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Animal Acoustics: Analyzing Sound Waves in Physics and Biology

Experiments

Mapping the Ocean Floor

- Go Direct® Motion Detector

Tones, Vowels, and Telephones

- Go Direct Sound Sensor

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Mapping the Ocean Floor

Oceanographers, marine geologists, and archeologists use echo sounders to investigate objects below the surfaces of bodies of water. An echo sounder incorporates a transducer that sends out and receives sound waves. A signal is sent out and bounces back from a submerged surface (see Figure 1). Scientists use the speed of sound in water and the time it takes for the signal to bounce back to calculate the depth of the object. The deeper the object, the longer it takes for the sound to return. A map of the ocean floor is made by sending out a series of "pings" in a grid pattern and recording the depths. Echo sounders use different frequencies to map different things on the ocean floor.

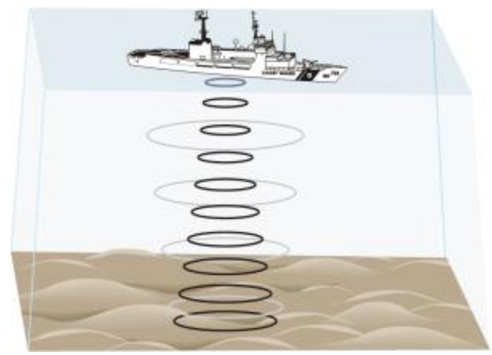

Figure 1

Sonar, which is short for **so**und **na**vigation **r**anging, is the name given to this echo sounding system. It was invented during World War I to detect submarines. In this activity, you will map objects on a simulated ocean floor using a motion detector that works very similarly to the sonar systems used to detect submarines.

OBJECTIVES

- Use a motion detector to measure distances.
- Map simulated ocean floors.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Motion Detector
1 m board or meter stick
masking tape or rubber bands
2 or more boxes

PRE-LAB QUESTIONS

1. What else can you think of that measures distance by sending out a sound signal?

2. What factors make it difficult to study the ocean floor directly?

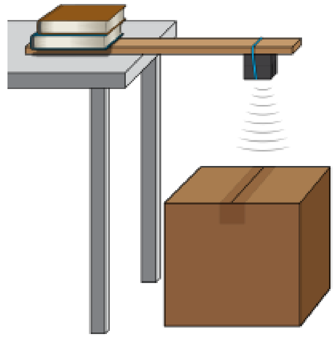

Figure 2

PROCEDURE

Part I Ocean Floor 1

1. Prepare the motion detector for data collection.
    a. Get the board that will act as the support for your motion detector.
    b. Securely attach the motion detector to one end of the board with tape or rubber bands. Make sure that the round screen of the motion detector is not covered.
    c. Place the board flat on the table, with the motion detector pointing downward (see Figure 2).
2. Prepare the ocean floor for data collection.
    a. Place the box on the floor underneath the motion detector. **Note**: The motion detector must be at least 0.2 m from the top of the box.
    b. Line up the motion detector so that when it is moved along the table edge it will pass over the box.
3. Launch Graphical Analysis. Connect the Go Direct Motion Detector to your Chromebook, computer, or mobile device.
4. Set up the data-collection mode.
    a. Click or tap Mode to open Data Collection Settings.
    b. Change Rate to 10 samples/s and End Collection to 15 s.
    c. Click or tap Done.
    d. Click or tap the Position meter and choose Reverse.
5. Zero the sensor and collect data.
    a. Move the board to position the motion detector to the left of the box.
    b. To zero the motion detector, click or tap the Position meter and choose Zero.

   c. When everything is ready, click or tap Collect to start data collection. Then, slowly slide the board across the tabletop so that the motion detector passes over and past the box.

6. Determine and record the height of the box.

   a. Identify and select the flat portion of the graph that represents the box.
   b. Click or tap Graph Tools, , and choose View Statistics.
   c. Record the mean (average) height of the box in meters in your data table.
   d. Dismiss the Statistics box.

7. Print or sketch your graph.

Part II Ocean Floor 2

8. Set up two boxes in the shape of steps to create a second simulated ocean floor. The tallest box must be at least 0.2 m from the motion detector.

9. Repeat Steps 5–7.

Part III Hidden Ocean Floor

10. Your teacher will have a hidden ocean floor for you to measure. Repeat Steps 5–7 for the concealed object or objects.

PROCESSING THE DATA

1. How did the shape of your graph compare to the actual object(s) in each case? Explain.

2. What was the most interesting result? What made it interesting?

3. What factors might affect the accuracy of real ocean-floor mapping?

DATA

Part 1 Data

	Box height (m)
Ocean floor 1 single box	

Sketch of Ocean Floor 1

Part II Data

	Box height (m)
Ocean floor 2 box 1	
Ocean floor 2 box 2	

Sketch of Ocean Floor 2

Part III Data

	Box height (m)
Hidden ocean floor box 1	
Hidden ocean floor box 2	
Hidden ocean floor box 3 (if detected)	

Sketch of Ocean Floor 3

EXTENSIONS

1. Try other hidden ocean floor arrangements.
2. Research the sonar process and compare it to what you did in this activity.

Tones, Vowels, and Telephones

In this experiment, you will use a Go Direct Sound Sensor to analyze various sounds. The data-collection program will display the waveform of each sound, and is used to perform a Fast Fourier Transform (or FFT) of the waveform. The FFT tells you the amplitudes and frequencies of a collection of sine waves that, when added together, would sound the same as the original waveform.

In the first part of the experiment, you will study the sound of a tuning fork, which produces a tone composed mainly of a single frequency. Next, you will observe the production of *overtones* on a tuning fork. Overtones whose frequencies are multiples of the fundamental are called harmonic; other overtones are called inharmonic. You will also analyze the sound produced when you say two vowels.

In the last part of the experiment, you will be given a problem to solve. How does the telephone company know which numbers are input on a land line?

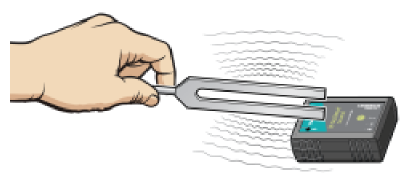

Figure 1

OBJECTIVES

- Use a Go Direct Sound Sensor to analyze the frequency components of a tuning fork and your voice.
- Record overtones produced with a tuning fork.
- Investigate how a land line phone works.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis Pro
Go Direct Sound
2 tuning forks (one ~256 Hz)
touch-tone sound source

PRELIMINARY QUESTIONS

1. Strike one of the tuning forks with a rubber mallet or the bottom of a rubber-soled shoe. Do not hit the tuning fork on a hard surface; doing so may damage the tuning fork. Listen to the sound. Now play a touch tone from the touch-tone sound source. Which sound do you think is more complex? Explain your answer.

2. Compared to the tuning fork and the touch tones, is the sound of a person humming a simple or a complex sound?

3. Try playing different touch tones. Can you observe any order to the tones? Does the pitch get higher or lower for larger numbers, or does it seem to be random?

4. How do you think the phone company recognizes the numbers that are input from a touch tone land line phone?

PROCEDURE

Part I Pure Tone

1. Launch Graphical Analysis app.

2. Connect the Go Direct Sound Sensor to your Chromebook, computer, or mobile device.

3. Click or tap Mode to open Data Collection Settings. Change End Collection to 0.2 s, then click or tap Done.

4. Gently strike a tuning fork with a rubber mallet and hold it near the sensor. Click or tap Collect to start data collection. If you strike the fork too hard, it will create overtones, a blend of higher frequencies in addition to the main frequency.

5. Export, print, or make a sketch of your graph.

6. Click or tap the graph to examine the data. Scan across your data to determine the average time interval between adjacent peaks, or one complete cycle. Record this value in your data table. **Note**: You can also adjust the Examine line by dragging the line.

7. Calculate the frequency and record it in the data table.

8. Determine the predominant frequency using the FFT.

   a. Click or tap Zoom to All Data, .
   b. Click or tap Graph Options, , and select Apply FFT.
   c. Click or tap the FFT graph to examine the data; the frequency values are displayed in the meter.
   d. Record the predominant frequency in the data table.
   e. Click or tap Close FFT.

9. Repeat Steps 4–8 with the second tuning fork.

Part II Overtones on a Tuning Fork

10. In this step, you will make the 256 Hz tuning fork produce an overtone. This time, strike the tuning fork on your knuckle and listen to the sound. Describe the difference.

11. Repeat Step 4 to set up the graph.

12. Strike the tuning fork on your knuckle and hold it near the sensor. Click or tap Collect to start data collection.

13. Determine the fundamental and first overtone frequencies using the FFT.

    a. Click or tap Zoom to All Data, .

    b. Click or tap Graph Options, , and select Apply FFT. Notice there are at least two peaks on the graph.

    c. Click or tap the FFT graph to examine the data; the frequency values are displayed at the bottom of the Examine line.

    d. Record the predominant frequency of the leftmost frequency peak, which represents the frequency of the fundamental.

    e. Record the predominant frequency of the second peak, which represents the frequency of the first overtone.

    f. If there are any additional frequency peaks, record the predominant frequency of those as well.

    g. Click or tap Close FFT.

14. Compare the waveform and the FFT to the ones produced in Part I. Discuss the similarities and differences with your classmates.

Part III FFT of Two Vowels

15. Hold the sensor near your mouth, say the vowel “e” and sustain the sound while you click or tap Collect.

16. Follow the method described in Step 9 for generating the FFT.

17. Export, print, or make a sketch of your FFT graph.

18. Repeat Steps 15–17 for the vowel “o”.

Part IV FFT of Telephone Tones

19. In this part of the experiment, you will analyze the sound made by a touch-tone sound source. Hold the speaker of the sound source near the Microphone, play the touch tone corresponding to number “1,” then click or tap Collect to start data collection. Using the FFT display, follow the approach described in Step 12 to record the two predominant frequencies for this sound.

20. Repeat Step 18 for numbers “2” through “9”.

DATA TABLE

Part I Pure Tone

	Tuning fork 1	Tuning fork 2
Frequency stamped on tuning fork (Hz)		
Period from waveform (s)		
Frequency from waveform (Hz)		
Frequency from FFT graph (Hz)		

Part II Overtones on a Tuning Fork

Frequency stamped on tuning fork (Hz)	
Fundamental frequency (Hz)	
First overtone frequency (Hz)	
Second overtone frequency (optional)	
Third overtone frequency (optional)	

Part IV Touch-tone Frequencies

Number	1	2	3
Low frequency (Hz)			
High frequency (Hz)			
Number	4	5	6
Low frequency (Hz)			
High frequency (Hz)			
Number	7	8	9
Low frequency (Hz)			
High frequency (Hz)			

ANALYSIS

1. For each tuning fork, compare the frequency calculated from the waveform and the FFT to the value stamped on the tuning fork.
2. Describe the difference in the frequency structure between the two vowels examined in Part III.
3. Examine the data for the touch tones. What pattern do you observe?
4. Which frequency is higher, the row frequency or the column frequency?
5. What is the row frequency for numbers 4, 5, and 6?
6. What is the column frequency for numbers 2, 5, and 8?
7. Summarize how the telephone company decodes what numbers are dialed from the touch tones.

EXTENSIONS

1. Use Go Direct Sound to examine the waveforms of notes from some musical instruments. Which instruments produce the purest tones? Is a C note on one instrument the same frequency as a *C* note on another? Does the waveform shape change as the loudness of the sound changes? Does the waveform shape change as the frequency of the sound changes?

2. If an electronic keyboard is available, use Go Direct Sound or reference material to determine which keys or musical notes are closest to the frequencies that make up your telephone number. Write the music for your phone number. If no one in the lab group can read music, seek help from a music student or music teacher. Play your phone number on the keyboard.

3. Extend your analysis of vowel sounds to the remaining three (a, i, u). Try to develop a means of producing the different vowels with combinations of overtones. This is the basis for making artificial voices sound real.

4. Extend your investigation to singers in your school choir. Have them make vowel sounds while trying for different sounds. Note the differences that a single singer can make and investigate how they go about making these differences.

5. Extend your investigation of touch tones to include the bottom row: *, 0, and #. Does the row pattern seen earlier apply here too?