Properties of Waves - Doppler Effect

<table>
<tr><td colspan="2">This 5E model for instruction will be useful to help students gain an understanding of the concept of waves and the Doppler Effect.</td></tr>
<tr><td colspan="2" align="center">Student Science Performance</td></tr>
<tr><td>Grade Level: 9-12 Physical Science
Topic: Waves and the Doppler Effect</td><td align="center">Title: Doppler Effect, Can You Hear That?</td></tr>
<tr><td colspan="2">Performance Expectations for GSE:
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.</td></tr>
<tr><td colspan="2">Performance Expectations for Instruction:
● Plan and carry out an investigation to determine the relationship between wavelength, frequency and energy in waves.
● Analyze and interpret the data from the investigation to determine patterns in the results of the investigation.
● Develop and use a model to explain the relationship between wavelength, frequency and energy in waves.
● Observe the Doppler Effect using demonstrations or video to identify the changes in wavelength, frequency and pitch that cause the Doppler Effect.
● Develop and use a model to explain the wave phenomena of reflection, refraction, interference, and diffraction.

Additional notes on student supports</td></tr>
<tr><td colspan="2">Materials:
● Tennis ball on string, YouTube videos or Doppler Effect kit (from many science suppliers)
● Large spring- if Doppler Effect demo is used
● Additional equipment in Wave Properties Lab
● Access to online resources</td></tr>
<tr><td>Engaging Learners</td><td>Phenomenon: When a sound from a car or other object moves toward me, it sounds differently than when the sound moves away from me.

Teacher Notes:
First allow your students to experience the Doppler Effect
1. Multiple YouTube videos that illustrate the Doppler Effect. Any of these work well to allow students to hear the phenomena.
2. Simple experimental setups can also be found online, such as: Exploratorium Doppler Effect
3. Doppler Effect demonstration kits can be purchased from most science supply catalogs.
4. Walk outside to the nearest street and listen to cars that pass by or have a car pass by blowing the horn and students can hear the Doppler Effect.</td></tr>
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	***Communicating*: 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 sentence 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. Additional notes on topic, focus, and phenomena.
• **Exploring**	***Obtaining:*** In this phase of the lesson, students are exploring several different wave phenomena, these can be linked back to the original Doppler Effect phenomenon or presented separately. The intent is that students begin to ask questions, develop models, and analyze data concerning multiple wave properties. 1. Students will conduct an investigation using a PhET simulation to determine the relationship between frequency, wavelength, amplitude and speed of a wave. *Teacher Notes: Both of the PhET simulations linked below allow students to measure the wavelength and amplitude of a wave. The goal of this investigation is to allow students to understand the relationship between frequency and wavelength of a wave. The simulations also allow students to collect data for amplitude and to discover its relationship to other wave properties.* PhET: Wave on a String PhET: Sound (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu) The student data sheet is included. 2. Lesson level phenomenon: *The first radio wave transmissions from the 1800s is still traveling in space.* Elicit student questions about how this could be possible and what differences there might be for sound waves. Consider the following sources for student use: • CK-12: Radio Waves • CK-12: Electromagnetic Waves • CK-12: Mechanical Waves 3. To allow for more student exploration, the Wave Properties Labs/Demos give students experience with reflection, refraction, interference, and diffraction. As students complete activity, they should be developing models that illustrate the above phenomena. The student report sheet is included. Teacher notes are included in the document.

	4. An additional activity to explore refraction specifically, is the Snell's Law lab; students measure the index of refraction. Consider combining this with demonstrations of light from light boxes or laser pointers being refracted through different materials. Additional data should be presented concerning how different materials affect wave speeds. CK-12: Wave Speed could be a possible resource.
	Evaluating and Communicating: Students will consider their proposed model for the Doppler Effect and revise it based on observations made in the investigation and discussions with other students. Now that students have learned about basic wave properties, they can formulate a better explanation and diagrams of the wave properties.
Explaining	***Obtaining:*** Students will develop questions about the Doppler Effect as they revisit the initial phenomenon. In their lab work and responses, students should be developing models. These questions could include: 1. Does the Doppler Effect work only for sound? a. Allow students to investigate the astronomical uses for the Doppler Effect and light. Astronomers refer to red-shifted and blue-shifted objects in space. Students may come across these references in their search of Doppler Effect. The effect is the same and makes for excellent extension activities for students. 2. The sound appears to get louder when it comes towards me. Is that due to the Doppler Effect? a. There are apps for IOS and Android devices that can measure frequency and decibel level. These can be used to investigate the Doppler Effect. The sound does get louder but this is not due to the Doppler Effect. 3. Does the medium that the wave is travelling in make a difference for the Doppler Effect? 4. Is the Doppler Effect the same thing as a wave being refracted?
	Communicating: Based on all the investigations and information students should communicate a model for the Doppler Effect. Students should have the following understandings: 1. The Doppler Effect is due to the movement of the source of the sound towards or away from the observer. 2. The Doppler Effect can also result from movement of the observer towards or away from the source 3. The Doppler Effect is not a change in the actual frequency of the sound. 4. The Doppler Effect occurs with all types of waves including sound, light and water waves. *Teacher Notes: For students that are having a difficult time understanding the Doppler Effect, an effective teaching technique would be to use a spring attached to the "toy car" and held by the observer as a conceptual model. The spring is attached to the front of the "car" and held by the observer. As the "car" drives toward the observer the spring will contract much like the sound waves. As the "car" goes away form the observer the spring will stretch just like the sound waves. A good activity is to get a spring and do this activity in class with two students. One student is the "car" and the*

	other is the observer.
Elaborating	***Communicating:*** Using the understanding of the Doppler Effect, students will propose how the Effect is used in weather predictions and astronomy. 1. Doppler Radar is used to predict the weather. Students can be asked to propose how this system works. 2. The movement of planets, stars and galaxies in space is determined using the Doppler Effect. Students can propose how this is accomplished.
Evaluation	Students should make one final revision of their doppler model. ***Assessment of Student Learning*** • Students will explain the Doppler Effect and the relationship between wavelength, frequency and pitch observed by a person based on their position relative to a moving source of sound. • Students can explain the similarities and differences of electromagnetic and mechanical waves. • Students can explain why movement of the source or the observer of the sound is necessary for the Doppler Effect. • Students can use a model to predict the frequency or wavelength heard by an observer based on their position or movement relative to the source of the sound. • Students can develop and use a model to explain the wave phenomena of reflection, refraction, interference, and diffraction.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	• Asking questions and defining problems • Developing and using models • Analyzing and interpreting data • Constructing explanations
Crosscutting Concepts	• Patterns • Cause and Effect • Systems and System Models
Disciplinary Core Ideas	From A Framework for K-12 Science Education: PS4.A: Wave Properties PS4.B: 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:

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Reading:

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

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Writing:

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.

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Math:

1. Provide calculators as needed.
2. Provide graph paper as needed.

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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 could first ask students to think of hearing sirens. Have students describe what they heard as the sirens passed them.
2. The teacher should use as many of the ways that students can experience the doppler effect as possible.
3. The teacher should give students a template for the students to propose a model. The teacher should be aiming for students to have a simple model of the waves at this point.
4. The teacher should remind students that there is no right or wrong at this point.

Exploring:

1. The teacher may need to explain to students how to use PhET and what they should be recording as they move through the interactive.
2. The teacher should provide a data sheet to the students for observations, data and claims.
3. The teacher should consider giving students resources to use for their research.
4. The teacher should provide the student report sheet to students for the wave demo for ideas, observations and data.
5. The teacher needs to explicitly explain how to do the labs and be prepared to repeat directions as needed.
6. Students may need additional time to revise their model.
7. The teacher should consider giving students a rubric to allow students to assess their work. This would allow students to have more ownership of their model.

Explaining:

1. The teacher should record the questions that students develop on the board. Then the teacher can help students identify the most important questions that they need to try and answer in the lesson.
2. The teacher should consider giving students resources to use for their research.
3. Students may need additional time to revise their model.
4. The teacher should have students complete a formative assessment and then use that information to determine which students need re-teaching, reviewing and enriching.

Elaborating:

1. Students may need to research doppler effect and it's uses in weather and astronomy.
2. Students may need additional time to construct their proposal.

Evaluating:

1. The teacher should be sure to check for understanding throughout the lesson and build in re-teaching, review and enrichment as needed by each student.
2. The teacher should provide tangible and constructive feedback for students throughout the lesson.
3. The teacher should provide multiple formats for students to express their knowledge. These formats could include writing, drawing or designing a play.
4. Students may need additional time to revise their model.

Properties of Waves Lab

Name:_________________________________ Date:____________

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.

Description	
Drawing	

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.

Amplitude	Frequency	Wavelength (cm)	Description (describe or draw the wave)
0.75 cm	1.50 Hz		
1.25 cm	1.50 Hz		
0.75 cm	1.00 Hz		
1.25 cm	1.00 Hz		
1.25 cm	3.00 Hz		
0.50 cm	3.00 Hz		

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

Amplitude	Frequency	Wavelength (cm)	Speed (cm/s)
0.75 cm	1.50 Hz		
1.25 cm	1.50 Hz		
0.75 cm	1.00 Hz		
1.25 cm	1.00 Hz		
0.50 cm	3.00 Hz		

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?

As frequency is increased wavelength ...

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Wave Properties Labs/Demos

Teacher's Notes and Instructions

The thought behind this activity is to perform a set of demonstrations, or have the students rotate through a series of stations with each phenomenon. It is important that students experience the phenomena and begin developing models to explain them. Although vocabulary is important for students to learn as they use correct terminology, it would probably be best to have the students look up definitions of the concepts, or discuss as a class, after students have developed models and explanations for the phenomena.

Discussion:

Waves are a very important part of everyday life. Light and sound are two very important categories of waves. Light is a type of wave known as a transverse wave which has crests (high points) and troughs (low points) moving up and down at right angles to the direction in which the wave's energy moves. Sound is a type of longitudinal wave or compressional wave which has alternating compressions and rarefactions moving in the same direction that the wave's energy is moving.

Transverse waves may or may not require matter as a medium through which they travel. Light, for example, does not need matter but ocean waves do. Longitudinal waves are types of mechanical waves because they do require matter to make the compressions (high pressure or density areas) and the rarefactions (low pressure or density areas). All waves have a characteristic velocity, wavelength and frequency.

Most waves share additional properties such as reflection, refraction, diffraction, and interference.

In reflection, a wave strikes a barrier and then bounces off at the same angle. For example, this occurs when sunlight hits a shiny surface and then bounces into your eyes.

In refraction, waves travel from one type of matter into another. When this occurs, the waves change speed which also causes slight changes in direction. There is a value, the index of refraction, that can be calculated for transparent materials. The index of refraction is the ratio of the speed of light in a vacuum, divided by the speed of light in the given material. The larger the value for the index of refraction, the greater the change in speed and the greater amount that the light "bends" when it enters the new material. Refraction is why contact lenses and prescription glasses work.

Diffraction is the bending of a wave around a barrier. This is what is happening when you can hear noise from around a corner or around an open door.

Interference is when waves travel through the same substance at the same time so that they combine. In *constructive interference,* the waves add together reinforcing each other, like when two people sing together and their voices blend or harmonize. *Destructive interference* occurs when the waves interact in a way to disrupt or cancel each other out

Resonance is the situation in which a vibrating object causes a nearby stationary object to vibrate as well. All objects have a natural frequency called a "resonant frequency." If a force is applied to an object that matches the natural (resonant) frequency of the object, resonance will occur so that the amplitude of the wave will increase. This is demonstrated by the vibration of a window pane when a large truck goes down the street.

Polarization is the condition in which light is vibrating in only one plane (e.g.; along either the x or y axis). A good analogy is partially closed mini-blinds: only light coming in is that which is moving in the direction to come between the blinds. All other light is reflected.

Purpose: To explore the wave properties of reflection, refraction, diffraction, interference, resonance and polarization in waves and distinguish among them.

Materials needed:

long demonstration spring

tape or string,

shallow square or rectangular pan (preferably clear glass 9 x 13 casserole dish)

overhead projector

water

flashlight or lamp

2 small rocks or metal washers

Measuring tape (metric)

modeling clay,

dull kitchen knife (butter knife or plastic to cut & shape clay)

pitcher or measuring cup

coffee cup

dime

other transparent liquid (cooking oil or isopropyl alcohol)

2 identical glasses with thin rims (preferably stemmed)

2 polarized sunglasses lenses

1 non-polarized sunglasses lens

Procedure:

Part I – Transverse and Longitudinal Waves, Reflection, Interference

Section A:

1. Put the spring down on a smooth floor. Anchor one end of a spring by tying it to a table having another person hold it in place.

2. Stretch the spring out so that it is fairly taut and hold it in place there.

3. Displace the end that you are holding about 1 foot sideways very quickly and then move it back to the original position.

4. Watch the wave produced as it travels down the spring and hits the other end. Answer the questions on the Report Sheet under Part I, Section A.

Section B:

1. Hold the spring like you did in section A, pulling it taut.

2. Pinch together several coils, then release them suddenly.

3. Watch as the wave travels down the spring. Answer the questions on the Report Sheet under Part I, Section B.

Section C:

1. Tie a piece of string in the middle of the spring and repeat the procedure in section A.

2. Observe the movement of the string. Answer the question on the report sheet under Part I, Section C.

Section D:

1. Hold the spring on the floor tautly and have another person hold the other end.

2. At the same time, both of you send a wave down the same side of the spring from opposite ends by moving it about a foot sideways.

3. Note what happens when the 2 wave pulses meet. Answer the question on the report sheet under Part I, Section D.

Section E:

1. Repeat the experiment when the spring stops moving, but this time 1 person should move it sideways in 1 direction and the other person displace it sideways on the opposite side at the same time.

2. Note what happens when the 2 waves meet. Answer the questions on Part I, Section E on the Report Sheet.

Part II – Reflection, Interference, Diffraction

Section A. Circular Transverse Waves

1. Fill the pan half full of water and place it on a level surface.
2. Wait until the water is still before beginning the experiment.
3. Turn on the flashlight or lamp and position it directly above the pan, shining it straight downward OR place the pan on top of an overhead project and turn it on.
4. Drop the rock or washer down into the center of the pan and observe the ripples. Notice the light and dark areas (crests and troughs) caused by the different depths of the water.
5. Repeat and observe again for clarification. Describe their appearance and direction of movement of the wave on the Report Sheet under Part II, Section A.

Section B.

1. Remove the rock or washer and wait until the water is stationary again.
2. Then drop 2 rocks or washers at the same time about 3 inches apart and observe again.
3. Record your observations under Part II, Section B on the Report Sheet.

Section C. Horizontal Transverse Waves, Part 1

1. Remove the rocks or washers and wait until the water is stationary again.
2. Hold the ruler horizontally with the sharp edge downward.
3. Push the edge of the ruler up and down in a regular rhythm into the water on 1 side of the pan.
4. Observe the waves as they travel down the length of the pan.
5. Record your observations and answer the questions under Part II, Section C on the Report Sheet

Section D. Horizontal Transverse Waves, Part 2

1. Pour out the water and dry the pan.
2. Build a clay dam about 2 inches high and ½ inch wide all the way across 1 end of the pan about 6 inches from 1 end. Be sure that the base of the dam sticks to the bottom and sides of the pan.
3. Take the knife and cut a ½ inch gap in the middle of the dam all the way to the pan.
4. Position the light over the pan.
5. Hold the ruler horizontally with the edge down, parallel to the dam but about 4 inches away from it.
6. Make a series of regular waves so that they hit the dam.
7. Observe them as they hit and watch what happens on the other side of the space.
8. Describe what you see under Part II (D) (1) on the Report Sheet.

9. Cut out another gap in the dam about 1 inch from the other one.
10. Create another series of regular waves with the ruler and observe what happens at each space and on the other side of the space.
11. Describe what you see and answer the questions under Part II Section D on the Report Sheet.

Part III – Refraction, Polarization and Resonance

Section A.

1. Fill a pitcher, large glass or measuring cup with water.
2. Put a dime face up in the bottom of a tall coffee mug so that it touches the side nearest to you.
3. Move the dime toward the side closes to you until it touches the inside edge of the bottom of the cup.
4. Move so that you can look into the cup and barely see the edge of the dime.
5. Without moving your head, slowly add water to the cup until you can see as much of the coin as possible (without overflowing the cup).
6. Measure the depth of the water cm and record it under Part III Section A on the Report Sheet.

7. Clean the cup and return the dime to the original position.
8. Try the experiment again with a different liquid that is transparent but not mostly water, such as rubbing alcohol (70% or more isopropyl alcohol) or cooking oil.
9. Pour this liquid into the cup until you see approximately the same amount of the dime that you did with the water.
10. Measure the depth of this liquid in cm and record it under Part III, Section A on the Report Sheet.

Section B.

1. Look around until you find glare or a reflection off a shiny surface.
2. View it through the polarized sunglasses lens and then through the regular sunglasses lens. Explain any difference that you see under Part III Section B on the Report Sheet.

3. Position the two polarized lenses one in front of the other so that you can look through both lenses at the same time.
4. Look up at a light or at a distant object through both lenses.
5. Slowly rotate one lens 90 degrees, continuing to look through both lenses.
6. What do you notice about the appearance of the light or the object? Record your answer under Part III Section B on the Report Sheet.

7. Continue to rotate the same lens another 90 degrees in the same direction, while looking at the light or the object, so that the lenses are now 180^{o} from where you started.
8. What do you notice about the appearance of the light or the object? Record your observations under Part III (B) (3) on the Report Sheet.

9. Continue to rotate until the glasses are back in the original position.
10. How did the appearance of the light or the object change during the last 180 degrees? Record your observations under Part III Section B on the Report Sheet.

Section C.

1. Get 2 identical drinking glasses made of clear glass, preferably with a thin rim.
2. Wash your hands with soap to remove the oil from your skin.
3. Fill 1 glass half full of water.
4. Wet your finger with water and rub it around the rim of the glass, changing the speed until it makes a sound.
5. Repeat with the 2nd glass but with a different volume of water.
6. Record your observations and answer the questions under Part III Section C on the Report Sheet.

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Wave Properties Lab Name:______________________________

Part I – Transverse and Longitudinal Waves, Reflection, Interference

Data:

Spring:

Section A. Is this a transverse or longitudinal wave? ________________________

What happens when the wave gets to the end of the spring? Does it disappear, move back up the spring on the same side as it went down, or travel back up on the opposite side?

Section B. Is this a transverse or longitudinal wave? ______________________________What happens when the wave gets to the end of the spring? Does it disappear or move back up the spring?

Section C. Does the matter making up the string move away from you or does the energy move away from you?

Section D. When two waves are sent down the same side from opposite ends down the spring at the same time meet, they _______________________(add together, cancel each other out) and __________________(stop, keep going down the spring in their original directions)

Section E. When two waves are sent down opposite sides from opposite ends of the spring at the same time meet, they _______________________(add together, cancel each other out) and __________________(stop, keep going down the spring in their original directions)

Conclusions for Part I:

(1) When a wave hits a barrier or travels from 1 substance to another with a different density, part or all of the wave bounces back. This is called _____________________.

(2) When two transverse waves traveling in opposite directions meet on the same side and add together, this is called __________________(constructive, destructive) interference.

(3) When 2 transverse waves traveling in opposite directions on opposite sides meet and subtract, this is called __________________(constructive, destructive) interference

Part II – Reflection, Interference and Diffraction

Data:

Section A. Water in pan - Circular Waves – 1 mass

Describe the appearance and direction of movement of the wave.

Section B. Circular Waves – 2 masses

Observations:

Is this the same or different from what you observed with one mass? Explain.

When two waves pass through the same material at the same time and either add together or subtract, the wave property of ________________________ is observed.

Section C. Horizontal Waves, Part 1 -Observations:

What happens when the waves hit the end of the pan?

Section D. Horizontal Waves, Part 2 -Observations

(1) Describe what you see:

The wave property illustrated by what you observed after the wave passed through the barrier was

____________________________.

Conclusions for Part II:

(1) How were the waves produced by the rock and the ruler in part A different from each other?

(2) When the single rock was dropped into the pan of water, the waves went out and bounced off the walls of the container. The wave property illustrated by the waves bouncing off the walls is called

______________________.

(3) When the 2 rocks (or washers) were dropped simultaneously into the water and their wave patterns overlapped, the property of ______________ was illustrated.

(4) In Part C (using the ruler without the dams), when two wave crests going in opposite directions run into each other making a higher wave, ____________ __________ (2 words) has occurred.

Draw a sketch of this process in the space below using a before and after picture.

Before	After

(5) When a crest from one wave meets a trough of another wave going the opposite direction, ________________ ________________(2 words) occurs.

Draw a sketch of this process in the space below using a before and after picture.

Before	After

(5) In part D, when part of the wave goes through a small gap in a barrier, it spreads out on the other side of the barrier. This wave property is called _____________.

(6) Were the waves produced in the above procedures longitudinal waves or transverse waves?

Part III – Refraction, Polarization and Resonance

A. Liquid in cup with dime: water

Depth of water = _______________ cm

Identity of 2^{nd} liquid __________________

Depth of 2^{nd} liquid = ___________cm

B. Polarized sunglasses:

(1) Explain any difference that you see between the polarized and unpolarized sunglass lenses.

(2) What do you notice about the appearance of the light or the object as you rotated the lens 90^o?

(3) What do you notice about the appearance of the light or the object as you rotated the lens another 90^o (for a total of 180^o from where you started)?

(4) How did the appearance of the light or the object change during the last 180 degrees?

C. Two glasses: Do they sound the same when you run your wet finger around the rim?

What do you think accounts for this difference/similarity?

Conclusions for Part III:

(1) In part A (liquid in cup), the wave property illustrated by the appearance of the dime in the cup due to the bending of light when it goes from 1 transparent substance into another is called

_________________________.

(2) Liquid in cup -Why were the depths of the liquids different when the same amount of the dime could be seen? (This is also why thick glass corrective lenses have been replaced by much thinner plastic lenses for the same person's prescription.)

(3) Polarized sunglasses:

Do you often wear sunglasses?

If yes, do you wear polarized or nonpolarized sunglasses?

What could be the advantage, if any, of wearing polarized lenses?

Section C

The wave property illustrated by the "singing glasses" is called ______________________.

Are the pitches of the two glasses the same? What might account for this observation?

Section D

The resonant frequency of most earthquakes is the same as that of most 3 or 4 story buildings. Taller buildings also have problems during strong earthquakes. In areas prone to earthquakes, such as California, modifications to buildings are made to help reduce earthquake damage. Using the internet, research two methods for building "earthquake proof buildings" and describe how and why the methods work.

Method 1:

Method 2:

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Snell's Law

Name: ________________________________Period: ______________ Date:___________

Light actually travels at different speeds, depending on the material the light is traveling through. The speed is dependent on the density of the material. Imagine a light ray entering the water from the air. Light travels slower in water than in air (water is denser). When light rays enter the water at any angle other than 90 degrees (perpendicular to the surface), the light is bent as enters the water due to the change in speed. The amount the light ray is bent and the direction the ray is bent is related to the change in velocity, which is determined by the density of the material. The index of refraction is a ratio between the speed of light in a vacuum to the speed of the ray of light in the material the ray is entering or exiting.

$$n = \frac{speed\ of\ light\ in\ vacuum}{speed\ light\ in\ the\ material}$$

Problem: Accurately measuring the speed of light is EXTREMELY difficult under any conditions, and impossible in a high school physics lab.

The index of refraction, however, can also be obtained from the use of Snell's Law. Snell's Law is an equation used to describe the relationship between the angle of ***incidence*** (incoming ray) and angle of ***refraction*** (outgoing ray) of a light ray passing through a boundary between two different media, such as air and glass. The law says that the ratio of the sine of the angle of incidence and sine of refraction is a constant. This constant (n) varies depending on the densities of the material.

$$n = \frac{\sin \theta_i}{\sin \theta_r}$$

Objectives

1. To see how a ray of light bend as they go from one media to another.
2. Measure the angle of incident and the angle of reflection as the ray passes through a glass block.
3. Calculate the index of refraction for your glass block.

Materials

transparent plastic refraction block (approx. 10cm x 8cm x 2 cm)

Protractor

Ruler (metric)

Plain white paper

Procedure

1. ***<u>Look at figure A before you read any direction!</u>***
2. Place your block in the center of your sheet of paper. Then trace the outline of the block.
3. Remove the block and construct a normal line (a line that is perpendicular to the block) approximately ¾ of an inch in from the left side of the block, mark one end of the line as N_1 and the other end of the line as N_2. **See figure A for proper labeling**.
4. Where the normal line strikes the side of the block, mark this as point ***B*** at this point. **See figure A for setup**.
5. Use a protractor and measure angle ABN_1 at 30° angle from the normal line, and then draw a heavy line starting from the edge of the block **moving away** from the block. Label the end of the line as point ***A***. This angle is called the Angle of Incidence. See figure A so you get the proper setup.
6. Replace the block over the outline on the paper. Rotate the paper so your line ***AB*** is on the opposite side of you. With your head at the same level as the block sight along the edge of your ruler until you line up the edge of your ruler with line ***AB***. Sighting down the edge of your ruler draw line Label the point by the edge of the block as point ***C*** and label the end of the line as point ***D***.
7. Connect points ***B*** and ***C*** with your ruler.
8. **See your teacher** to make sure that your diagram is correct. If your diagram is correct move onto step 8 if you are incorrect repeat steps 4 – 6 until you are checked off by your teacher.
9. Label angle ABN_1 as the angle of incidence (***i***) and label angel N_2BC as the angle of refraction (***r***).
10. Use your protractor and measure angles ABN_1 and N_2BC and record them in your data table.
11. **Turn your paper** over and repeat steps 1 – 9 using and angle of 45°.

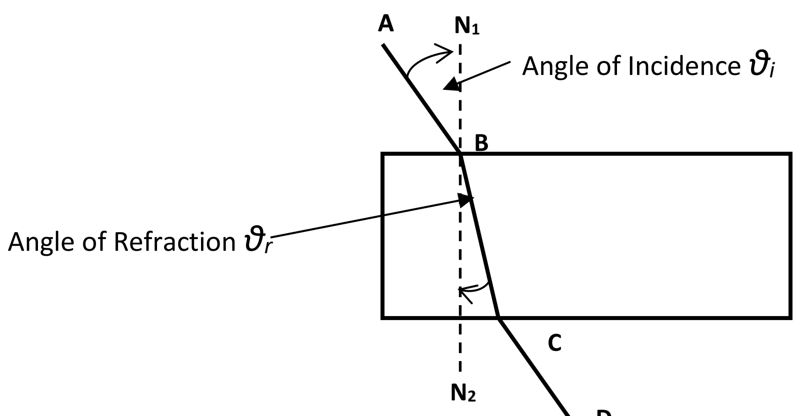

Figure A

Data Table

Angle of Incidence	Angle of Refraction	sin θ_i	sin θ_r	Index of Refraction (***n***)
30°				
45°				

Interpretation

1. Why do you think that lines ***AB*** and ***CD*** don't line up with each other? Explain your answer.

2. According to your diagrams, as the light passes from the air into the glass, are light rays refracted away from or towards the normal (hint: is your angle of incidence greater or less than your angle of refraction)? Support your claim with evidence from your data.

3. Construct a normal at point ***C*** on one of your diagrams. According to your diagrams, as the light passes from the glass into the air, are light rays refracted away from or towards the normal (hint: is your angle of incidence greater or less than your angle of refraction)? Support your claim with evidence from your data.

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Patterns in Waves GSE: SPS9a,b,c,d,e; SPS7a			
Anchoring Phenomenon: The Doppler Effect			
Topic	**Focus**	**Lesson Phenomenon**	**GSE/Notes/Language**
Electromagnetic and Mechanical Waves	• Students will compare and contrast electromagnetic and mechanical waves, particularly in the way they transfer energy. • Students will recognize that the energy of a wave is determined by its characteristics (wavelength, frequency, amplitude, type of wave). • Students should understand that mechanical waves must have a medium for propagation (You can't have sound in a vacuum.), while electromagnetic waves do not have to have a medium.	*The first radio wave transmissions from the 1800s is still traveling in space.* We use radio waves for many applications, the technology of radio waves revolutionized our society.	SPS9a. Analyze and interpret data to identify the relationships among wavelength, frequency, and energy in electromagnetic waves and amplitude and energy in mechanical waves. SPS9b. Ask questions to compare and contrast the characteristics of electromagnetic and mechanical waves
Light	• Students should understand and observe reflection, refraction, interference, and diffraction of light. • Students will explain what happens when two waves meet (interference). • Students should understand what happens to light when it meets an obstacle or opening (reflection, refraction or diffraction).	*Images shift when looking through water.* Due to the refraction of light moving through water, images can appear to change direction.	SPS9c. Develop models based on experimental evidence that illustrate the phenomena of reflection, refraction, interference, and diffraction. SPS9d. Analyze and interpret data to explain how different media affect the speed of sound and light waves.
Sound	• Students should know from previous courses that sound is caused by	*Sonic booms are created by an object traveling*	SPS9d. Analyze and interpret data to explain how different media affect the

	vibration, however, it is essential that teachers pre-asses this understanding. ● The pitch of a sound is determined by frequency. ● Students should know that the speed of sound is affected by what material the sound is traveling through.	*faster than the speed of sound.* In a sonic boom, the speed of the object moving is moving faster than the speed of sound, causing the sound waves to build up behind the object (videos can be found online).	speed of sound and light waves.
Doppler Effect	Students will understand that as a car or other vehicle moves, it distorts the waves causing the sound to change as it moves past.	*The Doppler Effect* When a car or other vehicle passes the sound produced changes as it moves by you due to the change in shape of the waves.	SPS9e. Develop and use models to explain the changes in sound waves associated with the Doppler Effect.
Energy in Waves	Students should know that waves carry energy that can be transformed or transferred.	*Energy in tidal waves can be used to generate electricity.* In a practical application of wave energy the motion of mechanical waves in tides can be used to turn turbines to generate electricity.	SPS7a. Construct explanations for energy transformations within a system. (Clarification statement: Types of energy to be addressed include chemical, mechanical, electromagnetic, light, sound, thermal, electrical, and nuclear.) The focus on energy of waves should center on mechanical, light, and sound while relating them to the transformations that might occur with these forms of energy.
Anchoring Phenomenon:			

As cars pass or rockets break the sound barrier they cause waves.

Students will explain the phenomenon using the following concepts:

- Students will explain how objects traveling faster than the speed of sound cause waves to distort their shape (also in the Doppler effect) causing a sonic boom.

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