Name:

13.1 Harmonic Motion

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

1 The pendulum

There are no questions to answer in Part 1.

2 Setting up the pendulum

There are no questions to answer in Part 2.

3 The three pendulum variables

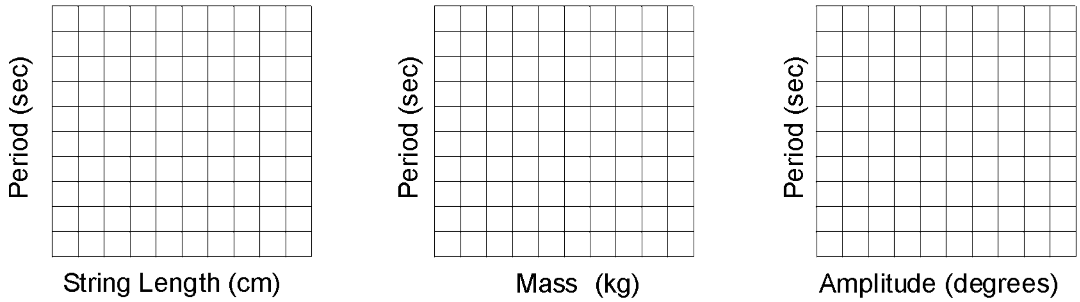
Table 1: Period, amplitude, mass, and length data

Mass (g)	Amplitude (degrees)	String length (cm)	Time from Timer (seconds)	Period of pendulum (seconds)

4 Analyzing the data

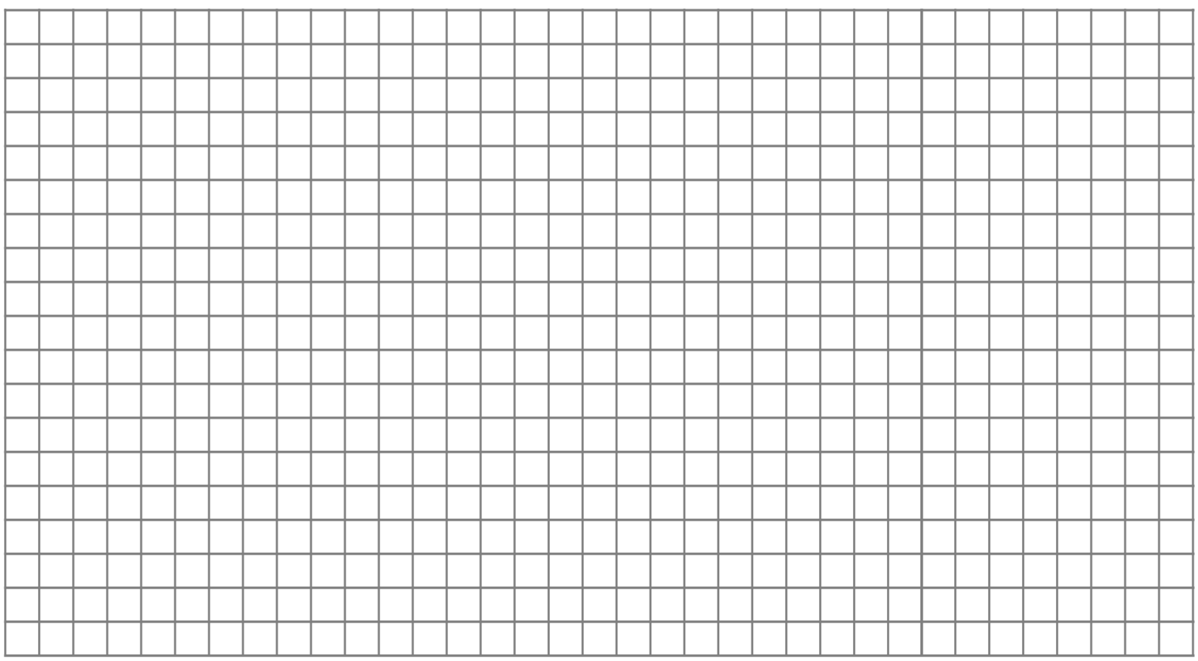
a. Of the three things you can change (length, mass, and angle), which one has the biggest effect on the pendulum, and why? In your answer, you should consider how gravity accelerates objects of different mass.

b. Split up your data so that you can look at the effect of each variable by making a separate graph showing how each one affects the period. To make comparison easier, make sure all the graphs have the same scale on the *y*-axis (period). The graphs should be labeled as shown in the example below:



Title: ____________________

y label: ____________________



x label: ____________________

Title: ______________________________

y label: ______________________________

x label: ______________________________

Title: ______________________________

y label: ______________________________

x label: ______________________________

5 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 Timer set to stopwatch mode.

b. Mark on your graph 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 be heavy?

e. Calculate the percent error in your prediction of time from your pendulum clock.

6 Phase

a. What is the relationship between the lengths of the strings if one pendulum has twice the period of the other?

b. Describe how the phase of the pendulums in step 3 changes over time.

Name:

13.2 Why Things Oscillate

Question: What kinds of systems oscillate?

1 Stable and unstable systems

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 Restoring forces

There are no questions to answer in Part 2.

3 Building an 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 can be safely assembled.

b. Draw a sketch of your system and identify what makes the restoring force.

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

4 The natural frequency

There are no questions to answer in Part 4.

5 Changing the natural frequency

a. Describe and test a way to increase the natural frequency of your oscillator. Increasing the natural frequency makes the oscillator go faster.

b. Describe and test a way to decrease the natural frequency of your oscillator. Decreasing the natural frequency makes the oscillator go slower.

Name:

13.3 Resonance and Energy

Question: What is resonance and why is it important?

1 What is resonance?

There are no questions to answer in Part 1.

2 Creating resonance in a system

There are no questions to answer in Part 2.

3 Reflecting on what you observed

a. Explain how the force applied by the wiggler causes the response of the pendulum. Your answer should make direct reference to your observations and explain why the natural frequency is important.

b. Make a rough sketch of a graph showing amplitude versus period. Your *x*-axis (period) should range from zero to at least twice the natural period. The graph is NOT a straight line or simple curve.

4 Energy and harmonic motion

a. If the *frequency* of an oscillator is increased, what happens to the total energy? Your answer should state whether you think the total energy goes up, goes down, or stays the same. Explain the physical reasoning behind your answer.

b. If the *amplitude* of an oscillator is increased, what happens to the total energy? Your answer should state whether you think the total energy goes up, goes down, or stays the same. Explain the physical reasoning behind your answer.

5 Resonance and energy

There are no questions to answer in Part 5.

Name:

14.1 Waves and Wave Pulses

Question: What is the speed of a wave?

1 The speed of a wave pulse

There are no questions to answer in Part 1.

2 Reflecting on what you observed

a. Describe how the speed of a wave differs from the speed of a moving object such as a car. HINT: What is it that moves in the case of a wave?

b. How did the tension affect the speed of the wave pulse?

3 Measuring the speed of a wave

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)

4 Changing the string tension

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 you think the higher tension makes the waves move faster.

Name:

14.2 Motion and Interaction of Waves

Question: How do waves move and interact with things?

1 Making plane 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 four arrows that show the direction in which each part of the wave moves.

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

3 Diffraction

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 Reflection

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 although you cannot see them. Do any of your observations provide a clue to how 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 and performing calculations:

Name:

14.3 Natural Frequency and Resonance

Question: How do we make and control waves?

1 Setting up the experiment

There are no questions to answer in Part 1.

2 Waves on the vibrating string

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			

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. 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.

4 Frequency and energy

Table 2: Frequency vs. amplitude data

Harmonic #	Frequency (Hz)	Amplitude (cm)

5 Interpreting the data

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

Title: ______________________________________

y label: ____________________

x label: ____________________________

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

c. How does the energy of a wave depend on its frequency? For a given frequency, the amplitude of a wave depends on energy. More energy means larger amplitude. Assume the wiggler supplies the same amount of energy to each wave, independent of frequency. Use your observations of amplitude and frequency to propose a relationship between frequency and energy.

d. Suppose you had two waves of different frequencies but the same amplitude. Which has more energy, the lower-frequency wave or the higher-frequency one?

Name:

15.1 Properties of Sound

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

1 How high can you hear?

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 determine how high a frequency people can hear.

b. Make a histogram showing your class response to frequencies between 10,000 and 20,000 Hz. You should have 10 bars, one per 1,000 Hz. Each student who raises a hand is counted as a positive response on the graph.

c. 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.

3 Doing a more careful experiment

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 people whose choices matched the key all five times at each frequency. It is hard to fake a response (or guess) because you have to choose correctly five times for each frequency. This kind of experiment is called a double-blind test since neither you nor the researcher can see anyone else's response. The results from a double-blind experiment are much more reliable than other forms of surveys. Researchers use the double-blind method to test new medicines.

4 Probability, chance, and experiments

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

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

c. Suppose there were three choices for each question. What is the chance of randomly guessing the right answer for a single question with three choices?

d. You design an experiment to compare three sets of stereo speakers (A, B, and C). The same song plays sequentially on each set of speakers and people pick whether the first, second, or third sounded best. You set up a screen so your listeners cannot see the speakers. To rule out chance, you scramble the order in which you play each speaker and repeat the test three times. You figure if a person picks the same speaker all three times, it really must sound better than the other two. What is the chance that someone could randomly select the same set of speakers three times in a row?

5 Perceiving differences in frequency

Make a data table like Table 3 that is large enough to hold all your results.

Table 3: Comparative frequency data

Frequency A (Hz)	Frequency B (Hz)	Frequency diff. (Hz)	Percent diff.	# of correct responses
1,000	995	5	0.5%	1
1,000	1,050	50	1%	15
1,000	1,001	1	.1%	0

a. Calculate the percent difference in frequency for each test.

b. There are two ways to look at sensitivity. In one way, the ear responds to *absolute* differences in frequency. If the ear was sensitive to absolute differences, you would hear a 5 Hz difference no matter if the two frequencies were 500 and 505 Hz, or 5,000 and 5,005 Hz. The second possibility is that the ear only hears proportional differences. For example, suppose you could hear a proportional difference of 1%. That means you could tell the difference between 500 Hz and 505 Hz because the difference of 5 Hz is 1%. However, you could *not* hear the difference between 5,000 and 5,005 Hz because 5 Hz out of 5,000 Hz is a proportional difference of only 0.1 percent. To hear a 1% difference from 5,000 Hz, the second frequency would have to be 50 Hz higher or lower. Which model does the data support?

Name:

15.2 Sound Waves

Question: Does sound behave like other waves?

1 Beats

There are no questions to answer in Part 1.

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 bought tickets to a concert! Why do we usually not hear interference from stereos even though they have two speakers?

3 Resonance

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, for example, like 429 Hz - 451 Hz.

c. Strike the tuning fork and hold the bottom end against a hard, thin surface such as 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 it touched.

5 Resonance in other systems

Table 2: Resonant frequencies of glasses of water

Trial #	Water height	Frequency (Hz)

Name:

15.3 Sound, Perception, and Music

Question: How is musical sound different from other sound?

1 Chords

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

b. Describe the sound of the three frequencies 264 Hz, 311 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?

2 Consonance and dissonance

a. Give three examples of frequency pairs that are dissonant.

b. Give three examples of frequency pairs that are consonant.

3 The musical scale

a. Find two notes that sound dissonant when played together.

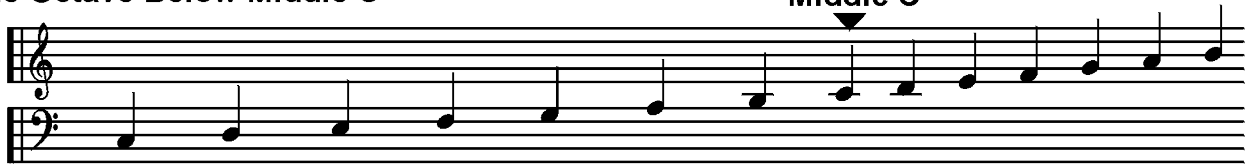
b. Find two notes that sound consonant when played together.

c. Suppose you wish to design a musical chime to play the notes C, E, and G. If the chime that plays the note C is 1 meter long, how long should you make the chimes that play the notes E and G?

4 Octaves

Calculate the missing frequencies for each of the notes below using the rules for the octave.

The Octave Below Middle C **Middle C**



Note	C	D	E	F	G	A	B	C	D	E	F	G	A	B
Frequency								264	297	330	352	396	440	495

5 The interpretation of sound

a. Describe the construction of the human ear. What are the three major components? What part converts the vibration of a sound wave into signals that are carried by the auditory nerve?

b. Research how many different frequencies of sound the human brain and ear can respond to. As a comparison, the eye contains about 120 million photoreceptors that each see a dot of brightness. The brain assembles the individual signals (dots) into a picture. The ear works in a similar way. The brain assembles a sonic "picture" from the signals received on the auditory nerve.

c. Describe how an electronic keyboard or synthesizer is able to sound like many different instruments at the touch of a button.

d. Suppose a 1.2 meter long string vibrates at a frequency of 440 Hz. What length of string would vibrate one octave higher? What length would vibrate one octave lower? Assume the tension in the string is the constant.

e. (Challenge question) The western musical scale has 8 notes: do-re-mi-fa-so-la-ti-do, where the 8th note is an octave above the first. A piano keyboard has 12 keys spanning an octave. Describe why there are five extra keys (the black keys) between one note and the same note one octave higher. Your answer should be a short paragraph.

f. (Challenge question) What sounds “good” to your ear is largely due to the sounds you heard during your childhood years. Different cultures use different musical scales. Some scales emphasize dissonance, others emphasize consonance. Research the musical scale of a different culture and describe the relationships between the notes.