TEACHER INFORMATION

Experiment
32

Sound Waves and Beats

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. This experiment cannot be done with Easy or Go! Products since data collection rates are greater than 200 samples/second. The microphone requires sample rates around 10,000 samples per second. You must use a multi-channel sensor interface for this experiment.

3. In the first part of this lab, the students are investigating pure tones, such as those produced by a tuning fork. It is important to use quality tuning forks with large tines. These tuning forks produce a relatively loud signal. Tuning forks with frequencies from 256 Hz to 512 Hz are recommended. When using tuning forks, they have to be struck by a soft object such a rubber mallet, rubber sole, or the fleshy part of the hand. When struck with hard objects, the tuning forks produce overtones. It is also important to hold the tuning fork close to the Microphone.

4. When doing a sinusoidal curve fit on the data from a single sound source, the results may not match the data as expected. To get a better match of the data, adjust the region used for the curve fit by moving the brackets ([or]) to make the region smaller. See *Appendix B* or *C*.

5. An electronic keyboard also works well, but it needs to be set to a voice which produces as nearly a sine wave as possible. On some keyboards, this is the "flute" sound. Disable any vibrato effects, since they work by varying the frequency of the tone.

6. Since an important part of this lab is observing beats, it is important to make a good choice of frequencies. A good combination for tuning forks is C at 256 Hz and D at 288 Hz. On the keyboard you can use B and G. The difference between the notes should be at least 40 Hz.

7. Collecting a beat pattern with tuning forks is difficult to do. Try to strike each of them equally hard and hold them equidistant from the Microphone.

8. The TI-Nspire must be in radian mode for this experiment.

   For Handhelds: To verify the mode, hover the cursor over the battery indicator. To change the setting, press [⌂on] then select Settings ► Settings ► General.

   For Computers: To verify the mode, hover the cursor over Settings label along the bottom of the screen. To change the setting select Settings ►Document Settings from the File menu.

9. You may want to have your students model the data instead of doing a sinusoidal regression.

   a. Choose Model from the Analyze menu.
   b. Enter the equation, a*sin(2π*b*(x – c)) + d.
   c. Enter your estimate for the amplitude as your value for **a**.
   d. Enter your the frequency of your sound source as your value for **b**.
   e. Initially use zero for **c** and **d**.
   f. Select OK.
   g. Adjust the values in your model to obtain a good match.

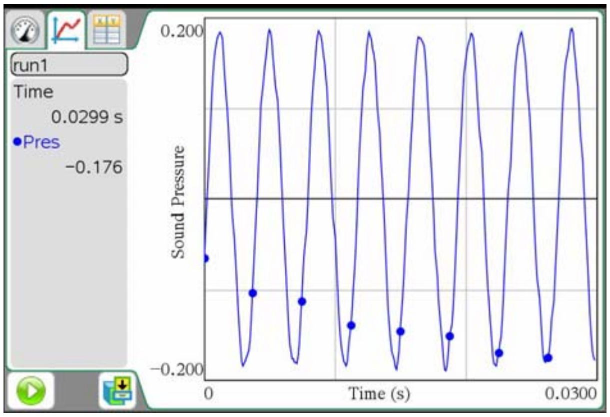
ANSWERS TO PRE-LAB QUESTIONS

1. If they are not tuned, the sound is unpleasant. If the tuning is particularly bad, beats may be heard.

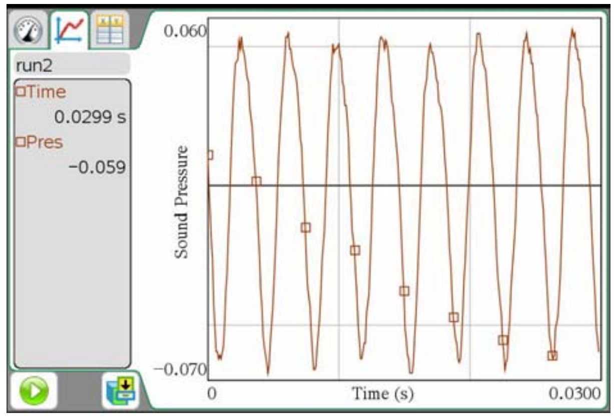
2. If a pressure increase and a pressure decrease from two different waves were to occur in the same location, the net effect would be a small pressure change or no pressure change.

SAMPLE RESULTS

Part I Simple Waveforms



Frequency of 256 (C) Hz



Frequency of 288 (C) Hz

Table 1

Tuning fork or note	Number of cycles	First maximum (s)	Last maximum (s)	Δt (s)	Period (s)	Calculated frequency (Hz)
C – 256 Hz	7	0.0012	.0281	0.0269	0.00384	260
D – 288 Hz	7	0.0026	0.0278	0.0252	0.0036	278

Table 2

Tuning fork or note	Peak	Trough	Amplitude
C – 256 Hz	0.184	–0.183	0.184
D – 288 Hz	0.053	–0.067	0.060

Table 3

Tuning fork or note	Parameter **a**	Parameter **b** (s^{-1})	Parameter **c**	Parameter **d**	Calculated frequency (Hz)
C – 256 Hz	.183	1637	–0.375	0.001	261
D – 288 Hz	0.057	1731	3.137	0	276

Part II Beats

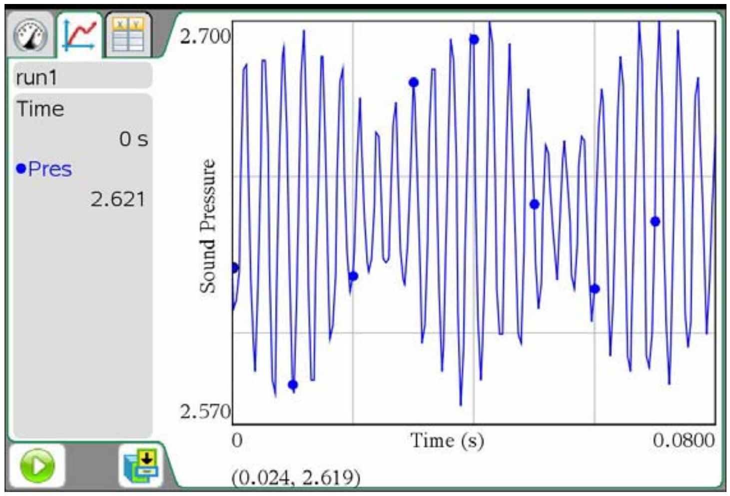


Table 4					
Number of cycles	First maximum (s)	Last maximum (s)	Δt (s)	Period (s)	Calculated frequency (Hz)
2	0.010	0.071	0.061	0.0305	32.8

ANSWERS TO QUESTIONS

1. The model should match the data. Often there are variations in the amplitude of the collected data while the curve fit will not show any variation. The frequency should be a close match.

2. The frequency determined by the curve fit takes into account all the data, while the peak-counting method uses only select parts of the data. As a result, the curve fit frequency should be more accurate.

3. The percent error for the note C-256 from the sample data is $\frac{|261-256|}{256}\times 100 = 2.0\%$.

   The percent error for the note D-288 is $\frac{|276-288|}{288}\times 100 = 4.2\%$.

4. These values should be close. The amplitude determined by the curve fit takes into account all the data, while the adjacent crest and trough method uses only select parts of the data. As a result, the curve fit amplitude should be more accurate.

5. The beat frequency is equal to the difference in frequency of the two individual tones. The expected value for the sample data is 32 Hz. The experimental value was 32.8 Hz.