## Big Idea/ Topic

Wave properties and behavior

## Standard Alignment

**SPS9. Obtain, evaluate, and communicate information to explain the properties of waves.**

a. Analyze and interpret data to identify the relationships among wavelength, frequency, and energy in electromagnetic waves and amplitude and energy in mechanical waves.

b. Ask questions to compare and contrast the characteristics of electromagnetic and mechanical waves.

c. Develop models based on experimental evidence that illustrate the phenomena of reflection, refraction, interference, and diffraction.

d. Analyze and interpret data to explain how different media affect the speed of sound and light waves.

e. Develop and use models to explain the changes in sound waves associated with the Doppler Effect.

Connections to other contents:

**ELAGSE9-10W1:** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

**ELAGSE9-10W2:** Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

**ELAGSE9-10R18:** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid, and the evidence is relevant and sufficient; identify false statements and fallacious reasoning.

**ELAGSE9-10S14:** Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

**ELAGSE9-10W7:** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
Instructional Design

Engage:

**Phenomenon:** When a sound from a car, a siren, or other object moves toward me, it sounds differently than when the sound moves away from me.

Consider demonstrating the Doppler Effect for students through video or prompting them to think about when they have heard a car horn or siren pass by how the sound has changed. There are multiple videos online that show the effect. After experiencing the phenomenon, students are prompted to explain the effect.

Students will propose a model for this behavior of the sound waves based on their observations. The Doppler Effect is a very easy phenomena to hear but can be difficult for students to explain. The model that they propose needs to focus on why they observe the difference in the sound. Many students will try to just describe what they have heard and call that a model. A model needs to explain why the phenomena occurs and is in the form of words or a diagram. A simple diagram with a few sentences for an explanation will be a good place to start. The goal is for these models to explain what properties of the sound are changing and which properties are staying constant. For example, a student could explain that the frequency and the wavelength of the sound from the car coming towards me are different than the frequency and wavelength of the sound from the car as it goes away from me. Students will revisit the initial models and refine as the unit progresses.

Unplugged: students without access to technology will most likely have experienced the Doppler Effect before, but they may need access to printed resources and prompts for them to develop their initial models.

Explore

In this section of the lesson, students build an understanding of wave properties and behavior through the PhET Simulation: Waves Intro (Attribution: PhET Interactive Simulations, University of Colorado Boulder; [https://phet.colorado.edu](https://phet.colorado.edu)). Students complete the corresponding lab sheet as they explore waves.

Although students have learned about waves in previous courses, this simulation will connect prior knowledge to the lesson phenomenon as well as introduce wave properties. As a culminating activity for this section of the lesson, students could return to their initial models and add more information and revise the initial thinking about the Doppler Effect. A class or small group discussion would be beneficial for students to share their findings from the simulation and questions that remain about wave properties and behavior.

Other explorations that could take place include refraction using a glass filled with water; students can observe objects in the water or view objects on the opposite side of the glass (like arrows drawn on paper). Encourage students to develop models about what they observe; as they learn more about wave behavior, they will improve their models.
Unplugged: for students unable to access the online simulation, consider providing printed resources that give examples and describe the properties and behaviors of sound and light waves. If possible, screenshots from the simulation could be printed and shared with students so they could have a similar experience with variables and visuals.

**Explain**

In this phase of the lesson, students are explaining several different wave phenomena, these can be linked back to the original Doppler Effect phenomenon. The intent is that students ask questions, develop models, and analyze data concerning multiple wave properties. Students use the PhET simulation: *Wave on a String* (Attribution: PhET Interactive Simulations, University of Colorado Boulder; [https://phet.colorado.edu](https://phet.colorado.edu)).

Students complete the *student sheet* for Waves on a String simulation.

Unplugged: for students unable to access the above simulation, consider how data could be shared with students that is generated from the simulation, such as printouts, screenshots, etc. Students will need access to materials that discuss wave properties.

**Elaborate**

Students continue learning about wave properties of reflection, refraction, and wave speed through at-home labs and virtual simulations. Students are prompted to develop an initial model about refraction with a simple at-home setup: as they use the simulation, they will return to the initial model to refine ideas. Students will use the PhET simulation: *Bending Light* (Attribution: PhET Interactive Simulations, University of Colorado Boulder; [https://phet.colorado.edu](https://phet.colorado.edu)) and the accompanying *Bending Light Student Sheet*. The simulation does not contain sound waves. The *GPB Physics in Motion* series has an excellent video discussing sound wave properties such as speed; in addition, there is a lab associated with this resource that could be modified for student to complete at home with supervision. After the simulation, consider having group and class discussion where students can share their results and questions. Students should be using models and data from these simulations as they communicate their findings.

In the next part of the segment, students elaborate on wave properties of interference and diffraction using the *GPB Physics in Motion* series; this includes a video and an online simulation.

With simulations completed, students are prompted to return to the initial phenomenon of the Doppler Effect and refine their initial thinking and models.

Another resource that could be shared with students for this section is the *GPB Physics in Motion* series a lesson on Doppler Effect with videos and materials.

Unplugged: for students unable to access the above simulations, consider how data could be shared with students that is generated from the simulation, such as printouts, screenshots, etc. Students will need access to materials that discuss wave properties.
Evaluate

Student should demonstrate their understanding as they communicate verbally and through written work about wave types, properties, and behaviors. As a culminating activity, students return to their initial models about the Doppler Effect and provide evidence from their investigations and research and refine the initial explanations.

Lesson Goals Checklist

SPS9. Obtain, evaluate, and communicate information to explain the properties of waves.

☐ Analyze and interpret data to identify the relationships among:
   ☐ wavelength, frequency, and energy in electromagnetic waves
   ☐ amplitude and energy in mechanical waves.

☐ Ask questions to compare and contrast the characteristics of electromagnetic and mechanical waves.

☐ Develop models based on experimental evidence that illustrate the phenomena of:
   ☐ Reflection
   ☐ Refraction
   ☐ Interference
   ☐ Diffraction

☐ Analyze and interpret data to explain how different media affect the speed of sound and light waves.

☐ Develop and use models to explain the changes in sound waves associated with the Doppler Effect.

Evidence of Student Success

Student mastery is assessed throughout this unit using formative and summative components. Student discussion, explanations and products should reflect the understanding indicated in the sections above. Each activity in the segment functions as an assessment opportunity as well to plan targeted supports or provide extension items. Formative options using the self-evaluation checklist and at various points during the segment.
Distance Learning Supports

The vision for science education in the state of Georgia is as follows: All Students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields.

The learning experiences provided for students should engage them with fundamental questions about the world and with how scientists have investigated and found answers to those questions.

This lesson includes the disciplinary core ideas, science and engineering practices and crosscutting concepts to actively engage students in exploring science concepts with real world topics. As part of the vision we must support the inclusion of all students in science learning. Some general ideas to consider when designing things to support students that struggle are as follows:

- Be sure that students can access the information that you they are learning. Make sure that you can answer the following questions:
  - Do students have what they need to get the information? This is about them having the book or internet access to get to the information.
  - Once students obtain the information, are students able to determine what information is important? This is about the students having materials on the appropriate grade level and that is in a format that students can understand.
  - Is the material presented in multiple ways that allows all students to interact with information in a way that works for them? Such as video, audio, and articles.
  - Consider read aloud as a potential option for students that have reading deficits as an option to assist students in accessing the material. This could be done using video, read aloud or via phone.
- Students may need ideas about where to find information. Providing students with information about what a reliable source is and even where to find reliable sources may be beneficial for students.
- Some students may find it difficult to complete the entire lesson workload. Some students may benefit from a reduced workload (note: this should be used only when absolutely necessary). Be sure that the information that is removed will not negatively impact the student’s understanding of the disciplinary core idea.
- Consider how students show their knowledge. Students need multiple ways and opportunities to show their knowledge. Things to consider:
  - Recording video or audio
  - Drawing
  - Writing
  - Typed
  - Verbal
- Provide students with a way to ask questions in a forum that does not cause anxiety. Frequently students do not want to ask questions in front of their peers because they are afraid of what their peers may think of them. So, be sure to provide students a way to ask questions that is private or anonymous.
- Consider materials that students need to complete the assignments.
  - Do students have needed materials?
  - What are some alternative materials that students may have available to them?
• Have a clear and consistent set of guidelines for providing consistent feedback to all students.
• Utilize graphic organizers such as those from the Wonderofscience.com
• Use high leverage and evidence-based practices to reach all students.

Some ideas for supporting this lesson specifically would be to make sure to consider the following:

• The teacher should consider using a video or diagram of the doppler effect to emphasize what is happening.
• The teacher could ask students to find examples of the Doppler Effect. These examples can occur in real life and, also, can be seen in videos.
• The teacher should consider providing students with a rubric for assignments that way students understand the expectations and can self-evaluate their work.
• The teacher should be sure that students have multiple ways to obtain information.
• The teacher should provide students with options for showing their knowledge.
• The teacher may need to provide students with question stems to help them frame their questions in a way that can be used to obtain information.
• The teacher should consider providing students with graphic organizers to organize their thoughts, ideas, and information.
• The teacher should provide students with an opportunity to discuss their findings and questions as they move through the lesson.
• The teacher should have clear and consistent guidelines for discussions. These guidelines should help students feel comfortable and be more likely to participate in the discussion.
• The teacher should provide students with an opportunity to revise their models and explanations as they work through the lesson and obtain more information.
• The teacher should provide clear and consistent feedback to help students make meaningful changes to their work. It will, also, help students incorporate the correct knowledge into their schema.

Engaging Families
Additional resources to support this segment can be found at GPB: Georgia Home Classroom.
Waves Intro Simulation Student Sheet

PhET Simulation: Waves Intro (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu)

Open the wave simulation and click on water; answer the following questions with this part:

1. What is the amplitude of the wave? Using pictures or screenshots, show in the top view and side view what the amplitude of the wave is.
2. With amplitude slider, select three different amplitudes and measure them.
3. In the side view setting, explain how changing the amplitude affects the water level.
4. Does changing the amplitude of the wave change how fast it moves? Use the timer and explain with diagrams.
5. Does changing the amplitude of the wave change the wavelength? Use the measuring tool and explain with diagrams.
6. How would you describe the wave property of amplitude without using diagrams?

Go back to the simulation start screen and open the sound part; answer the following questions with this part of the simulation:

1. To start, select the Waves and start the wave. What is similar or different compared to the water wave from before?
2. Now, select particles only. The particles represent the parts of the medium that the wave is traveling through, such as the molecules in air. How is this different that the water wave?
3. Describe how a sound wave travels across the surface. You can change the wave parameters or only send one wave to slow and down and observe.

4. With one wave selected, what happens to the particles after the wave passes?
5. With the graph displayed, what part of the wave matches with when the particles are close together? Explain with a diagram.
6. When play tone is selected, how does the sound change when the amplitude is changed?
7. When play tone is selected, how does the sound change with the frequency is changed?
8. Using the measuring tools, select two different frequencies and measure how fast the wave is traveling and measure the wavelength for the same points. How does the wavelength change when the frequency is changed? Explain with a diagram.
9. When you change the amplitude, what affect does it have on the frequency and wavelength of the sound wave? Explain.
10. Think back to the Doppler Effect demonstration that started this lesson; What could you add to your initial model to help describe how the Doppler Effect happens?

For the final part of this investigation, open the Light simulation and answer the following:

1. Select a color of light for the wave and using the measuring tools, measure the wavelength. When the frequency is changed, what happens to the wavelength? Explain with a diagram.
2. What color of light has the highest frequency? The largest wavelength?
3. Describe the similarities and differences between light waves and sound waves. Use diagrams and/or models in your explanation.
Properties of Waves Lab
Go to: PhET: Wave on a String

1. Click the button for the ruler, set damping to “NONE” and click the button for “no end”
2. Click the “Oscillate” button. Describe what is happening.

<table>
<thead>
<tr>
<th>Description</th>
<th>Drawing</th>
</tr>
</thead>
</table>

3. Next, we are going to measure wavelength of different waves. Move the Frequency and Amplitude sliders to the numbers listed in each row. Let the wave run for a few seconds and then pause the wave and use the ruler to measure the wavelength. Record your findings in the table with a description.

<table>
<thead>
<tr>
<th>Amplitude</th>
<th>Frequency</th>
<th>Wavelength (cm)</th>
<th>Description (describe or draw the wave)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75 cm</td>
<td>1.50 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.25 cm</td>
<td>1.50 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.75 cm</td>
<td>1.00 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.25 cm</td>
<td>1.00 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.25 cm</td>
<td>3.00 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.50 cm</td>
<td>3.00 Hz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Use the measurements for each wave above and calculate the speed of each wave in the table below.

<table>
<thead>
<tr>
<th>Amplitude</th>
<th>Frequency</th>
<th>Wavelength (cm)</th>
<th>Speed (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75 cm</td>
<td>1.50 Hz</td>
<td></td>
<td></td>
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<tr>
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<td>3.00 Hz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. How does changing the **Frequency** affect the wavelength? (may use illustrations to help explain)

6. How does changing the **Amplitude** affect the wavelength?

7. How does changing the **Frequency** affect the energy of the wave?

8. How does changing the **Amplitude** affect the energy of the wave?

9. The **amplitude** of a wave is related to the energy of a wave. Did you see anything on the screen that made you think this or could prove your point? How could you demonstrate this relationship?

10. What are the relationships that are present between **frequency**, **wavelength**, and **amplitude** of a wave?
Bending Light Student Sheet: Reflection, Refraction, and Wave Speed

Chances are you have experienced reflection and refraction before, and not just in science class. Take a pencil, or other straight object, and place in a glass of water. What do you observe as you look from different angles?

Develop an initial model of what you observe. What is causing things to look different in the glass?

Using the PhET Simulation Bending Light, open the intro section and play with different controls and variables to see how the light behaves.

1. How does the light behave when going from air to water? Use a model in your explanation.
2. How does the light behave when going from water to air? Use a model in your explanation.
3. What is different or similar between your models in #1 and #2?
4. How does this relate to the object you placed in a glass of water?
5. When you change the angle of incidence, how does this affect how light is reflected or refracted? Use a model in your explanation.

Move to the prisms section of the simulation and experiment with changing variables and parameters.

1. Now with light moving through an object, what can you determine about the angle of refraction? Use a model or screenshot in your explanation.
2. How is it possible to make light split into a rainbow? Show a screenshot of your experiment setup that causes this.

How does light refract and why? Open the More Tools section of the simulation and experiment with changing variables and parameters.

1. Describe what the index of refraction means. As light goes to a medium with a higher index of refraction, what happens? To a lower medium? Explain with models.
2. The speed tool measures how fast the light is traveling in increments of “c” the speed of light in a vacuum. Experiment with changing the index of refraction between the surfaces and explain how the speed of light is affected by the index of refraction.
3. Collect data from the simulation or research that supports your explanation in #2.