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INVESTIGATION 19A

Harmonic Motion

1 Make a pendulum

a. Write one sentence about the motion using the word "cycle."

b. The ***amplitude*** is the maximum amount the pendulum swings away from its resting position. The resting position is straight down. One way to measure amplitude is the angle the pendulum moves away from center. Write one sentence describing the motion of your pendulum using the word "amplitude."

c. Draw a sequence of sketches that describe one complete cycle using arrows to indicate the direction the pendulum is going at that point in the cycle.

2 Oscillators and period

a. Use the stopwatch to measure the period of your pendulum. Time ten cycles Do three trials and use Table 1 to record your data.

b. Divide the average time for ten cycles by 10 to get the period.

c. Write a one sentence description of how you measured the period.

Table 1: Pendulum period data: Time for 10 cycles (sec)

Trial 1	Trial 2	Trial 3		Average
		Period of pendulum (average divided by10)		

3 Measuring period with a photogate

There are no questions to answer in part 3.

4 Thinking about what you observed

a. Write down the time measurement you get from the Timer.

b. Is the time you get from the Timer the period of the pendulum? Explain why the time is or is not the period of the pendulum (hint: compare to your results from part 2).

c. Explain how the time measured by the Timer is related to the period of the pendulum.

5 What variables affect the period of a pendulum?

a. Think of three experiments you can do to see what variables affect the period of the pendulum. Write down one sentence describing each experiment.

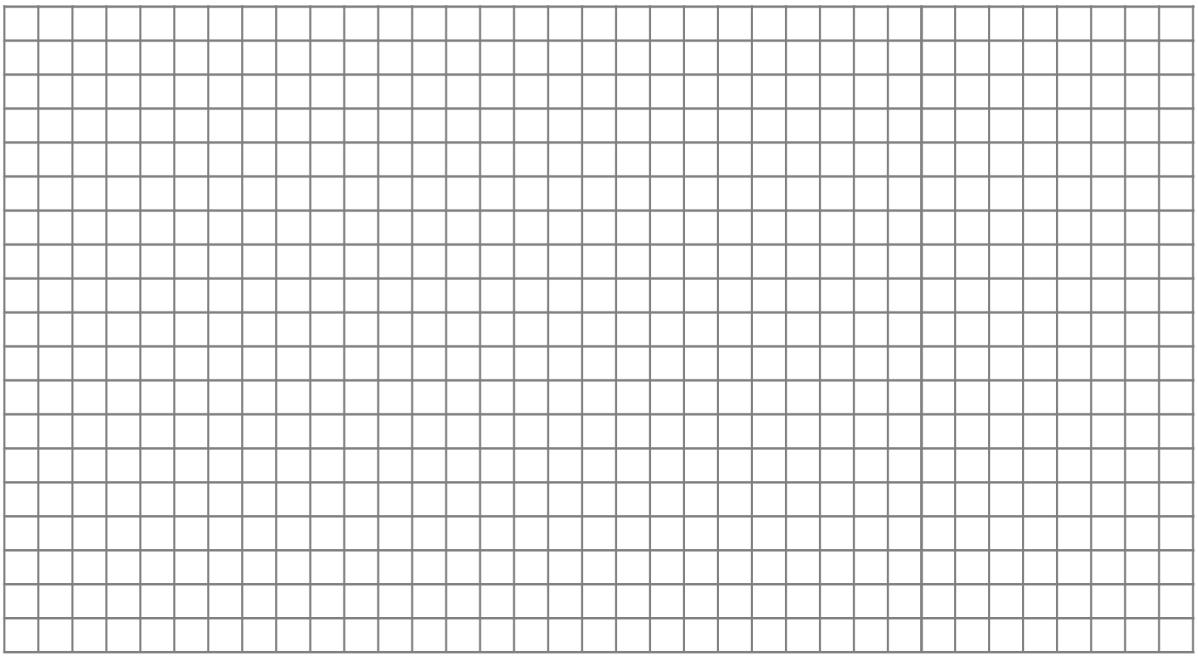
b. Do the three experiments and record the measurements you make to assess the effect of changing each variable.

c. Write a sentence about the effect of each variable. Write a second sentence explaining how the data you took support the statement you made about each variable.

6 Sketch a graph of the motion using amplitude and period

Title: _____

y label: _____



x label: _____

a. How many complete cycles does your graph show?

b. Describe how to determine the amplitude of motion from a harmonic motion graph.

c. Describe how to determine the period from a harmonic motion graph.

d. What is the amplitude and period of the motion shown on the graph in the diagram?

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INVESTIGATION 19B

Natural Frequency

1 Make an oscillator

There are no questions to answer in part 1.

2 Measure the natural frequency

Table 1: Natural frequency data (Hz) for 1 washer with 2 rubber bands

Trial 1 Period (sec)	Trial 2 Period (sec)	Trial 3 Period (sec)		Average Period (sec)
		Natural Frequency (Hz)		

3 Thinking about what you observed

a. Does the washer-and-rubber-band oscillator have a natural frequency? How do you know?

b. Explain in one or two sentences how you measured the natural frequency. (Hint: describe the washer's motion relative to the photogate.)

c. What would happen to the natural frequency if you made the rubber bands stronger? Would the natural frequency get higher, lower, or stay about the same? Explain your reasoning in a few sentences.

d. What would happen to the natural frequency if you made the washer heavier by adding more mass? Would the natural frequency get higher, lower, or stay about the same? Explain your reasoning in a few sentences.

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INVESTIGATION 19B

4 Changing the force in your oscillator

There are no questions to answer in part 4.

5 How the natural frequency depends on mass and force

Table 2: Natural Period and Frequency Data (sec)

	2 Rubber bands 1 Washer	4 Rubber bands 1 Washer	2 Rubber bands 2 Washers	4 Rubber bands 2 Washers
Trial 1				
Trial 2				
Trial 3				
Average period				
Natural frequency (Hz)				

6 Thinking about what you observed

a. Did the results agree with your answers to questions 3d and 3e? If not, give new answers based on your observations.

b. The natural frequency depends on the ratio of two variables. One from the rubber bands and one mostly from the steel washer(s). What are the two variables and how should they be arranged as a ratio?

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INVESTIGATION 20A

Waves

1 Making a wave pulse

There are no questions to answer in part 1.

2 Thinking about what you observed

a. How is the motion of a wave pulse different from the motion of a moving object such as a car. (HINT: What is it that moves in the case of a wave?)

b. What happens to the wave pulse when it hits the far end of the string? Watch carefully. Does the pulse stay on the same side of the string or flip to the other side? Use the word "reflect" in your answer.

3 Transverse waves

Table 1: Wave Frequency and Period Data

Wave Pattern	Trial 1 Time for 10 cycles (sec)	Trial 2 Time for 10 cycles (sec)	Trial 3 Time for 10 cycles (sec)	Average Time for 10 cycles (sec)	Period (sec)	Frequency (Hz)

4 Thinking about what you observed

a. Imagine you removed one rubber band in the middle, making two unconnected chains. Do you think the wave could cross the break. Discuss the reasoning behind your answer in a few sentences.

b. Why does the wave move along the chain from one washer to the next?

c. Use the data you collected to complete Table 1 and calculate the natural frequency and period of the different wave patterns you observed.

d. Did you find a relationship between the frequencies at which you had to shake the chain to get the three different wave patterns? What relationship did you find?

5 Waves in water

There are no questions to answer in part 5.

6 Thinking about what you observed

a. The wave front of a water wave is an imaginary line drawn to show the shape of the crest of one wave. 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. Draw another sketch that shows the circular wave fronts and include at least four arrows that show the direction in which each part of the wave moves.

d. At every point along the wave, are the wave fronts more parallel or perpendicular to the direction in which the circular wave moves?

e. Sketch the shape of the wave fronts before and after wave passes through the 1 cm opening.

f. 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.

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INVESTIGATION 20B

Resonance and Standing Waves

1 Setting up a standing wave experiment

There are no questions to answer in part 1.

2 Thinking about what you observed

a. The string is 1 meter long. The *wavelength*, λ, is the length of one complete wave. Without using a meter stick, how can you determine the wavelength of each standing wave?

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INVESTIGATION 20B

3 Finding the standing waves

Table 1: Frequency, harmonic, and wavelength data

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

4 Thinking about what you observed

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

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

c. Give an equation relating frequency (f) and wavelength (λ) that best describes your observations.

d. If the frequency increases by a factor of two, what happens to the wavelength?

e. Propose a meaning for the number you get by multiplying frequency and wavelength.

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INVESTIGATION 20B

5 Frequency and energy

Table 2: Frequency vs. amplitude data

Harmonic #	Frequency (Hz)	Amplitude (cm)

6 Thinking about what you observed

a. What happens to the amplitude of the waves as their frequency increases?

b. How does the energy of a wave depend on its frequency if the amplitude stays constant? How is your answer supported by your observations of the vibrating string?

7 Resonance

There are no questions to answer in part 7.

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INVESTIGATION 21A

The Properties of Sound

1 What do different frequencies sound like?

Table 1: How we hear frequencies of sound

Description	Frequency (Hz)
Low	
Medium	
High	
Very high	

2 How high can you hear?

There are no questions to answer in part 2.

3 Thinking about what you observed

a. Make a histogram showing your class response to frequencies between 10,000 and 20,000 Hz. You should have 5 bars, one per 2,000 Hz.

b. Do you think the method of counting raised hands is likely to give an accurate result? Give at least one reason you believe the method is either good or bad.

4 The interference of two sound waves

There are no questions to answer in part 4.

5 Thinking about what you observed

a. Read about beats. Using the diagram above, write a few sentences explaining why beats occur and how they are created by the wave properties of sound.

b. If the two frequencies are exactly the same do you hear beats?

c. Would you expect to hear beats from an 800 Hz and a 805 Hz sound played together? Would you expect to hear beats from an 800 Hz and a 845 Hz sound played together? Explain why or why not.

d. What determines the frequency of the beats?

6 Finding a mystery frequency

There are no questions to answer in part 6.

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INVESTIGATION 21B

Wave Properties of Sound

1 Controlling frequency and wavelength

There are no questions to answer in part 1.

2 Thinking about what you observed

a. How is sound created by the kazoo?

b. Why does the frequency change with the length of the straw? Think back to your experiments with the vibrating string.

c. Identify at least three musical instruments that use vibrating air columns or objects of different lengths to make sounds of different frequencies.

3 Complex sounds

There are no questions to answer in part 3.

4 Thinking about what you heard

a. Describe the sound of the four frequencies 264 Hz, 330 Hz, 396 Hz, and 528 Hz when you hear them together.

b. Describe the sound of the four frequencies 264 Hz, 317 Hz, 396 Hz, and 528 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?

5 Musical scales

There are no questions to answer in part 5.

6 Thinking about what you heard

a. What notes have frequencies of 264, 330, and 396 Hz? What is this combination of 3 notes called?

b. What notes have frequencies of 264, 317, and 396 Hz? What is this combination of 3 notes called?

c. What is the relationship between the frequencies of notes with the same name?

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INVESTIGATION 21B

7 Making an instrument

For the last part of the Investigation you will make a musical instrument that plays the scale.

Table 1: Musical chimes

Column 1 Note number	Column 2 Frequency ratio	Column 3 Length of first chime	Column 4 Length ratio	Length of chime for this note (= Col. 3 x Col. 4)
1	1		1.00	
2	9/8		0.94	
3	5/4		0.89	
4	4/3		0.87	
5	3/2		0.82	
6	5/3		0.77	
7	15/8		0.73	
8	2		0.71	

8 Thinking about what you made

a. How were the properties of waves used to design your musical instrument?

b. Do some research and find out how the length ratio is related to the frequency ratio for panpipes.