NUMB3RS Activity: Seeing in the Dark
Episode: "Guns and Roses"

Topic: Using sound waves to measure distance **Grade Level:** 7 - 10

Objective: Use CBR™ 2 technology to recreate an "acoustic fingerprint"

Time: 15 minutes

Materials: TI-84+ graphing Calculator, CBR™ 2

Introduction

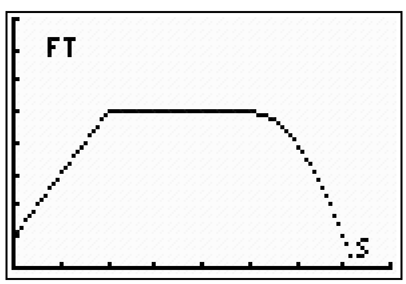
When an ATF officer apparently commits suicide in her house, the sound of the gunshot was recorded from multiple sources, creating an "acoustic fingerprint" of the room and its contents. Charlie recreates this acoustic fingerprint, and by understanding how bats "see" using sonar, he is able to determine that something is missing from the room.

This activity uses the Texas Instruments CBR™ 2 device to simulate a bat's sonar, and will show how Charlie was able to determine that something was missing from the room.

Discuss with Students

Bats and other members of the animal kingdom are not the only ones to use sonar technology. It is also widely used in military ships and submarines. The basic premise is to measure the time required for a sound wave to be sent to an object and be reflected back (like the bat in Charlie's explanation).

In the activity, students will be asked to interpret distance vs. time graphs and to find piece-wise equations to model the graph. They will be expected to find both linear and quadratic functions to fit the data. If you think that your students need more direction before beginning the activity, use the graph to answer the following questions:



1. Describe how a person could walk back and forth in front of a CBR™ 2 device to produce the graph.
2. Find a piece-wise equation to model the curve.
3. Explain why a piece-wise equation is needed to model the data.

For this activity, make sure the Vernier EasyData™ App is installed on students' calculators. It can be downloaded for free from the Web site below:

http://education.ti.com/educationportal/sites/US/productDetail/us_easydata_83_84.html

This activity can also be used with the CBR and the Ranger program. The directions are similar to those for this activity.

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Discuss with Student Answers:

1. Start 1 foot away from the device and walk away from it at a steady rate of 2 feet per second for 2 seconds. Stop for 3 seconds. Move toward the device at an increasing rate.

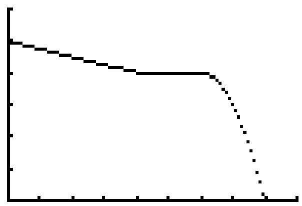
2. $$f(x)=\begin{cases} 2x+1 & 0\le x\le 2 \\ 5 & 2\le x\le 5 \\ -(x-5)^2+5 & 5\le x\le 7.23 \end{cases}$$

3. An equation is needed to model each different movement, and the model only applies over a restricted domain.

Student Page Answers:

1b.
$$f(x)=\begin{cases} x & 0\le x\le 3 \\ 3 & 3\le x\le 5 \\ (x-5)^2+3 & 5\le x\le 8 \end{cases}$$

2a. Sample graph:



2c. Sample function:

$$f(x)=\begin{cases} -0.25x+5 & 0\le x\le 4 \\ 4 & 4\le x\le 6 \\ -(x-6)^2+4 & 6\le x\le 9 \end{cases}$$

3a. A person was standing 8 meters away from the CBR™ 2 and started walking toward it at a steady rate of 2 m/sec for 3 seconds. Then, the person stood still for 4 seconds, and walked away from the motion detector at an increasing rate of speed for 2 seconds.

3c. $$f(x)=\begin{cases} -x+4 & 0\le x\le 3 \\ 1 & 3\le x\le 6 \\ (x-6)^2+1 & 6\le x\le 8 \end{cases}$$

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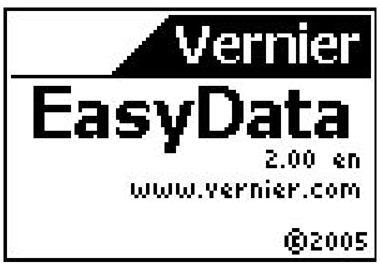
Name: ________________________________ Date: _______________

NUMB3RS Activity: Seeing in the Dark

When an ATF officer apparently commits suicide in her house, the sound of the gunshot was recorded from multiple sources, creating an “acoustic fingerprint” of the room and its contents. Charlie recreates this acoustic fingerprint, and by understanding how bats “see” using sonar, he is able to determine that something is missing from the room.

The CBR™ 2 used in this activity works in the same way as a bat’s sonar. The CBR™ 2 sends out a sound wave and records how long it takes for it to travel to an object and bounce back. Because sound travels at a constant rate, the distance to the object can be computed by using the formula Distance = Velocity × Time ($d = vt$). Because the sound wave bounces back, the distance to the object is half the total distance the wave travels. The calculator program performs the calculation and reports the actual distance from the device.

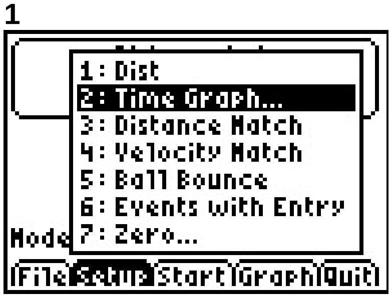
Setting up the CBR™ 2
Turn on the TI-84+ graphing calculator. Attach the USB cable to the CBR™ 2 and to the calculator. The calculator will automatically launch the EasyData App your teacher has installed, and the following two screens will appear.



The CBR™ 2 emits a clicking noise and numbers are displayed on the calculator. The “clicks” are the sound waves being sent out (much like a bat’s.) The numbers displayed are the distances the object is from the CBR™ 2, and are given in meters. Try measuring a few distances and compare them with measurements made using a meter stick. (To stop the CBR™ 2 from “clicking,” press the TRIGGER button on front of the device.)

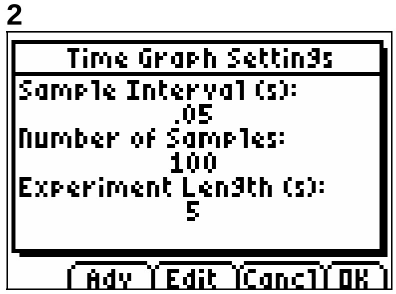
Now that the CBR™ 2 is set up, you will now see how Charlie determined that something was missing from the room.

1



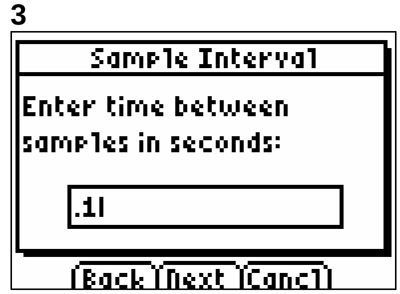
Choose **Setup** by pressing WINDOW and selecting **Time Graph...**

2



These are the default settings for the CBR™ 2. To change them, choose **Edit** by pressing ZOOM.

3



Change the value to 0.1. This makes the CBR™ 2 emit sound waves every 0.1 seconds. Choose **Next** by pressing ZOOM.

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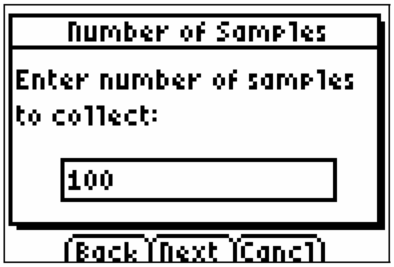
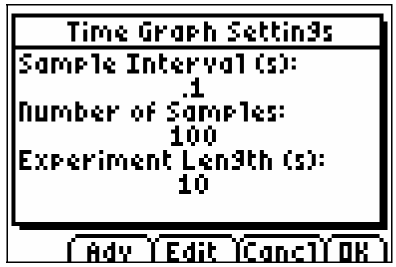
4



Make sure the number of samples is 100. This makes the CBR™ 2 emit 100 sound waves. Choose **Next** by pressing ZOOM.

5

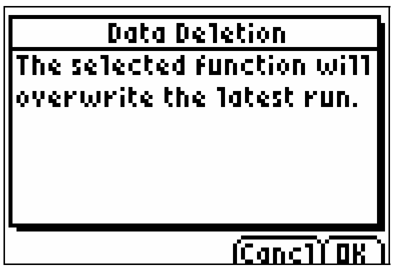


Your screen should look like this. Note that the experiment will last 10 seconds. Choose **OK** by pressing GRAPH.

6

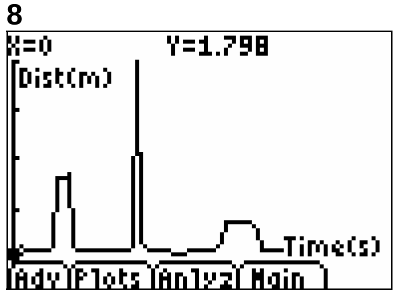
Before continuing, position yourself with the calculator and CBR™ 2 in the corner of the room. Have three people stand in an arced pattern 6 feet away from you. Hold the CBR™ 2 level, facing the person on the end.

7



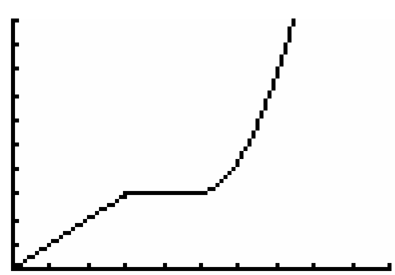
Choose **Start** by pressing ZOOM. You may get the message shown. If you do, choose **OK** by pressing GRAPH. Once the key is pressed, hold the CBR™ 2 at a constant height and sweep the CBR™ 2 in an arc at a constant speed that covers the area where the individuals are standing.

8



This is an example of the "acoustic fingerprint" of the three people (they are the peaks). To find their distance, use the arrow keys. Have one of the individuals leave, choose **Main** by pressing TRACE, and then choose **Start** by pressing ZOOM. Notice that this results in a different "acoustic fingerprint," indicating that someone is missing. Charlie notices the same thing and concludes that it is the shooter.

1. Suppose Charlie analyzes an acoustic fingerprint from one recording source and obtains the graph at the right. In the graph, time is measured in seconds and distance measured in decimeters.



a. Arrange objects on your desk so that when the CBR™ 2 is held at a constant height and moved horizontally across the desk at a constant speed you match this "acoustic fingerprint." Use your CBR™ 2 to check the results.

b. Describe this fingerprint as a piecewise function.

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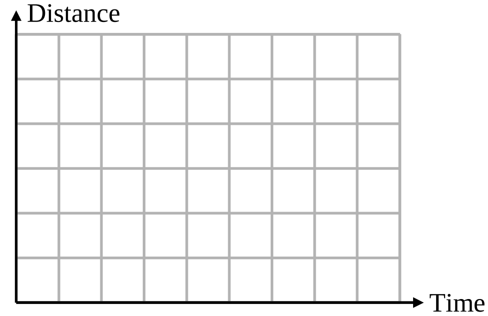
2. Suppose a person stands 5 meters away from the CBR™ 2 and starts walking toward it at a steady rate of 0.25 m/sec. for 4 seconds. The person then stands still for 2 seconds, and then walks toward the CBR™ 2 at an accelerating rate for 3 seconds.

a. Draw a sketch of an acoustic fingerprint that would match this walk.

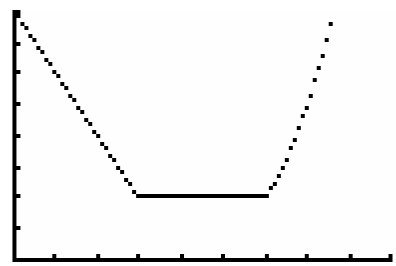
b. Try doing this walk using a CBR™ 2 and see how it matches your sketch.

c. Find a piecewise function to match the walk.



3. Look at the graph to the right:

a. Describe how a person could walk in front of a CBR™ 2 to match the graph shown. Assume that the horizontal axis measures time in seconds and the vertical axis measures distances in increments of 0.5 meters.



b. Try doing this using a CBR™ 2 and see how it matches the graph shown.

c. Find a piecewise function to match the walk.

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The goal of this activity is to give your students a short and simple snapshot into a very extensive math topic. TI and NCTM encourage you and your students to learn more about this topic using the extensions provided below and through your own independent research

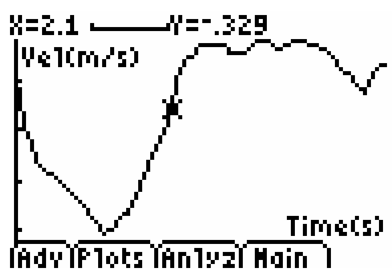
Extensions

Activity: Using the CBR™ 2 to Measure Velocity and Acceleration

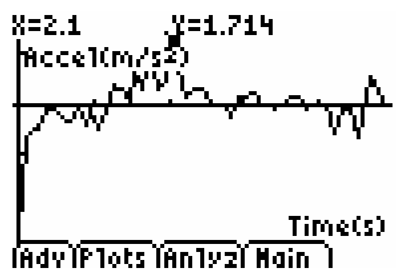
Introduction

The CBR™ 2 not only measures distance; it can also be used to measure speed and acceleration.

Set up your CBR™ 2 to **Time Graph** (under **Setup** in the **Main** window.) Choose **Start** and have someone walk toward you at varying speeds. Once the CBR™ 2 has gathered and displayed the data, choose **Plots** to view the velocity graph or the acceleration graph. The arrow keys allow you to find the exact velocity or acceleration at a specific time.



Velocity Graph



Acceleration graph

For the Student

- You can use the CBR™ 2 to measure the speed and acceleration of a track athlete. You can experiment to find which athlete on your school's track team has the fastest velocity, and which is able to keep his or her acceleration positive during a 100 m race.

- This activity shows how the CBR™ 2 can be used to map an unknown terrain, such as the ocean floor or a jungle.

  http://education.ti.com/educationportal/activityexchange/activity_detail.do?activityid=2615&cid=us

Additional Resources

For more activities using CBR™ 2 technology, visit the Texas Instruments activity exchange at **http://education.ti.com/exchange** and search for CBR.

Related Topic

For more on the mathematics of bat sonar, see the *NUMB3RS* Activity "Bat Sonar" which can be downloaded for free from the Web site below.

http://www.cbs.com/primetime/numb3rs/ti/activities/Act2_BatSonar_GunsandRoses_final.pdf

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