ACTIVITY 9

Add Them Up

Math Objectives:

- Graphing scatter plots
- Multiplication as repeated addition
- Using a pattern to develop a formula

Materials:

- TI-83/TI-84 Plus Family
- Vernier EasyLink™
- Voltage sensor
- Vernier EasyData™ Application
- 5 same size 1.5 volt batteries (e.g., AA, AAA)

OVERVIEW

People benefit every day from batteries when they use a flashlight, their calculator, CBR 2, or any other battery-operated device. Have you ever put batteries into a flashlight or your calculator? How much power do you think they get from the batteries inside?

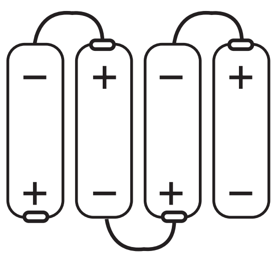
Look on the outer jacket of a battery. There is a *positive terminal* (+) and a *negative terminal* (–) at the ends of the battery. You will also see the size, e.g., AAA, AA. The voltage is also listed on the battery, e.g., 1.5 VOLTS.

If you look at the position of the batteries in many flashlights, you will notice that the batteries are lined up in a column or a *series*. They are lined up so that the positive terminal (+) of one battery touches the negative terminal (–) of another battery.

Observe the position of the batteries in the calculator. You will notice that even though the batteries are not in a row, the battery terminals alternate and there is a piece of metal connecting the positive terminals (+) to the negative terminals (–). These batteries are connected in *series* or serial arrangement. **See figure below.**

Batteries supply electrical energy to electronic devices when a *circuit* is created. It might help to think of a circuit as a path linking the positive terminal to the electronic device (the *load*) and then back to the negative terminal. This investigation will help you explore how many total volts several batteries in a series provide to a battery-operated device.

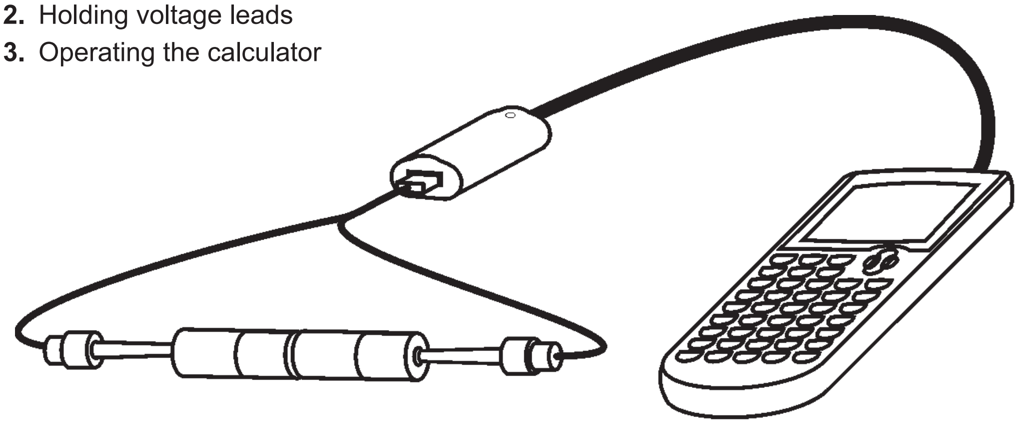
Use five batteries of the same size and voltage. It is best if new batteries are used or a set of batteries that have been used in the same device. The batteries can be held in place using a battery holder, a ruler with a ridge down the center, or even the grout line between tiles on a table or floor. The batteries should be lined up with a positive terminal (+) touching a negative terminal (–).



SETUP

Briefly discuss the data collection procedure with the class. Have students collect the data in groups of 3 or 4. First, have them measure the voltage of each of their five batteries. Next, they need to measure the voltage of one battery, then a series of two batteries, then three batteries, and so on. They should keep going until they measure the voltage of a series of five batteries. There are three tasks that will help accomplish this experiment. Have the students assign each one to a different group member.

1. Positioning the batteries
2. Holding voltage leads
3. Operating the calculator



DATA COLLECTION

1. Connect the EasyLink to your TI-84 Plus using the mini-USB port.
2. Connect the voltage sensor to the other end of the EasyLink.
3. The EasyData App will launch automatically. The EasyData App information screen is displayed for about 3 seconds followed by the main screen. The EasyData App identifies the voltage sensor. The main screen of EasyData is shown on the right. **See Figure 1.**

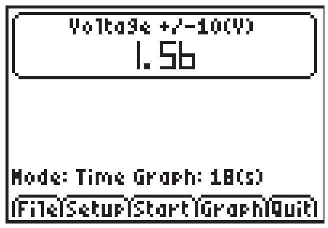


Figure 1

4. Press the [Y=] key to access the **File** menu and select **1:New** by pressing [1]. Or, since **1:New** is highlighted, you can press [ENTER]. This resets the program and clears out old data. **See Figure 2.**
5. Place one battery in a battery holder or on a ruler. Touch and hold the appropriate voltage leads to the appropriate terminal; red to (+) and black to (–). A series circuit has now been created with the calculator.

Figure 2

6. Wait for the voltage reading to stabilize and then, one at a time, read the voltage of each of the five batteries. Record these readings on question 1 of the **Add Them Up** worksheet. These readings should be very close to the same for each battery measured. Notice that the voltage can be seen in the upper center of the EasyData main screen. **See Figure 1.**
7. From the **Setup** menu, choose **4:Selected Events. Mode: Selected Events** will be displayed on the home screen. Next, collect data as the circuit is increased by one battery at a time. **See Figures 3a–b.**

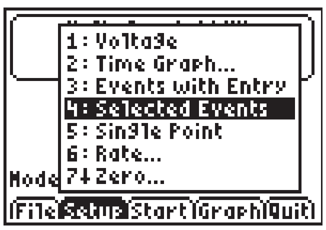


Figure 3a

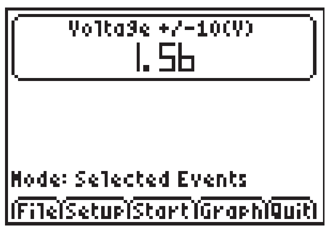


Figure 3b

8. Select **Start** to begin collecting data. The current voltage is displayed in the upper, right corner of the screen. Touch the red voltage lead to the (+) terminal and the black voltage lead to the (–) terminal of one battery and wait for the voltage reading to stabilize. Select **Keep** to record the reading. **See Figure 4.**

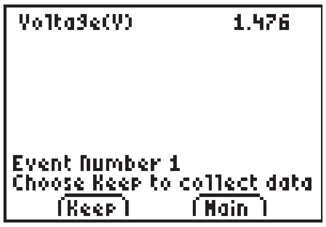


Figure 4

9. Line up two batteries in series. Touch and hold the appropriate voltage leads to the ends of the line of batteries. Select **Keep** to collect the voltage of the two batteries. The **Selected Events** feature will keep track of which reading you are on and increase it by one each time you select **Keep.** **See Figure 5.**

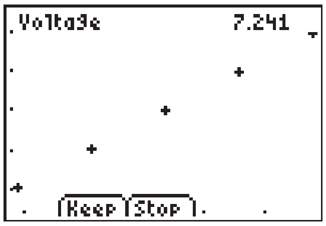


Figure 5

10. Continue for a total of 5 trials. With each recorded value, a new data point will be displayed on the graph. You are given the option to **Keep** or **Stop** the data collection after each trial. When finished, select **Stop**. A graph of your data points will be displayed. Use the right and left arrow keys to view the values of the coordinates of the points. **See Figure 6.**

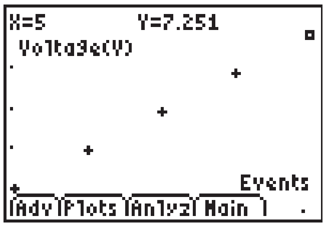


Figure 6

11. To confirm a description of the plots, select the **Plots** soft key. **See Figure 7.** This is a good time to reinforce the use of proper vocabulary. Guide the students to identify the **Voltage** as the dependent variable and the **Events** as the independent variable. Have the students answer questions 2–7 on the **Add Them Up** worksheet.

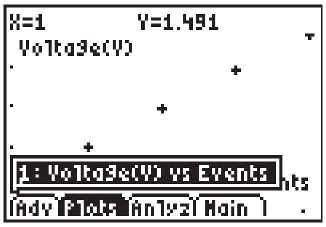


Figure 7

12. Select **Anlyz** and choose **2:Linear Fit** from the menu. **See Figure 8.**

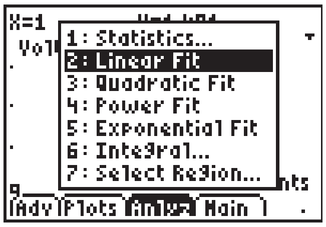


Figure 8

13. The calculator will display an equation for the line of best fit. Select **OK**. Have students answer question 8 on their worksheet. **See Figure 9.**

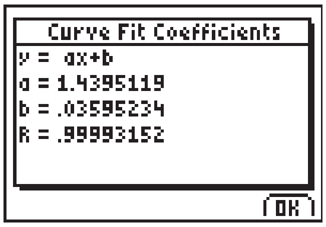


Figure 9

14. The data points will be connected as the regression equation is drawn on the same coordinate plane. **See Figure 10.**

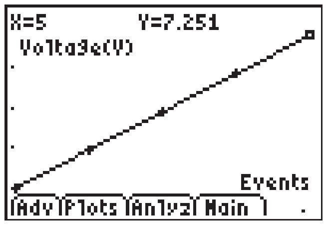


Figure 10

15. Select the **Main** menu and then select **Quit**. A screen will display where the data from your activity is stored. Select **OK** to exit the App. **See Figure 11.**

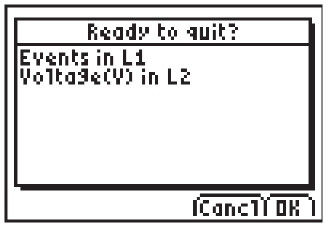


Figure 11

DATA ANALYSIS

1. Have a discussion with your students about slope. Help them understand that the slope of a line is a measure of the steepness or the rate of change of the line. The numerical value of the slope can be related to many physical models. The unit of the slope in this model is voltage/battery. An equation that is often used for this linear model is called the slope-intercept form. It is Y = AX + B, where A = the slope and B = the intersection of the line with the **Y**-axis (or the value of Y when X = 0). This intersection is also called the **Y**-intercept. Let the students know that they may have seen this equation written as Y = mX + b, where m is the slope. Have them re-examine their answer to question 7 on their worksheet.

2. After exiting the EasyData App, the regression equation for the data can be found in one of several different ways. When you quit the EasyData App, your data was stored in **L1** and **L2**. The following directions will use the **Manual-Fit** feature of the calculator to find the regression equation. Press [STAT] [ENTER] to view the lists. **See Figure 12.**

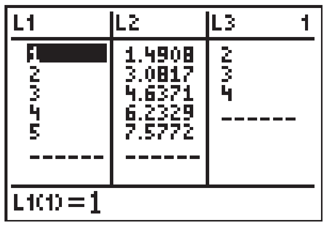


Figure 12

3. If you press [2nd] [Y=] to access the [STAT PLOT] menu, you will see that **Plot1** from this activity is still turned on. **See Figure 13.**

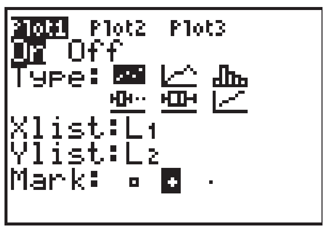


Figure 13

4. Press [GRAPH] to see the plots graphed. Notice that the line of best fit is no longer in the picture. **See Figure 14.**

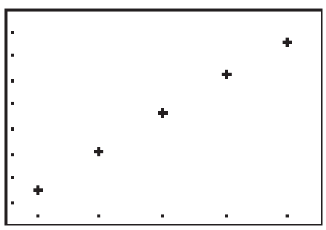


Figure 14

5. The line is still in the [Y=] window, but its equal sign is no longer highlighted. This indicates that the equation is turned off and is not being graphed. The **Manual-Fit** feature will overwrite **Y1**. The current **Y1** will need to be stored in **Y2**. This will allow the **Manual-Fit** line to be compared to the regression equation. **See Figure 15.**

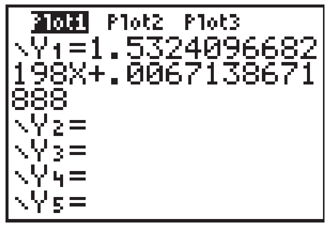


Figure 15

6. Position your cursor next to the equal sign to the right of **Y2**. **See Figure 16.**

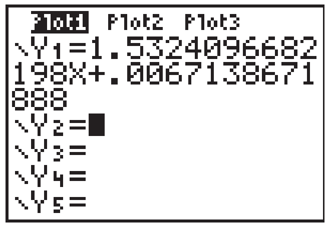


Figure 16

7. Recall **Y1** and paste it into **Y2**. To do this, press [2nd][STO▸] to access [RCL]. **Rcl** (for Recall) should be at the bottom of the screen. **See Figure 17.** Press [VARS], arrow over to **Y-VARS**, select **1:Function** from the menu, and **1:Y1** from the next menu.

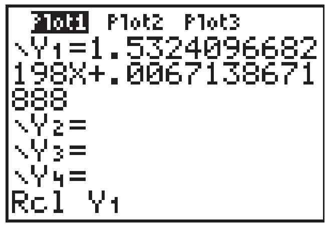


Figure 17

8. Press [ENTER] to complete the command. This will paste **Y1** into **Y2**. This will also highlight the equal sign beside **Y2**. **See Figure 18.** When an equal sign is highlighted, the equation is turned on and the equation will be graphed in the graph window.

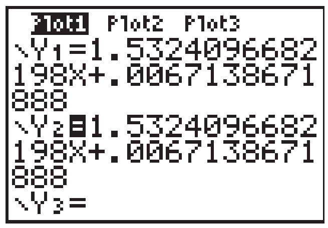


Figure 18

9. Press [GRAPH] to be sure this is the regression equation. **See Figure 19.**

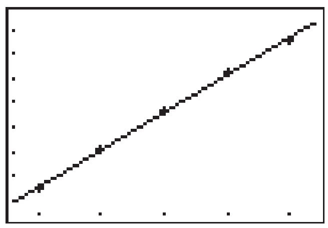


Figure 19

10. Go to the [Y=] window and turn off the equal sign beside both equations. To do this, position the cursor on each equal sign and press [ENTER]. This is a toggle switch. If the equal signs are highlighted, after you press [ENTER], they will be turned off. If they are not highlighted, they will be turned on. **See Figure 20.**

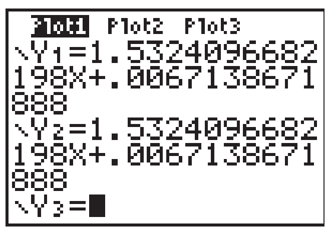


Figure 20

11. Press GRAPH. This will move you to the graph screen. Press STAT, arrow over to **CALC,** and then scroll down until **D:Manual-Fit** is highlighted. **See Figure 21.**

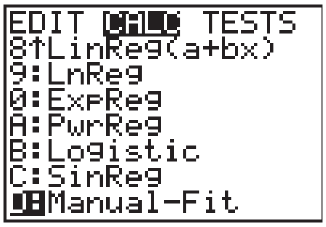


Figure 21

NOTE Most of the menus on the calculator are "wrap around" menus. **Manual-Fit** is the last entry in the **CALC** menu. Instead of starting at the top of the list and having to press the down arrow multiple times, press the up arrow once and you will be taken to the bottom of the list where **Manual-Fit** will be highlighted.

12. Press ENTER. Now you are back to the graph. Use the arrow keys to move the cursor so it is as close as possible to one of the points on the left side of the screen. When there, press ENTER. Next, move the cursor to one of the points on the right side of the screen. **See Figure 22.**

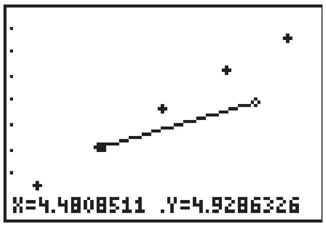


Figure 22

13. When satisfied with the position of the cursor, press ENTER. **See Figure 23.**

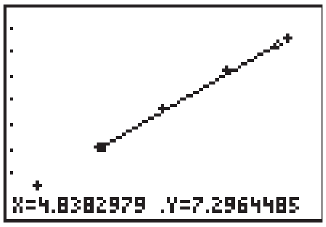


Figure 23

14. The entire line will fill in and its equation will be written across the top of the screen with the slope highlighted. **See Figure 24.**

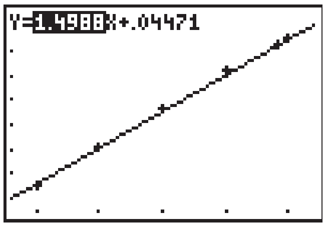


Figure 24

15. Round the slope to the nearest tenth. Type the rounded slope value into the calculator. This new value for slope will be displayed along the bottom left side of the screen. Press ENTER to see the rounded slope value entered into the equation. **See Figure 25.**

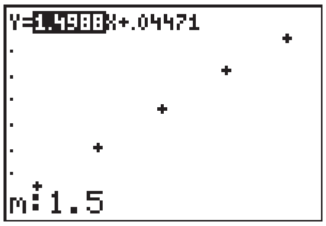


Figure 25

16. Press the right arrow key to highlight the **Y**-intercept. Repeat the process above to change it. Zero is a good choice for the **Y**-intercept because zero batteries would register no voltage. **See Figure 26.**

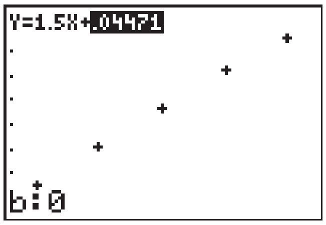


Figure 26

17. Pressing [Y=] will take you out of the **Manual-Fit** program. Your line of best fit will stay in **Y1**. **See Figure 27.**

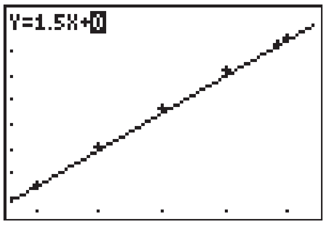


Figure 27

18. To compare how closely the regression equation you found matches the one the calculator found, graph them both at the same time. Vary their graph style so that you can distinguish one line from the other. From the [Y=] window, turn on both **Y1** and **Y2**. Leave **Y1** with the default graph style. Use the left arrow key to highlight the slash icon in front of **Y2**. Repeatedly press [ENTER] until you see the symbol shown in the screenshot on the right. This symbol has a ball with a small line to the left of the ball. **See Figure 28.**

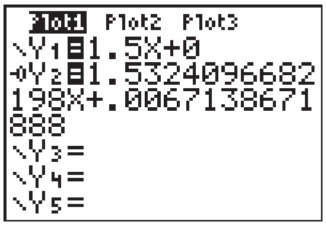


Figure 28

19. Press [GRAPH]. You will see **Y1** graphed normally. A small ball will mark the trail as **Y2** is graphed. This is used to demonstrate how closely your graph matches the graph the calculator found. **See Figure 29.**

20. Have students complete questions 9–11 on their worksheet.

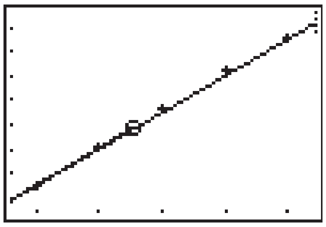


Figure 29

TEACHER NOTES

When batteries are lined up in series, the total voltage is the sum of the voltage of each battery. Notice that the total voltage is calculated by repeated addition. For this example, the total voltage could be calculated by repeatedly adding 1.5 volts. After gathering their data, students should use inductive reasoning to notice that the sequence of voltage can be generalized to the expression, 1.5X, where X is the number of batteries. This gives a simple linear model of the relationship of voltage versus the number of batteries.

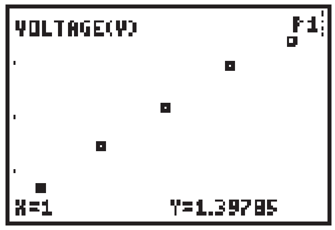
If the batteries are approximately 1.5 volts, the linear equation should be approximately Y = 1.5X + 0, where Y is the total voltage of the series and X is the number of batteries. The slope, or rate of change of the total voltage, is 1.5 volts per battery. The **Y**-intercept is at (0, 0) which represents that zero batteries have zero volts. Have students write the equation using variable names that fit the voltage example.

Students should compare the formula they developed using reasoning and number sense with the Linear Regression line found using the calculator. Point out that for this problem, they were able to develop the model using reasoning skills as opposed to using a calculator.

Discuss with students that they could have used (B, V) instead of the variables (X, Y) to describe the model. The letters B and V may have more meaning in this physical problem. Notice that there could be confusion if B is used to replace X and is also used for the **Y**-intercept. Also, ask students how the linear equation used in the activity, Y = AX + B, compares to the use of Y = mX + b in their math classes. Point out that A = slope = m.

NOTE If the batteries are brand new, the voltage might be greater than 1.5 volts.

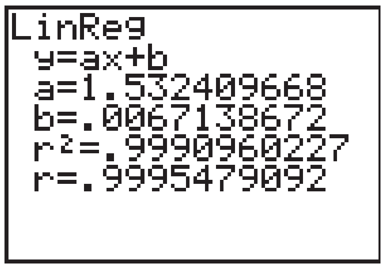
WORKSHEET ANSWERS



1. Answers will vary.
2. Sample graph on right:
3. The general shape of the graph should be a straight line if the batteries are all close to the same voltage.
4. Example: All batteries in this example are 1.5 volts. Adjust your answer accordingly.
5. As you add a battery to the series, the total voltage increases by about 1.5 volts.
6. 9, 15, 30, 1.5n
7. Y = 1.5X, A = 1.5, B = 0

# of Batteries X	Voltage Y
1	1.49
2	3.08
3	4.64
4	6.23
5	7.58

8. See the sample screen. Answers will vary depending on the voltage of each battery.
9. A = slope and B = Y-intercept. If the batteries have slightly different voltages, the value of the calculated slope will be the mean of the voltages. Responses will vary.
10. Look for the correct use of the vocabulary: *slope*, *intercept*, *terminal*, *volts*, and *series*.



ACTIVITY 9

Name: ____________________

Add Them Up Worksheet

Math Objectives:

- Graphing scatter plots
- Multiplication as repeated addition
- Using a pattern to develop a formula

Materials:

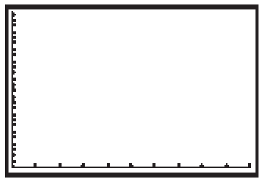
- TI-83/TI-84 Plus Family
- Vernier EasyLink™
- Voltage sensor
- Vernier EasyData™ Application
- 5 same size 1.5 volt batteries (e.g., AA, AAA)

For recording purposes, round all decimals to the nearest hundredth.

1. Record the voltage for each of the five batteries in the table below.

Battery	1st	2nd	3rd	4th	5th
Voltage					

2. Draw the graph of the data collected from measuring the series of one battery, then two batteries, then three, and so on. Label the axes with the appropriate units.



3. If the points on the graph were connected, describe the general shape of the graph. ____________________

4. Press the arrow keys to trace along the data points and record your data, the voltage, in the table provided.

# of Batteries **X**	**Voltage** **Y**
1	
2	
3	
4	
5	

5. What do you notice about the voltage measurements?

____

6. Predict the voltage of a series of six of your batteries. ________

of 10? ________ of 20? ________ of *n* batteries? ________

7. If X = number of batteries and Y = the voltage, use your data to write an equation that describes the relationship of voltage to the number of batteries. Use your equation to fill in A = ______ B = ______ where Y = AX + B.

8. Record the values from the calculator when you used the Linear Fit feature.

A= __________ B= __________ Y= __________

9. Record the values when you used the Manual-Fit feature.

A= __________ B= __________ Y= __________

10. For the equation of the line, Y = AX + B, A is called the __________ and B is called the __________. Are the calculator values of A and B the same as *your* values for A and B? Write a comparison explaining any differences. ____________________

11. Summarize your investigation. Write a description of the total voltage a battery operated device will receive if several batteries are lined up in series. Include a sketch of the batteries in series on the back of this page.

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