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LAB C6: INVESTIGATING SOUND WITH THE COMPUTER AND OSCILLOSCOPE

PRE-LAB READING: Walker, chapter 14 (particularly sections 1-2, 4, 8)
NCSSM Pre-calculus book, section 6.5, 2nd edition
Handout on trig identities and beats from 1st edition precal book may be available

In this lab, you will use a computer with a LabPro blue-green box attached. The microphone should be plugged into Channel 1. Access Logger Pro Version 2.1.1 at *Start Menu* → *Programs* → *Vernier Software*, or look for the Logger Pro icon on the *Desktop*.

If a window comes up asking you to Scan for the LabPro, do the scan.

- 1) When the program opens, first go to *File* → *Close*.
- 2) Then select *File* → *Open* → *Probes and Sensors* → *Microphone* → *Microphone*. This will open one window, a Sound Level vs. Time graph. Make sure that both axes of the graph window are set to auto-scale. (You can get Axis Options by clicking in the middle of the graph window)

To see if the microphone has been recognized by the computer, look under Setup, Sensor; you should see the CH1 icon highlighted with a picture of microphone inside. Also, the Sensor and Calibration windows must both be showing Microphone

IF NOT, your microphone is not being recognized and you must do the following:
Go to File, then Preferences, and on the Folder Locations tab, select Modify for the calibration folder and set the path to
C:\PROGRAM FILES\VERNIER SOFTWARE\LOGGER PRO 2.0\Calibrations\

Next, select Modify for the Experiments folder and set the path to
C:\Program Files\Vernier Software\Logger Pro 2.0\Experiments\Probes & Sensors\Microphone\

- 3) select *Setup* → *Data Collection*. Enter the following settings in their respective locations:

Mode → Real Time Collect
Experiment Length → .1 seconds
Sampling Speed → Drag the square to 50,000 Samples/Second
Averaging → Off
Triggering → Off (not enabled)

The Casio SK-1 keyboard will be used to produce sound. Appendix 1 contains information on the Casio keyboard, including the frequencies of various notes that the Casio produces. A microphone will convert the sound to a voltage that the computer recognizes and plots on the vertical axis as a function of time.

The microphone is directional; it should be pointed toward the Casio speaker. Do not rest the microphone on the Casio speaker; otherwise you pick up vibrations from the Casio box. Avoid sound pollution: your Casio should not be so loud as to be heard by other groups' microphones! If your Casio does not produce a very nice looking sinusoidal wave for the flute, its batteries may be running low; ask for new ones.

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To collect data, click on the Collect button (or press Enter). When you have made a sound level vs. time graph, you can select *Analyze* → *Examine* (or click on the equivalent icon) to be able to read voltage and time values at the location of the cursor.

PART 1: AMPLITUDE AND FREQUENCY OF A PURE TONE (10 minutes)

For this part we need a pure sine wave, i.e., a wave of a single frequency. Produce this on the Casio by choosing the flute sound and then depressing any white or black key. You may notice that the loudness of the sound oscillates slightly; turn this annoying vibration off by depressing the vibrato button once. (Depressing it again turns it back on; it's a toggle switch.) The Casio will continue to produce a flute sound until it is turned off or until another "musical instrument" button is depressed.

If the waveform appears distorted instead of sinusoidal, the volume may be too high or the microphone may be too close to the speaker of the Casio. Another possible problem is that the batteries of the Casio are weak. Weak batteries often produce a tinny sound.

A) AMPLITUDE AND LOUDNESS: For this part, select ***Repeat*** under *Mode* (instead of the ***Real Time*** option); *Experiment Length* should still be **.1 second**. Now depress (and continue to hold down) any black or white key. Click Collect (or press the Enter Key). Vary the volume control on the keyboard. What happens to the wave on the screen? Try another key and again vary the volume control. What conclusions can you draw about the relationship between the loudness of the sound and the amplitude of the wave? Can you increase the amplitude of the wave on the screen in a way other than changing the volume control? How?

B) FREQUENCY AND PITCH: An octave is a particular musical interval between two notes. On a keyboard, there are thirteen keys (eight white ones and 5 black ones) between two notes that are separated by an octave. Play two complete octaves of notes (i.e. 26 successive white and black keys) in sequence, beginning with a low pitch and proceeding up to higher pitches. How does the wave pattern change as the sequence of notes is played? Does the wave shape change from note to note? Does the amplitude change from note to note? [NOTE: amplitude and frequency are, in general, independent. Unfortunately, the Casio manufacturers have produced a keyboard in which the sound does change in amplitude - and therefore loudness - with a change in frequency.]

PART 2: MEASURING THE FREQUENCY OF A PURE TONE (10 - 15 minutes)

For this part, select ***Real Time Collect*** for *Mode*; ***Experiment Length*** should remain .1 sec. You will measure the frequency of a "concert A" note, produced by depressing the key labeled A4 (refer to the labeled keyboard diagram in Appendix 1 to see which key this is). You will determine the frequency by measuring the period of the wave. Continue to use the flute sound in this part. Depress the A4 key to produce a pure tone.

- A) In order to obtain the most accurate measurement of the period, how much of the screen display should you use? Why? You may change the X-axis settings to display a different number of cycles on your screen.
- B) Use the graph to accurately determine the period of the wave. Draw and label a diagram that shows the full screen and the two places on the wave that you used to measure the period.

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- C) Determine the frequency from your result in part B.
- D) Determine the frequency of the A5 note (one octave above A4). Show measurements and calculations in a neat and organized manner.
- E) Determine the frequency of the A3 note (it is one octave below A4). Show measurements and calculations in a neat and organized manner.
- F) What general conclusions can you make about the frequencies of notes that are an octave apart?

PART 3: WAVE ADDITION

- A) In class, we showed how to determine the sum of two waves with frequency 20 and 15. Draw the predicted sum of two sine waves of frequency 18 and 14
- B) Define beat period in words, without referring to a math operation. Be specific and be sure to make mention of amplitude and loudness.

On your sketch of the beat pattern produced by the wave addition in part A, clearly label the beat period (= reciprocal of the beat frequency) and the period associated with the wave average frequency (of the two added waves).
Also numerically evaluate the beat period and the beat frequency for the specific examples in A
- C) You can test whether your answer is correct by using the *Wave Addition* program on the network, under Academic Applications, Physics.
- D) Select Wave Additions from the menu and verify your two predicted graphs. Your screen should look something like:

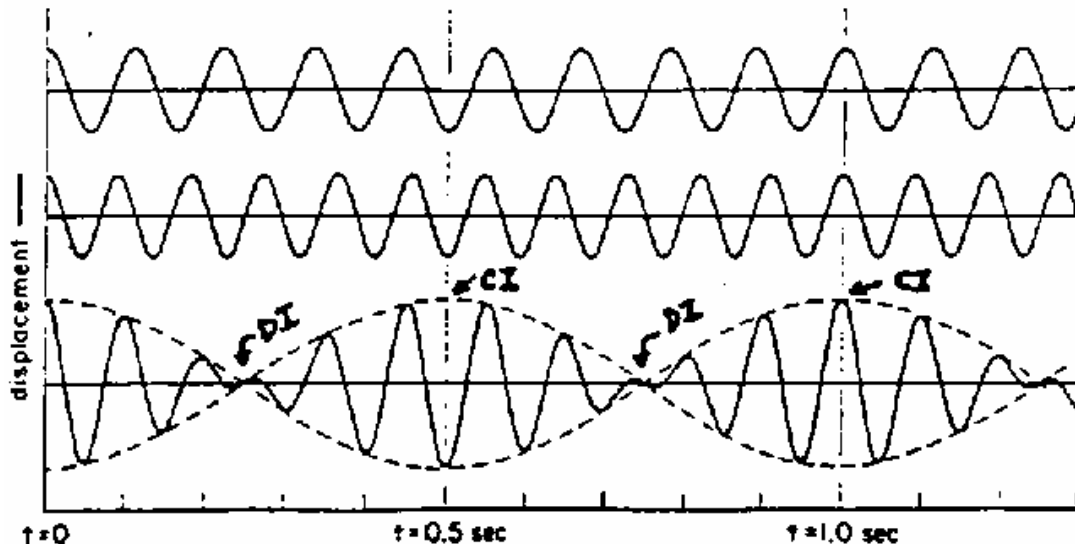


Figure 1: "beats" produced by the addition of two waves of nearly the same frequency

In Figure 1, the addition of a wave of frequency 11 Hz and of a wave of frequency 9 Hz result in a wave of frequency 10 Hz (the average of the two individual frequencies) that peaks in amplitude

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(i.e., constructive interference, CI) with a frequency of 2 Hz. Equivalently, the period of these beats is 0.5 second; note the time scale at the bottom of the figure.

PART 4: MEASURING THE BEAT FREQUENCY (10 - 15 minutes)

Continue to use the flute sound for this portion of the lab. Select the **Real Time** option instead of **Repeating**. Change the number of samples to 33000/second.

- A) Click on the time axis. Select *Manual Scaling* and set the right limit to 0.25 seconds. Depress the F3 and F3-sharp keys simultaneously. The F3# key is the black key to the right of the F3 key.
- B) Measure the beat frequency of the F3/F3# combination using the method introduced in Part 2. Show measurements and calculations in an orderly manner.
- C) Can you measure the beat frequency aurally using your watch or a clock? What result do you get and how does it compare with that in part B?
- D) Calculate the expected beat frequency, using the known frequencies of F3/F3# notes; see Appendix 1. % Difference?
- E) Experimentally determine what happens to the beat frequency if you depress two keys together that are farther apart in frequency (e.g., F3 and G3 or F3 and G3#). Sketch your observations and draw appropriate conclusions.
- F) Experimentally determine what happens to the beat frequency if you depress two adjacent keys that are much higher up the scale. You may need to change the right limit on the time axis. Sketch your observations and draw conclusions.

Part 5: THE EQUAL-TEMPERED SCALE

The purpose of this part is to investigate the mathematical relationship between successive frequencies of the twelve semitones of an octave. When we ask for frequency, report the dominant frequency if there is a clear peak. If not, sketch the frequency spectrum.

Select *File* → *Open* → *Probes & Sensors* → *Microphone* → *fft* in the pop-up window. This will open 2 windows: an oscilloscope and a “frequency spectrum,” which means how much of each pure tone is superimposed to make the sound the microphone “heard.” Note: The “FFT” window will make a frequency spectrum with range of 1/time range to 1/sampling period – so if your *Sampling Speed* is **1000 Samples/second** and your *Experiment Length* is **1 second**, then the FFT will measure frequencies from 1 Hz to 1000 Hz – a good rule of thumb range. Make sure that you turn off *Triggering* Under *Setup* → *Data Collection*

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Note: The FFT Display will pick up background frequencies at 60 Hz as well as 120 Hz (where do these come from ?). By turning up the Volume of the Casio to at least 1/2, you can allow the Casio frequencies to be louder than the background frequencies.

A) Use the flute setting (Turn the vibrato off!) in order to obtain pure tones. Measure the frequencies of the 13 notes from C4 to C5 and record them in a table in your lab book.

Note	Frequency (Hz)	Note	Frequency (Hz)
C (4)		G	
C#		A ^b	
D		A	
E ^b		B ^b	
E		B	
F		C (5)	
F#			

B) Your goal is to find a relationship between the frequency and the number of the semitone. (Hint: consider C4 as 0 and C5 as 12, with the other semitones numbered consecutively.)

The best method of coming up with a relationship is not brute-force plotting and fitting on the calculator. Look at your frequency-vs-semitone data set. Why can you rule in/out a linear relationship without plotting a graph? What other relationship can you rule in/out by considering how consecutive semitone frequencies relate to one other? A hint of this relationship was first provided back in Part 2 wherein you learned about octaves. Check your formula with an instructor or lab assistant.

C) Use your relationship to predict the frequency of a note not measured in your table. Then check your prediction.

D) Using your measurements, calculate the ratios of the frequencies of the following notes. Express each ratio as a fraction of two integers.

E4:C4 _____ F4:C4 _____ G4:C4 _____ C5:C4 _____

What's special about these ratios (mathematically)?

What's special about these tones (musically) when played simultaneously?

Part 6: MEASURING THE SPEED OF SOUND

In this part of the investigation, you will determine the speed of sound in air and in a solid.

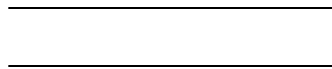
A) Standing waves in open and closed air columns

First, an overview/ review... In two columns in your lab book, draw the standing wave pattern of the fundamental (or first harmonic) for an open tube and a closed tube, and then draw the pattern for the next harmonic up.

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OPEN

CLOSED



In each case, write down the expression, based on your diagram above, for the length of the air column L in terms of the wavelength λ of the standing wave and the harmonic number n . Be sure to indicate what n stands for each kind of tube.

In each case, determine an expression for the frequencies of the standing waves in terms of the velocity of the sound wave (v), the length of the column L , and the harmonic number n .

Use at least one closed and one open tube to determine the speed of sound in air at room temperature. Show all steps and measurements, including symbols first and then numbers.

Examples of OPEN tubes are
Organ pipes or plastic recorders/flutes

examples of CLOSED tubes are
organ pipes or wine/pop bottles

Choose the appropriate software to measure the frequency now that you are experienced with several methods. Record the method used.

Does your tube resonate at the fundamental frequency? How can you tell? Be sure to write down the mode of vibration (i.e., the harmonic number) that actually corresponds to your measurements.

Compare (i.e., % difference) your answers to the expected values. If the answers aren't close to the expected values, you are probably doing something wrong; find out what it is!

B) Standing waves in solid aluminum

Set the time scale set to the smallest time/division possible (but *not* "as fast as possible").

Produce a longitudinal standing wave in a vibrating aluminum rod:

Hold the rod exactly at its midpoint, and either

- 1) Strike one end (NOT the SIDE of the end) with a metal hammer, or
- 2) Ding the end against the floor

You may have to wait for a second or two to let the high harmonics die away. Where should you place the microphone to get the most intense sound signal?

Repeat the procedure in part A (beginning with a diagram) to determine the speed of sound in the aluminum rod. Compare the experimentally determined speed of sound in aluminum with the known value (where will you find this known value?).

Part 7: WHISTLES, VOICES, AND FINGER SNAPS

A) So far we have experimented only with the Casio flute sound, which is equivalent to a pure tone (a tone of single, well-defined frequency) which appears as a perfect or near-perfect sine wave on the oscilloscope. We will now investigate the wave shapes of other simple sounds. Try whistling, singing a note or the whole scale, blowing air over a pop bottle, striking a tuning fork, or snapping your fingers to make a sound. Adjust the time scale as needed. You might also try other instrument options on the Casio (trumpet, organ, etc.).

Which of these sounds is close to a pure tone? Which has the most complicated shape?

B) Another useful feature of the Casio SK-1 is the sampling feature, which allows the user to sample or “save” a sound in the Casio’s memory.

Sampling with the Casio SK-1’s Built-in Microphone

- 1) Press the “sampling” button while in Record mode, just below the built-in microphone in the upper right corner of the keyboard.
- 2) Produce a sound to be sampled near the built-in microphone. Sampling lasts for 1.4 seconds; a sharp metallic click will sound when the sampling operation has ended.
- 3) Press the “reset” button.
- 4) Press the “sample” button (just below the “jazz organ” button).
- 5) Press any of the keyboard keys to hear the sampled sound. (The sound produced will last as long as the original sound, even if the keyboard key remains depressed. To have the original sound continue to be played as long as the key is depressed, press the “loop set” button, and then any of the keyboard keys.)

Try playing the sampled sound with various keyboard keys. Does the wave shape remain the same even though the frequency of the sampled sound changes?

C) Some questions, which test your knowledge of what you have learned:

- 1) After producing a sampled sound of the manner described above and re-playing the sound on several keys, figure out a way to decide which of the keyboard keys produces the same tone as the initial sound. Once you’ve decided, ask the instructor if you are correct. Describe your method.
- 2) Use the sampling feature to determine the minimum time between two successive snaps of your fingers. (You may need to snap your fingers three times: once to start the sampling, the other two times for the measurement. In replaying the sound for the oscilloscope period measurement, remember to use only the key decided upon above.
- 3) Use the same sampled sound to determine the time that a single finger snap lasts.
- 4) Now you should understand what the Casio does to the sound it samples. Call your instructor over so you can explain it orally to him/her.