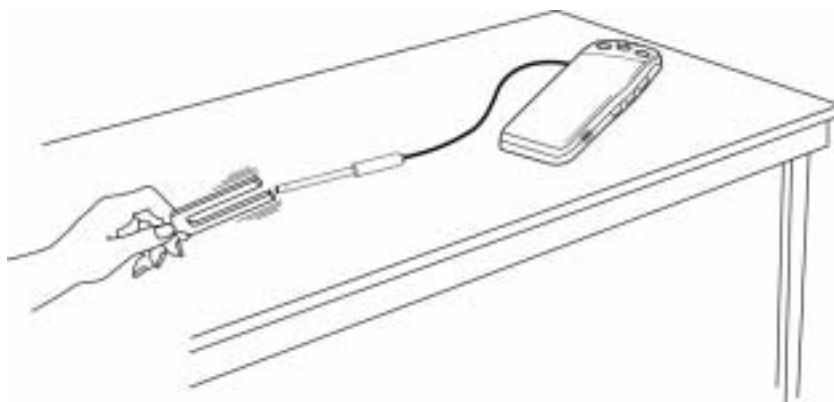


Stay Tuned: Sound Waveform Models

If you throw a rock into a calm pond, the water around the point of entry begins to move up and down, causing ripples to travel outward. If these ripples come across a small floating object such as a leaf, they will cause the leaf to move up and down on the water. Much like waves in water, sound in air is produced by the vibration of an object. These vibrations produce pressure oscillations in the surrounding air which travel outward like the ripples on the pond. When the pressure waves reach the eardrum, they cause it to vibrate. These vibrations are then translated into nerve impulses and interpreted by your brain as sounds.

These pressure waves are what we usually call *sound waves*. Most waves are very complex, but the sound from a tuning fork is a single tone which can be described mathematically using a cosine function $y = A\cos(B(x - C))$. In this activity you will analyze the tone from a tuning fork or keyboard by collecting data with a microphone.



OBJECTIVES

- Record the sound waveform of a tuning fork or keyboard.
- Analyze the waveform to determine frequency, period and amplitude information.
- Model the waveform using trigonometric functions.

MATERIALS



computer
Vernier computer interface
Logger Pro

Vernier Microphone
256 Hz tuning fork or electronic keyboard

PROCEDURE

1. Connect a Vernier Microphone to the Channel 1 input of the interface.
2. Launch Logger Pro and open the file “24 Stay Tuned” in the *Real-World Math with Computers* folder.
3. To center the waveform on zero, you must zero the microphone channel. With the room quiet, click .



Activity 24

- If you are using a keyboard, set it to a flute sound. Use middle C as the note. If you are using a tuning fork, strike it against a soft object such as a rubber mallet or the rubber sole of a shoe. Striking it against a hard object can damage it. If you strike it too hard or too softly, the waveform may be rough. Produce a sound with a tuning fork or keyboard, hold it close to the Microphone and click .
- After data collection ends a graph will appear. Your waveform should resemble a sine function. Check with your instructor if you are not sure if you need to repeat data collection. To repeat, sound your fork or keyboard, and click  again.

DATA TABLE

period (s)	
amplitude A	
angular frequency B	
time offset C	
frequency (measured)	
frequency (marked)	

ANALYSIS

- Click the Examine button, , and use the mouse to trace across the graph. Record on the line below the times for the first and last peaks of the waveform. Record the number of complete cycles that occur between your first measured time and the last. Divide the difference, Δt , by the number of cycles to determine the period of the waveform. Record the period, to three significant figures, in your data table. For example, 0.00230 has three significant figures.
-
- Trace across the graph again, and note the maximum and minimum y values for an adjacent peak and trough. Calculate the amplitude of the wave by taking half of the absolute value of the difference between the maximum and minimum y values. Record the amplitude A , to two significant figures, in your data table.
 - The sinusoidal model has a parameter B that represents the number of cycles the sinusoidal function makes during the natural period of the sine function. Find B by taking 2π (the natural period of the sine function) divided by the period of the waveform (the time for one cycle). Record the value for B in your data table.
 - Since the cosine function starts at a maximum value when its argument is zero, you can use the location of a maximum to determine the value of C , which represents the horizontal shift of the data. Trace across your data to any maximum and read the time (x) value. Record this value as C in your data table.
 - To compare the model to your data, use the manual fit function of *Logger Pro*.
 - Click once on the graph to make it active.
 - Select Curve Fit from the Analyze menu. Choose the Manual Fit Type option.
 - Click the Define Function button.
 - Enter the expression $A*\cos(B*(t-C))$ in the Define Custom Function field. Click .

- e. In the A field enter the amplitude of the waveform.
 - f. In the B field enter the angular frequency.
 - g. In the C field enter the horizontal time offset value.
6. How well does your model equation fit your data? If your fit is acceptable, write the model equation below, and suggest explanations for any discrepancies. If the fit of the model is not acceptable, deduce which of your parameters is producing the problem. Make changes as necessary to the parameters, and discuss why the changes were necessary. Write out the equation that produced a good fit. Click to close the manual fit dialog box.
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7. The frequency of a sound wave is the number of cycles per second. The period is the number of seconds per cycle. Explain the relationship between frequency and period.
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The unit Hertz, or Hz, is equivalent to cycles per second. Calculate the frequency of the tuning fork in Hz and record it in your data table.

8. Most tuning forks are marked with its frequency. Check the tuning for you used and record its frequency in the data table. If you used a keyboard, note that middle C is approximately 263 Hz.
9. The amplitude of a sound wave increases with the loudness of the sound. Explain how you could alter the value of A if you repeated this investigation.
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10. *Pitch* is associated with the frequency of the tuning fork. A higher pitched tone would have a higher frequency. Explain how your graph would change if you used a tuning fork of higher frequency.
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How would the value of the period change if the frequency were higher? Explain your reasoning clearly.

11. How many different values of C are possible in order to match this graph? Explain your reasoning. Find another value of C that will work and record it below. Check this in your equation, and discuss your reasoning.
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12. How would the parameters A , B , and C change if you were to use the sine function $y = A \sin(B(x - C))$ instead of the cosine function? Predict your values below and explain your reasoning for each.
-

Activity 24

13. Test your predictions by changing your model equation to a sine function and entering appropriate values for the three parameters using the same method you used above. How well does your sine model fit the data? Explain any discrepancies.

EXTENSION

Logger *Pro* can automatically fit a sine function to your waveform data. The format of the Logger *Pro*'s fit is a little different than the one you used: $y = A \sin(Bx + C)$. You will need to work out the translation for the new usage of the parameter C .

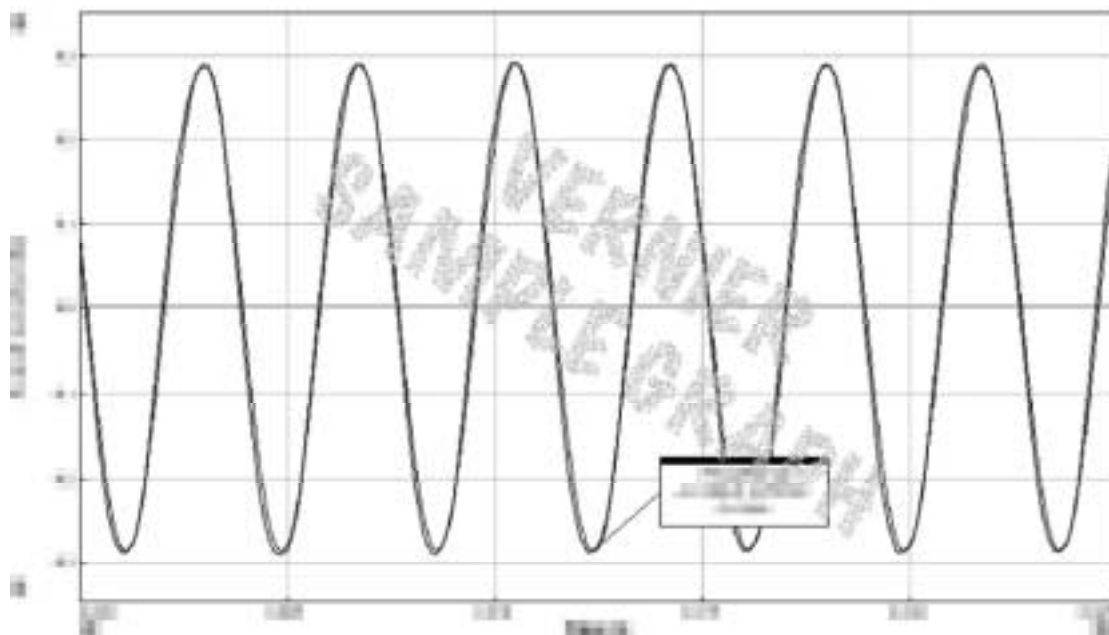
Use Logger *Pro* to fit a sine curve to the waveform data. How do the fit parameters compare to those of your model?

TEACHER INFORMATION

Stay Tuned: Sound Waveform Models

1. An inexpensive electronic keyboard produces a cleaner and louder waveform than does a tuning fork, so the keyboard is the preferred sound source. The flute setting will give a sine waveform. Turn off any vibrato to obtain clear frequency measurements. Middle C will produce a frequency of about 263 Hz, appropriate for this exercise.
2. If you use a tuning fork, one with a relatively low frequency works best. Use tuning forks with frequencies between 256 and 300 Hz. Use a rubber mallet (or the sole of a rubber shoe) to strike the tuning fork to obtain a clean sinusoidal curve. If the fork is struck on a hard surface there will be overtones, which will yield a rough waveform. Note that the fork must be loud enough to hear. If you can't hear the fork over the room noise, neither can the microphone.
3. You may want to introduce the term *sinusoidal curve* to your students as a curve that has an equation of the form $y = A\cos(B(x - C))$. Many books use the form $y = A\cos(Bx + C)$. Written the latter way the parameter C is an angular offset, while in the first form C is a time offset. The time offset is easily determined from the graph, so the first form is used in the activity. The latter form is more difficult for most students to understand, but could be used if you prefer it.
4. Data collection is very brief; the fork or keyboard must be sounding when the button is clicked.

SAMPLE RESULTS



DATA TABLE

period (s)	xxxx
amplitude A	xxxx
angular frequency B	xxxx
time offset C	xxxx
frequency (measured)	xxxx
frequency (marked)	xxxx

ANSWERS TO ANALYSIS QUESTIONS

Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.