EXPLORATIONS

Activity 12

Math Concepts

- Measurement
- Data Analysis
- Algebra

Science Concepts

- Data Collection
- Experimental Design
- Physical Science

You'll Get a Charge Out of This!

Materials

- TI-73 calculator
- CBL™
- Voltage probe
- Data link cable
- TI-GRAPH LINK™ (optional)
- 7 different types of "batteries," some items that might be good are: potato, lemon, lime, apple, orange, grapefruit, banana, broccoli
- Zinc washer
- Penny (1959-1982)
- Knife to make slots in the object to hold the penny and washer
- Ruler to measure centimeters
- Water in a dish to clean penny and washer between batteries
- Towel to dry objects

In this activity you will:

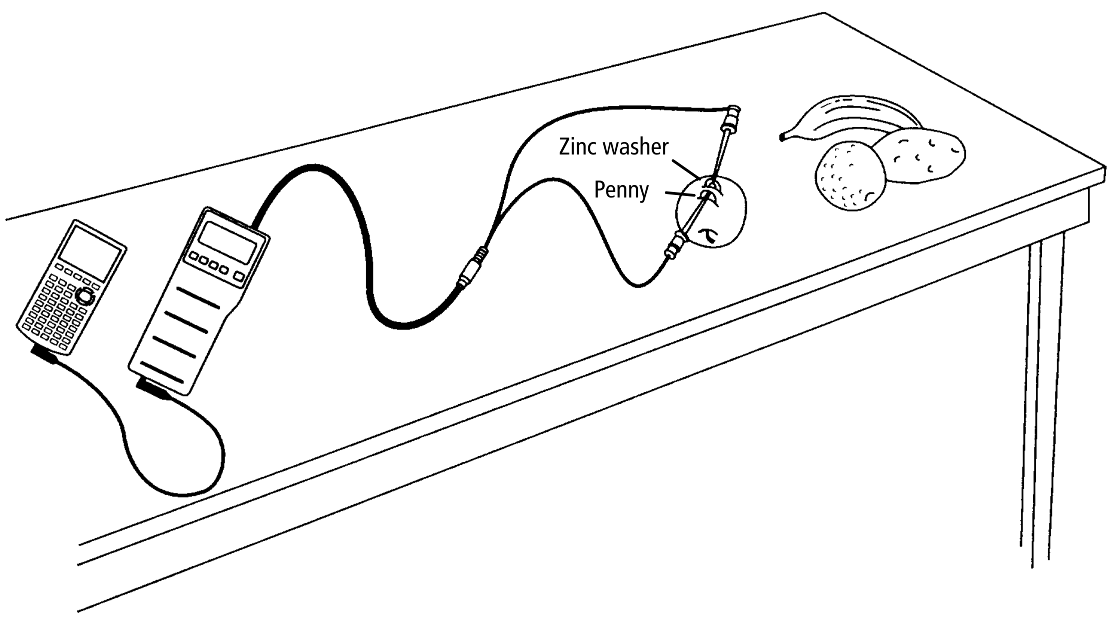
- Collect data on voltage and graph in a histogram
- Compare the values of different batteries with the use of the graph and lists
- Determine the rate of change of voltage over time by measuring the best battery over time. In addition, the mean of the voltages will be determined

Introduction

You may have heard of the potato battery that you can make with a penny and a zinc washer. Have you wondered if this really works? In this investigation, you will explore several items for their ability to become a battery. The amount of electricity you can gather from a particular item will be a key factor. The material of the potato or other object serves as an electrolyte in the battery. These electrolytes allow ions to dissociate and this allows for the flow of electricity. The reaction is a result of many factors: the two metals, the type of material they are connected through (electrolyte), the distance between the two metals, and the amount of contact with the fluid. In this experiment, you will try to control all the variables but one, the electrolyte, and discover the best battery!

The Problem

You want to find the "best" battery made from common items serving as the electrolyte between a copper penny and a zinc washer. To do this, collect seven potential batteries to test with the CBL™ and the voltage probe using the TI-73 to hold and analyze the data. The set up of materials and the placement of the penny and washer is shown below.



The Set Up

1. To start the experiment, control all the variables except the one that you wish to measure, which is the voltage produced when the particular item is used as the electrolyte in the battery.

a. First, select a copper penny that is dated between 1959 and 1982 inclusive.

b. Then you need a zinc washer to use as the other metal. This item can be of any size, but once selected it must be used throughout the experiment. A washer the same diameter and thickness as the penny would do well.

c. Clean these items with soap and water and dry them.

✎ Answer question 1 on the student data sheet.

2. Collect a container of water to clean the two metals as you switch from one item to the next. You'll also need a set of paper towels, a knife, or some device to cut notches in the items to insert the penny and washer, and a ruler to help measure that distance between the notches. This should be the same for all batteries.

3. Collect the seven items to test. The order that you test them in is not important, but you will need to give them each a name that has no more than six letters. Decide on the names to use before you start the experiment.

✎ Answer question 2 on the student data sheet.

Activity

Collecting Data

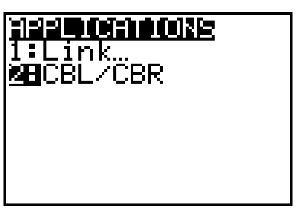
1. Hook up the voltage probe to the CBL™, placing it into **CH1**, and turn on the CBL. Connect the CBL and the TI-73 with the data link cable.

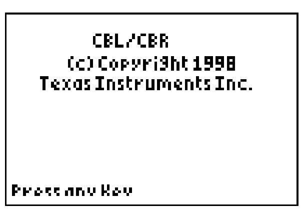
a. Press [APPS] and then select option **2:CBL/CBR** from the **APPLICATIONS** menu.

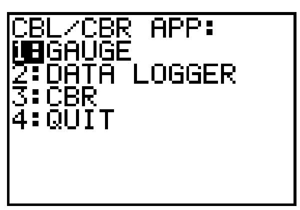
b. Press any key to pass the next screen and then select option **1:GAUGE** from the **CBL/CBR APP** menu.

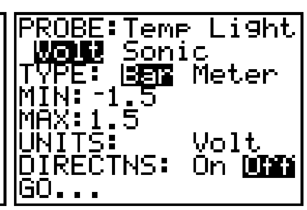
c. Set up the screen as shown below, move the cursor to the word **GO**, and wait to press [ENTER].

d. Select **DIRECTNS: On** if you are having trouble with the set up.







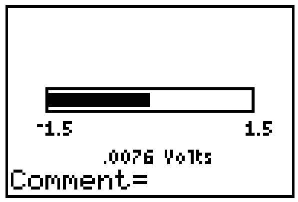


2. Connect the leads to the penny and washer before inserting them into the item to be tested. Make sure you connect the red lead (+) on the penny (copper) and the black lead (-) on the washer (zinc) unless you want negative voltages. The connection should be very stable, with a good hold on the metals by the leads. You want to see if the metals will create a charge without the electrolyte. This is a control for the experiment to see what happened when you do nothing.

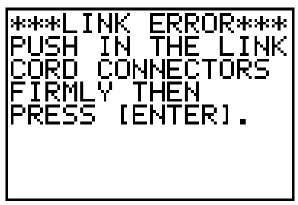
a. Press [ENTER] to start the **GAUGE** reading. You should see a measure of voltage on the CBL™ screen and on the bar on the screen of the TI-73. You will get a reading of 2.00 volts if nothing is connected; this is a default value that occurs when contact is not good. If you get this reading, you will need to adjust the connections.

b. Touch the clean penny and washer together and observe the reading. This value should be very small.

✎ Record the value in question 3 on the student data sheet.



3. If your connection is faulty, you will get the error shown below. If this happens, check all the connections and try again.

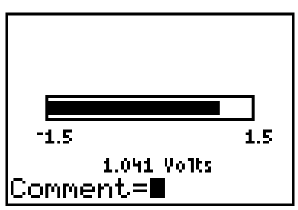


4. Now that you see that the voltage is small without an electrolyte present, insert the penny and the washer about half-way into the slots that you created (about 1.0 centimeter apart) on the first item to test.

a. Re-hook the leads from the voltage probe as indicated above.

b. When the voltage has stabilized, press [ENTER] and then move to the text editor to key in the name of the battery in the Comment field.

c. Press [2nd] [TEXT] and select the letters for the name of this item, selecting the word **Done** when finished.



5. Repeat this process for the next six items.

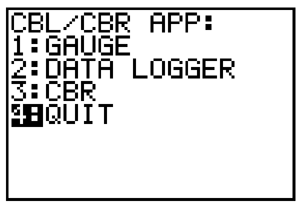
a. Clean the washer and the penny between objects with the water and then dry them with the towel. Make the transition in a fairly rapid fashion, letting the **GAUGE** continue to run.

b. Wait till the voltage stabilizes (and it should be very stable when the contact is good) before pressing [ENTER] and recording the name of the item as a comment. If you make a mistake, just add another comment. You can delete the bad value from the list later.

c. Notice the physical changes in the washer and penny as the experiment continues.

d. Press [CLEAR] and [2nd] [QUIT] and then select **4:QUIT** from the **CBL/CBR APP** menu when finished with all seven items.

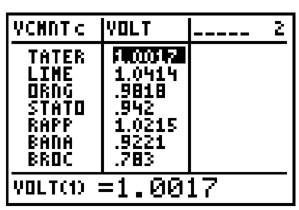
✎ Answer questions 4 - 6 on the student data sheet.



Analyzing the Data

1. Now look at the data you collected. These values are stored in lists named **VCMNT** (for the names of the items) and **VOLT** (for the measure of the voltages involved). Press [LIST] to view these lists. If you had any extra data entered due to mistakes, now is the time to remove that data. Remember that these are pairs of data (name and voltage), so move to the item to remove and press [DEL], then move to the adjacent column and remove the value that was associated with the item just deleted.

✎ Answer question 7 on the student data sheet.



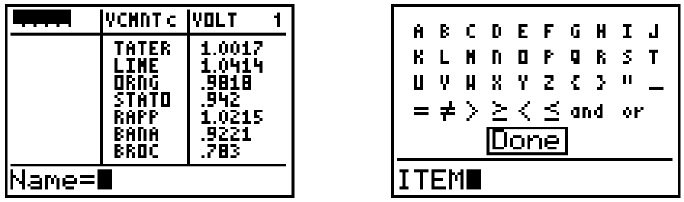
2. To see the data in a graphical form, you can set up several types of plots.

a. In some types of graphs, the names used in the categorical list **VCMNT** need to be replaced by numbers.

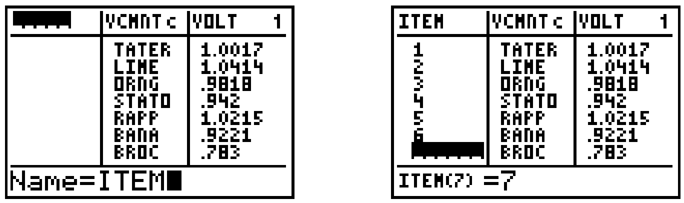
b. Call each item by a number in a list called **ITEM**, just calling the first item tested 1, and so on.

c. Move to the top of the first column in the screen and press [2nd] [INS] to add a blank column.

d. Press [2nd] [TEXT] and enter the name of this list, selecting the word **Done** when finished.

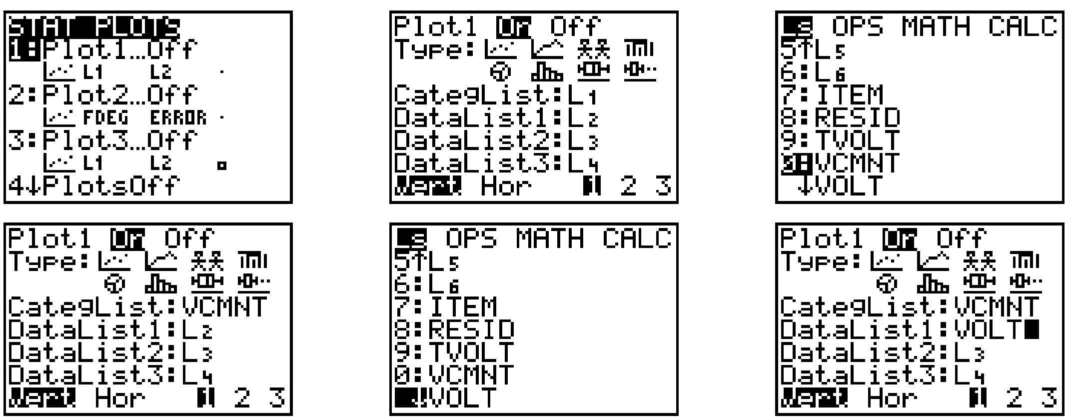


e. Fill this list with the numbers 1 – 7 after you press [ENTER] to name it and move down into the column.



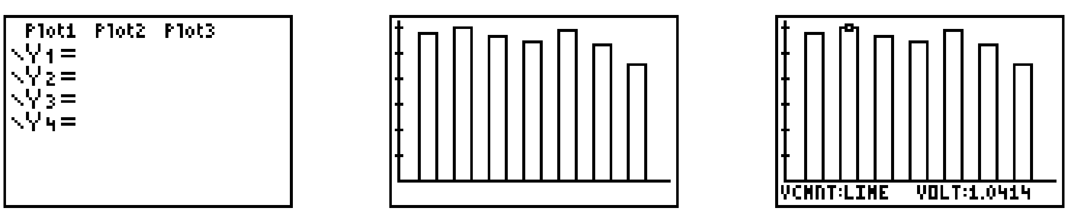
f. Set up a bar graph of the data by pressing [2nd] [PLOT]. Check to see if all the plots are off. If there are plots on, select **4:PlotsOff** from the **STAT PLOTS** menu and press [ENTER].

g. Set up **Plot1** as shown below. Get the list names from the text editor (key in the names) or press [2nd] [STAT] and select them from the **Ls** menu.

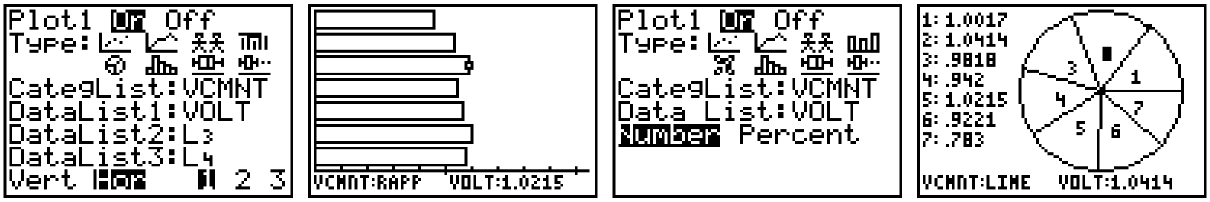


3. Press [Y=] and check to see that the editor is clean (or that all functions are turned off). Then press [GRAPH]. Press [TRACE] and explore this data.

✎ Answer questions 8 - 9 on the student data sheet.

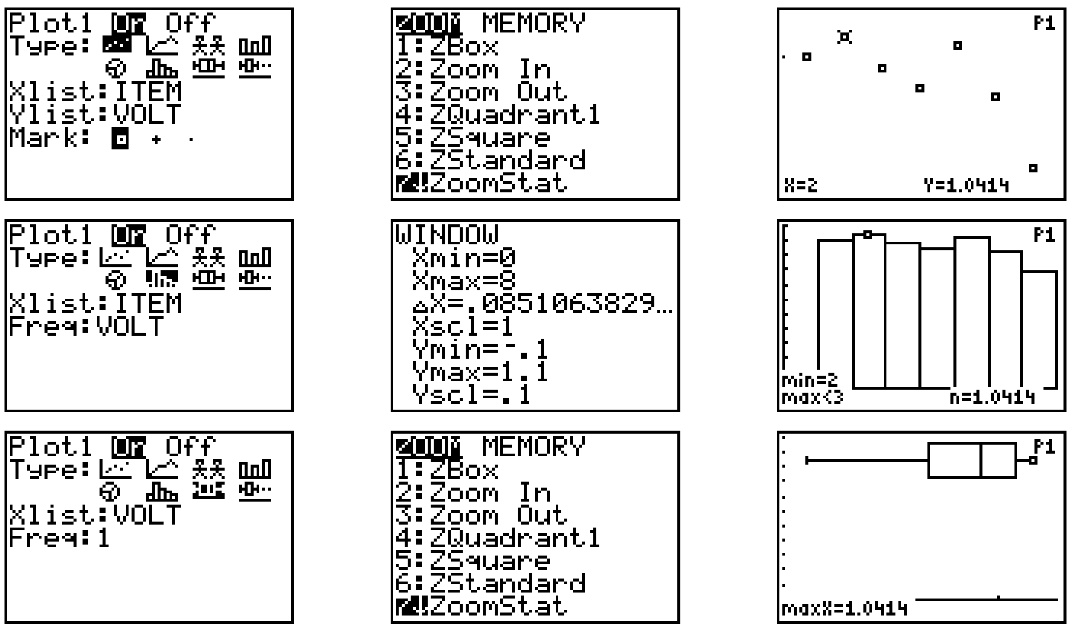


4. Examine other graphs using the categorical list **VCMNT** and the values of the voltage **VOLT**.



✎ Answer question 10 on the student data sheet.

5. You can look at the other plots, using the numerical representations for names (**ITEM**) and the **VOLT** list.



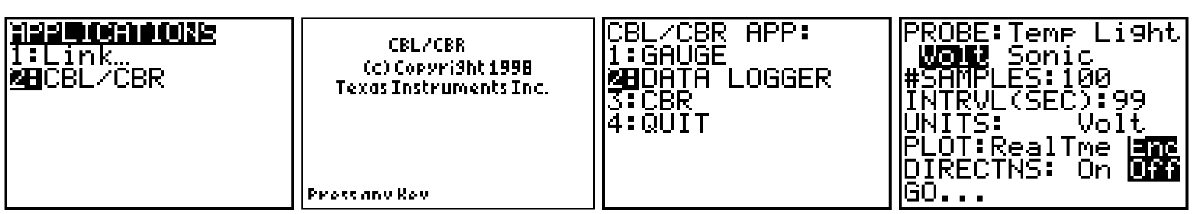
✎ Answer questions 11 and 12 on the student data sheet.

6. To see if the best battery has any staying power, you will need to collect data on the battery over a long period of time.

a. Set up the data logger as shown below and let it collect data when connected to the item of choice with the penny and washers as set up before.

b. Press [APPS] and select **2:CBL/CBR** from the **APPLICATIONS** menu.

c. Press any key to move past the next screen and then select option **2:DATA LOGGER** from the **CBL/CBR APP** menu.



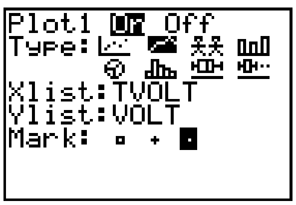
7. Once set up, with the item plugged in with the penny and washer and the CBL™ turned on with the voltage probe in **CH1**, highlight the word **GO** and press [ENTER] to start the data collection. Set the experiment aside and come back at the end of the set time. You can determine this by multiplying the number in **#SAMPLES** by the number in **INTRVL(SEC).**

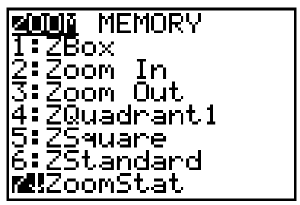
✎ Answer question 13 on the student data sheet.

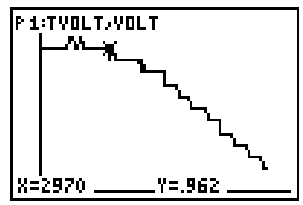
8. When the experiment is finished, the CBL will say **DONE** and the TI-73 will return to the **PROBE** menu, or they both will have gone into "sleep" mode.

a. Press [2nd] [QUIT] and select **4:QUIT** from the **CBL/CBR APP** menu, or just turn on the TI-73. If there was a change in voltage over the time, you can examine it by pressing [GRAPH].

b. If there was no change, the **WINDOW** will need to be set up to view the information. The Plot should be set up as below, press [ZOOM] and select **7:ZoomStat** from the **ZOOM** menu.







c. [TRACE] over the data.

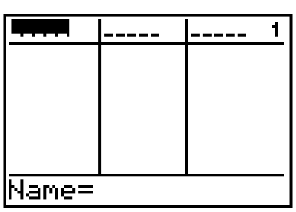
✎ Answer questions 14 and 15 on the student data sheet.

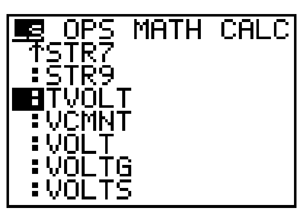
9. Since the data was collected in seconds and volts, you may want to look at the time in more appropriate values.

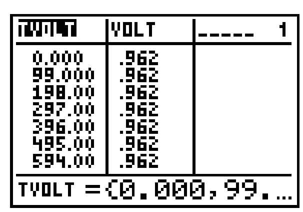
a. To do this, move to the list editor by pressing [LIST] and remove all the other lists by pressing [DEL] at the top of all the list columns until you have a blank screen.

b. To place the list for time in the first blank column, move the cursor to the top of that column and press [2nd] [STAT] and select the list **TVOLT** from the **Ls** menu.

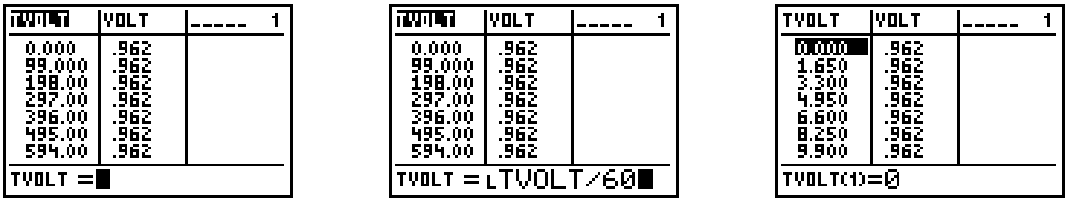
c. Repeat the process in the next column for the list of volts (**VOLT**), pressing [ENTER] to fill the columns.



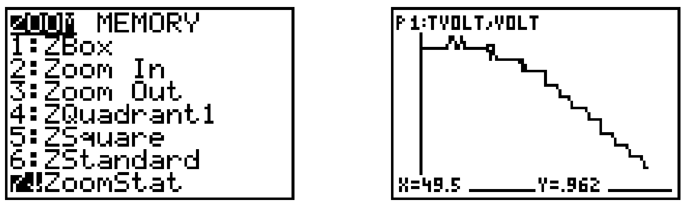




10. To convert the time values from seconds to minutes, move to the top of the list (**TVOLT**) and press [CLEAR] to get a clean edit line at the bottom. Then place the name of the list in this place [2nd] [STAT] and press [÷] **60** [ENTER]. This will fill the list with time in minutes.



11. To examine the graph again, you will need to adjust the **WINDOW** by pressing [ZOOM] and selecting **7:ZoomStat** from the **ZOOM** menu. Again [TRACE] over the data and examine.

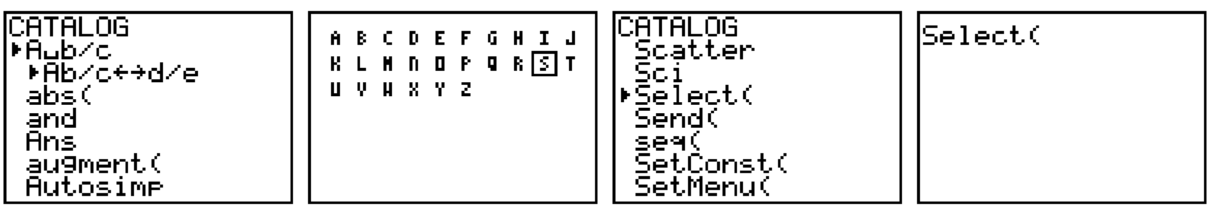


✎ Answer questions 16 - 18 on the student data sheet.

12. You may want to select a segment of the data to examine.

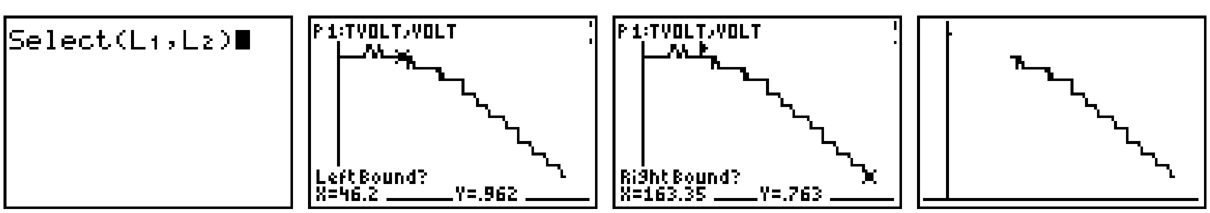
a. To do this, move to the Home screen by pressing [CLEAR] [CLEAR] [CLEAR]. This will give you a clean screen to work with.

b. Move to the **CATALOG** by pressing [2nd] [CATALOG] and then jumping to the commands starting with **S** by pressing [2nd] [TEXT] and pressing [ENTER] when the cursor is on the letter **S**. This will move you to the segment of the catalog that contains the option **Select(**, which is what you need.

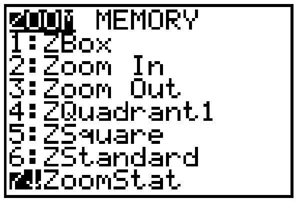


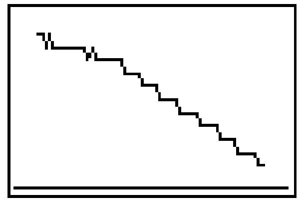
13. Now select two lists to hold the selected segment of time and voltage. This may be **L1** and **L2** as picked from the **LS** menu ([2nd] [STAT]).

a. Once selected, press [ENTER] to move to the graph and then move to the left of the screen, selecting the **Left Bound** of the segment by pressing [ENTER], then move to the right to select the **Right Bound**.

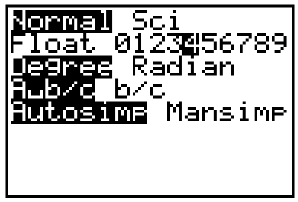


b. You can focus in on this data by selecting **7:ZoomStat** from the **ZOOM** menu.

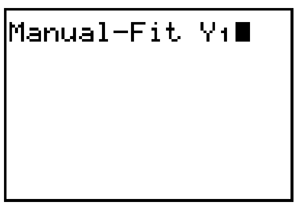


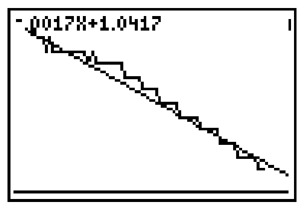


14. The mode setting for the next part needs to be checked and adjusted. Press [MODE] and check the **Float** line to have at least **4** digits set.

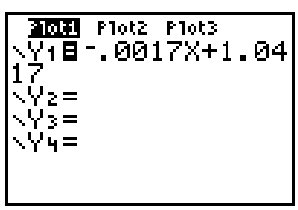


15. You need to create a manual-fit on this data to get a feel for the rate at which the voltage is dropping. See the TI-73 manual for instructions on this function.





16. To look at the rule (equation) created from the **Manual-Fit** calculation, press [Y=]. **Y1** is the voltage of the battery created by the item studied (Lime). **X** is the time in minutes when this voltage occurs. The value of 1.0417 in the sample screen below is the voltage at time zero (this should be close to the voltage that you got from the first data collection). The number in front of **X** is the rate of decay of voltage in minutes (in this case –0.0017 volts per minute).

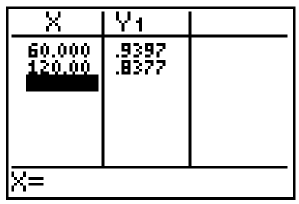


✎ Answer question 19 on the student data sheet.

17. To use the line to project what would happen at different times in the experiment, set up a table.

a. Press [2nd] [TBLSET] and set up as shown below.

b. Then press [2nd] [TABLE] and key in values for time in minutes. In the case of the sample, you would have a voltage of 0.8377 after 120 minutes (or 2 hours).

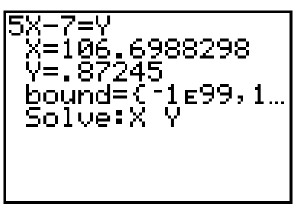


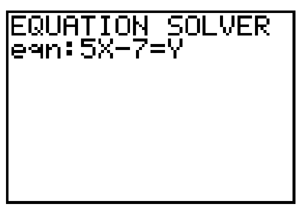
✎ Answer question 20 on the student data sheet.

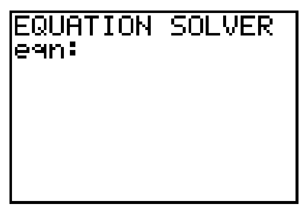
18. Another way to examine this relationship would be to use the solver option on the TI-73.

a. To do this press [MATH] and select **6:Solver** from the **MATH** menu.

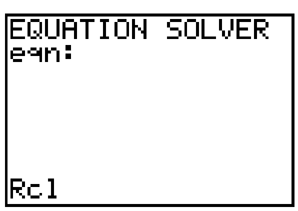
b. To place the equation from **Y1** into the **EQUATION SOLVER** menu, move up to the **eqn:** line and press [CLEAR] if there is already an equation there.

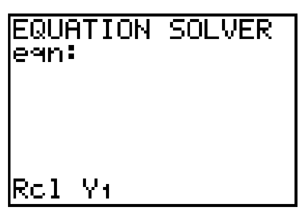




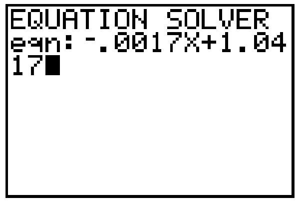


c. Now you need to recall the values stored in **Y1**. To do this, press [2nd] [RCL] [2nd] [VARS] and select **Y1** from the **Y-Vars** option as before.

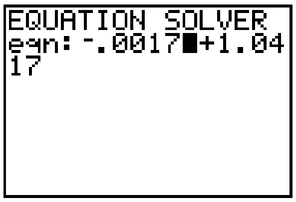


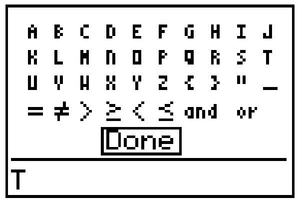


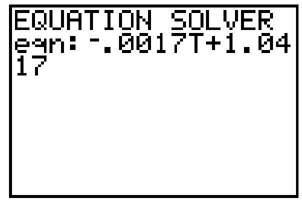
d. Press [ENTER] to place this value into the window.



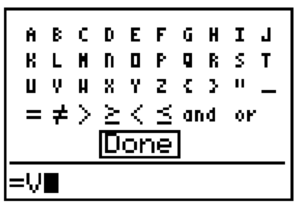
e. Now change the **X** to a more appropriate symbol, like **T** for time. To do this, move the cursor on top of the letter **X** and select the letter **T** from the text editor ([2nd] [TEXT]).

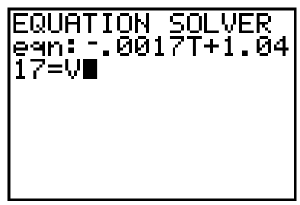




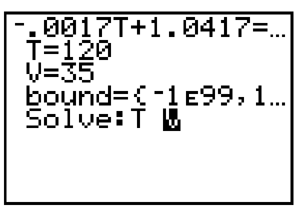


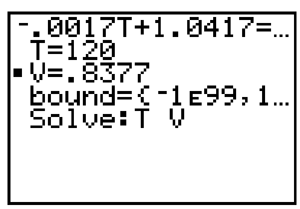
f. Move to the end of the equation and set it equal to the voltage (**V**) as shown below using the text editor.





19. Now that you have this rule set up in the solver, you can just key in values for **T** (time in minutes) or **V** (voltage in volts) and ask the TI-73 the value of the other variable that will make the expression true. In this case, the value of **V** was solved for a **T** of 120 minutes.





✎ Answer questions 21 and 22 on the student data sheet.

Going Further

1. List seven other items that you would like to test as battery makers. Explain your reasoning.
2. Given the following data, create two plots showing the relationships of the voltages. (Recall that to make a categorical list you must put the first name in quotes.)

Name	Voltage
Chocolate pie	1.500
Onion	1.777
Cricket	0.977
Earthworm	1.077
King Snake	1.277
Black Snake	1.333
House Mouse	1.457

3. Explain why you selected the graphs as shown in question 2.
4. If you tested the onion overnight as a battery, and did a Manual-Fit on the data getting the following rule: **Y1** = -0.0777 **X** + 1.775, give the meaning of each number. Assume that you changed the time from seconds to minutes as you did in the investigation.
5. Use the rule in question **4** to complete the table below.

Time (minutes)	Voltage
0	
10	
	1.000
36	
1	

6. What time would it take to get a voltage of zero out of the onion? How do you know?

____

____

Student Data Collection and Analysis Sheet

Name(s) ______________________

Date ______________________

Activity 12

You'll Get a Charge Out of This!

1. Give the date of the penny: ____________; the full diameter of the washer: ____________; sketch the washer in the space below, including a tracing of the thickness.

2. Complete the table below, using the full name of each item, and the short name to use on the TI-73 (6 letters or less).

Long Name of Item to Test	Short Name

3. Voltage without the electrolyte (like the potato): ______________________

4. Which item produced the highest voltage? ______________________

5. Which item produced the lowest voltage? ______________________

6. As the experiment progressed, did you see any change in the condition of the washer or the penny? ______________________

____

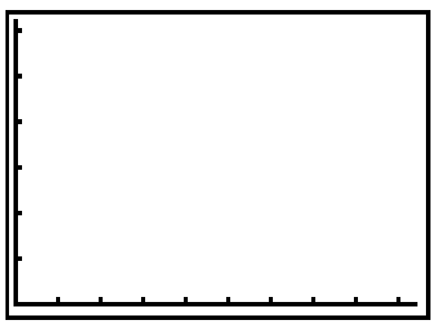
7. Place the data you have collected in the table below.

Item Name	Voltage

8. How would you compare the items that were tested, from the information shown on the graph? ____

____

9. Sketch the graph in the space below, and label it, or print the graph using the TI-GRAPH LINK™.

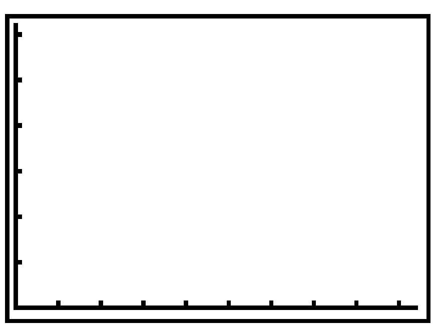


10. Which of these graphs is most revealing? Why?

____

____

11. Sketch your best graph to date, if you have not done so yet, and label it. Use the TI-GRAPH LINK to print if you wish. Explain why you like it best.



12. Which item made the best battery? Why do you believe this?

____

____

____

13. If you are collecting 100 data points every 99 seconds, how many hours, minutes, and seconds will this take?

________ hours; ________ minutes; _________ seconds.

14. What appears to be happening to the voltage as time goes on?

____

____

15. Explain the horizontal lines on the graph, if there are any.

____

____

16. At what time was the voltage first at its minimum? ____________________

17. How much did the voltage drop over the time observed? ________________

18. When had the voltage dropped half that amount? ______________________

19. State the rule (equation) shown in **Y1**: ________________________________

20. Complete the table below.

Time (minutes)	Voltage
1	
30	
50	
77	
100	
	0.555
1 000	
2 000	

21. Check your values in the table above using the **Solver** option. Explain any disagreement.

____

____

22. What is the time that would need to pass so that the voltage is zero?

____

Teacher Notes

Math Strands: Data Analysis, Measurement, and Algebra

Students will collect data on voltage and graph in a Histogram, comparing the values of different batteries with the use of the graph and list of values. The mean of the voltages will be determined. For an additional investigation, students could take the best battery and measure it over time and model the rate of change of voltage.

Science Strands: Data Collection, Experimental Design, and Physical Science

The creation of a battery using metals of different types and the analysis of the data collected using graphs and statistical analysis. In addition, observations of the event and controlling variables as a part of experimental design will be part of the investigation.

Classroom Management and Safety

When finished with the experiment, **don't eat** the materials used for batteries or cut them up and put them out for the birds or other critters. The acid type batteries (grapefruit, lime, and so forth) might squirt into the eye of the cutter of the slots, or the inserter of the penny and washer. In this case, safety glasses, or just glasses, should be used. The fluids from the batteries will get on the probes, the CBL™, the table, the students, and the TI-73, so care should be taken here. The need to collect consistent and "quick" data leads to the need to assign jobs. Suggested areas would be: CBL watcher, TI-73 driver, battery-cutter, penny and washer inserter, and voltage probe connector. Once the data has been collected, clean up the work area and the equipment, link and get the data into the calculators of all team members and save the lists on the computer with the TI-GRAPH LINK™ or as a program, as explained in *Appendix A: Saving Lists*. One set up will be needed to collect the time and voltage over night to get a decay of the "best" battery if that extension is selected. Place the red lead (+) on the penny (copper) and the black lead (-) on the washer (zinc) unless you want negative voltages.

The Set Up

- Collect the items to be tested beforehand. One scenario would be to have stations set up for kids to bring their CBLs to and test. In this case, use the same type of penny and same size/type of washer at each station. If the data can be collected in a short time this will work, but if you need several days, the better method would be to have each group have their own items to test. The trade-off between efficiency and experimental control needs to be weighed. One item (apple) could be used by as many as three groups if it is large enough to have the slots cut in it far enough apart from the others.

- In 1983, the U.S. Treasury department started making the zinc copper-clad penny. This mixture will change the nature of the data, but might be worth exploring. (See the extensions mentioned below.)
- The washers can be standard (silver-looking) hardware store variety. Avoid very thick ones, and ones that are much more than 3 centimeters in diameter.
- Set the **Mode** to show enough digits to be relevant, usually **4**. **Float** would also work.
- When nothing is connected on the CBL except for the voltage probe, you will get a reading of 2.00 volts. This will be an indicator of the lack of a good connection. Most voltages will be below this value in the 0.5 to 1.5 volt range.
- The Categorical list graphs are limited to 7 items. So if you wish to have a plot using this information, an error will occur with more than 7 items.
- You can write a program or use a program like **PHYSCI.73g** from Vernier Software (**http://www.vernier.com/cbl/progs.html**) to set up the probe to collect voltages over night. The rate of drop in voltage is so slow that the probe will record the same voltages for several time periods (since a 99-second interval is as large as is allowed with the Data Logger option).
- If there is no drop in voltage over the interval of time selected, the internal attempt to do a **ZoomStat** will cause an error due to no change in the y-value. Just set the window to have a variation of **Ymin** and **Ymax** over an appropriate interval to see the graph.
- When you run the Data Logger, you will lose the data in the **VOLT** list collected in the first part. To avoid this, write a program to hold the data or save it using the TI-GRAPH LINK™.

Activity

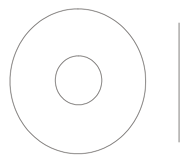
- Examine the effect of distance between the penny and the washer. Start at 4 centimeters, get a reading, then move to 3 cm, 2cm, 1cm, 0.5 cm, and get voltages.
- Test the same type of item (lime) with several different limes. Since some of the limes are more or less limey (acidic), they may produce different levels of voltage. Get a mean voltage for the item.
- Try liquids. Place the penny and the washer (when attached to the voltage probe leads) in water, sugar water, hot water, cold water, salt water, tea, orange juice, and so forth. Keep the distances between the penny and washer at the same value, and the depth in the liquid the same.
- Test other coins. Use a new penny (after 1982), a nickel, dime, quarter. Do these metals with the same zinc washer produce in the same (best?) battery.

- Try different zinc washers with the same penny. Look at diameter (which would change surface area) or thickness.
- Explore various types of an item as a battery. For potatoes, try the following: sweet potato, red potato, potato chips, and so forth.
- Try the experiment with two other metals, and use just one of the better electrolytes to compare to the voltage produced when using the penny and washer (copper and zinc).

Note: *Sample data is in a program named* **TATER.73p** *with the list* **VOLTG** *being the values from the 7 batteries.*

Student Data Collection and Analysis Sheet – Key

1. Look for a year date 1959 to 1982. The diameter should be 2.5 and 1.5 centimeters.

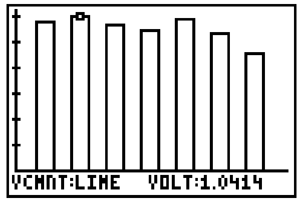


2. Look for descriptive names in the long name list; for example, red apple or green apple versus apple1 or apple 2. Look for unique, descriptive, names of 6 letters or less in the short name column.

Long Name of Item to Test	Short Name
Potato	TATER
Lime	LIME
Orange	ORNG
Sweet Potato	STATO
Red Apple	RAPP
Banana	BANA
Broccoli	BROC

3. About 0.0076 volts.
4. The potato, lemon, or lime would probably be highest.
5. The weird stuff like cake or broccoli would be lowest.
6. The penny gets shinier, and the washer turns black. This idea is used in electroplating and cleaning certain metals.
7. The data from the calculator.
8. The high scores and the low scores should be mentioned.

9. Something like this:



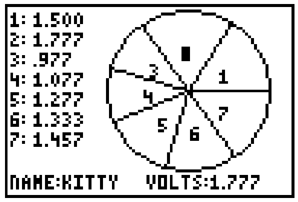
10. Type name and reason for selection best.
11. Look for a reason for the graph that is the best (from all that were created).
12. The one with the highest voltage, or second highest based on the ease of use (and cost).
13. 2 hours 45 minutes 0 seconds.
14. The voltage is dropping at an increasing rate over time.
15. The horizontal lines are periods of time with the same voltage (or voltage changes too small for the probe to measure).
16. The first time (in minutes) that the minimum had been reported.
17. Starting voltage – ending voltage.
18. The experiment lasted for 165 minutes, the halfway point of voltage should have occurred at over 60% of the total time. Use of Median would be cool!
19. Something like Y = -0.0017X+1.0417.
20. Use the rule from number to check the values, with the table.

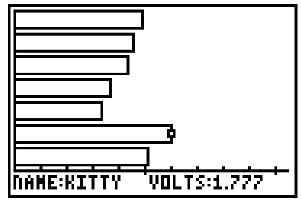
Time (minutes)	Voltage
1	
30	
50	
77	
100	
	0.555
1 000	
2 000	

21. Look for mistakes and reasons that the numbers didn't match.
22. In this case, it would take 612.76 minutes.

Going Further - Key

1. The seven items with some reasoning based on the results of the experiment.
2. Various graphs would be acceptable, but the three lists as shown below and the use of the 5 or less charter names of the data should be apparent.





3. Answers will vary. Rationale for the types of graphs used.
4. **Y1** = -0.0777 **X** + 1.775 **Y1** is the Voltage of the onion battery after a certain time X in minutes, -0.0777 is the rate of change of voltage over time (volts per minute); and 1.775 is the voltage of the onion battery at the start.
5. As shown below:

Time (minutes)	*Voltage*
0	**1.775**
10	**0.998**
9.974	1.000
36	**-1.0222**
1	**1.6973**

6. The voltage will be zero when **Y1** is zero so you have 0 = -0.0777 **X** + 1.775 which gives **Y1** = 22.8 minutes.