

Physics 197 Lab 2: Sound Waves and Beats

Equipment:

Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Laptop Computer		1	8	8			
Installed Vernier Software Folder	Logger Pro 3.9	1	8	8			
LabQuest Mini Interface Box	Vernier	1	8	8			
Microphone with interface cord	Vernier	1	8	8			
E (320 Hz) and F (341.3 Hz) Tuning Fork		1 set	8	8 set			
“Unknown” Tuning Fork		1	8	8			
Rubber Stopper on Screwdriver		1	8	8			
Printer with paper		shared	8	shared			

Layouts:

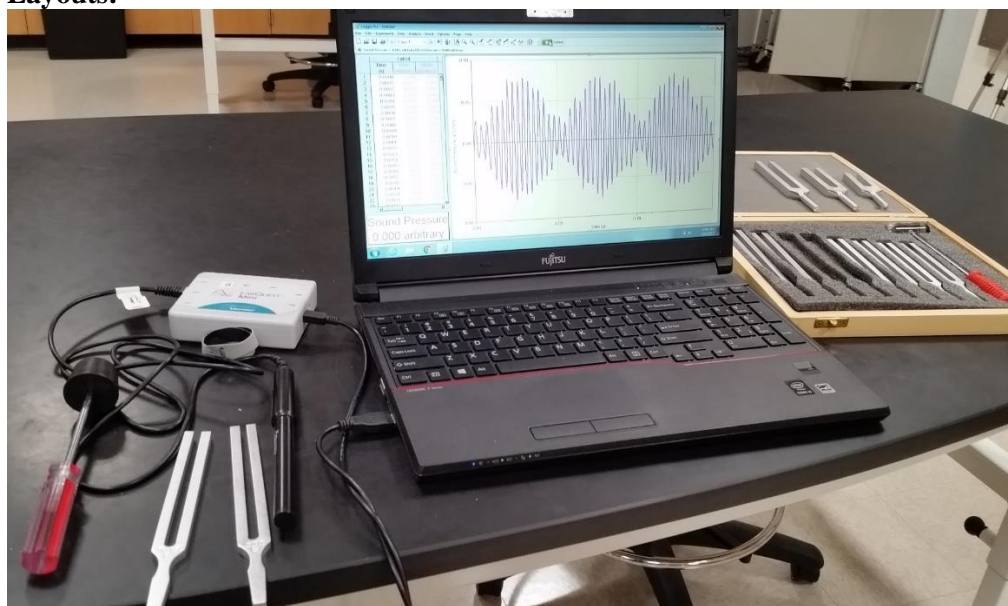


Figure 1: Equipment for Sound Waves and Beats

Summary:

In this lab, students will investigate sound waves by measuring and plotting sound pressure versus time from a microphone held near tuning forks with various resonant frequencies. Sound data will be collected for two tuning forks, one with a pitch of E (320 Hz) and one with a pitch of F (341.3 Hz). Later, both tuning forks will be struck at the same time, and the beat signal will be observed, and compared mathematically to the sum of the two individual signals. Finally, by measuring the pressure versus time of an “unknown” tuning fork, its frequency will be determined.

PreLab:

The sound pressure versus time from the “E” tuning fork should look like a cosine wave with some amplitude and a frequency of 320 Hz. The sound pressure versus time from the “F” tuning fork should look like a cosine wave with some amplitude and a frequency of 341.3 Hz. (If both tuning forks are vibrating simultaneously, there will also be some phase shift between the two signals). In a spreadsheet program such as Excel or a data plotting program, make a plot of what you would expect to observe as the pressure versus time for each tuning fork over a total time duration of 0.15 seconds, assuming they both have the same amplitude (set amplitude = 1 for your calculations). You probably want about 500 data points. Also, make a plot of the mathematical sum of the two amplitudes which should show a beat signal something like what is in Figure 1. Either include printouts of the plots in your notebook, or include fairly accurate sketches of what they look like. How many peaks do you count for the individual tuning forks, and how many peaks do you count for the sum signal? How many peaks are in the “envelope” signal?

Lab 2A: Sound Wave from an “E” Tuning Fork

Connect the microphone to channel 1 of the LabQuest Mini interface, and connect the LabQuest Mini to the computer. Under the Start Command and Programs look for the Vernier Software Folder. Open that and run Logger Pro 3.9. It should come up with an interface of Sound Pressure vs. Time. Click on the *Sound Pressure Bar and Zero the sensor. Now it should be possible to strike the “E” tuning fork on the rubber stopper, hold it near the microphone, and click on the Green Collect arrow to obtain a plot which looks like a cosine wave of the sound pressure from the tuning fork. Use the Autoscale (Letter A in first quadrant of a cartesian coordinate scale) icon to adjust the vertical scale. (I had good results manually setting this scale from -0.1 to 0.1). Use the time scale icon (L in a circle in first quadrant of a cartesian coordinate scale) to change the collection time. Please set this at 0.15 seconds. This will collect a large number of cycles, but that will be useful for the third part of the lab on beats.

With practice, you should be able to obtain a plot which looks like figure 2 below:

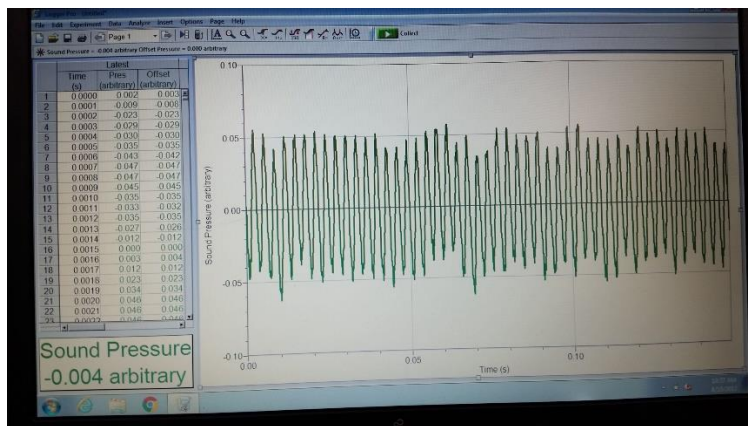


Figure 2: Sound pressure from E tuning fork at 320 Hz.

Make a data table with rows for 5 measurements. Have columns for “Number of Cycles”, “Time Interval (s)”, Period “s”, “Calculated Frequency (Hz)”, and “Amplitude”.

Count the number of full peaks on your plot after the first peak, and put that number in the first column of your table. Click the “Examine” Button, which looks like an x with a sine wave over it, and drag the mouse between the first and last peaks of the waveform. This should give a time interval to put in the second column. Divide this by the number of cycles to get the period (third column) and from this calculate the frequency (fourth column). In a similar manner to how you calculated the time interval (dragging the mouse), measure and record the amplitude (the total delta y divided by 2). Repeat this process 5 times to get 5 sets of data recorded in the 5 rows. Take the average of your frequency measurements, and compare to the stated frequency of 320 Hz. Calculate the Percentage Difference between your measured frequency and the stated frequency.

Save one of your Data Runs by choosing “Store Latest Run” from the Experiment Menu. Make a sketch in your notebook of the run. (The first 10 peaks or so should be sufficient for the sketch). Hide this run by choosing “Hide Data Set” from the Data menu and selecting Run 1 to hide.

Lab 2B: Sound Wave from an “F” Tuning Fork

Repeat the procedures from Lab 2A, this time using an “F” Tuning fork at 341.3 Hz. Make a data table with 5 measurements. It is not necessary to make an additional plot. Make sure to save one of the data sets, which should be stored as Run 2. The later analysis will be best if the amplitude of Run 2 for the “F” tuning fork is similar to the amplitude of Run 1 for the “E” tuning fork.

Lab 2C: Beats between “E” and “F” Tuning Fork

Attempt to strike both the “E” and “F” tuning forks simultaneously and record the sound with the microphone. It should be possible (after many careful tries) to obtain a waveform that looks like the one in figure 3 below:

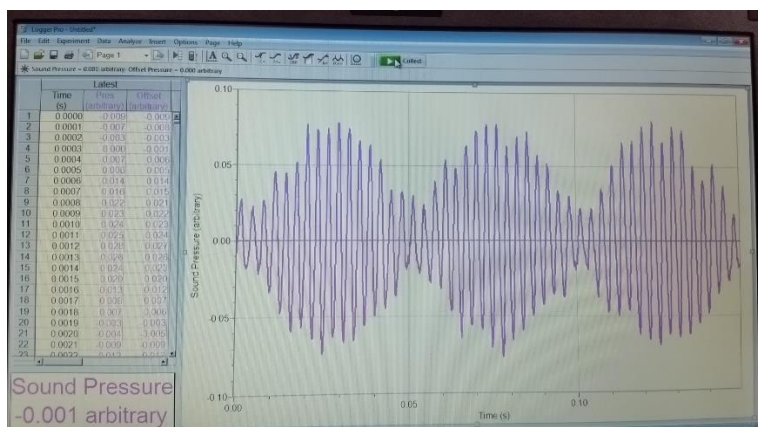


Figure 3: Sound waves from E and F tuning forks together showing beats.

Save your best attempt at showing beats (using Store Latest Run as before). This should be stored as Run 3. Count the number of cycles, and use the Examine button as before to find the total time interval. Divide the total time interval by the number of cycles to get the period of each cycle, and then calculate the high frequency. Compare this to the sum of the “E” and “F” frequencies divided by 2. Similarly, measure the period between minima in the slow envelope variation, and take the inverse of this to calculate the “beat” frequency. Compare this to the difference in the “E” and “F” frequencies. Make a sketch in your notebook of your best beat frequency waveform. You can also print this out and include the printout in your notebook.

Lab 2D: Analysis of waveforms

LoggerPro allows you to make a best fit to your stored waveforms (Run 1, Run 2). Choose “Show Data Set” from the Data Menu and select Run 1 to show the waveform from the “E” tuning fork. Keep the other runs hidden. Click the curve fit button (which looks like $f(x)$ with some waveforms above it) and select Run 1 from the list of columns. Select $A*\sin(B*t+C)+D$ (Sine) from the list of models. Click “Try Fit” to perform the curve fit. Click “OK” to return to the graph. Record the parameters A and B. Since B corresponds to $2\pi f$, you can determine the frequency f from the curve fit. Compare A to the amplitude you measured for this run previously. Compare f to the frequency you measured previously. Repeat this process for Run 2.

As you saw in the prelab, the Beat Frequency is due to the linear sum of the two separate frequency signals. You can sum Run 1 and Run 2 from Logger Pro, and compare this to the actual beat signal measured in Run 3. This sum should look like the signal below (here it is superimposed on Run 3 and there is a phase shift):

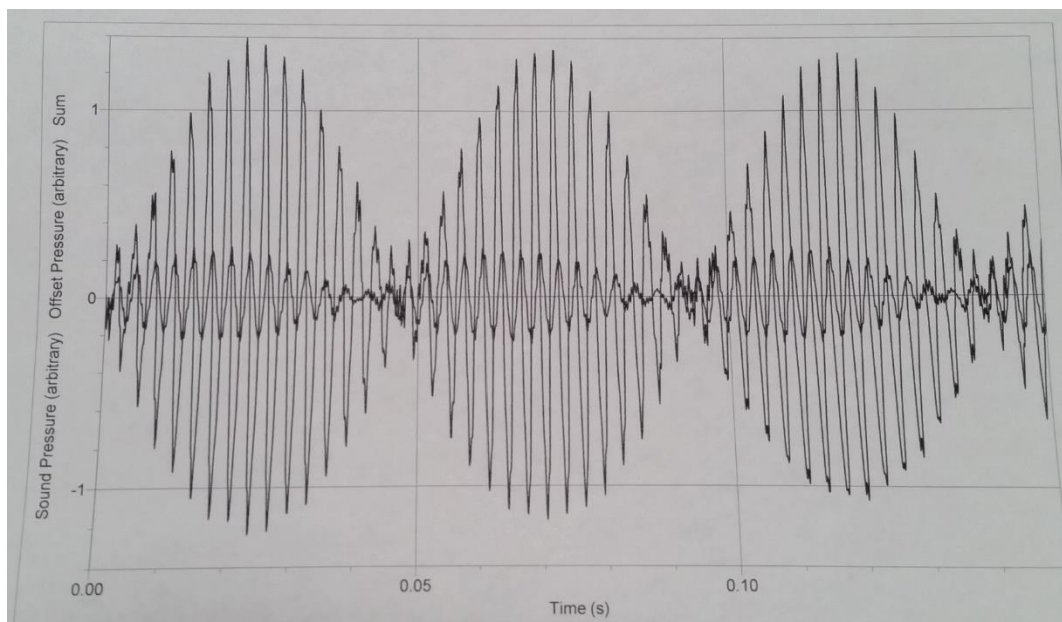


Figure 4: Numerical Sum of signals from E and F tuning forks, compared to beat signal

To perform this sum, do the following:

- Show Run 3 only (the waveform of the actual beats)
- Choose New Calculated Column from the Data menu. Give the column the name “Sum”
- Click once in the equation field to place the cursor there. Choose Run 1: Sound Pressure from the Variables (Choose Specific Column) menu, type the addition symbol “+”, and choose Run2:Sound Pressure from the Variables (Choose Specific Column) menu. The resulting equation will read “Run 1:Sound Pressure”+”Run2:Sound Pressure”.
- Click Done. Click No if Logger Pro asks if you want to select a specific Data Set.
- A new column, representing the sum of the two waveforms, will be created in each Data Set.
- Drag the Sum column header of Run 3 from the data table area to the y axis area to plot the Sum column.
- Click on the y-axis label to show the y-axis selection dialog and uncheck all but the Sum column in Run 3. Click OK. You now see the mathematical sum of Runs 1 and 2. It is hard to see with both plots on the screen at once, so look at one at a time. How is the sum similar to the real data? How are they different? Do the graphs support the model of additive sound wave superposition? Print your combined graph and include it in your notebook.
- Use the trigonometric identity $\sin x + \sin y = 2\sin\left(\frac{x+y}{2}\right)\cos\left(\frac{x-y}{2}\right)$ to explain the observed frequencies in the beat signal. (These are called the sum frequency and difference frequency).

Lab 2E: Unknown Tuning Fork

Using the microphone and analysis of the recorded waveform, determine the frequency of the “Unknown” tuning fork.