Sound Waves

<table>
<tr><td colspan="2">The focus of this instructional segment is the characteristics and behavior of mechanical waves. These mechanical waves will be evaluated using sound as the context. This is part 1 of 3 instructional segments for waves.</td></tr>
<tr><td colspan="2" align="center">Student Science Performance</td></tr>
<tr><td>Grade or course: 9-12 Physics
Topic: Waves</td><td align="center">Title:
Sound</td></tr>
<tr><td colspan="2">Performance Expectation for GSE:
SP4. Obtain, evaluate, and communicate information about the properties and applications of waves.
a. Develop and use mathematical models to explain mechanical and electromagnetic waves as a propagating disturbance that transfers energy.
(<u>Clarification statement:</u> Mathematically describe how the velocity, frequency, and wavelength of a propagating wave are related.)
c. Construct an argument that analyzes the production and characteristics of sounds waves.
(<u>Clarification statement:</u> Includes, but not limited to, Doppler Effect, standing waves, wavelength, the relationship between amplitude and the energy of the wave, and the relationship between frequency and pitch.)
g. Plan and carry out investigations to describe changes in diffraction patterns associated with geometry and wavelength for mechanical and electromagnetic waves.</td></tr>
<tr><td colspan="2">Performance Expectations for Instruction:
Students will
● analyze the structure and characteristics of sound waves.
● use their analysis of the characteristics of sound waves to explain the relationship between energy and amplitude as well as frequency and pitch.
● describe real world situations involving the Doppler Effect.
● relate the structure of standing waves to the characteristics of sound waves and standing waves.
<u>Additional notes on student supports</u></td></tr>
<tr><td colspan="2">Materials
● Computer
● Speakers
● Interactive Whiteboards</td></tr>
<tr><td colspan="2">Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.</td></tr>
<tr><td rowspan="2">Engaging Learners</td><td>Phenomenon: A higher frequency produces a higher pitched sound.</td></tr>
<tr><td>Obtaining
Students will use one of the following simulations to gather information around refraction PhET: <u>Sound</u> or <u>Wave Interference</u>. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; <u>https://phet.colorado.edu</u>)

Students should enable the sound and adjust the frequency of the sound. They should also (in a separate trial) adjust the amplitude of the sound.</td></tr>
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	Students will then informally write about the nature of the sound when the frequency is adjusted as well as the amplitude.
	Evaluating Students will write down a series of questions that they have based on the simulation. *Possible questions:* ○ *Why does loudness cause hearing damage?* ○ *Why can dogs hear sound that humans cannot hear?* Students will then write down a claim regarding the relationship between frequency and pitch.
	Communicating Students will form groups between 2 and 4 to share their claims about the relationship between frequency and pitch and amplitude and loudness. Students will make adjustments and formulate general claims as a class. They will add their evidence and reasoning to their class claim around pitch and frequency.
Exploring	*Obtaining* Students will use the following Phet Simulation: Wave on a String to analyze standing waves. The following handout will be used to guide students through the lab: Standing Wave Lab . *Make sure that students are able to relate the frequency to the pitch. This will help them relate the frequencies to the harmonics. You may also want to provide an illustration that shows the nodes and antinodes as a reference.*
	Communicating Students will use the activity to develop a poster that explains the relationship between standing waves, harmonics, and frequencies. The class will engage in an argumentation session to justify their claim.
	Evaluating Students will finalize their claim based on the argumentation session.
	Formative Assessment of Student Learning
Explaining Finalizing Model	*Obtaining* Students will obtain information about characteristics of sound waves using print or online resources, such as cK-12: Waves. Students, or in groups, are to develop models that show how waves, mechanical and electromagnetic, transfer energy. Models should include the influence of velocity, frequency, and wavelength—as well as real-world applications. Models can be two or three-dimensional and interactive and should show variable relationships/calculations.
	Evaluating Evaluate student models for correct descriptions and calculations
	Communicating Students will share wave models with other groups or the whole class.
Elaborating Applying Model to Solve a Problems	**Phenomenon:** Objects making sound and in motion are perceived to have a changing pitch. (Doppler Effect)

	Obtaining Students will watch a video that demonstrates the Doppler Effect for an approaching vehicle, a stationary vehicle, and the same vehicle driving away. Students should document what they hear for each scenario. This demonstration can be done with a tuning fork or small speaker attached to a string—rotate the fork or speaker in a circle above your head and students will perceive the difference in pitch.
	Evaluating Students will use the following Phet Simulation: Sound to analyze the Doppler Effect. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu) Students should use their prior knowledge on the nature of sound waves (longitudinal) and the relationship between pitch and frequency. Students will complete the Doppler Effect Investigation
	Communicating Students communicate findings and analysis on the student lab sheets.
Evaluation	***Assessment of Student Learning***
	Students are continually assessed throughout segment during labs, argumentation sessions, and class discussion.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	● Developing and using models ● Engaging in argument from evidence ● Planning and carrying out investigations
Crosscutting Concepts	● Cause and Effect ● Energy and Matter ● Patterns ● Structure and Function
Disciplinary Core Ideas	From *A Framework for K-12 Science Education:* ● PS4A: Wave Behavior ● PS4B: Electromagnetic Radiation

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. Provide calculators as needed. 2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should consider using both PhET simulations.
2. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include drawing, diagramming, writing or verbally explaining.
3. The teacher should consider providing students with question stems to assist students in generating questions.
4. Then the teacher can assist students in determining which questions are most related to the standard and lesson.
5. The teacher should have clear and consistent guidelines for class discussions. These guidelines are to help students feel more comfortable and be more likely to participate.
6. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student groupings.
7. The teacher should provide multiple ways for students to share their work. These formats could include using technology, gallery walks or presentations.

Exploring:

1. The teacher should give lab sheets to the students for students to record data and remember the procedure.
2. The teacher should consider a formative assessment to determine which students need re-teaching, reviewing or enriching.
3. The teacher should be prepared to repeat directions as needed.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include drawing, diagramming, writing or verbally explaining.
5. The teacher should consider providing students with an organizer to assist in designing a model.
6. The teacher should provide multiple ways for students to share their work. These formats could include using technology, gallery walks or presentations.
7. The teacher should have clear and consistent guidelines for the argumentation session. These guidelines should help the students feel more comfortable and be more likely to participate.

Explaining:

1. The teacher should consider providing students with sources to use in their research.
2. The teacher should use intentional and flexible grouping to group students. Best practice is to use data to drive student grouping.
3. The teacher should consider providing students with an organizer to record their research, design their model and record the calculations.
4. The teacher should consider a formative assessment to determine which students need reviewing, re-teaching or enriching.
5. The teacher should provide students with multiple ways for students to share their work. These formats could include using technology, gallery walks or presentations.

Elaborating:

1. The teacher should consider showing the video more than once to allow students to make observations.
2. The teacher should consider trying to make this real world by having students look for examples of the doppler effect in their lives. This could lead students to feel more connected to the material.
3. The teacher should consider providing students with an organizer to record observations, data and draw conclusions.

Evaluating:

1. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.
2. Students may need additional time to complete their assignments.

Standing Waves Lab

Resource: PhET: Waves on a String

In this simulation you can investigate the behavior of waves on a string.

Part 1 Waves on a string with no end

Challenge: Determine the speed of the waves at each tension setting (high, medium and low). Explain what measurements you made to calculate the speed.

Settings: amplitude: 0.75 cm damping: zero

high tension:

medium tension:

low tension:

Does the speed of the wave depend on the frequency or is it the same for all frequencies? Collect data to support your answer:

Part 2 Waves on a string with a fixed end

The reflected wave interferes with the original wave and creates a standing wave composed of nodes and antinodes if the frequency is just right. A node will always exist at the fixed end because the phase of the wave is inverted upon reflection and therefore always destructively interferes at that position. Adjust the frequency until maximum amplitude results. (You can use the reference line to help you detect small changes in the amplitude as you fine tune the frequency.)

Challenge: Draw and measure the frequencies of the 4^{th}, 3^{rd}, 2^{nd}, and 1^{st} harmonics.

Settings: amplitude: 0.05 cm tension: high damping: none

(4 antinodes)	(3 antinodes)	(2 antinodes)	(1 antinode)
f_4 = _________ Hz	f_3 = _________ Hz	f_2 = _________ Hz	f_1 = _________ Hz

Divide each higher harmonic by the first harmonic:

f_4 / f_1 = ______ f_3 / f_1 = ______ f_2 / f_1 = ______

Are the higher harmonics whole-number multiples of the first harmonic (fundamental frequency)? _______

Predict the frequency of the 5th harmonic: (show calculation)

Set the wave driver to that frequency and draw the result here:

Part 3 Waves on a string with a loose end

The reflected wave interferes with the original wave and creates a standing wave composed of nodes and antinodes if the frequency is just right. Instead of a node, an antinode will always exist at the loose end. (This happens because the phase of the wave is **not** inverted upon reflection from a loose end and therefore always constructively interferes at that position.)

Challenge: Draw and measure the frequency of the 1st harmonic (node near driver end followed by an antinode on loose end)

Settings: amplitude: 0.05 cm tension: high damping: none

What fraction of a wavelength is this? ___________

f_1 = _________ Hz

Predict the frequencies of several higher harmonics:

Use the wave simulator to test each of your calculated harmonics. Note which ones appeared and which ones did not appear!

Draw and label the standing waves for each of the harmonics you discovered:

Divide each higher harmonic by the first harmonic:

Are the higher harmonics even-number or odd-number multiples of the first harmonic? ______

Explain why there are missing harmonics for standing waves on a string with a loose (free) end. (Hint: Is there a pattern to how much of a wavelength fits between the ends of the string with a loose end?)

Extra credit: The speed of a transverse wave on a string of length **L** and mass **m** under tension **T** is given by the formula

$$v = \sqrt{T / (m/L)}$$

If the maximum tension in the simulation is 10.0 N, what is the linear mass density (m/L) of the string?

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The Doppler Effect

I. Background

The Doppler effect is the change in frequency of a wave for an observer moving relative to its source. It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and moves away from an observer. The received frequency is higher during the approach, it is identical at the instant of passing by, and it is lower while it moves away.

II. Objectives

Students will be able to:

Draw pictures of high and low frequency wave fronts.

Explain why the pitch of a car horn changes as it approaches and then drives past.

Explain the Doppler effect, with diagrams, and give examples of where it can be heard.

III. Materials

Tuning Fork (with a string tied to the handle)

Internet connection

IV. Key Terms

Pitch – How low or high a tone sounds to a person

Frequency – wiggles per second (moves back and forth)

Doppler Effect – As the source of a wave (sound or light) approaches an observer, the observer sees/hears a higher frequency than the source actually is emitting. As the source moves away from an observer, the observer sees/hears a lower frequency wave than the source actually is emitting.

V. Procedure

1. Go to the PhET simulation Sound

2. Choose "Listen to A Single Source", check Enable Audio, and alter the frequencies.

3. Draw a picture of a low pitch sound wave and high pitch sound wave.

Low Pitch Sound Wave High Pitch Sound Wave

4. Go to the following website : Example of Doppler Shift using car horn.

5. Describe what you heard.

____

____

6. Draw a picture (with wave fronts) illustrating the Doppler Effect of the car and horn as it approaches and moves away in the video.

7. BEING CAREFUL, take the Tuning Fork with string tied to it and tap the fork with a mallet while it is dangling. Then, swing the tuning fork in a circular motion (in front of you or above your head) being sure that you do not hit anything or anyone.

8. Describe what you heard.

____

____

9. Draw a picture (with wave fronts) illustrating the Doppler Effect of the Tuning Fork being swung around your head.

VI. Analysis & Conclusions

1. When an automobile moves towards a listener, the sound of its horn seems relatively:

    a. low pitched b. high pitched c. normal

2. When an automobile moves away from a listener, its horn seems relatively:

    a. low pitched b. high pitched c. normal

3. The changed pitch of the Doppler Effect is due to changes in:

    a. wave speed b. wave frequency c. wave amplitude

4. Describe (in your own words) how the Doppler Effect works.

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5. Which of the following scenarios would produce the Doppler Effect? *Check all that apply.*

__________ A moving sound source (such as an airplane passing overhead)

__________ A moving observer of a source (such as a person running past a loud stereo)

__________ A moving source and moving observer

(such as kids chasing an ice cream truck that is playing music)

__________ A non-moving source and non-moving observer

(such as person watching television on a couch)

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