Section: Monday / Tuesday (circle one)

Name: ______________________________

Partners: ______________________________

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/ 29 pts

Explore adding synthesis component to Spectrum lab – Audacity has a tremolo effect; may find other effects for varying attack, tremolo, vibrato, and decay

PHYSICS 107 LAB #7: SOUND SPECTRUM

Equipment: LoggerPro, Vernier microphone, function generator, BNC Female – Banana Female adapter, 2 banana cables, speaker, headphones, headphone splitter, loadedstring applet, misc. sound sources: tuning fork, keyboard, organ pipe, cell phone, ...

If you play an instrument, feel free to bring it so you can see its spectrum.

OBJECTIVE

1. Relate a sound, its Pressure vs. Time plot, and its spectrum of frequencies.

Overview

We can easily distinguish the voice of an oboe from that of a violin and that of one person from that of another. Each of these voices can be described by a different combination of pure, sinusoidal tones. We will use a computer to reveal the different pure tones, and their relative strengths, that produce a variety of sounds, i.e., that sound's "spectrum." This is known as Fourier *Analysis*. We'll then use a spectrum to reconstitute a voice from pure tones – Fourier *Synthesis*.

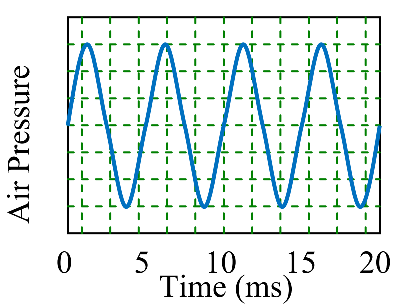
Readings:

Reading: Sections 8.1 & 8.2.

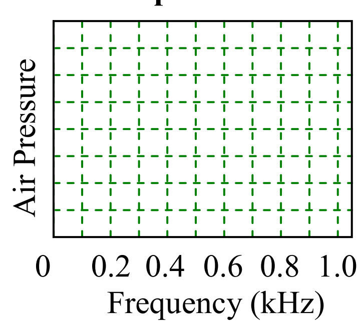
Prelab

Sketch what you'd expect the spectrum of a pure sine wave at 200 Hz to look like.

Wave Form

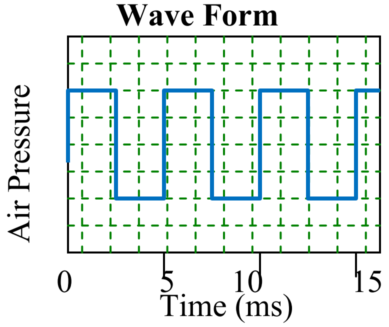


Spectrum

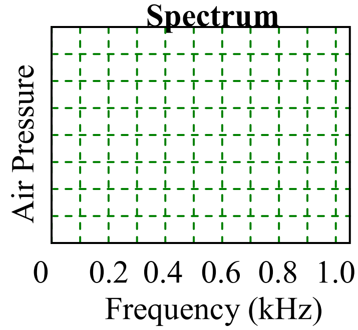


Sketch what you'd expect the spectrum of a square wave with base frequency 200 Hz to look like.

Wave Form

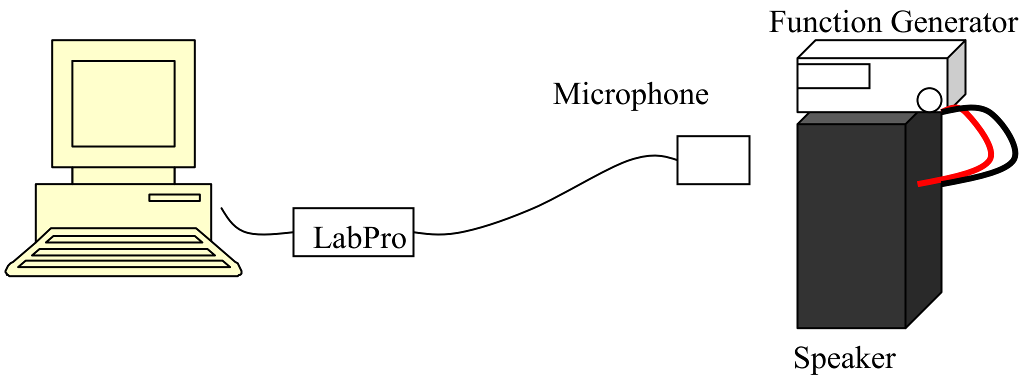


Spectrum



Set-up

This will mostly be done for you, but make sure of that



1. Plug the Microphone into the Channel 1 plug of the LabPro.
2. Connect the Speaker to the function generator's Output with two banana cables.
3. Open "Sound Spectrum" from the "Physics Experiments" folder on the desktop.

Experiment

First you'll see the waveform (upper plot) and spectrum (lower plot) of a single pure tone.

4. Fire up the function generator to produce a 200 Hz sine wave.

   Question: Qualitatively, does the sound the speaker's producing sound "simple" or "complex", "warm" or "bright"?

5. Holding the microphone near the speaker, press the "collect" button in the program.

   Question: In the upper window, which displays the *waveform* (what the sound pressure is doing over time), measure the frequency. You can do that by first finding the period by placing the cursor over one peak and then dragging to the next and reading off the Δt value just below the plot.

   Frequency (from wave form) = ________________ Hz

   Question: According to the *spectrum*, displayed in the lower window, what's the dominant frequency? You can find that by placing the cursor on top of the largest peak in the spectrum plot; the frequency value should be displayed below the plot.

   Frequency (from spectrum) = _______________ Hz

   Hopefully these two measurements are quite similar.

6. How do the waveform and spectrum plots compare with those you'd predicted one the first page?

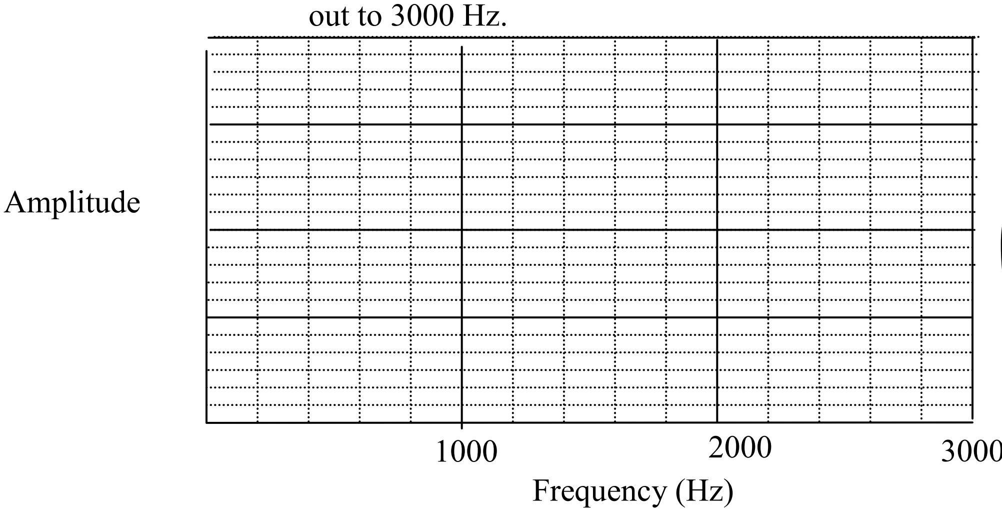
Next, you'll listen to and look at the wave form and spectrum of a 200Hz* square *wave.

7. Switch the function generator over to producing a square wave – to do that, push the "waveform" button, turn the "voltage" knob (it does double duty as the selection dial) to select "square" and then push the "voltage" knob to confirm your selection. Note: this is much louder than the square wave, so you might want to dial down the voltage.

   Question: Is the sound that the speaker's now producing "simple" or "complex", "warm" or "bright" compared with that of the sine wave?

8. With the microphone in front of the speaker, click on the "collect" button in the program. (Once the *waveform* and *spectrum* have been plotted, you can dial the voltage all the way down so you don't have to keep hearing the square wave.) The waveform won't actually look like a square (because the speaker doesn't respond perfectly to the voltage driving it, but the spectrum and sound are quite close to that of a square wave).

9. Sketch the *spectrum*, being careful with the relative peak heights and frequencies out to 3000 Hz.



Spectrum of sound produced by function generator sketched with *solid* line: ———

Spectrum of sound produced by computer synthesis program sketched with a *dashed* line: - - - - -

(Don't worry about this part yet; you'll get to it on page 4)

Question: How does the *spectrum* compare with what you expected (see page 1)? (the *waveform* doesn't look too square, but speaker doesn't produce all frequencies with the right *amplitudes*, but it should be producing the right *frequencies*.)

Synthesize a* square-wave *tone

Set-up

10. Open the Fourier Synthesis applet from the Physics Experiments folder. It should already be set to produce a square wave (if not, click that button at the right).
11. Check the "sound" box to the right, and then adjust the "Playing Frequency" to 200 Hz.

Synthesis

12. Just below the vibrating string is a horizontal row of dots; you can move the dots up and down to control the relative strengths of the corresponding harmonics – for example, moving the first dot twice as high as the 3rd would make the first harmonic twice as strong as the 3rd harmonic. With that in mind, in the applet, roughly reproduce the spectrum that you see in LoggerPro.

13. Hold the microphone up to one of the headphone's speakers and use the other program, LoggerPro, to record the sound you've synthesized in the applet.
14. Compare the relative levels in this new spectrum plot to those of the old one (recorded on page 3); if they don't quite agree, tweak the levels in the Applet and repeat step 14 to get a new spectrum.
15. When satisfied with the match, add that to the plot on the bottom of page 3, using *dashed* lines for the synthesized sound's spectrum peaks.

    Question: How do the *spectrums* synthesized sound and the sound produced by the function generator compare?

    Question: Listening over the headphones, how does its *sound* compare with that of the sound the function generator had produced?

Take the spectrum of someone whistling

The waveform and spectrum should be quite similar to those of a sine wave (aside from being a different frequency) with one notable exception – it's hard hold the pitch and volume perfectly steady while whistling, so on a time scale that's longer than the period the waveform probably wavers. In the spectrum, this long-time-scale wavering shows up as a low-frequency peak and possibly a broadening of the strongest peak in the spectrum.

Question: It's hard not to slowly waver when whistling, in the plot of the waveform, do you see a slow waver (you may need to zoom in and out a little)?

Question: In the spectrum, do you see some low-frequency peaks representing the slow wavering?

Take the spectrum of someone singing a sustained note.

Question: To the ear, singing produces a more 'complex' sound than does whistling; qualitatively, how do the waveform and spectra of the singing compare with that of the whistling?

16. From the *waveform*, measure the fundamental frequency by first finding the period between two (nearly identical) peaks. That's the basic 'pitch' you sang. (To get a more accurate measurement, you can find the time over a few periods and divide that by the number of periods.)

$f_{fundamental}$ (from waveform) = ___________________ Hz

Question: Looking at the *spectrum,* what is the lowest frequency at which there's a tall peak?

$f_{fundamental}$ (from spectrum) = ___________________ Hz

What's the percent difference between the fundamental frequency you measured from the *waveform* and that which the program measured and reported in the *spectrum*?

17. From the wave-form, measure the frequency of one of the harmonics that's present by first finding the time between two consecutive peaks in the waveform (not over one full period, but looking at the ripples *within* a single period.)

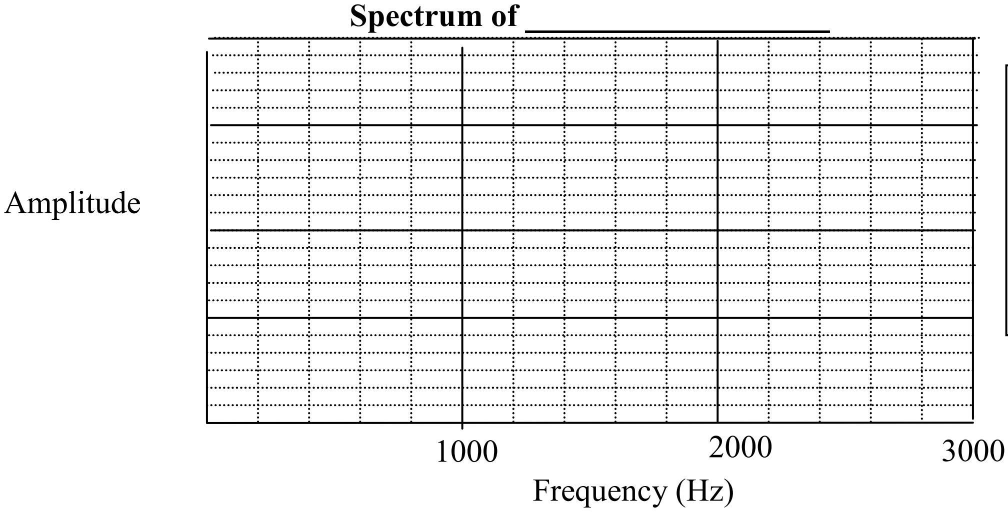
$f_{harmonic}$ (from waveform) = ____________________ Hz

Question: Find a peak on the *spectrum* at a frequency near this (it's hard to eyeball a harmonic's frequency by looking at a waveform, so there probably won't be a perfect match, but something in the neighborhood.) Counting the fundamental as the 1st, what number peak is it?

Enjoy taking the spectrum of some other sound source of your choice – an instrument that one of you brought in or something that I provide.

18. Sketch the spectrum below, and label the plot with the name of what it's a spectrum of (flute, recorder, cheesy keyboard,…)

Spectrum of ____________________



Spectrum of real sound sketched with *solid* line: ——

Spectrum of sound produced by computer synthesis program sketched with a *dashed* line: -----

Question: Qualitatively, relate the complexity of the *sound* you heard to that of the *waveform* and the *spectrum* plotted.

19. Now, use the Fourier Synthesis applet to try to synthesize *this* sound as you did for the square wave (see steps 10 -14 above).

a. Note: a feature of a "square wave" is that it's built of only every-other harmonic: 1^{st}, 3^{rd}, 5^{th},…, so you'd needed to adjust the levels of only ever-other dot in the synthesis program; the sound you've made now may well involve even harmonics too, so you'll likely want to adjust the even number balls as well as the odd.

20. When you've gotten the synthesized sound's spectrum to match the original sound fairly well, add its peaks (with dashed lines) to the plot on page 6.

Question: Listening over the headphones, how does its sound compare with that of the actual instrument (aside from probably not getting the pitch exactly the same)?