constructive comments. Pg. 50
- **Conclusion and Reflection**
  Conclude by reflecting on the process of creating the poster. Discuss the importance of communicating scientific findings effectively and how these skills can be applied to future projects or everyday life.

End of Day 5

🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪🧪

Project Title:

Names (including Mentor):

Data Table

	Variables (cup material, wire, magnets, track, other)	Decibel Level (dB)
Design 1		
Design 2		
Design 3		
Design 4		

From Day 4 in your Student Workbook

- -

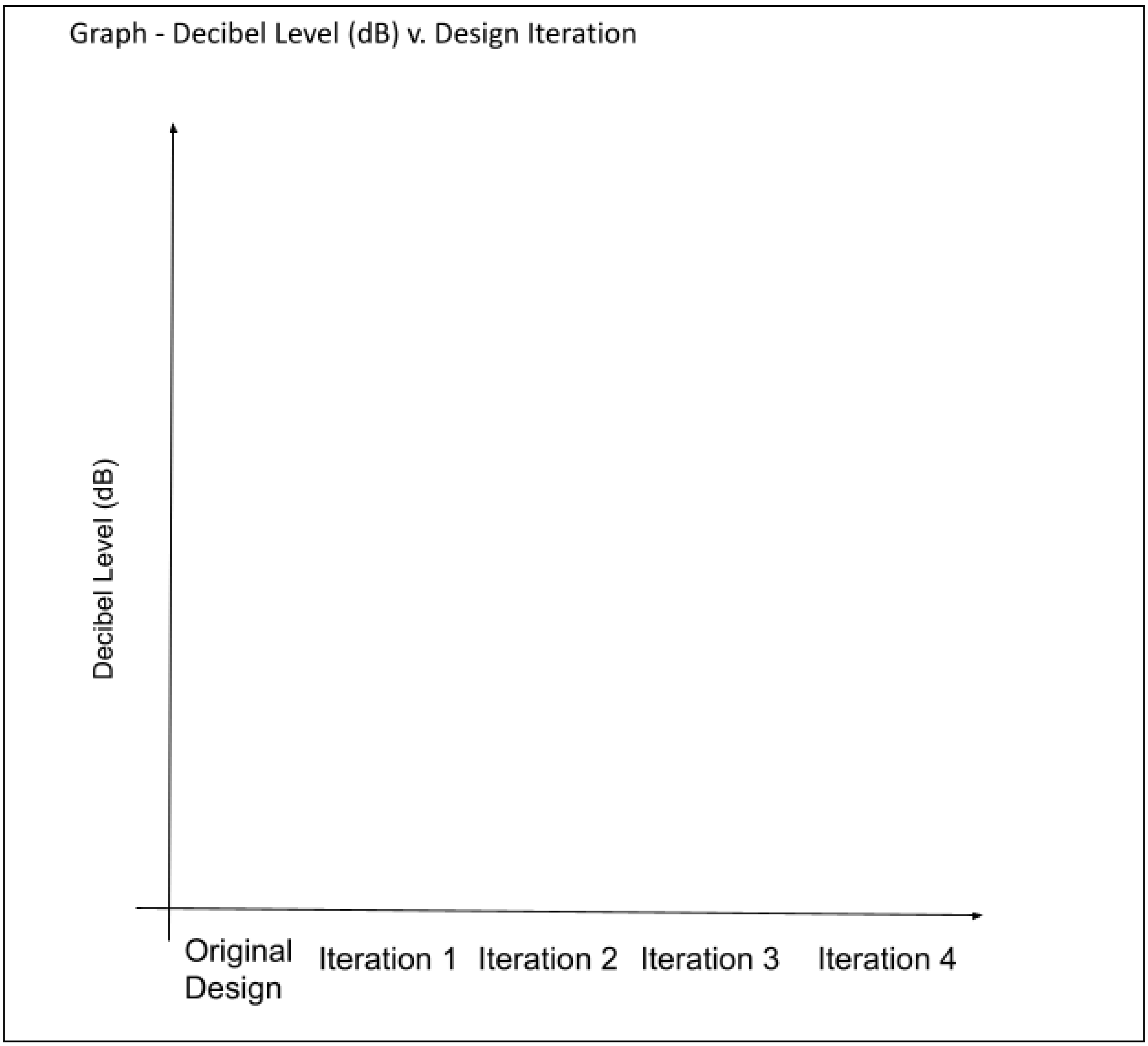
Draw a **labeled** diagram of you **loudest** speaker design below:

<u>*Instructions*</u>:

1. *Go back in your workbook and the trials from* ***Day 4 of this Module****.*
2. *Make a bar graph (example to the right) of those results using the plot below.*

- -

Graph of Key Results



Conclusion

Which design was the loudest and why?

List 3 important concepts about waves that you learned from this lesson.

Concept #1	
Concept #2	
Concept #3	

SciTrek is an educational outreach program that is dedicated to allowing 2nd - 12th grade students to experience scientific practices firsthand. SciTrek partners with local teachers to present student-centered inquiry-based modules that not only emphasize the process of science but also specific grade level NGSS performance expectations. Each module allows students to design, carry out, and present their experiments and findings.

If you would like to donate to the program or find out how you can get your company's logo on our notebooks please contact scitrekadmin@chem.ucsb.

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