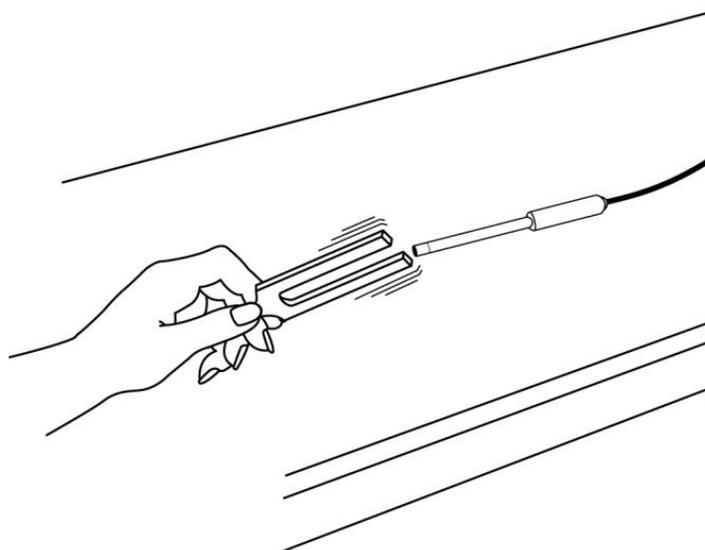


## Stay Tuned: Sound Waveform Models

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 that 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 by collecting data with a microphone.



### OBJECTIVES

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

### MATERIALS

TI-Nspire handheld **or**  
computer and TI-Nspire software  
data-collection interface

Vernier Microphone  
tuning fork or electronic keyboard

## PROCEDURE

1. Ensure that the TI-Nspire software is set to perform angle calculations in radians.
2. Connect the Microphone to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.
3. Choose New Experiment from the  Experiment menu to set up DataQuest for data collection. For this experiment, the default data-collection parameters for a Microphone will be used (Rate: 10000 samples per second; Duration: 0.03 seconds). The number of points collected should be 301.
4. To center the waveform on zero, you need to zero the microphone channel. With the room quiet, choose Set Up Sensors ► Zero.
5. 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. **Caution:** 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 start data collection (.

6. After data collection ends, a graph will appear. The waveform should resemble a sine function. Check with your instructor if you are not sure if you need to repeat data collection. If you need to repeat data collection, repeat Step 5.

## DATA TABLE

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

## ANALYSIS

1. Click any data point and use ► and ◀ to examine the data pairs on the displayed 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,  $\Delta t$ , by the number of cycles to determine the period of the waveform. Record the period in your data table.
2. 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,  $A$ , 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 cosine function. Find  $B$  by taking  $2\pi$  (the natural period of the cosine 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.
  - Choose Model from the  $\mathcal{A}$  Analyze menu.
  - Enter  $A*\cos(B*(x-C))$  as the equation for your model. Select OK.
  - Enter the amplitude of the waveform as the value for  $A$ .
  - Enter the angular frequency as the value for  $B$ .
  - Enter the horizontal time offset value as the value for  $C$ .
  - Select OK to view the model displayed on the graph and answer Analysis Questions 1 and 2.
- Most tuning forks are marked with its frequency. Check the tuning fork you used and record its frequency in the data table. If you used a keyboard, note that middle  $C$  is approximately 263 Hz.

Answer Analysis Questions 3–7.

## ANALYSIS QUESTIONS

- How well does your model equation fit the data? If your fit is acceptable, record the model equation, and suggest explanations for any discrepancies. If the fit of the model is not acceptable, deduce which of the parameters is producing the problem. Make changes as necessary to the parameters, and discuss why the changes were necessary. Record the equation that produced a good fit.
- 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.

The unit hertz, or Hz, is equivalent to cycles per second. Calculate the frequency of the sound wave in Hz and record it in the data table.
- 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.
- 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.

How would the value of the period change if the frequency were higher? Explain your reasoning clearly.

## DataQuest 23

---

5. 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. Check this in the equation, and discuss your reasoning.

6. 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 the values and explain your reasoning for each.
7. Test your predictions by storing any changed values in the three parameters  $A$ ,  $B$ , and  $C$  using the same method you used earlier. Also change the model equation to a sine function using the method you used earlier. Redisplay the graph to compare your data and sine model. How well does your sine model fit the data? Explain any discrepancies.

## EXTENSION

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

Fit a sine curve to the waveform data. How do the fit parameters compare to those of your model?

- First, clean up the graph by removing the model that you created earlier. To do this, choose Remove Model from the  $\mathcal{A}$  Analyze menu.
- Choose Curve Fit ► Sinusoidal from the  $\mathcal{A}$  Analyze menu.
- Use the parameters a, b, c, and d to write down the fitted equation.
- Select OK to see the graph.