Framing Questions

1. When we hear a recording of our own voice, most of us feel that the recorded voice sounds different from the voice we normally hear. Are we victims of an illusion or is the difference real?

2. When you are in a quiet room put both thumbs in your ears and listen carefully: you will hear a low rumbling sound. What produces this sound?

3. In the shower, even a bad singer's voice can occasionally sound beautiful. What causes this illusion?

4. A high pitched sound is produced in air and then travels in water. What changes for this sound when it travels through water: pitch (frequency), wavelength, or speed?

5. What happens when two sound waves meet in a region?

6. A steel tent stake can be driven into hard ground easily and will fit snugly, while an identically shaped wooden stake is hard to drive in and will end up fitting loosely. Why such a dramatic difference?

Exploring Waves Lab

Purpose:

What is a wave, what affects the motion of a wave?

Materials:

- Slinky- metal or plastic
- A flexible rope – 5 m long, about ¼" thick
- Ripple tank and accessories
- Battery, string and motor (standing wave apparatus)
- Three glasses with water
- Dominoes
- Groaning tube
- Boom whackers
- Meter stick

Station 1: Slinky

Stretch the slinky and hold one end fixed (do not allow that end of the slinky to move). Move the other end left and right. What do you see? Stretch the slinky more and repeat. What differences do you notice?

Station 2: Rope

Tie one end of the rope to a table leg or a doorknob. Quickly move the free end up and down several times in rapid succession. What do you observe? Now stretch the rope as much as you can and repeat. What differences do you notice?

Station 3: Water tank

Carefully (so you don't splash) move the plastic rod up and down in the water tank. What do you observe? What changes can you make in your motion and how do those changes affect the behavior of the water in the tank?

Station 4: String, battery, and motor

Insert the battery in the battery holder. Hold the string at one end and let it hang. What do you observe in the string? Draw a diagram in your notebook. What can you change to make the pattern in your string different?

Station 5: Dominoes

Arrange the dominoes so they stand close to one another. After you have about 20-30 dominoes standing up, push the first one and observe what happens. What can you change to make the motion through the dominoes different?

Station 6: Groaning tube

Raise the groaning tube above your head and holding it at one end start rotating it. What do you hear? Rotate the tube faster or slower. Is the sound created the same?

Station 7: 3 glasses of water (with different amounts of water each)
Dip your finger in the water. Pushing slightly on the rim of the glass, move your finger around the rim so you make a sound. Try the other glasses too. What sound pattern do you notice?

Station 8: Boom whackers
Take one of the tubes and slightly hit it against your palm. What do you hear? Repeat with the other tubes. What differences do you observe? Place a cap on the tube and compare the sound with and without the cap. Is the sound the same?

Station 9: Vibrating meter stick
Hold a meter stick down against the table with about 50 cm sticking out. Pull down on the free end of the meter stick and make the meter stick vibrate. Change the length of the vibrating end. What do you observe? What sound patterns do you notice?

Post-lab discussion:

1. What happened to the string/slinky when the pulse moved through it?

2. What moved along the string/slinky?

3. What is a wave, and how would you describe it?

4. Did the string and the pulse/wave move in the same direction?

5. Did the pulse/wave move with the same speed when the slinky was more stretched?

6. Can you draw a wave?

7. What are other examples of waves?

8. What are some applications of waves?

9. What does a wave carry?

10. Where are some places (in real life) where waves are useful?

Snakey Spring Lab

Purpose:

What are the properties of waves/pulses?

Materials:

- Snakey Spring (2)
- Stretched snakey spring (different linear density, see explanation below)
- Slinky spring (metal)
- Spring scale
- Meter stick
- Stopwatch
- Safety goggles

Pre lab discussion

1. How is the motion of a pulse different from the motion of a moving object such as a car?

2. In your notebooks sketch what you observed when a pulse traveled through the slinky. Label any parts of the pulse that you think are important.

3. Explain in detail how a particle on the spring (a point somewhere on the snakey) moves when the pulse passes through it.

4. Predict the factors that will influence the speed of a pulse through a snakey spring.

5. Design an experiment in which you can verify whether the speed of the pulse changes or stays constant and also allows you to change the speed of a pulse. What should be kept constant in such an experiment?

Directions

1. Use LoggerPro to analyze a video of a pulse traveling down a snakey spring. Describe the motion of a point somewhere on the spring. You may place a small mark on one of the coils of the slinky and follow only that motion.

2. Diagram the motion.

3. Predict which variables affect the speed of the wave: type of slinky, amplitude of the pulse, large pulse vs short pulse, large linear density vs small linear density, large tension vs small tension.

4. Using two identical slinkies and then two different slinkies, have students test the predictions. All observations should be qualitative.

5. Plot position vs. time for the pulse for the first leg of the trip.

6. Plot position vs. time for the pulse for a later leg of the trip.

7. Calculate the slope of the graph to determine the speed of the pulse.

Post Lab Discussion

1. What can you tell about the position vs time graph? What type of relationship is there between the position and time?

2. By looking at the position vs time graph, what can you tell about the speed of the wave?

3. Does the speed of the wave change as the wave travels along the spring?

4. Does the amplitude of the wave change as the wave travels along the spring?

5. Does the speed depend on the type of slinky used? What was different in those slinkies?

6. What do you need to change in order for the speed of the wave to change?

Reflection and Transmission of Pulses Lab

Purpose:

What happens to the shape, amplitude, and speed of a pulse as it travels down the slinky and back?

Materials:

- Snakey spring
- Plastic slinky (2-3)
- Safety goggles

Pre-lab discussion:

1. What are the properties of a traveling pulse?

2. Predict what will happen to a pulse that reaches a barrier: a fixed end (like a wall) or a free end (nothing stops the end of the slinky from moving).

3. Predict what will happen when a pulse passes from one medium to another, what changes, what stays the same?

Post-lab Discussion:

Before completing the questions below, open the "Wave on a String" simulation on the Phet website, at http://phet.colorado.edu/en/simulation/wave-on-a-string. Repeat the experiment you saw using the simulation. Make observations and then fill out the tables below:

Reflection from a fixed boundary

Compare	Reflected pulse vs Incident pulse
Amplitude	
Speed	
Frequency	
Wavelength	
Same side or inverted	

Reflection from a free boundary

Compare	Reflected pulse vs Incident pulse
Amplitude	
Speed	
Frequency	
Wavelength	
Same side or inverted	

Transmission from a thin rope to a thick rope

Compare	Reflected pulse vs Incident pulse	Transmitted pulse vs Incident pulse
Amplitude		
Speed		
Frequency		
Wavelength		
Same side or inverted		

Transmission from a thick rope to a thin rope

Compare	Reflected pulse vs Incident pulse	Transmitted pulse vs Incident pulse
Amplitude		
Speed		
Frequency		
Wavelength		
Same side or inverted		

1. Draw the shapes of the pulses before and after reflection from the boundary (free end or fixed end) and describe what you saw.

2. What stays the same?

3. What changes?

4. Draw the shapes of the pulses before and after passing from one medium to another and describe what you saw.

5. What stays the same?

6. What changes?

Pulse Propagation and Interference Lab

Purpose:

What happens when two waves/pulses meet? What changes, what stays the same?

Materials:

- Slinky

Pre-lab discussion:

1. Predict what happens when two identical pulses displaced on the same side reach the same point in a medium.

2. What changes?

3. What stays the same?

4. Predict what happens when two identical pulses displaced on opposite sides reach the same point in a medium.

5. What changes?

6. What stays the same?

Post-lab discussion:

Think about the 4 different scenarios you have seen:

a) single pulses of equal size displaced on the same side
b) single pulses of different size displaced on the same side
c) single pulses of equal size displaced on opposite side of the slinky
d) single pulses of different size displaced on opposite side of the slinky.

1. Were the cups knocked down in each case?

2. In which case where the cups knocked down?

3. What happened when you sent two pulses on the same side of the slinky that are just smaller in amplitude than the cup line?

4. What happened when you sent two pulses on opposite sides of the slinky that are just large enough to knock down all of the cups?

5. What changed for the two pulses when they met?

6. What stays the same for the two pulses?

7. When the two pulses superimpose, what is affected?

8. How can one determine the shape of the resulting pulse?

Standing Waves Lab

Purpose:

What is the graphical and mathematical relationship between the frequency of a disturbance and the wavelength of the resulting standing wave?

Materials:

- snakey

Pre-lab Discussion:

1. On the floor, stretch the snakey, by holding both ends down, to about 5 m and generate a short series of periodic pulses. Sketch what the traveling train of pulses on the spring would look like at a point in time (snapshot).

2. By looking at the sketch, can you identify on it frequency, period, crest, trough and wavelength?

3. Create a series of pulses and concentrate on what happens near the fixed end of the slinky. Are there incident and reflected pulses?

4. What happens when these two meet?

5. Hold the snakey spring off the floor, stretching it about 5 m and try to create a standing wave of one segment, one loop only (one-half cycle). Then try to create two loops, three loops and so on. Draw a picture in each case.

Directions:

Snakey spring (low tech option)

1. Stretch a snakey spring to a length of 4m.
2. Shake the spring and adjust the frequency to get a standing wave in the fundamental mode of vibration.
3. Record the time that it takes to complete 10 full cycles of this wave.
4. Repeat for the next 4 modes of vibration. Make a data table of frequency vs wavelength.

5. After you are done, do a video analysis of a pulse traveling in your spring stretched to a length of 4m.

6. Make a graph of wavelength vs. frequency. You will have to calculate the wavelength by knowing how many wavelengths are contained in the 4m spring. You will have to calculate the frequency from the time recorded for 10 full cycles of the wave. Linearize the graph and conduct a mathematical analysis to obtain the relationship between frequency and wavelength.

Post-lab Discussion:

1. What do you know about the speed of the wave in a non-changing medium?

2. How do you know the speed of the wave is constant?

3. What are your independent and dependent variables?

4. For a constant velocity wave, how is frequency related to wavelength?

5. Explain how your data shows that frequency and wavelength are inversely proportional.

6. Does the slope have any meaning? Do the units look familiar?

7. How can we verify that the slope is the speed?

8. How are the standing waves formed?

9. How do the reflected and outgoing wave interact?

10. Which principle are we using?

11. Explain the superposition principle.

12. Was a standing wave formed at every disturbance frequency of the wave?

13. What is the connection between the frequency of the first harmonic and the rest?

14. How can you calculate the speed of the traveling wave?

15. What happened when the disturbance frequency did *not* form a standing wave? (This is a nice bridge into a discussion of resonance.)

Sound Waves Simulation Lab

Purpose:

How do we know that sound is a wave? What is the relationship between frequency and the pitch of a sound you hear?

Materials:

Sound Phet Simulation

Pre-lab discussion:

1. What are some ways that we experience our surroundings?

2. How do we detect sound?

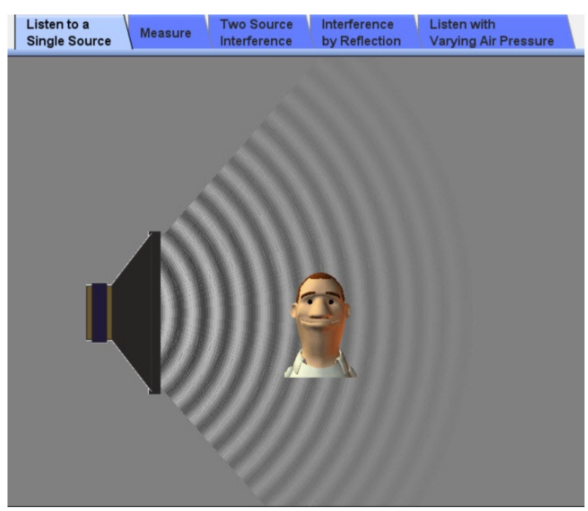
3. Is sound a wave? What experimental evidence proves that sound is a wave?

4. If two sounds reach you at the same time, what happens?

Directions:

1. Go to the Interactive Simulations website at the University of Colorado Boulder (http://phet.colorado.edu/) and click on "Play with sims". Select Physics -> Sound and Waves, and open the simulation "Sound". Select "Download" to start the simulation. Select the "Listen to a Single Source" tab in Sound Waves simulation window. Turn on the Audio Enabled so you can hear the sound.

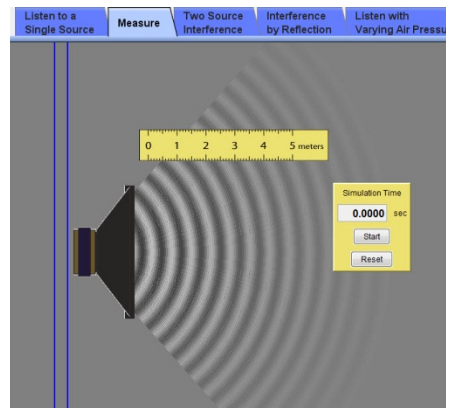
2. When you change the frequency, how does the sound change? How does the visual model change?



3. How does changing the amplitude affect the sound and its model?

4. Sound is produced when something vibrates; this movement causes disturbances in the surrounding air pressure. Investigate how the speaker cone moves to produce different sounds. Then, explain the relationships between the movement of the speaker cone and the sound that is made; include drawings to support your explanation.

5. Use the tools on the Measure tab to find the speed of sound in air. Make a data table that demonstrates you have a good experiment and show sample calculations. Note: use the two blue lines for measuring distances accurately.



6. How do your results compare to information that is published?

7. How could you find the wavelength of a sound? Test your idea with several different sounds. Check to see if the results for wavelength make sense.

8. Describe how you might use the simulation tools to find the period of a wave without using the frequency information.

9. Test your idea with a variety of waves. Check your method by calculating the period using the frequency. Show data and calculations for several trials. Make corrections to the original plan as necessary.

10. Describe how you would find the frequency of a wave if the frequency slider did not have a number display.

11. Test your idea with a variety of waves. Show data and calculations for several trials. Make corrections to the original plan as necessary.

Postlab discussion:

1. What does the collected data tell you about sound?

2. What is sound and how can we characterize it?

3. What do you think that music is?

Speed of Sound Lab

Purpose:

How fast does sound travel? What affects the speed of sound?

Materials:

- speed of sound apparatus
- set of tuning forks
- boom whackers
- twirling tube
- glass bottle
- singing tube and singing rod for demo

Pre-lab discussion:

1. What is sound?

2. Gently blow across the top of the empty bottle. Can you produce a sound?

3. Fill about ¼ of the bottle with water. Blow again across its top. Were you making the same sound?

4. Fill about ½ of the bottle with water and repeat the steps above. Have you produced the same sound?

5. Can you find a connection between the sound you hear and standing waves?

6. Draw a few of the standing waves that can form in the bottle.

Directions:

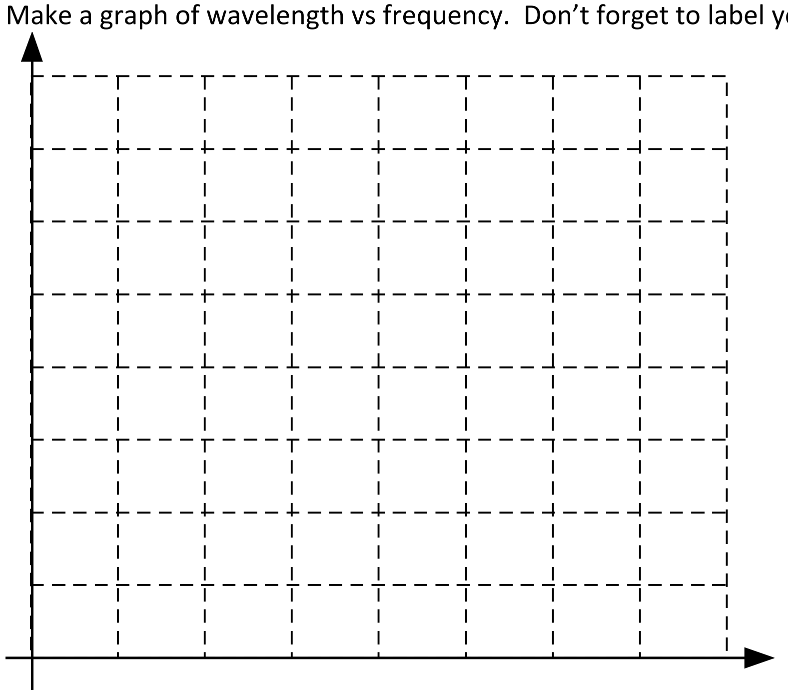
1. Using the sound waves apparatus, design an experiment that will allow you to determine the speed of sound. Use the different tuning forks, the apparatus and a ruler to produce a graph which will allow you to find the speed of sound in the room.

Note: Make sure that the amount of water in the sound apparatus is such that when the cup is at its lowest point, the water does not spill out of it.

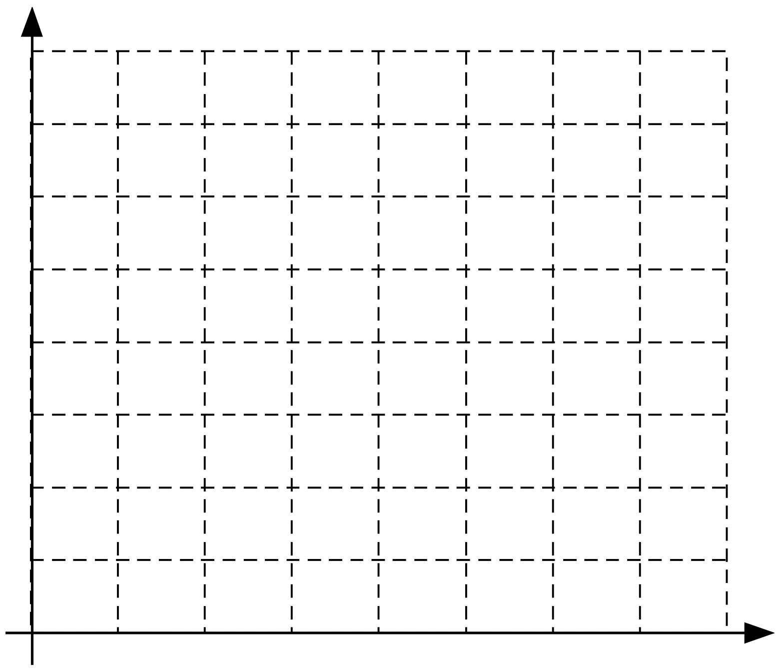
2. Fill out the table below:

Length of air column	Tuning fork	Sound Wavelength

3. Make a graph of wavelength vs frequency. Don't forget to label your axes.



4. Linearize the graph by calculating 1/frequency and graphing wavelength vs. 1/frequency.



5. Calculate the slope of this graph.

6. What does it represent?

Post-lab discussions:

1. What is the speed of sound that you were able to determine?

2. Is the speed of sound the same everywhere?

3. What factors might determine the speed of sound?

4. Why do wind instruments change intonation when the temperature changes?

5. Do they become sharp or flat as they get warmer?

6. Is this expected?

7. How does the speed of sound lab help you explain how boomwhackers and the twirling tube work?

Exploring Light Lab

Purpose:

What is light, and what properties does it have?

Materials:

- Ray box set with mirrors, prisms, lenses, light source, etc.
- Red and green laser pointers
- Diffraction grating card with several different gratings
- Soap bubbles and a source of light

Pre lab discussion:

1. What is light? How would you describe light?

Visit each station and follow the instructions:

Station 1: Reflection

Use the ray box set. Shine a laser on a mirror and look what happens to the direction of motion for the laser wave. Make a drawing in your notebook.

Station 2: Refraction/Transmission

Use the ray box set. Shine the laser through the transparent objects in your set and observe the path of the laser beam. Make drawings in your notebook.

Station 3: Diffraction

Shine the laser through a diffraction grating and project the image on a wall. Observe the difference between the different gratings. Shine a red laser and a green laser through the finest grating. Record all your observations.

Station 4: Interference

Look at the solution of soap bubbles and shine a light on it. Describe what you see. Shine a source of white light through a prism and try to project the light coming out on a screen. Describe what you see.

Postlab Discussion:

1. What do you think that light is?

2. How is light like a wave?

3. How is light different from the waves you have learned about?

4. What properties should light have if it is a wave?

5. What type of phenomena would you expect to see when playing with light?

6. Which one of the phenomena observed does not agree with what you have learned about waves?