Section: Monday / Tuesday (circle one)

Name: ______________________________

Partners: ______________________________

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PHYSICS 107 LAB #12: PERCUSSION PT 2

Equipment: *function generator, 2 banana wires, PASCO oscillator, vibration bars, tuning fork, tuned & un-tuned marimba bars, LoggerPro, LabPro, & Vernier microphone, make-shift mallet, ruler*

OBJECTIVES

1. Relate a bar's modes to its length and identify whether or not they're harmonically related.
2. Compare "tuned" and "un-tuned" bars.

Overview

The possible vibrational modes of a string are easy to picture: one hump, two humps, three humps…and they're all evenly spaced. Similarly, their frequencies of oscillation are evenly spaced, i.e., members of a harmonic series.

The vibrational modes of a thin bar are qualitatively similar, but the bar's stiffness makes shorter and shorter wavelengths increasingly difficult to support and makes the associated frequencies considerably higher. While a struck or plucked bar may have one or two particularly strong modes, and thus produce identifiable pitches, they are *not* harmonically related, so they are not perceived to be aspects of a single, complex musical sound. When musical instruments do make use of struck bars, those bars are often modified to enhance and approximate harmonically-related modes.

Readings:

Reading: Section 9.4

Bar – clamped at one end

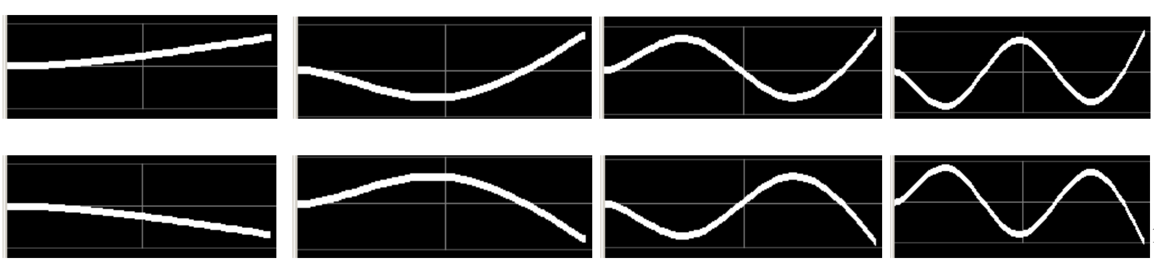
Background

A bar of rectangular cross-section that's anchored at one end and free to move at the other is expected to have its lowest frequency of oscillation be

$$f_1 = \left(0.162a\sqrt{Y/D}\right)\left(\frac{1}{L^2}\right) \qquad (1)$$

where a is the thickness, L is the length, D is the density (mass per volume) and Y is a measure of its stiffness (akin to a spring constant).

The four lowest frequencies are


[1]

$f_1 = \left(0.162a\sqrt{Y/D}\right)\left(\frac{1}{L^2}\right)$, $f_2 \approx 6.27\, f_1$, $f_3 \approx 17.55\, f_1$, and $f_4 \approx 34.39\, f_1$.

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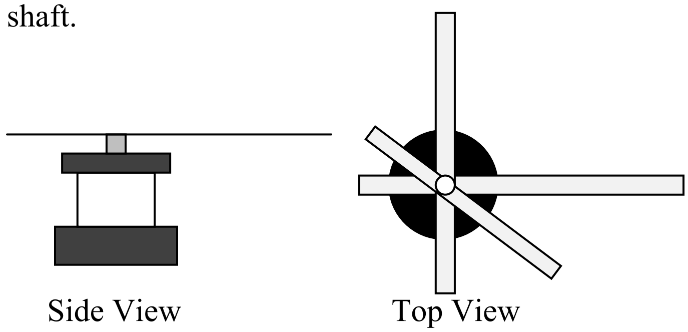
[1] Images from http://www.falstad.com/barwaves/)

Clearly *not* integer multiples of the lowest mode. So the sound of plucking such a bar (as in a simple music box) is rather 'rough.'

Set-up (first three steps should be done for you)

1. Plug a function generator into the PASCO wave driver.
2. With the wave driver's shaft clamped into "Lock" position, plug the resonance strips into the end of the shaft and splay the strips.
3. Un-lock the shaft.



4. You'll observe that there are three metal strips joined by a screw such that there are six spokes of different lengths; you can consider each one of these spokes as an individual bar. Measure each of the six spoke's lengths from the screw to its tip and fill in the first column of the table below and then calculate and fill in the values for the second column (you'll use them shortly).
5. Turn on the Function Generator and set the frequency to 20 Hz and the voltage to around 1 V.
6. Set the function generator so you can adjust the frequency by 0.1 Hz steps.

Experiment

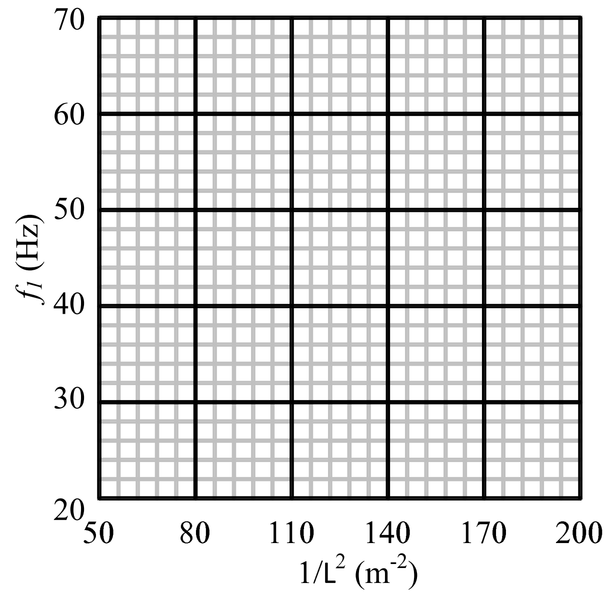
7. Dial up the function generator's frequency until one of the beams begins oscillating strongly, when you've adjusted the frequency as to maximize the oscillation, you're driving the bar at its first mode's frequency, f_1; enter that into the table below. Do the same for each bar.

	L (m)	$1/L^2$ (m^{-2})	f_1 (Hz)	f_2 (Hz)	f_2/f_1
(longest)					
(shortest)					

Note: don't worry about f_2 and f_2/f_1 columns just yet, you'll be asked to come back and fill them in later.

Comparison with theory

8. Equation 1 asserts that the frequency of a bar's first mode is proportional to $1/L^2$. So, if you plot frequency against this, you should get a straight line. Give it a try.



Question: Qualitatively, do they line up fairly well?

9. The frequency of the second mode is predicted to be $f_2 \approx 6.27\, f_1$. To see those, increase the voltage to 2V (you may need even higher for some of them) and continue dialing up the frequency and record in the table on the previous page the frequencies when each bar's second mode is excited (Note, the longest beam's 3rd mode will actually occur before the shortest beam's 2nd mode; that's fine, just keep dialing up.) Then find the ratios of these frequencies for each beam and enter those into the last column of the table.

10. Calculate the average f_2/f_1 ratio that you've measured.

$f_2/f_{1\,\text{average}}$ = ________________

Question: What's the percent difference between the average ratio you've calculate and the predicted ratio of 6.27?

Tuning fork: 2 bars clamped together at one end

Background.
A tuning fork is essentially *two* bars anchored together at one end, so the relationship between the first and second modes (the two you hear most strongly) is roughly the same as for a single bar, $f_2/f_1 \approx 6.27$. The exact shape of their joint can shift this ratio slightly, in fact, if the base is shaped just right, then $f_2/f_1 \approx 6.0$ which is a much more musical relation. You'll see what the ratio is for our tuning forks.

Set-up

1. Plug the Microphone into the Channel 1 plug of the LabPro.
2. Open "Sound Spectrum" from the "Physics Experiments" folder on the desktop.

Experiment

3. Strike the tuning fork and record its waveform and spectrum by pressing "collect" while you hold the fork near it. Note: if the first peak is too small, try again but hold the microphone closer to the tips of the tuning fork; if the second peak is too small, try again but holding the microphone halfway along the fork's length.

Questions: What are the frequencies of the two strongest / lowest-frequency peaks? Note: if you can't see a second one, you may need to zoom out, your instructor can help you.

f_1 = ______________________ Hz

f_2 = ______________________ Hz

What is their ratio?

f2/f1 = ______________________

Is it closer to 6.0 or 6.27?

Looking back at the pictures on page 1, observe that the *tip* of the bar is moved the most due to the low-frequency first mode, while the *middle* of the bar is moved the most due to the higher-frequency second mode.

Questions: So, if you strike the tuning fork and then hold it up to your ear,…

What part of the fork do you want to be lined up with the ear for you to hear the low-frequency first mode best?

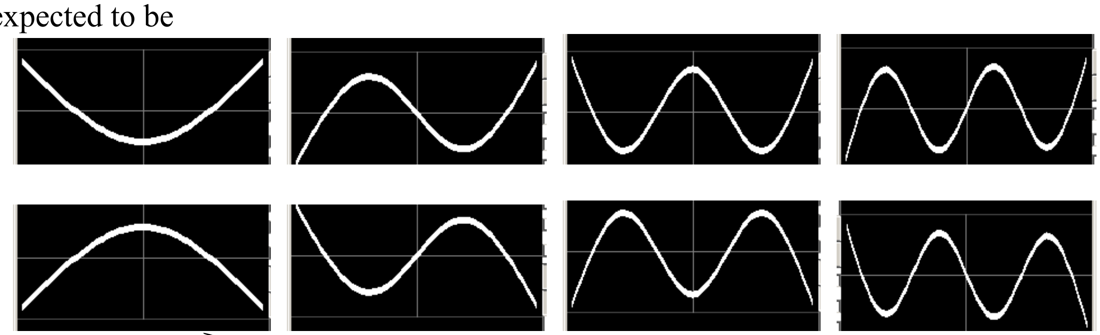
What part of the fork do you want to line up with your ear to hear the high-frequency second mode best?

4. Try it.
   Question: Were you right?

P.S. You don't have to try it, but the same effect would be detectable with the microphone – held near one point of the tuning fork, it would report a stronger low-frequency peak in the spectrum and held near another point it would report a stronger high-frequency peak in the spectrum.

Bar – free at both ends

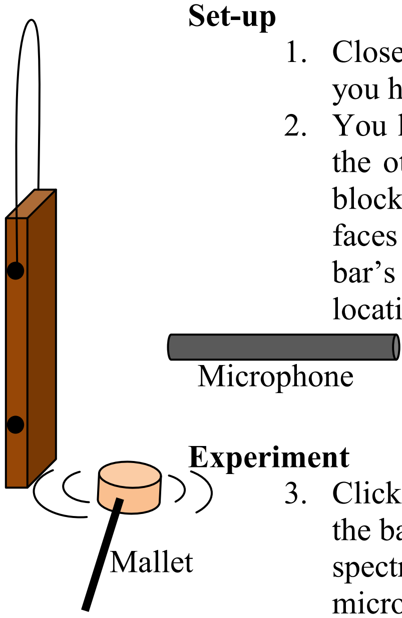
Background
A bar of rectangular cross-section that's free at both ends is the essential element of the idiophone instruments (xylophones and marimbas). The four lowest frequencies are expected to be



$f_1 = 1.028\,(t/L^2)\sqrt{Y/D}$ $\quad f_2 \approx 2.76\, f_1,$ $\quad f_3 \approx 5.40\, f_1,$ and $\quad f_4 \approx 8.93\, f_1.$
The higher frequencies are clearly not integer multiples of f_1, so a struck bar doesn't sound so "musical."

Set-up

1. Close "Sound Spectrum" and open "Sound Spectrum Trigger" instead (after you hit "collect" this waits for a loud sound before it starts taking data.)
2. You have two wooden bars, one has a uniform rectangular cross section and the other has a scoop carved out in the middle, you'll be using the uniform block first – pick it up by the string and let it hang so that the microphone faces the broad side of the bar, is aimed at the middle, and at least half the bar's length away (so it's not too insensitive to modes with a node at its location.)



Experiment

3. Click on "collect" and then strike the plain wooden bar near the bottom end of the bar so you excite all modes. This should record the sound's waveform and spectrum. Note: If you strike the bar just in the middle and position the microphone in the middle, you can suppress the 2nd mode from the recorded

spectrum since it has a node there – it might be fun to see if you can do this, but ultimately, you want both peaks.

Questions: What are the frequencies of the two strongest / lowest-frequency peaks? (Note: depending on how you strike the bar, you sometimes get two peaks quite near each other, if that happens, try again.)

f_1 = ______________________ Hz

f_2 = ______________________ Hz

What is their ratio?

f_2/f_1 = ______________________

Question: What's the percent difference between this and the predicted ratio of 2.76?

The two holes drilled through the bar and the fact that wood is not a perfectly uniform material may be responsible for the discrepancy.

4. Before moving on, under the Experiment menu, select "store latest run"; this will keep your spectrum and wave form so you can compare it against what you get in the next section.

Marimba Bar

Harmonic Modes

To make the bar more "musical", it can be sculpted (thinned through the middle) to make it less stiff in the middle, which is where most of the flexing happens for the first mode; thus the first mode's frequency can be lowered (while other mode's frequencies would also be effected, this would be the most dramatic effect.) A marimba bar is sculpted so that $f_2 \approx 4.0 f_1$, which produces a steadier, and thus more "musical" tone, since f_2 is approximately a harmonic of f_1.

Experiment

5. As you did with the plain bar of wood, strike the marimba bar (the one that's scalloped on the underside) and record its waveform and spectrum using the "Sound Spectrum trigger" program.

Question: What are the frequencies of the two strongest / lowest-frequency peaks?

f_1 = ______________________ Hz

f_2 = ______________________ Hz

What is their ratio?

f_2/f_1 = ______________________

Question: What's the percent difference between this and the desired ratio of 4.0?

6. Striking one and then the other bar, which (the "plain bar" or the "marimba bar") has a more pleasing sound?

Timbre

The book points out that you can change the timbre of an instrument by applying the impetus at different locations since modes with a node at that location will be suppressed and those with anti-nodes there will be strengthened. So, striking at different locations you can change the relative strength of the different modes and thus the timbre of the overall sound produced.

Question: Following that logic, where could you strike the bar in order to suppress the second mode?

7. Try it – As before, us the microphone and LoggerPro to capture the spectrum and see how well you can suppress the second mode / diminish the second prominent peak in the spectrum.

Question: Compared to when you hit the bar near its end, the overall *pitch* should be the same but the timbre should be noticeably different; was the sound's timbre "brighter/colder" or "darker/warmer" when you suppressed the second mode? Thinking of what modes (and frequencies) remained prominent, explain this change in timbre.