Name:

11.1 Harmonic Motion

Question: How do we describe the back-and-forth motion of a pendulum?

1 Setting up the pendulum

There are no questions to answer in part 1.

2 Testing the three variables

Follow the procedures and record your data in Table 1.

Table 1:Period, Amplitude, Mass, and Length Data

Number of washers	Amplitude (degrees)	String length (cm)	Time from timer (seconds)	Period of pendulum (seconds)

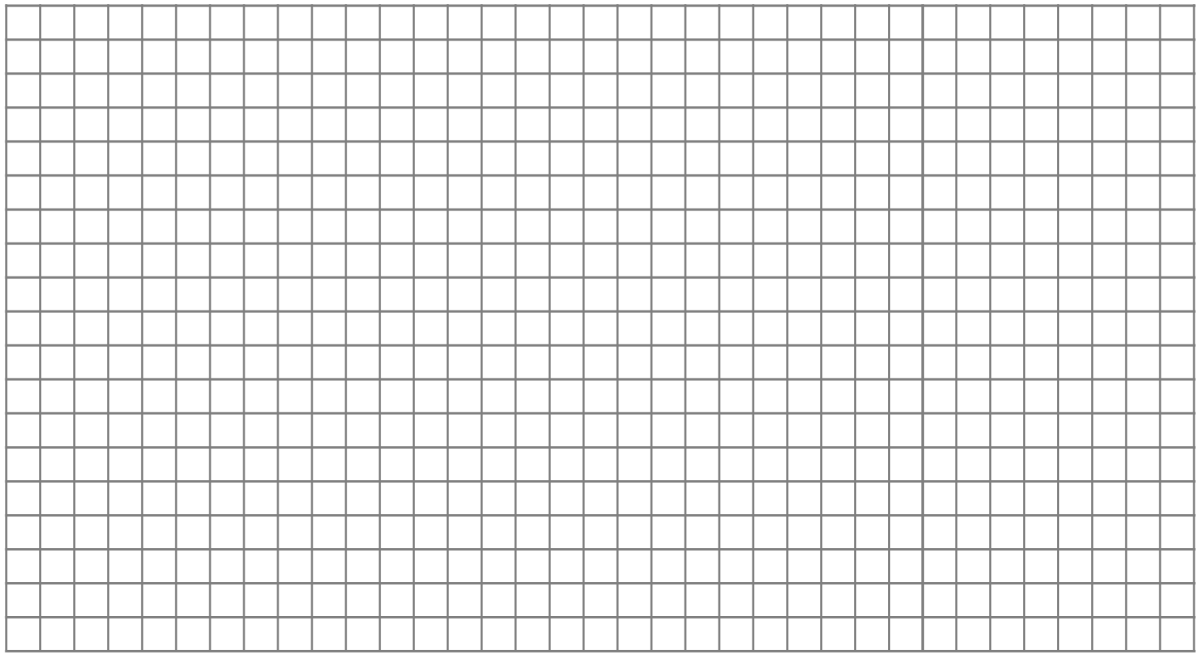
3 Analyzing the data

a. Of the three things you can change (length, mass, and angle), which one has the biggest effect on the pendulum, and why? In your answer you should consider how gravity accelerates objects of different mass.

b. Make three graphs, as instructed in the Investigation.

Title: _____

y label: _____



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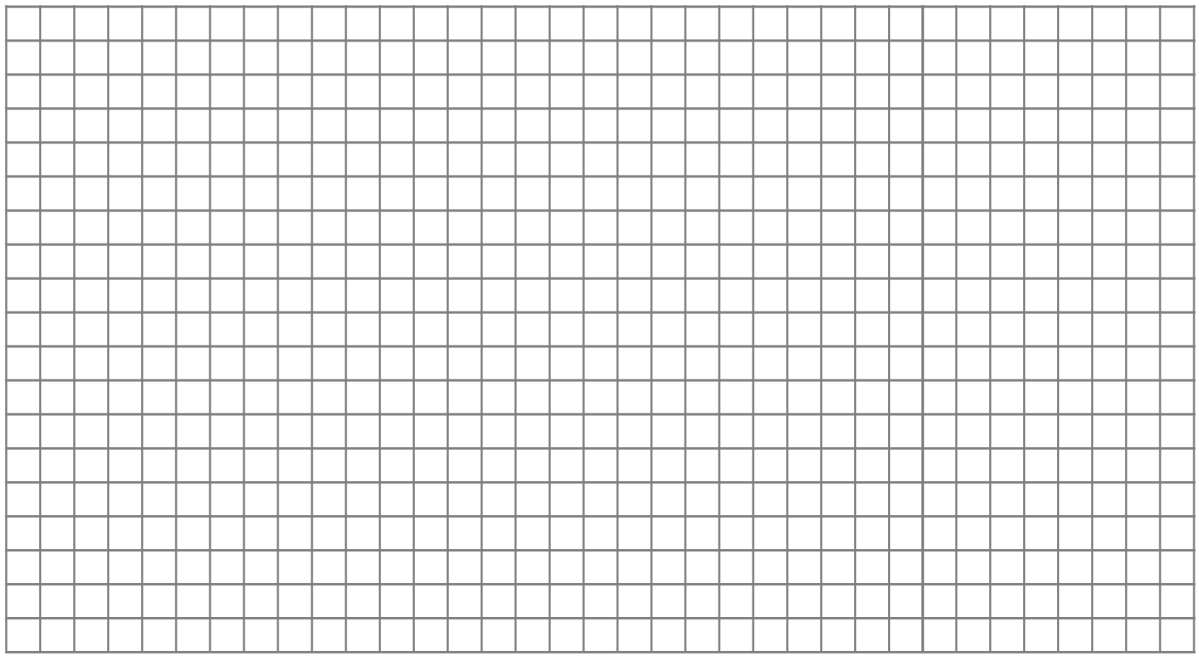

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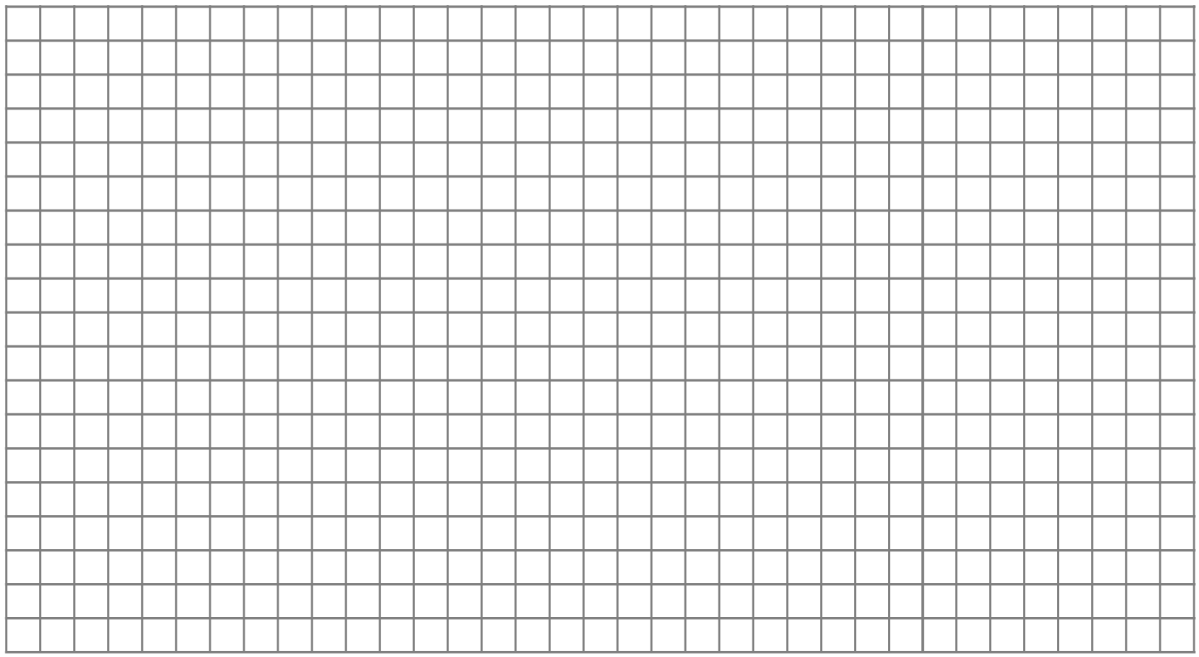


x label: _____

4 Applying what you know

a. Using your data, design and construct a pendulum that you can use to accurately measure a time interval of 30 seconds. Test your pendulum clock against the electronic stopwatch.

b. On your graph from part 3, mark the period you chose for your pendulum.

c. How many cycles did your pendulum complete in 30 seconds?

d. If mass does not affect the period, why is it important that the pendulum in a clock is heavy?

e. Calculate the percent error in your prediction of time from your pendulum clock. The percent error is 100 times the difference between your prediction and 30 seconds, divided by 30 seconds.

f. You notice in a magazine that a watch manufacturer advertises that its quartz watch loses no more than 5 seconds per month. Assume that the watch loses the maximum amount (5 seconds) in 31 days. Calculate the percent error of the quartz watch by comparing 5 seconds to the number of seconds in a month.

5 Damping and energy loss

Follow the procedures and record your data in Table 2.

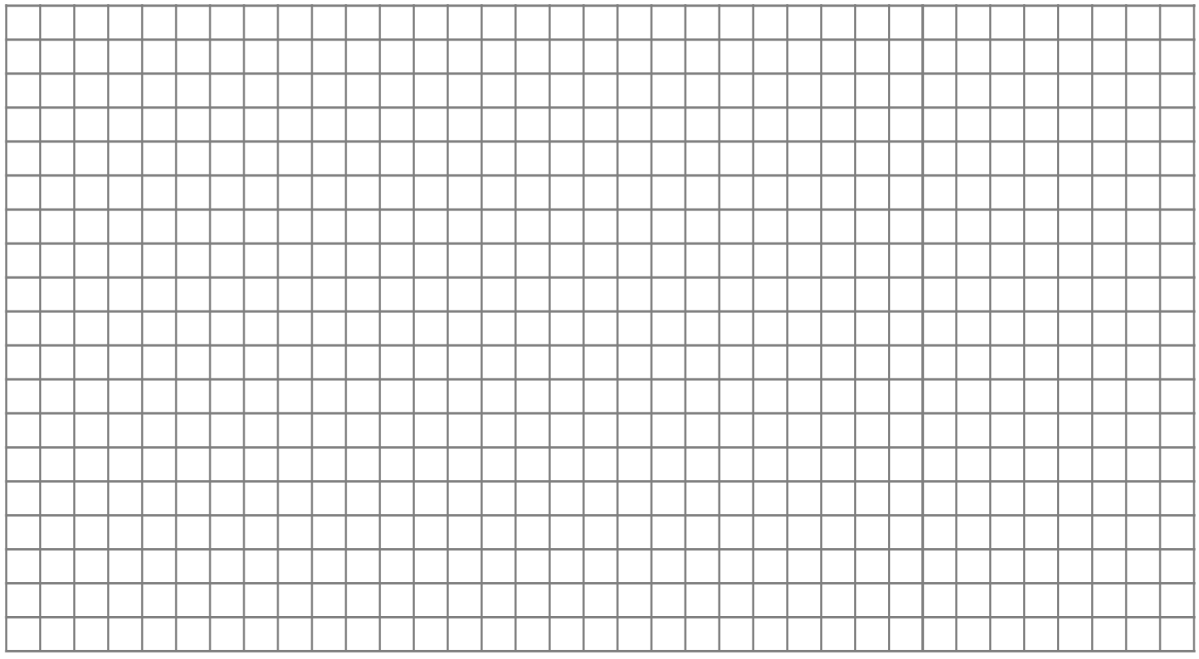
Table 2: Damping Data

Mass (washers)	String length (cm)	Time to decay from 30 degrees to 10 degrees (sec)

a. Plot two graphs that show how the damping time changes with mass and string length.

Title: _____

y label: _____



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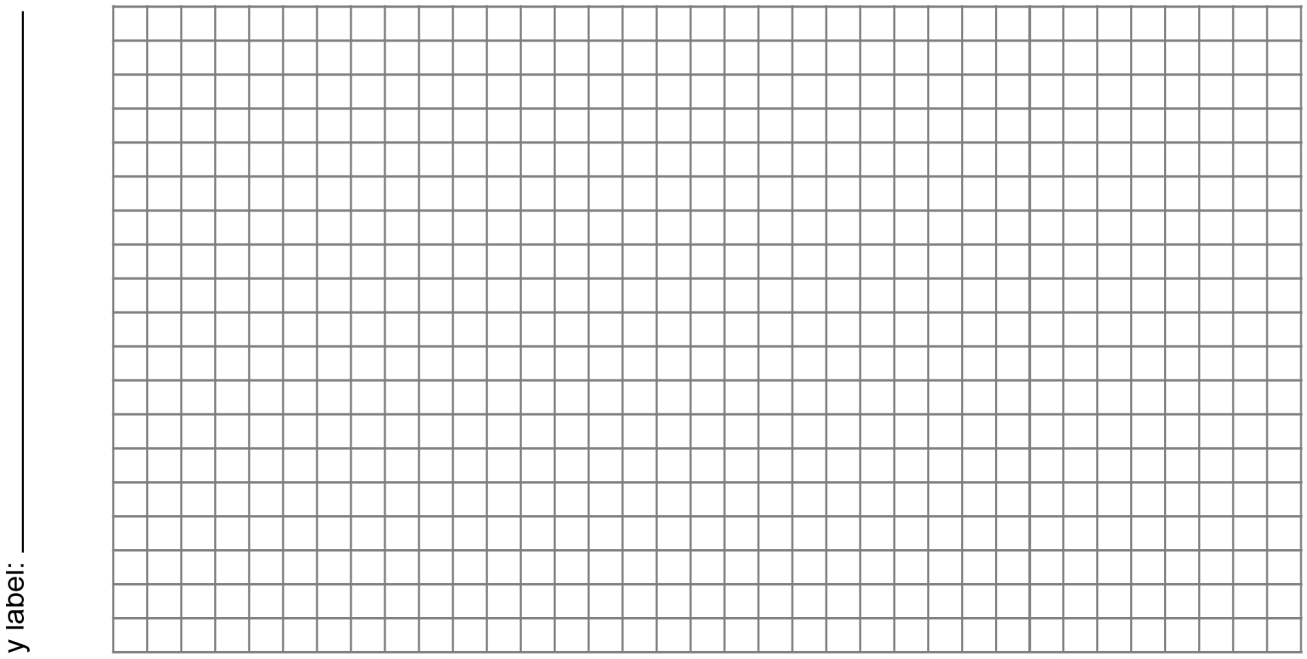
Title: _____



x label: _____

b. Suppose you had to design a real pendulum clock that would keep swinging for many days. From the results of your experiment, how would you choose string length and mass? Explain how your choices are based on your observations.

Name: _____

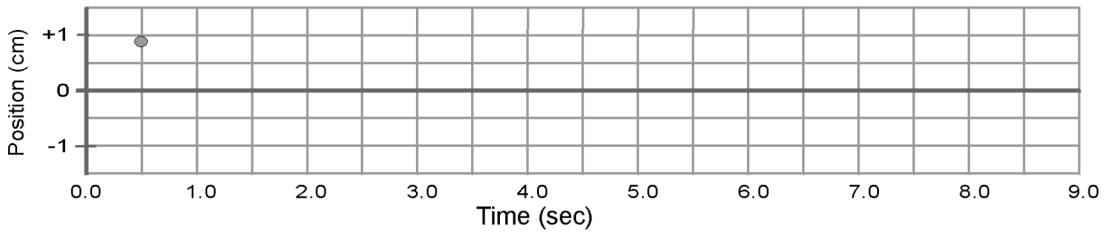
11.2 Graphs of Harmonic Motion

Question: How do we make graphs of harmonic motion?

1 Simple harmonic motion graph

Graph the data from part 1 and answer the questions.

time (sec)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
position (cm)	0.9	0.9	0.0	-0.9	-0.9	0.0	0.9	0.9	0.0	-0.9	-0.9	0.0	0.9	0.9	0.0	-0.9	-0.9	0.0



a. What is the amplitude of the graph in centimeters?

_____

_____

b. What is the period of the graph in seconds?

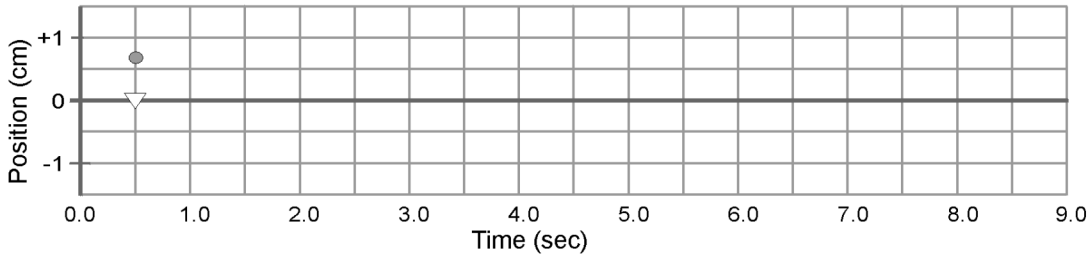
_____

_____

2 Comparing harmonic motion graphs

Graph the data from part 2 and answer the questions.

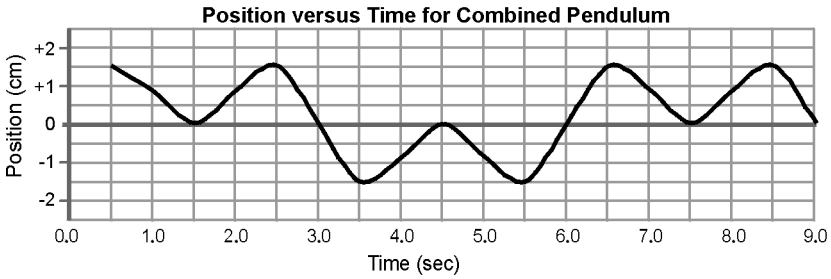
time (sec)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
position #1 (cm)	0.7	1.0	0.7	0.0	-0.7	-1.0	-0.7	0.0	0.7	1.0	0.7	0.0	-0.7	-1.0	-0.7	0.0	0.7	1.0
position #2 (cm)	0.0	0.7	1.0	0.7	0.0	-0.7	-1.0	-0.7	0.0	0.7	1.0	0.7	0.0	-0.7	-1.0	-0.7	0.0	0.7

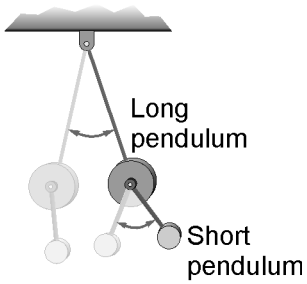


a. Which pendulum was most probably released first? In your answer you must use the word "phase" to explain how you chose which pendulum started first.

b. How much time was there between the start of the lead pendulum and the start of the other pendulum?

3 A complex harmonic motion graph





a. What is the amplitude of the combined pendulum in centimeters?

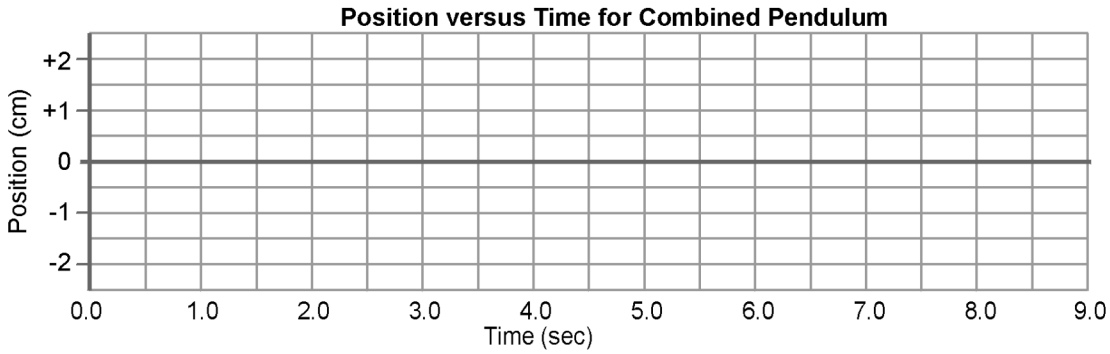
b. What is the period of the combined pendulum in seconds?

c. In one or two sentences, describe the difference between the graphs of the single pendulums and the graph of the combined pendulum.

4 How you get a complex graph

Graph the data from part 4 and answer the question.

time (sec)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
Long Pendulum (cm)	0.5	0.9	1.0	0.9	0.5	0.0	-0.5	-0.9	-1.0	-0.9	-0.5	0.0	0.5	0.9	1.0	0.9	0.5	0.0
Short Pendulum (cm)	1.0	0.0	-1.0	0.0	1.0	0.0	-1.0	0 0	1.0	0.0	-1.0	0.0	1.0	0.0	-1.0	0.0	1.0	0.0
Long plus Short (cm)																		



Does the graph confirm or disprove the inventor's theory? Explain your answer in a few sentences.

Name: _____

11.3 Simple Mechanical Oscillators

Question: What kinds of systems oscillate?

1 Find an example of a stable system and an unstable system

a. Describe your example of a stable system in one or two sentences. What happens when you push it a little away from equilibrium? Write one sentence that describes the motion.

b. Describe your example of an unstable system in one or two sentences. What happens when you push the unstable system a little away from equilibrium? Write one sentence that describes the motion.

2 Making a mechanical oscillator

a. Create a system that oscillates. You may use anything you can find, including springs, rubber bands, rulers, balloons, blocks of wood, or anything else that may be safely assembled.

b. Draw a sketch of your system in the space above, and identify what makes the restoring force.

c. On your sketch, also identify where the mass that creates the inertia is located.

3 Measuring and changing the period of your oscillator

a. Estimate or measure the period of your oscillator in seconds. You may use photogates or stopwatches to make your measurements. Describe how you made your measurement and write down some representative periods for your oscillator.

b. Describe and test a way to increase the period of your oscillator. Increasing the period makes the oscillator slow down.

c. Describe and test a way to decrease the period of your oscillator. Decreasing the period makes the oscillator get faster.

4 Applying what you learned

Trees are oscillators when they sway in the wind, or in an earthquake. A large tree, like an oak, has a very strong trunk and it takes a large force to bend it. A slender tree, like a willow, has a more flexible trunk that can be bent with much less force. Which tree do you think has a longer period of oscillation, a big oak tree or a slender willow tree?

5 Oscillating buildings

If the period is very short, the oscillator cannot move very far in one cycle and the amplitude is small. If the period is long, there is more time for movement and the amplitude can be much larger.

Tall buildings also sway in the wind, and in earthquakes. The same principle applies to buildings as to trees and pendulums. If a building is strong or short it is stiffer. Stiff buildings require more force to bend. A tall thin building, like a tower, bends under less force. Suppose you have a short, stiff building and a tall slender building. In one paragraph, explain which one is likely to sway more in the wind using the comparison of the period and amplitude of each building.

Name: _____

12.1 Waves

Question: How do we make and describe waves?

1 Setting up the experiment

Observe the wave pulse as it moves away from you. Would you describe the speed of the wave pulse as fast or slow? Record your observations in the space below.

_____

_____

_____

_____

_____

2 Measuring the speed of a wave

Record your data from part 2 in Table 1.

Table 1: Initial data on the speed of the wave pulse

Trial #	Distance between photogates (m)	Time from A to B (seconds)	Speed of pulse (m/sec)

3 Changing the string tension

Record your data from part 3 in Table 2.

Table 2: String tension data

String tension (N)	Distance between photogates (m)	Time from A to B (seconds)	Speed of pulse (m/sec)

a. What effect does changing the tension have on the speed of the wave pulses?

b. From what you know about forces, explain why the higher tension makes the waves move faster.

Name: _____

12.2 Waves in Motion

Question: How do waves move and interact with things?

1 Making waves in a ripple tank

a. Draw a sketch that shows the wave front of your plane wave. Also on your sketch, draw an arrow that shows the direction the wave moves.

b. Is the wave front parallel or perpendicular to the direction the wave moves?

c. Would you consider your water wave a transverse wave or a longitudinal wave?

2 Circular waves

a. Draw another sketch that shows the circular wave fronts and include at least 4 arrows that show the direction each part of the wave moves.

b. At every point along the wave, are the wave fronts more parallel or perpendicular to the direction the wave moves?

3 Passing through cracks

a. Sketch the shape of the wave fronts before and after the opening.

b. Does the wave change shape when it passes through the opening? If you see any change, your answer should say what kind of shape the wave changes into.

4 Bouncing off walls

a. Draw a sketch that shows what happens to the wave front when it hits the side of the tray.

b. Draw an arrow showing the direction of the wave approaching the side.

c. Draw another arrow showing the direction of the wave after it reflects from the side.

d. Do you see any relationship between the incoming and outgoing arrows?

5 Applying your knowledge

a. You can easily hear a person talking through a crack in the door, even though you cannot see them. Do any of your observations provide a clue to why sound can get through tiny cracks?

b. Ocean waves can get many meters high. Big waves on the ocean tend to occur on very windy days. Explain how wind might contribute to making big waves. Use a sketch in your explanation.

Extra space for notes:

Name:

12.3 Natural Frequency and Resonance

Question: What is resonance and why is it important?

1 Setting up the experiment

There are no questions to answer in part 1.

2 Waves and harmonics

Record your data from part 2 in Table 1.

Table 1: Frequency, harmonic and wavelength data

Harmonic #	Frequency (Hz)	Wavelength (m)	Frequency times wavelength (m/sec)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

3 Analyzing the data

a. In one or two sentences describe how the frequencies of the different harmonic patterns are related to each other.

b. Why is the word *fundamental* chosen as another name for the first harmonic?

c. In one or two sentences, describe how the product of frequency times wavelength changes compared to the changes in frequency or wavelength separately.

d. If the frequency increases, what happens to the wavelength? Your answer should say if the wavelength changes and by how much it changes compared to the change in frequency.

4 Frequency and energy

Record your data from part 4 in Table 2.

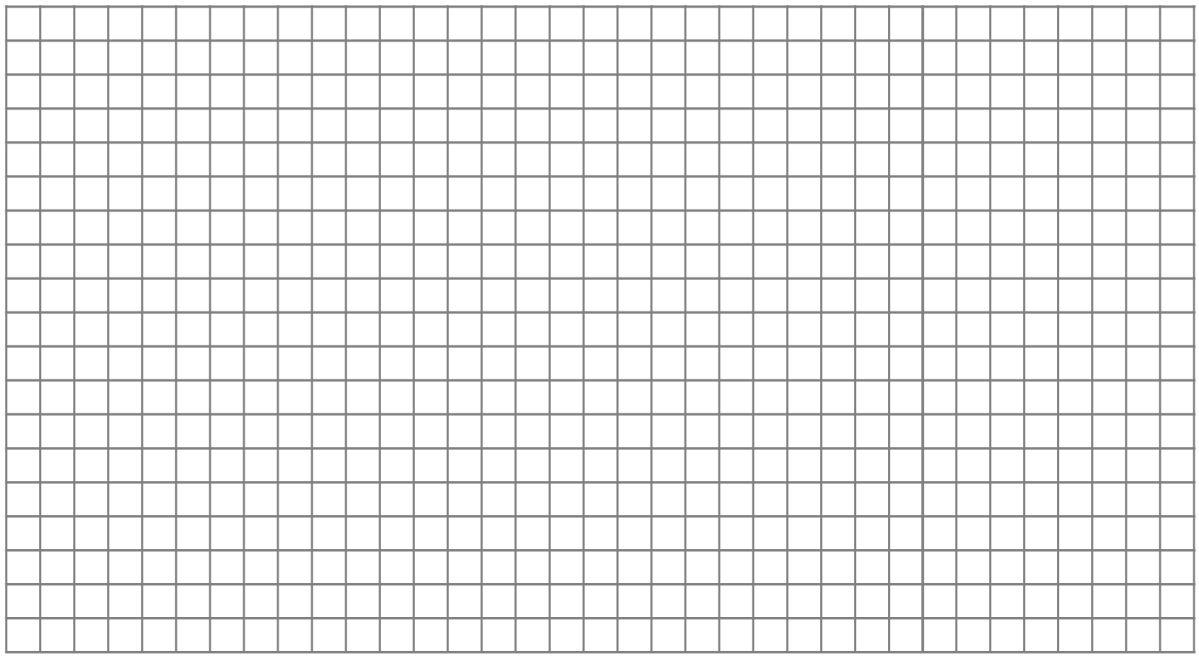
Table 2: Frequency vs. amplitude data

Harmonic #	Frequency (Hz)	Amplitude (cm)

a. Make a graph showing how the amplitude changes with frequency.

Title: _____

y label: _____



x label: _____

b. Suppose you had a wave maker which allowed you to adjust the input energy so all the waves could have the same amplitude. You then used this wave maker to create two waves with equal amplitude, but one had a higher frequency than the other. If the amplitude is the same, which wave has more energy, the higher frequency wave or the lower frequency wave? Use your results to explain your answer.

5 Force and natural frequency

Record your data from part 5 in Table 3.

Table 3: Frequency vs. string tension data

Harmonic #	Tension (N)	Frequency (hz)
3	0.5	
3	1.0	
3	1.5	
3	2.0	
3	2.5	
3	3.0	

6 Applying what you learned

a. What happens to the natural frequency as you increase the tension of the string? In your answer discuss why this is useful in tuning a musical instrument such as a guitar or piano. You may need to do some research to investigate how guitars and pianos are tuned.

b. As the tension is increased, making the string stiffer, what happens to the amplitude of the wave? An earthquake is like the wiggler in that it makes the ground shake back and forth with a certain frequency. How do your results relate to making tall buildings sway less in an earthquake? You should consider what happened to the amplitude of the wave when you increased the tension in the string to answer the question.

Extra space for notes:

Name:

13.1 Sound

Question: What is sound and how do we hear it?

1 How high can you hear?

Record your data from part 1 in Table 1.

Table 1: How we hear frequencies of sound

Description	Frequency (Hz)
Low	
Medium	
High	
Very high	

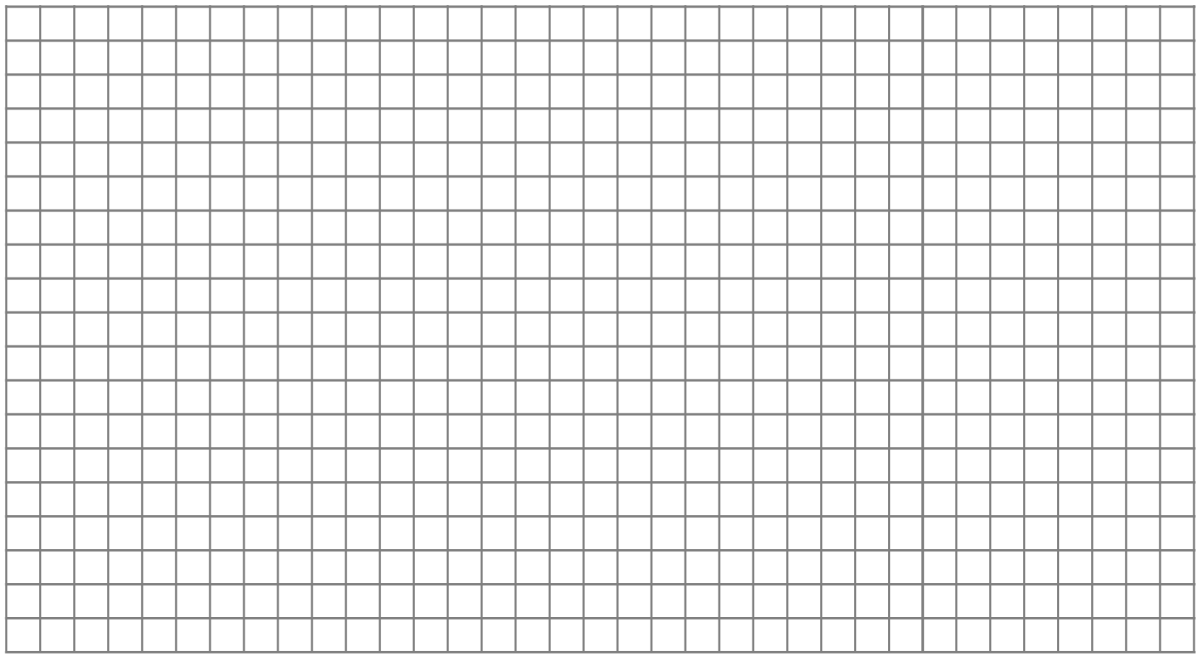
2 Testing the upper frequency limit of the ear

a. The objective of the test is to see what fraction of people can hear a particular frequency. Once the frequency gets too high, no one will be able to hear it, or at least no humans. Cats, dogs, and other animals can hear much higher frequencies than people. Do you think the method of raising your hands is likely to give a good result? Give at least one reason why you think the method is either good or bad.

b. Make a bar graph showing how your class responded to frequencies between 10,000 and 20,000 Hz. You should have ten bars, each one for a frequency range of 1,000 Hz. The height of each bar is the number of people who could hear that frequency of sound. If someone could hear the frequency they are counted as a positive response in the graph. This kind of graph is called a *histogram*.

Title: _____

y label: _____



x label: _____

3 Doing a more careful experiment

Record the frequencies you hear in the survey sheet below:

Trial	Yes	No	Trial	Yes	No
1			16		
2			17		
3			18		
4			19		
5			20		
6			21		
7			22		
8			23		
9			24		
10			25		
11			26		
12			27		
13			28		
14			29		
15			30		

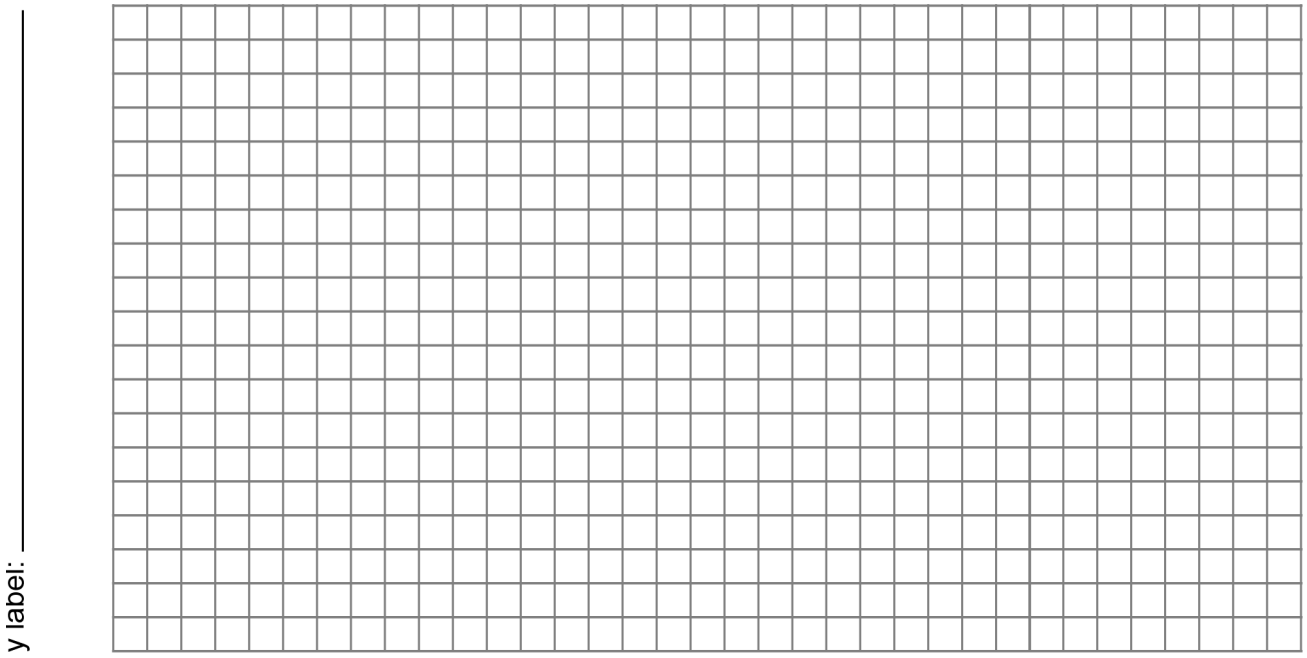
Collect the data from the survey sheets and record it in the chart below.

Table 2: Frequency survey data

# Right	10,000 Hz	12,000 Hz	14,000 Hz	16,000 Hz	18,000 Hz	20,000 Hz
5						
4						
3						
2						
1						

Plot another histogram showing only those people whose choices matched the yes/no on the key for all five times at each frequency.

Title: _____



4 Perceiving differences in frequency

Mark which frequency you think is higher below

Trial	A	B
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Complete Table 3.

Table 3: Comparative frequency data

Frequency A (Hz)	Frequency B (Hz)	Frequency difference (Hz)	Percent difference	# of correct responses

a. Calculate the percent difference in frequency for each test and record in Table 3.

b. There are two ways to look at sensitivity. In one way, we hear *absolute* differences in frequency. If the ear was sensitive to absolute differences, we would hear a 5 Hz difference no matter if the two frequencies were 500 Hz and 505 Hz, or 5,000 Hz and 5,005 Hz.

The second possibility is that we hear relative differences. We might be able to hear a 1 percent difference which would be 5 Hz at 500 Hz. But we could not hear the difference between 5,000 Hz and 5,005 Hz because the percentage difference is only 0.1 percent. To hear a similar difference at 5000 Hz, Frequency B would have to be 5,050 Hz, which is 1 percent higher.

Which model does the data support?

5 Chance and experiments

a. What is the chance of guessing correctly with five trials?

b. If 100 people did a test with five trials, and everybody guessed, how many people would be likely to make five correct choices in a row?

Additional space for notes:

Name:

13.2 Properties of Sound

Question: Does sound behave like other waves?

1 Beats, Consonance and Dissonance

a. What makes the beats get faster or slower? In your answer you should describe what you do to the frequencies to make the beats faster or slower.

b. Is the sound of beats pleasant to listen to, or unpleasant? The word *consonant* is used by musicians to describe sounds that fit smoothly together. The opposite of consonant is *dissonant*. Dissonant sounds tend to make people anxious and irritable. Describe the relationship between consonance, dissonance, and beats.

c. How could you use beats to match one frequency to another frequency? This is done every day when musicians in an orchestra tune their instruments.

d. How much different do the two frequencies have to be before you do not hear beats any more?

2 Interference

a. Try to make an approximate measure of the wavelength of sound by changing the separation of the two speakers. The speakers have been moved one wavelength when the sound heard by the observer has gone from loudest to softest, and back to loudest again. For this to work you need to keep the observer and both speakers in the same line.

b. Interference can be bad news for concert halls. People do not want their sound to be canceled out after they have paid for the tickets! Why do we not usually hear interference from stereos even though they have two speakers?

3 Resonance

Record your data from part 3 in Table 1.

Table 1: Resonant frequencies for tuning forks

Tuning fork description	Measured resonant frequency (Hz)	Labeled resonant frequency (if any)

4 Thinking about what you observed

a. Did you observe any relationship between the size (or shape) of the tuning fork and the frequency at which it was resonant?

b. What range of frequencies did you hear that seemed to match the frequency of the tuning fork? Give your answer in the form of a range written like 429 Hz - 451 Hz.

c. Strike the tuning fork and hold the bottom end against a hard, thin surface, like a window. Does the sound get louder, softer, or remain unchanged? Explain what you hear by describing what might be happening between the tuning fork and the surface you touched.

5 Resonance in other systems

Record your data from the experiment with glasses and water in Table 2.

Table 2: Resonant frequencies of glasses of water

Trial #	Water height	Frequency (Hz)

Record your data from the experiment with bottles of water in Table 3.

Table 3: Resonant frequencies of bottles of water

Trial #	Water height	Frequency (Hz)

6 Thinking about what you observed

What was the relationship between the frequencies and the heights? In coming up with your answer, remember the waves on the vibrating string and how the frequency and wavelength were related. Do you see similar behavior with the sounds and heights from the glass and bottle? For each case, what might be the vibrating element that would explain your observed changes in frequency?

Name:

13.3 Music

Question: What is music and how do we make music?

1 Making notes

a. Describe the sound of the three frequencies 264 Hz, 330 Hz, and 396 Hz when you hear them together. Which three notes are these?

b. Describe the sound of the three frequencies 264 Hz, 315 Hz, and 396 Hz when you hear them together.

c. Contrast the two sounds. Does one sound more happy or sad compared with the other? Does one sound spookier than the other? Which combination reminds you more of spring, which of fall?

d. Describe the effect of adding a frequency of 528 Hz to each group of frequencies.

2 Controlling frequency and wavelength

a. Make a straw kazoo and make some sound with it. Take a pair of scissors and cut off the end of the kazoo. What happens to the frequency of the sound it makes?

b. Take the scissors and cut a small hole exactly in the middle of your kazoo. Cover the hole with your finger. Blow through the kazoo and lift your finger to cover and uncover the hole. What happens to the sound? (Hint: What is vibrating in the straw is a length of air.)

c. Identify at least three musical instruments that use vibrating objects of different lengths like the sketch of the chimes above.