Decay of Sound Intensity with Distance Activity

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Teacher Notes

Objectives of Activity

The objectives of this activity are:

- To provide students with an opportunity to use a variety of measurement devices to collect data.
- To have students develop visual representations of the data they collect.
- To have students use their data to find the model that best fits their data. This includes using residual plots to determine if their model is a good fit.
- To show students how to use their model to predict values.
- To give students practice working with technology.

This activity addresses the following Michigan state standards and benchmarks:

- Math.I.1.HS.3 - Study and employ mathematical models of patterns to make inferences, predictions and decisions.
- Math.I.2.HS.2 - Develop a mathematical concept of function and recognize that functions display characteristic patterns of change (e.g., linear, quadratic, exponential).
- Math.I.2.HS.5 - Differentiate and analyze classes of functions including linear, power, quadratic, exponential, circular, and trigonometric functions, and realize that many different situations can be modeled by a particular type of function.
- Math.I.2.HS.6 - Increase their use of functions and mathematical models to solve problems in context.
- Math.II.3.HS.6 - Apply measurement to describe the real world and to solve problems.
- Math.III.1.HS.1 - Collect and explore data through observation, measurement, surveys, sampling techniques and simulations.
- Math.III.3.HS.5 - Employ investigations, mathematical models, and simulations to make inferences and predictions to answer questions and solve problems.

Curricular Placement

This activity can be used in a unit on functions and families of function as well as in a unit on curve fitting and modeling. By applying different regressions to their data, students become familiar with the various families of functions, including exponential, power and natural log functions. To use the activity in a unit on modeling, students develop residual plots for the various types of regressions. From the shape of the residual plots, students determine which model best fits their data, and then use that model to make predictions. In either unit, students need to be familiar with constructing regressions and residual plots before beginning the activity.

Equipment

To conduct this activity, you will need the following equipment/materials:

1. Sound level meter measuring in decibels (we used the Sound Level Meter SLM-BTA from Vernier)

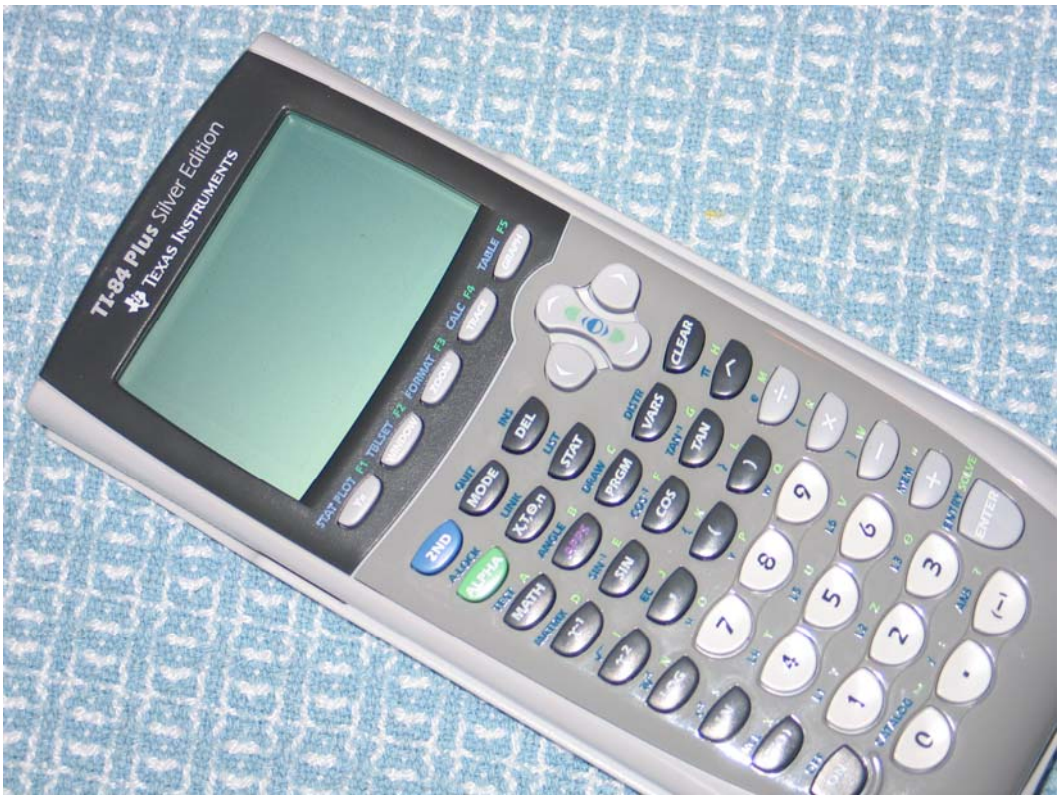
2. A sound generating device (we used computer speakers and a sound

generating program, Visual Analyzer 8 (available on-line at http://www.sillanumsoft.com) generating white noise. A battery-operated buzzer from Radio Shack could also be used).

3. Student Data Sheets

4. Meter Sticks

5. A classroom set of TI-84 Plus or TI-84 Plus Silver calculators. Each student will need their own calculator.



6. A set of Texas Instruments CBL2's. Each group of students will need one CBL2.

Set-up

- Arrange students in groups of 3 to 4 students. Each group of students will take turns using the sound level meter and sound generating device to collect data.
- Lay a meter stick flat on top of a desk, table, or the floor.
- Set the sound generating device at the "0" end of the meter stick with sound being directed down the length of the meter stick.
- If you are using speakers, you will need to lay the sound level meter on a prop that will place the collecting end of the sound level meter at the center of the speaker. The prop will help students maintain the elevation of the meter during each measurement. If a battery-operated buzzer is being used, this will not be necessary. The sensing end of the sound level meter should be pointed toward the source of the sound.

Procedure

Connecting the Equipment and Taking Measurements

1. To collect data, the sound level meter must be connected to the CBL2 and the CBL2 must be connected to the TI-84 Plus calculator. Plug the cable that came with the sound level meter into the meter. Plug the other end into the port labeled ~CH1 on the CBL2.

2. Use the short cable with the CBL2 to connect the CBL2 to the calculator.

3. Check the calculator to see that it has the DataMate program. To do this, push the "APPS" button and scroll down to "DataMate".

4. If you do not have "DataMate", set the calculator to receive the program from the CBL2 by pushing the blue "2nd" button, and then the "link" key. Push the right arrow and then "Enter". On the CBL2, push the "Transfer" button. This will transfer the DataMate program to your calculator.

5. To collect data, follow the instructions on the "Student Instructions for the CBL2 and DataMate" sheet.

Establishing the Background Noise Level

1. The purpose of the background noise level is to establish the ambient conditions that testing will take place in. This measurement will help account for the noise in the room that is beyond the teacher's (or the student's) control.

2. Each group of students should collect their own background noise level data before they start collecting the intensity vs. distance data.

3. Background noise level measurements need to be taken when the sound level in the room is about the same as it will be when intensity vs. distance measurements are taken. For example, if background noise data is collected when the room ventilation system is running, intensity vs. distance data must also be collected while the room ventilation system is running.

4. It is important that noise levels in the room be controlled so that the sound generated by the sound generating device is at least 10 decibels louder than the background noise level.

5. Before collecting the background noise data, be sure that the sound level meter is set to collect with a "C" or flat weighting and a slow response. The decibel range should be set on 50 – 100.

6. Following the instructions on the "Student Instructions for the CBL2 and DataMate" sheet, set the CBL2 to collect 22 samples at 0.25 second intervals. The CBL2 will collect 22 data points. Each data point represents an ordered pair of the following format (time in seconds, intensity in decibels).

7. To view this data, push the "STAT" key and then "ENTER". The data in L1 represents the number of seconds while the data in L2 represents the decibel reading at that time.

8. Because the CBL2 beeps at the beginning of data collection and this beep shows up as higher intensity sound, we need to delete the first two ordered pairs. It is important that the first two entries in <u>both</u> columns be deleted. Using the arrow keys, move the highlighted box to the first entry in L1. Push the "DEL" key. Move the highlighted box to the right and push the "DEL" key. Repeat this procedure for the second ordered pair of numbers.

9. We now need to evaluate the variability in the background noise level measurement. To do this we need to take the standard deviation of the intensity measurements in L2. To do this, push the "STAT" key, then the right arrow until the word "CALC" is highlighted. We want to run a 1-variable statistical analysis on the data in L2. Push "ENTER" then "2^{ND}" then the number 2. Push "ENTER"

10. If the standard deviation of the data in L2 is greater than 3 dB, you will need to reduce the amount of variability of the noise in the room and return to step 5.

11. If the standard deviation is less than 3 dB, record the mean value. This will be used for the background noise level.

<u>Taking measurements</u>

1. Have students take measurements at a minimum of six distances from the sound generating device with at least three of those measurements being less than 1m from the source. All data points should be less than 3m from the source.

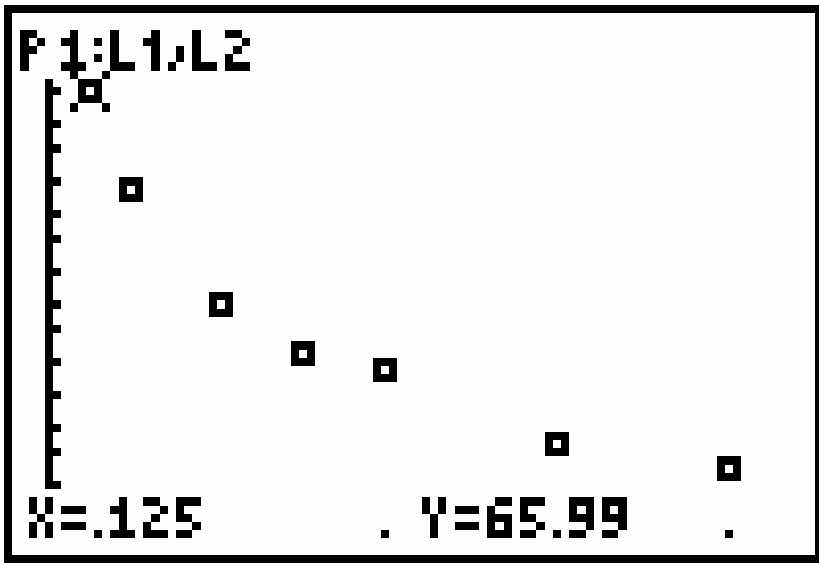
2. For each measurement distance, students should set the CBL2 to collect data for 5 seconds at 0.25 second intervals. The CBL2 will collect 21 data points during the interval.

3. As with the background level measurement, the first two ordered pairs must be deleted to eliminate data collected during the beep of the CBL2. To do this follow the directions given in the "Establishing the Background Noise Level" section.

Analysis of Data

Developing and Using Scatter Plots of the Data

Once students have collected the data for each distance and determined the mean intensity at each distance, they will use this data to create a scatter plot of sound intensity vs. distance. A typical scatter plot will look like:



They will be asked to make a labeled drawing of the scatter plot as well as observations about the shape of the graph if the points were connected. They will then be asked to make predictions based on the graph.

Curve Fitting and Regressions/ Developing and Analyzing Residual Plots

Once students have completed their scatter plots, they will try several regressions to determine which function best fits their data. Students should

have some familiarity with doing regressions on their calculators before beginning this activity. For each regression that they try, they should sketch the graph with the regression line, give the equation of the regression line and create a residual plot. From this information, they should decide if the regression line equation is a good model for the change in sound intensity with distance and write a short summary explaining why or why not.

Using Model for Prediction

Once students have decided on what they think the best model is, they will use that model to revisit the predictions that they made initially from the graphs.

Student Instructions for Using the CBL2 and DataMate

Set-Up

1. To collect data, the sound level meter must be connected to the CBL2 and the CBL2 must be connected to the TI-84 Plus calculator. Plug the cable that came with the sound level meter into the meter. Plug the other end into the port labeled ~CH1 on the CBL2.

2. Use the short cable with the CBL2 to connect the CBL2 to the calculator.

3. Check the calculator to see that it has the DataMate program. To do this, push the "APPS" button and scroll down to "DataMate".

4. If you do not have "DataMate", set the calculator to receive the program from the CBL2 by pushing the blue "2nd" button, and then the "link" key. Push the right arrow and then "Enter". On the CBL2, push the "Transfer" button. This will transfer the DataMate program to your calculator.

5. If you do have the "DataMate" program, use the arrow keys to move the highlighted box to "DataMate" and press "ENTER". The DataMate title screen displays, then the Main Screen appears.

6. On the Main Screen press "1" to enter the setup menu. Make sure that there is a triangle next to "CH1" indicating that channel 1 is selected. Use the down arrow to move the triangle to "CH1" if necessary. With the triangle next to "CH1" press "ENTER". A list of sensors will appear.

7. Press "7" to see more choices until "Sound(DB)" is one of the choices. Press the number beside "Sound(DB)" Press "1" to return to the Main Screen.

8. Now we need to set the data collection mode. From the Main Screen, press "1" to enter the setup menu again. Press the down arrow until the triangle is beside "Mode". Press "ENTER". Press "2" to enter the time graph settings. Press "2" again to change the time graph settings.

9. Key in 0.25 for the time interval between samples (in seconds). Press "ENTER".

10. Key in 22 for the number of samples and press "ENTER". The Time Graph Settings screen is displayed again. The experiment length in seconds is calculated automatically.

11. Press "1" to exit to the setup screen. Press "1" again for OK.

Collecting Background Data

1. You are now ready to begin collecting background data. To start your experiment, press "2" START on the DataMate main screen. The CBL2 will beep and begin collecting data.

2. When the CBL2 has finished collecting data, you will need to view the data. To view this data, push the "STAT" key and then "ENTER". The data in L1 represents the number of seconds while the data in L2 represents the decibel reading at that time.

3. Because the CBL2 beeps at the beginning of data collection and this beep shows up as higher intensity sound, we need to delete the first two ordered pairs. It is important that the first two entries in <u>both</u> columns be deleted. Using the arrow keys, move the highlighted box to the first entry in L1. Push the "DEL" key. Move the highlighted box to the right and push the "DEL" key. Repeat this procedure for the second ordered pair of numbers.

4. We now need to evaluate the variability in the background noise level measurement. To do this we need to take the standard deviation of the intensity measurements in L2. To do this, push the "STAT" key, then the right arrow until the word "CALC" is highlighted. We want to run a 1-variable statistical analysis on the data in L2. Push "ENTER" then "2ND" then the number 2. Push "ENTER"

5. If the standard deviation of the data in L2 is greater than 3 dB, you will need to reduce the amount of variability of the noise in the room and return to step 1 in this section.

6. If the standard deviation is less than 3 dB, record the mean value. This will be used for the background noise level.

Collecting Data

1. Place the sound level meter on the meter stick at the first distance you wish to measure. Make sure the sound level meter sensing end is facing the sound source. When you are ready to take a measurement, press "2" START.

2. You will hear the CBL2 beep twice, then in about 5 seconds it will beep again. When the CBL2 has finished collecting data, a graph of the data will be displayed. After viewing the graph, press "ENTER" to return to the main menu.

Analyzing Data

1. You are now ready to analyze the data that you collected at your first distance.

2. From the DataMate main menu, select “6” QUIT. This will take you out of the DataMate program. Press “ENTER” and you will return to your calculators home screen.

3. Press the “STAT” key and then press “ENTER”. The times for the data you collected are listed in L1, while the intensity values are listed in L2.

4. Because of the beep from the CBL2 we need to remove the first two ordered pairs. See the previous section on “Collecting Background Data” for instructions on how to do this.

5. Once the first two ordered pairs have been deleted, we can run a 1-variable statistical analysis to find out mean intensity for our distance. Press the “STAT” key again. This time use the arrow keys to move the highlight box to “CALC”. Press “ENTER”. Since our intensity data is in L2, we need to tell the calculator to use the L2 data for analysis. Press the blue “2^{nd}” key and then the “2” key. Press “ENTER” again and the calculator will perform a 1-variable statistical analysis on the data in L2.

6. Record the mean and standard deviation in your data sheet. Return to your STAT lists and clear both L1 and L2.

7. Return to the “Collecting Data” section and repeat this process for each of the other distances.

Student Data Sheet

Use the following data sheet to record the data that you have collected.

INCLUDE UNITS ON ALL DATA!

Background Noise Level:

Mean: _____

Standard Deviation: _____

Intensity at Several Distances:

Distance from Source	Average Sound Intensity	Standard Deviation

In the space below, sketch a graph of Sound Intensity vs. Distance. Be sure to give the graph a title and label the axes including the units.

If you connected the points on the graph, describe the general shape of the graph.

_____

_____

_____

What do you notice about the sound intensity measurements as the distance from the source increases?

_____

_____

_____

From you graph, predict the sound intensity at:

2.0 m _____ 4.0 m_____

8.0 m _____ 20.0 m_____

The human ear cannot hear sound that is less than about 10 dB. From your graph, predict at what distance you will no longer be able to hear the sound.

_____

Regressions and Model Development

Using your data, develop a model that best approximates your data. To do this you will complete several different types of regressions. With each regression, you must draw a scatter plot with the regression line, give the equation for the regression line, create a residual plot and provide a short summary that explains why this is or isn't a good model for this data.

Regression #1

Type of regression:_____

Scatter plot with regression line:

Equation for regression:_____

Residual plot for this regression:

Is this model a good fit for your data? Why or why not? (Be sure to use evidence from your residual plot, not just opinion!!)

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Regression #2

Type of regression:_____

Scatter plot with regression line:

Equation for regression:_____

Residual plot for this regression:

Is this model a good fit for your data? Why or why not? (Be sure to use evidence from your residual plot, not just opinion!!)

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Regression #3

Type of regression:_____

Scatter plot with regression line:

Equation for regression:_____

Residual plot for this regression:

Is this model a good fit for your data? Why or why not? (Be sure to use evidence from your residual plot, not just opinion!!)

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Regression #4

Type of regression:_____

Scatter plot with regression line:

Equation for regression:_____

Residual plot for this regression:

Is this model a good fit for your data? Why or why not? (Be sure to use evidence from your residual plot, not just opinion!!)

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Making Predictions Using Your Model

Which regression do you think best fits your data? Why?

_____

_____

_____

In the first part of this activity you made predictions from the graph of the data that you created. Using the model that you think best fits your data, make these predictions again.

2.0 m _____ 4.0 m_____

8.0 m _____ 20.0 m_____

Use your model to find the distance at which the sound intensity drops below 10dB. _____

How do the predictions that you made using the model you developed differ from your predictions when using the graph? Why?

_____

_____

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_____