Getting Started with Data Collection and the TI-84 Plus Family in High School Mathematics and Science

T³ Professional Development Categories and Learning Objectives

There are three categories of T³ Professional Development, each with a unique set of learning objectives. This workshop is focused on technology integration, and its objectives are as follows:

Technology Integration

- ➢ Emphasis on learning to use TI technology, with broad "how-to" coverage highlighting a wide range of features
- ➢ Subject/content-focused training on appropriate usage of TI technology in the classroom
  - I am comfortable with essential technology skills for exploring math and science content.
  - I can design opportunities for students to use technology as a tool to deepen their understanding of mathematics and science.
  - I can locate and download TI activities that align to my standards.
  - I can describe the role technology should play in the successful implementation of my standards, and I can implement a vision of a classroom where students routinely use technology to engage in the practice and content standards.

Workshops focused on instructional practices and content knowledge have the following objectives:

Instructional Practices

- ➢ Emphasis on classroom practices with technology as a tool to enhance student learning
- ➢ Models CCSS, TEKS, and STEM tasks using in-depth discussions, reflective practices, and essential technology skills
  - I can demonstrate the importance of teacher actions for students' engagement in the Practices, and I can take actions that will enable students to become mathematical and scientific practitioners.
  - I can describe the role that technology should play in the successful implementation of my standards, and I can implement a vision of a classroom where students routinely use technology to engage in practice and content standards.
  - I can design tasks for students to employ the Practices, using technology as a tool to deepen their understanding of mathematics and science.
  - I can ask questions designed to make student thinking visible – to push them to think about connections, make comparisons, or probe their understanding.

Content Knowledge

- ➢ Emphasis on content with technology as support
- ➢ Addresses critical, tough-to-teach topics and new content standards for CCSS or TEKS
  - I have a deeper understanding of the mathematics and science in my content area, and I am aware of the shifts in content that affect what I teach.
  - I can design opportunities for students to use technology as a tool to deepen their understanding of mathematics and science.
  - I can locate and download TI activities that align to my standards.
  - I can describe the role technology should play in the successful implementation of my standards, and I can implement a vision of a classroom where students routinely use technology to engage in the practice and content standards.

Getting Started with Data Collection and the TI-84 Plus Family in High School Mathematics and Science

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Pass the Ball
Student Activity

Name _____

Class _____

Objectives

- Graph scatter plots
- Graph linear functions
- Analyze proportional relations
- Interpret, predict, and analyze data and graphs

Compatible TI Technology

- TI-84 Plus CE, TI-84 Plus C Silver Edition, TI-84 Plus Silver Edition*, TI-84 Plus* (*OS 2.55MP)

Materials

- Stopwatch and small bouncing ball (tennis/racquet balls work well)

Number of People	Trial 1	Trial 2	Trial 3	Average Time in Seconds
4				

1. Fill in the table above.

2. Estimate how long you think it will take to do this activity with everyone in the room participating.

3. Enter the number of people in the group in **L1** and the time for that group to pass the ball in **L2**.

   - Turn on the [STAT PLOT] for **L1** and **L2** using the **9:ZoomStat** feature from the ZOOM menu to scale your window.
   - Make a sketch of these data points in the graph to the right.
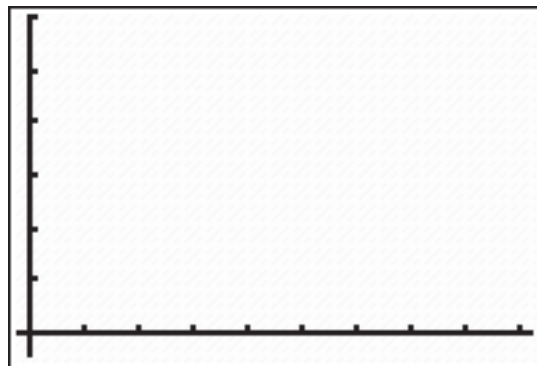
4. Draw what you consider to be a line of best fit.

Pass the Ball
Student Activity

Name _____

Class _____

5. Select two data points through which your line passes and use them to find the slope of your line.
   - Write the equation of your line here _____, enter it into the calculator beside **Y1 =**, and then press GRAPH.
   - Examine how closely the line you drew matches the line on your calculator.

6. It may be helpful to take control of the window settings rather than staying with the **9:ZoomStat** setting.

   - Press WINDOW.
   - Adjust the spread on the *x*-values to be a multiple of 47 as shown here to assure yourself of "friendly" numbers when scrolling.
   - Next, adjust the *y*-values to include the approximation of the time you expect the entire class will take to pass the ball.

```
NORMAL FLOAT AUTO REAL RADIAN MP

WINDOW
 Xmin=-1
 Xmax=65
 Xscl=5
 Ymin=-2
 Ymax=80
 Yscl=10
 Xres=1
 ΔX=.25
 TraceStep=.5
```

7. Press TRACE, and use the down arrow key to trace along the line **Y1**, not the data points.
   - Move to the right until your *x*-value matches the total number of students in your class.
   - Record your *y*-value of that point here and explain what it represents.

     $y =$ _____

8. Turn off **Plot 1**, and clear **Y1** before beginning the Extension activity.

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Pass the Ball
Student Activity

Name _____

Class _____

Extension Activity 1

1. Fill in the table below.

Number of People	Trial 1	Trial 2	Trial 3	Average Time in Seconds
4				

2. Estimate how long you think it will take to do this activity with everyone in the room participating.

3. Enter the number of people in **L3** and
    the time for passing the ball in **L4.**
    - Turn on the [STAT PLOT] for **L3** and **L4**.
    - Use the **9:ZoomStat** feature from the
      ZOOM menu to scale your window.
    - Make a sketch of these data points
      in the graph to the right.
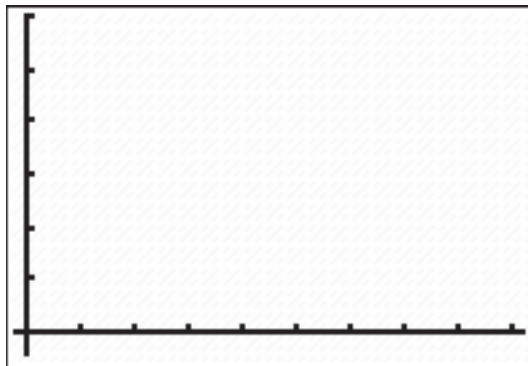
4. Draw what you consider to be the line of best fit.

5. Select two points through which your line passes and use them to find the slope of your line.
    - Write the equation of your line here_____, enter it into the calculator beside **Y1 =**,
      and then press GRAPH.
    - Examine how closely the line you drew matches the line on your calculator.

Pass the Ball
Student Activity

Name _____

Class _____

6. It may be helpful to take control of the window
    settings rather than staying with the
    9:ZoomStat setting.

    - Press [WINDOW].
    - Adjust the spread on the *x*-values to be a
      multiple of 47 as shown here to assure
      yourself of "friendly" numbers when you
      scroll.
    - Next, adjust the *y*-values to include the
      approximation of the time you expect the
      entire class will take to pass the ball.

> NORMAL FLOAT AUTO REAL RADIAN MP
>
> WINDOW
> Xmin=-1
> Xmax=65
> Xscl=5
> Ymin=-2
> Ymax=80
> Yscl=10
> Xres=1
> ΔX=.25
> TraceStep=.5

7. Press [TRACE], and use the down arrow key to scroll along the line entered in **Y1,** not the data points.

    - Scroll to the right until your *x*-value matches the total number of students in your class.
    - Record your *y*-value of that point here and explain what it represents.

    y = _____

8. Was your approximation for the time it took the entire class an exact match to the time you
    recorded from actually doing the activity?

    What could be the cause of any discrepancy?

Pass the Ball

TI PROFESSIONAL DEVELOPMENT

Activity Overview

Many things in everyday life follow patterns. Mathematics can be used to examine the patterns that occur in a specific scenario and then predict future events for that scenario. This activity includes two examples of such patterns. You will record the time it takes to pass a ball around a circle of people. The data will be used to make predictions about how long it will take to repeat that same task a certain number of times. The basic concept has relevance to many areas of math, science, and everyday life.

Objectives

- Graph scatter plots
- Graph linear functions
- Analyze proportional relations
- Interpret, predict, and analyze data and graphs

Compatible TI Technology

- TI-84 Plus CE, TI-84 Plus C Silver Edition, TI-84 Plus Silver Edition*, TI-84 Plus* (*OS 2.55MP)

Materials

- Stopwatch and small bouncing ball (tennis/racquet balls work well)

1. For this activity, begin by having four students stand in a circle.

   - The starter will bounce, catch, and pass the ball to the next person.
   - Continue bouncing, catching, and passing the ball until it is back to the one who started.
   - Explain to students the importance of working at a consistent pace rather than working too quickly.

2. Time how long it takes the ball to get all the way around the circle.

   - Start and stop with the same person.
   - Have students record three trials of this process on their worksheets and calculate the average time.
   - Have them record the average in the chart on their worksheet.

Activity Sample Data	
Number of People	Average Time in Seconds
4	6
6	9
9	16
7	13
15	28

3. Complete the table for five different sets of students.

   - There should be a different number of students for each set.
   - To maximize participation, do not allow the same student to be in more than one group.

4. For the last row in each table, have everyone in the room participate.

   - Before timing this trial, have students predict how long they think it will take and write it on their worksheet.
   - Ask them to share their predictions.
   - Then time the trial for the entire class.

Pass the Ball   TEACHER NOTES
TI PROFESSIONAL DEVELOPMENT

5. Press [STAT] [ENTER] to access the Stat List Editor
    window.

    - Have all students enter the data in L1 and L2. Do NOT
      include the data for the trial that included the entire
      class.
   - Have one student enter the data on the presentation
      calculator.

Data Analysis

6. Create a scatter plot.

    - Press [2nd] [Y=] to access the [STAT PLOT] menu.
    - **1: Plot 1** will be highlighted.
    - Press [ENTER].
    - Use the arrow keys to highlight the On choice, and
      press [ENTER] to select **On**.
    - Continue using the arrow keys to navigate through
      this screen and adjust it as shown in the screen shot.
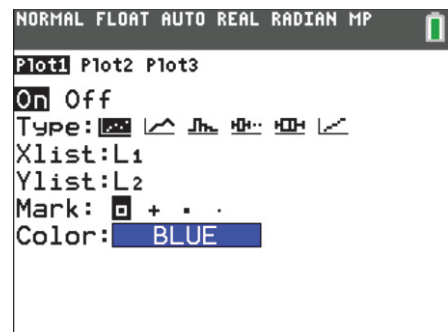
7. Press [ZOOM], and select **9:ZoomStat** by pressing [9]
    or by scrolling down until it is highlighted and pressing
    [ENTER].

    - This feature automatically adjusts the size of the
      graph window to include all the data points.
    - When the scatter plot is displayed, press [TRACE],
      and scroll right and left to see the coordinates of
      each point displayed below the graph.
    - Notice the **Plot1** in the upper left corner.
    - This tells you it is tracing the points from **Plot1**, and
      displays the lists that are the coordinates of the plot.
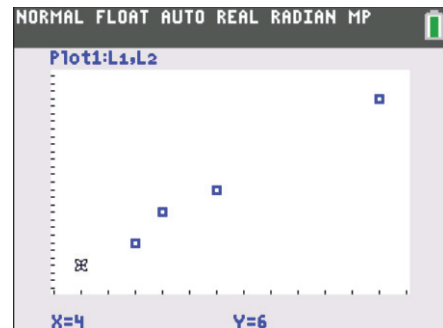
8. Have students fit the data with a function rule. There are several ways you can do this
    depending on your students' understanding of linear functions and features of the
    calculator. Below are three suggestions. Choose the one most appropriate for your
    students. Linear Regression and Manual-Fit Features are taught in subsequent lessons.

    - Use the Linear Regression feature of the calculator.
    - Use Manual-Fit feature of the calculator.
    - Use paper and pencil to sketch a line of best fit, and find its equation.
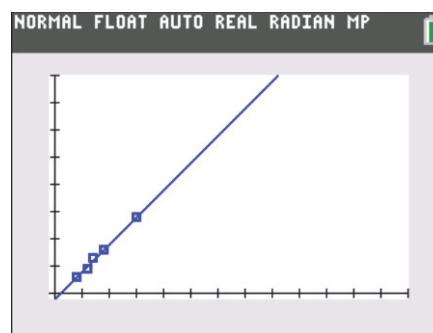
Pass the Ball

TI PROFESSIONAL DEVELOPMENT

The directions here will be for this last option.

a. It may be helpful to take control of the window settings rather than staying with the **9:ZoomStat** setting.

- You can assure yourself of "friendly" numbers (without a lot of places after the decimal point) when you scroll if the spread on the *x*-values is a multiple of 66 as shown.
- Expand the *y*-values to include the approximation of the time you expect the entire class will take to pass the ball.

b. Have students sketch their points in the screen provided on their worksheet. Next, have them sketch their approximation of the line of best fit.

c. After sketching the line on their worksheet, direct students to find an equation and enter it in Y1 of the Y= window.

- To do this, have them identify two points and use their *x*- and *y*-values to determine the slope of the line.

d. Discuss with your students why the point (0, 0) would be a point that should be included with this data.

- How many minutes did it take for no students to pass the ball?
- Add the (0, 0) point to your data lists.
- Since it is likely that the points do not lie in a straight line, have students work in groups and have each group choose two points from the lists.
- Have each group choose a different set of points. One possible answer is (28–6)/(15–4) = 2.

e. Using this slope, have students write the equation of the line in Y1 and compare their lines with each other. Have them graph the line to determine if their lines fit the plotted points.

9. Have students use either the trace or table feature to predict how long they would expect it to take the entire class to complete the activity. Discuss how close their predictions were to the actual time it took the whole class and possible reasons for any discrepancy.

10. Another option for predicting the time it took the entire class to pass the ball is to have the calculator find the *y*-value for a given *x*-value.

   - From the graph screen, press 2nd TRACE to access the [CALC] menu.
   - **1:Value** is highlighted already, so just press ENTER.
   - An X= is displayed in the bottom left-hand corner.
   - Enter the value for the total number of students in the class, and press ENTER.

   Note: The value you enter must be included in the domain that was set in the WINDOW screen.

   The corresponding *y*-value will be displayed, and a cursor will mark the ordered pair on the graph.
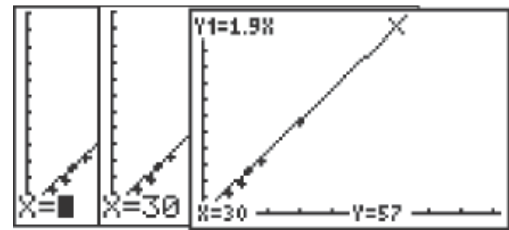
Extension Activity 1

1. Repeat the process, but this time pass the ball without first bouncing it. A list of sample data is shown.

2. After finding the regression equation and entering it into **Y1**, solve a problem that requires a prediction for values that are beyond the values in the recorded data.
   For example, "If it took 50 seconds, how many people were there?"

Extension Sample Data	
Number of People	Average Time in Seconds
5	3.98
7	4.91
9	6.42
11	8.54
15	11.93

3. The equation of the line for the sample question would be 50 = *mx*. If the slope was found to be 0.787, the equation becomes 50 = 0.787*x* and *x* ≈ 64 people.

Pass the Ball

TI PROFESSIONAL DEVELOPMENT

Extension Activity 2

1. To use the calculator's regression feature to get the best fit model, press [STAT], arrow to CALC, and select 4: LinReg(ax+b).

```
NORMAL FLOAT AUTO REAL RADIAN MP
EDIT CALC TESTS
1:1-Var Stats
2:2-Var Stats
3:Med-Med
4:LinReg(ax+b)
5:QuadReg
6:CubicReg
7:QuartReg
8:LinReg(a+bx)
9↓LnReg
```

2. Press [ENTER] and the LinReg Wizard will open. Configure as shown. To access L1 andL2 press [2nd] [L1] and [2nd] [L2].

    *   To access Y1, Press [ALPHA][F4] to choose where to store the equation.
    *   Highlight Calculate and Press [ENTER].

```
NORMAL FLOAT AUTO REAL RADIAN MP
        LinReg(ax+b)
 Xlist:L₁
 Ylist:L₂
 FreqList:L₂
 Store RegEQ:Y₁
 Calculate
```

3. The regression model will be displayed on the home screen.

```
NORMAL FLOAT AUTO REAL RADIAN MP
        LinReg
 y=ax+b
 a=1.996873797
 b=-1.912617962
```

4. Press [GRAPH] to see the model and the scatterplot.

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Pass the Ball

TI PROFESSIONAL DEVELOPMENT
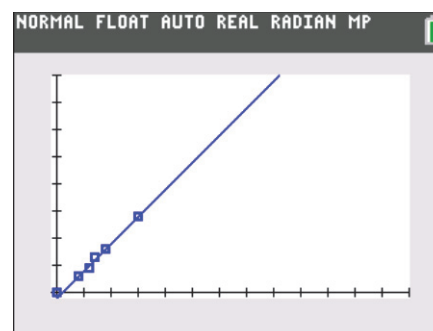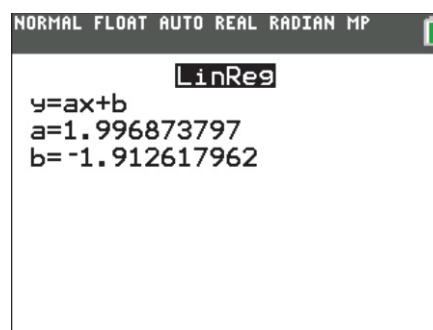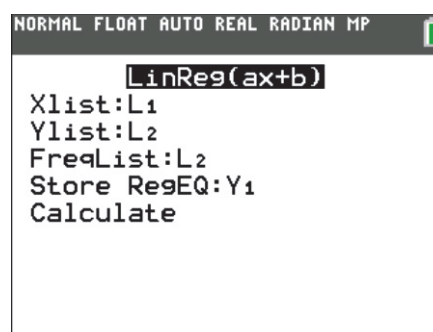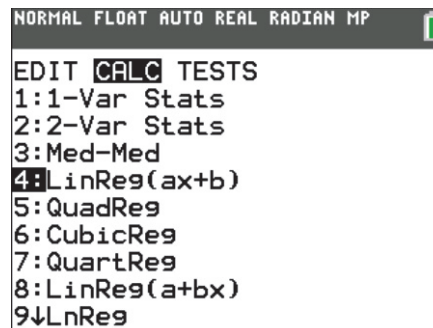
Extension Activity 3

1. Clear out the current Y1 equation. To use the calculator's Manual-Fit feature to get the best fit model, press STAT, choose CALC, scroll to D: Manual-Fit Y=mX+b, and press ENTER.

   Note: More information on **Manual-Fit Y=mX+b** is given in Appendix D.

2. Press ALPHA F4 to choose where to store the equation. Choose Y1, highlight Calculate, and press ENTER.

3. When you get the next screen, use the arrow keys to move the cursor to your first point and press ENTER to drop it.

4. Press the arrow keys to create a line to model the data.

Pass the Ball

TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES
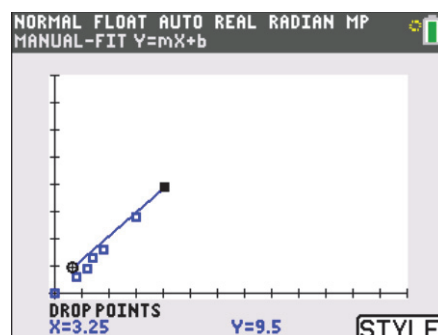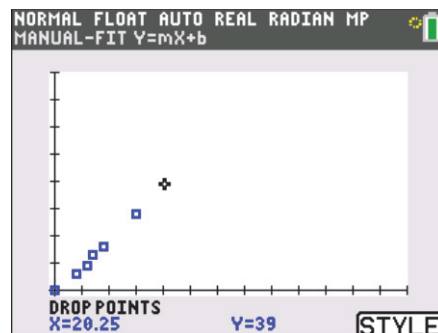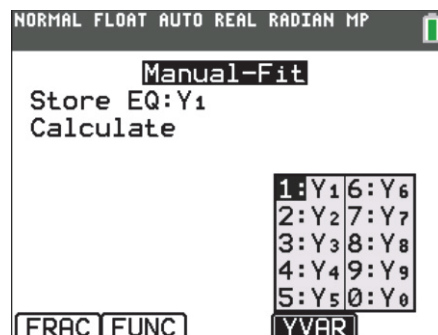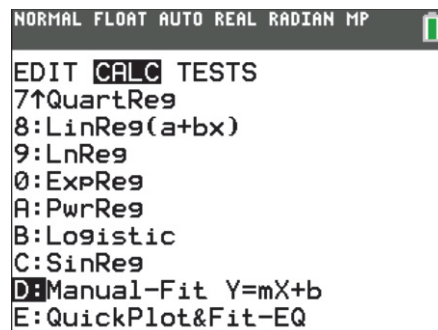
5. Press ENTER to set the end point. The graph will appear.
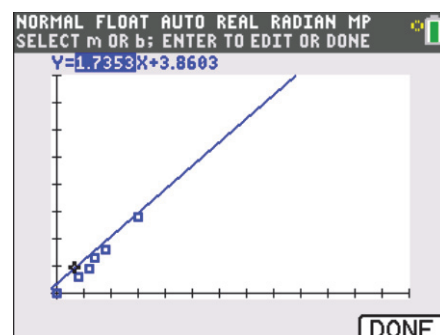
6. Use the left and right arrow keys to switch between the *m* and *b* values. Enter a number and press ENTER to change the value. Change *m* and *b* until you are happy with the fit. Then press 2nd [QUIT] or the **DONE** softkey.
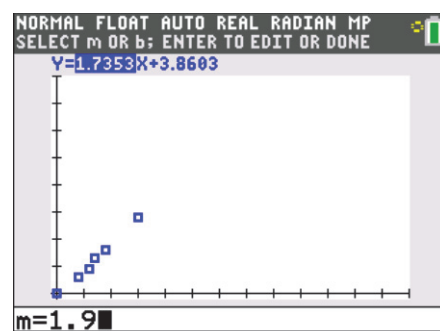
7. Press Y= to view your model.
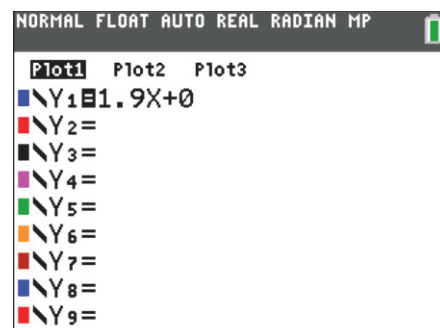
8. Press GRAPH to view the model and the scatterplot.

Pass the Ball
TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES
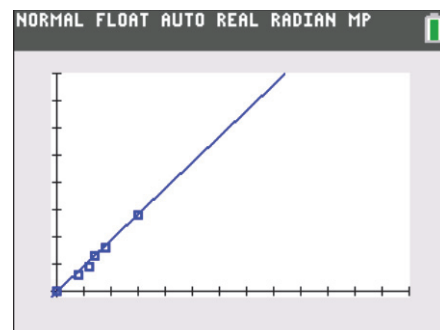
Discussion Notes

- Guide your students toward an understanding of the concept that a change in the *x*-values will cause a change in the *y*-values.

- Point out that if they were able to all pass the ball at exactly the same pace, they would be simulating a constant rate of change in the *x*-values that would bring about a constant and predictable change in the *y*-values.

- The fact that the estimation from the line of best fit is not an exact match to the actual time measured for the entire class is easily explained by human inconsistencies.

- The approximation from the line of best fit was not exact, but it should have been close enough to allow students to understand how this type of model building and reasoning could be used to predict future events with some reasonable degree of accuracy.

Worksheet Answers

The answers to the questions on the worksheet will vary depending on the data collected.

Mass Guessing
TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, you will guess the mass of various items, enter their estimated and actual masses into lists, and graph the results in a scatter plot.

Compatible TI Technology

- TI-84 Plus CE, TI-84 Plus C Silver Edition, TI-84 Plus Silver Edition*, TI-84 Plus* (*OS 2.55MP)

Materials

- Several items with different masses

1. Clear all default lists by pressing [2nd] [+] for [mem] and selecting 4:ClrAllLists.
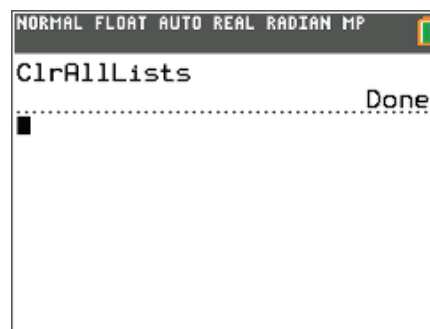
2. Pick up several objects and guess the mass of each.

   - Record the information in the data table.

   - Press [stat] and choose 1:**Edit** to get to the list editor.

   - Enter your predicted mass of each object into in L1. Be sure to enter them in order by assigned number.

Data Table – Be sure to record the units that are used for measuring mass.

Object Number or Description	Predicted Mass	Actual Mass

Mass Guessing

TI PROFESSIONAL DEVELOPMENT

3. Now, find the mass of each object and record the results on the data table and in L2. Be sure to match up items.

L1	L2	L3	L4	L5	2
50	60	------	------	------	
100	90				
25	19				
30	30				
35	38				
25	25				
60	60				
------	------				

L2(8)=

4. Create a scatter plot with the x-list (L1) and y-list (L2) by pressing [2nd] [y=] for [stat plot] and setting the parameters as shown.

Plot1 Plot2 Plot3
On Off
Type: ▨ ⬈ ⬛ ⊞ ⊞ ⬈
Xlist:L1
Ylist:L2
Mark :□ + ▪ ·
Color: BLUE

5. Make sure all Y= are clear, and use ZoomStat to display the ordered pairs (predicted mass, actual mass).

Press [trace] to explore the data points.
Discuss the ordered pairs.
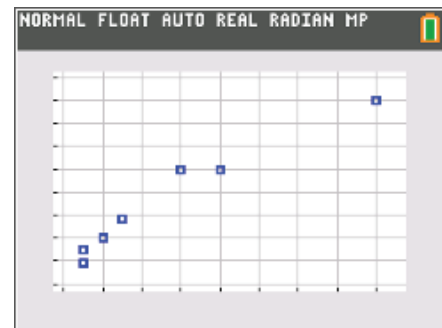
6. Use [y=] and [graph] to enter and display the graph of y = x. Make a sketch of your scatterplot and the line.
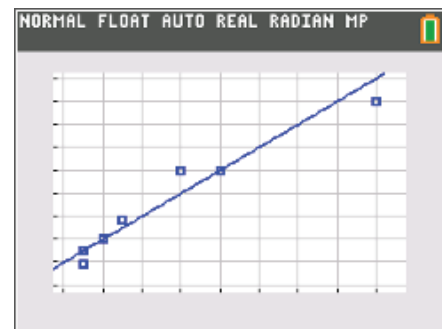
What is the relationship between the scatterplot and the line?

Grandma Ruth
TI PROFESSIONAL DEVELOPMENT

Activity Overview

As I grew up, I had the pleasure and misfortune of having my grandparents live close by. I enjoyed their company, and their constant desire to spoil their grandchildren by buying us things throughout the year. The downside of these shopping trips occurred in late summer when they would take me shopping for school clothes.

Grandma Ruth would insist in buying me several new outfits for school. These outfits would include everything from shirts and pants to shoes and underwear. There was something about buying underwear with your grandmother as a 14 year-old male that made the trip uncomfortable.

To make matters worse, Grandma Ruth had this strange notion that you could determine if a sock would fit your feet by wrapping it around your fist. So there I stood in the department store, wrapping socks around my fist to see if they were going to fit my feet. Grandma Ruth is gone now, and mixed in my fond memories of her is still the question of whether she was a little crazy in her notion of trying on your socks by using your fist rather than your feet.

Compatible TI Technology
- TI-84 Plus CE, TI-84 Plus C Silver Edition, TI-84 Plus Silver Edition*, TI-84 Plus* (*OS 2.55MP)

Materials
- Tape measure

Plan

1. This is your question to answer so that my faith in my Grandma's sanity can be settled. To settle this, you are to use all that you know about the scientific method. The question has been asked, "Does the diameter of your fist determine your foot size?"

2. Your team needs to develop your test, conduct the experiment, analyze the data, and reach a conclusion supported by the data.

3. Include the collection of fist and foot data.

4. Share your team's plan with the class.

5. During the discussion, the class should determine the exact methodology of the investigation. All teams will then conduct the experiment the same way.

Grandma Ruth

TI PROFESSIONAL DEVELOPMENT

Execute

1. The teams will conduct the accepted experiment as prescribed and modified by the class. Data should be collected and entered into the graphing calculator.

2. Place the data for the diameter of the fist (FIST) as the independent variable and the length of the foot (FOOT) in the list editor. Press STAT, and select **Edit** to see the list.

3. Highlight the name of a list, and arrow over to the right or left until you get the first unnamed list.

4. Enter the names **FIST** and **FOOT** in the first and second columns as shown. Now enter the data collected into your newly named lists.

Conclude

1. What did the data indicate? How were you sure? Did all of the variables you listed stay constant or controlled except for the FIST and FOOT?

2. What was your sample size? Was it large enough, how do you know?

3. How did your results compare with other team members?

4. What was the range of the data? Why would that matter?

5. How would you modify the experiment if repeated? Why?

6. Where was the science? What mathematic concepts were involved?

7. What questions come to your mind when you study the data?

Bungee Jumping Barbie®
Student Activity

Name _____

Class _____

Activity Overview

This activity involves a simulation of bungee jumping. The distance a person falls while attached to a bungee cord depends on their weight and the length of the cord. We will keep the person's weight constant by using the same object for the entire experiment. Our goal is to discover how far a person (represented by the doll) will fall based on how long the bungee cord is. Then we will predict how long a cord will be needed to fall from a known height without hitting the ground.

1. What variable do we control? This is the *independent variable*, or the *domain*.

2. What variable is not under our control? This is the *dependent variable*, or the *range*.

3. Make a rubber band chain attached to the ankle of the doll.

   • Begin with two rubber bands and drop it.

   • Add bands, one by one, and repeat until you get to eight rubber bands.

Number of Bands	Average Distance Fallen (cm)
2	
3	
4	
5	
6	
7	
8	

Bungee Jumping Barbie®
Student Activity

Name _____

Class _____

4. Graph the data on the grid provided below:

Bungee Jumping Barbie

Distance Fallen
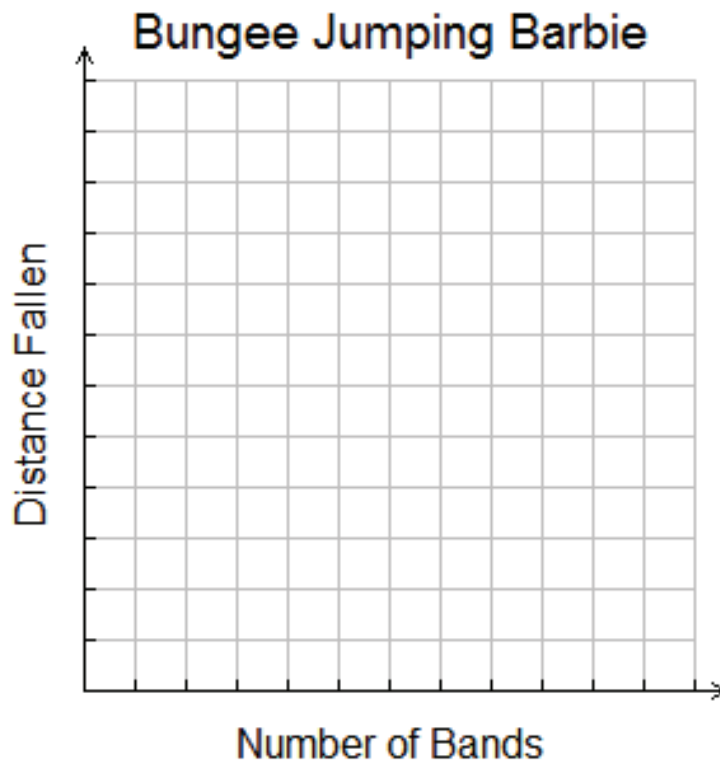
Number of Bands

5. Find a mathematical model using Manual Fit. What equation did you get?

6. Now use your model to predict the number of bands needed to come as close as possible (to get the maximum rush) without hitting from a given distance.

7. What is the given distance provided to you?

8. Using your equation, how many bands will you need? Show work.

Bungee Jumping Barbie®
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Activity Overview

This activity involves a simulation of bungee jumping. The distance a person falls while attached to a bungee cord depends on their weight and the length of the cord. We will keep the person's weight constant by using the same object for the entire experiment. Our goal is to discover how far a person (represented by the doll) will fall based on how long the bungee cord is. Then we will predict how long a cord will be needed to fall from a known height without hitting the ground.

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

Materials

- Dolls suitable for the experiment
- Boxes of sturdy rubber bands (must be the same size)
- Tape measures or meter sticks

Data Collection

1. Collect a doll and eight identical rubber bands.

2. Attach the first band to the ankle of the doll.

3. Attach the free end of the chain at a fixed point from which a tape measure is attached.

4. Release the doll from the fixed point and record the distance it falls. Repeat the experiment several times.

5. Carefully add bands one at a time and test the drop until the length is eight bands. Be uniform in the way these are joined. Use student work sheet to record results.

Data Entry

Enter the number of rubber bands in L_1 and the distances in L_2.

Create a scatter plot of L_1 versus L_2.

Bungee Jumping Barbie®

TI PROFESSIONAL DEVELOPMENT

Analysis

1. Perform a manual fit on this data.

    - Press [STAT] and choose CALC. Scroll to Manual-Fit Y=mX+b and press [ENTER].

    - Press [ALPHA][F4] to choose Y1 to store the equation as Y1. Select Calculate and then press [ENTER].
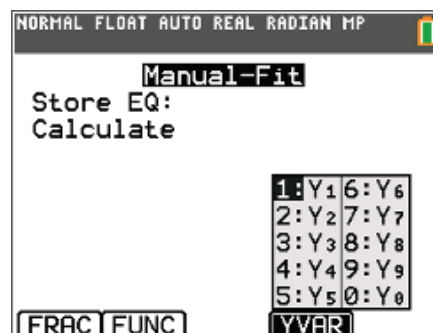
2. When you get the next screen, press [ENTER] to choose the first point.

    - Press the arrow keys to create a line, and press [ENTER] to set the end point. The graph will appear.

    - Change m and b until you are happy with the fit. Then select Done by pressing [f5].
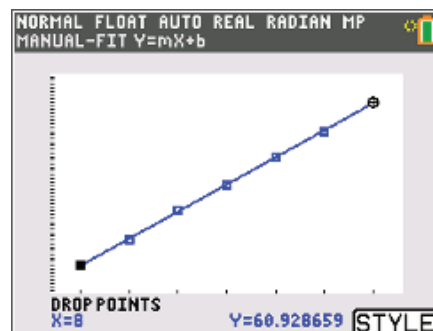
3. The equation is on the screen and can also be seen by pressing [Y=]. Record it here
    _____.

    - Using the resulting equation, predict how many rubber bands you will need to drop the doll from a new height given by the instructor.

    - Test your prediction.

Them Bones
Student Activity

Name _____

Class _____

Introduction

Scientists do not always find all of the bones needed to make real measurements of dinosaurs. They may find a leg bone, or a skull, or a few ribs. By calculating the relationship between the lengths of the bones found, they can estimate the size of the animal.

Artists also use such relationships to sketch the human body in proper proportion. For example, Leonardo da Vinci provided many proportional relationships in his sketch *Vitruvian Man*. Portions of this sketch are shown below. (From https://commons.wikimedia.org/wiki/File:Vitruvian_Man_Metrology.png)

elbow to wrist   heel to toe
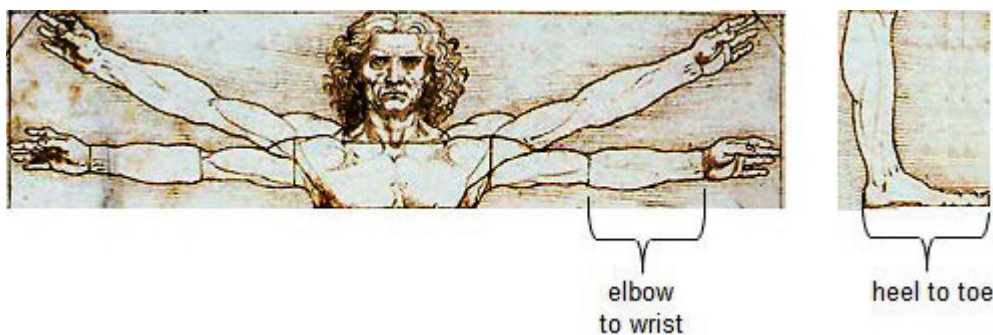
In this activity you will explore the relationship between the two lengths shown above.

Problem - Shoe length versus forearm length

1. Measure the length of your shoe, in cm, using a tape measure or meter stick. Measure your forearm from the bend at the wrist to the elbow using the tape measure or meter stick, in cm. Record each measurement in the data table.

2. Pool the class data (forearm length, shoe length). Your goal is to create a plot and a model similar to the one shown, find a possible formula, and interpret the meaning of the slope.

Use the following steps to enter your data:

3. Press [stat], and then press [enter] to access the Stat editor.

4. If L1 is not empty, press [▲] to move the cursor to the top of the list, and then press [clear] [enter] to clear L1.

5. Press [▲] to move to the top of L2, and repeat step 2 to clear L2.

Them Bones
Student Activity

Name _____

Class _____

6. Move to the first position in L1 [L1 (1)], enter the first value in the forearm length column, and press enter. Continue this process until all values in the forearm length column are entered.

7. Press ▲ to move to the first position in L2 [L2 (1)], and enter the first value in the shoe length column. Continue this process until all values in the column are entered.

8. Press 2nd y= to access stat plot and press enter to access the screen shown.

   - Adjust the settings to match those shown.

   - Use the arrow keys to move around the screen, and press enter to select the settings.

   - Set the viewing window and press graph to see a plot of shoe length versus forearm length.

```
NORMAL FLOAT AUTO REAL RADIAN MP
Plot1 Plot2 Plot3
On Off
Type:▦ ⌐ ⌐ ⌐ ⌐ ⌐
Xlist:L1
Ylist:L2
Mark: □ + .  .
Color:  BLUE
```

Analysis

   - Break off a piece of spaghetti approximately as long as the width of the graphing calculator screen.

   - Then place the spaghetti on the screen of your calculator, and move it around until it best follows the pattern of your points.

   - The spaghetti represents a graph of a line that would predict the relationship between the length of your shoe and the length of your forearm.

   - One way to determine this line is by calculating the Manual-Fit line.

Use the following steps to find the manual fit line for your data points:

   - Press stat ▶ to get the CALC Menu on your calculator for regression calculation.

   - Select option D:**Manual-Fit YmX+b**

```
NORMAL FLOAT AUTO REAL RADIAN MP
EDIT CALC TESTS
7↑QuartReg
8:LinReg(a+bx)
9:LnReg
0:ExpReg
A:PwrReg
B:Logistic
C:SinReg
D:Manual-Fit Y=mX+b
E:QuickPlot&Fit-EQ
```

   - Press alpha [f4] to select the storage location Y1 and press enter. Arrow to Calculate and press enter again. You will be taken to the Graph Screen.

```
NORMAL FLOAT AUTO REAL RADIAN MP
        Manual-Fit
 Store EQ:
 Calculate

                    1:Y1 6:Y6
                    2:Y2 7:Y7
                    3:Y3 8:Y8
                    4:Y4 9:Y9
                    5:Y5 0:Y0
 FRAC FUNC           YVAR
```
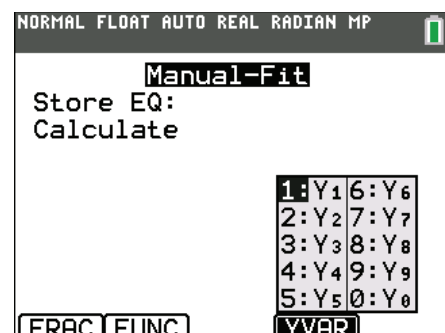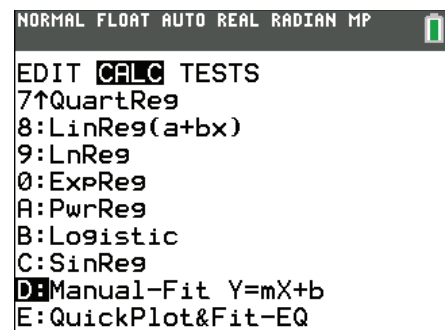
Them Bones
Student Activity

Name _____

Class _____

- Follow the prompts. Press the arrow keys to position the second point, press [enter] to drop the first point, then press the arrow keys to position the second point, and press [enter] to drop the second point

- Optional: Press [graph] [STYLE] to change the color of the manual fit line.
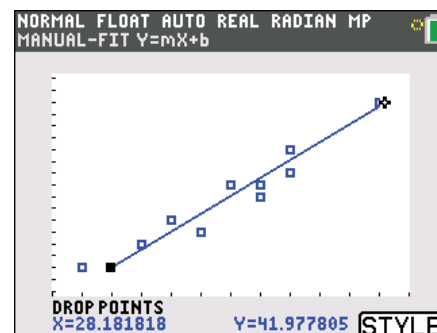
- Once both points have been dropped, the slope will be highlighted. Press [enter] to manually type a number on the entry line to adjust the slope, then press [enter] .

- If desired, you can also adjust the *y*-intercept: press the right arrow to highlight the *y*-intercept, press [enter] to type a number on the entry line, and press [enter].

- Once your line of best fit matches your raw spaghetti fit, press [graph] [DONE] to finish.
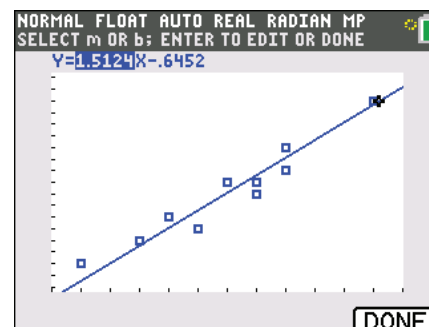
9. Report the formula of your line: _____

10. What are the units of the slope?   _____

11. What does the slope of the line tell you about the relationship between the length of one's shoe and the length of one's forearm?

12. When you spread your fingers, compare the maximum width of your hand to the length of your forearm. If you were to plot the date (forearm length, maximum hand length) what would be the equation of the line containing this data? _____
Is this line *steeper* or *less steep* than the line containing the (forearm length, shoe length) data?
_____

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Them Bones
Student Activity

Name _____

Class _____

Record your data here:

Student Name	Forearm Length (cm)	Shoe Length (cm)

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Them Bones

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About the Lesson

In this activity, students will measure their bones and explore the relationships between the various bone sizes. As a results students will:

- Take measurements and create a scatterplot of (forearm length, shoe size).
- Use raw spaghetti to determine a possible best fit line to model the data.
- Create a scatter plot and use **Manual-Fit YmX+b** to find a formula and graph of a best fit line.
- Interpret the slope in the context of the problem situation.

Vocabulary

- Slope
- Proportional relationships.
- Equivalent fractions
- Conversion factor

Teacher Preparation and Notes

- Students should be familiar plotting points. The student worksheet or teacher notes have tips for how to enter data in lists and create a scatter plot on the TI-84 Plus family of graphing calculators.
- Students work in small groups to perform measurements and discuss their observations. If students are in pairs, they can work cooperatively on their calculators.
- The student worksheet is intended to guide students through the main ideas of the activity. It also serves as a place for students to record their answers. Alternatively, you use the questions posed to engage a class discussion.

Activity Materials

- Meter sticks or measuring tapes
- Raw spaghetti
- Compatible TI Technologies:
  TI-84 Plus*
  TI-84 Plus Silver Edition*
  🌐TI-84 Plus C Silver Edition
  🌐TI-84 Plus CE

* with the latest operating system (2.55MP) featuring MathPrint™ functionality.

Tech Tips:

- This activity includes screen captures taken from the TI-84 Plus CE. It is also appropriate for use with the rest of the TI-84 Plus family. Slight variations to these directions may be required if using other calculator models.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials
- Any required calculator files can be distributed to students via handheld-to-handheld transfer or by using TI-Connect™ CE software.

Lesson Files:

- ThemBones_Student.pdf
- ThemBones_Student.doc

Them Bones

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Introduction

Scientists do not always find all of the bones needed to make real measurements of dinosaurs. They may find a leg bone, or a skull, or a few ribs. By calculating the relationship between the lengths of the bones found, they can estimate the size of the animal.

Artists also use such relationships to sketch the human body in proper proportion. For example, Leonardo da Vinci provided many proportional relationships in his sketch *Vitruvian Man*. Portions of this sketch are shown below. (From https://commons.wikimedia.org/wiki/File:Vitruvian_Man_Metrology.png)

elbow to wrist

heel to toe
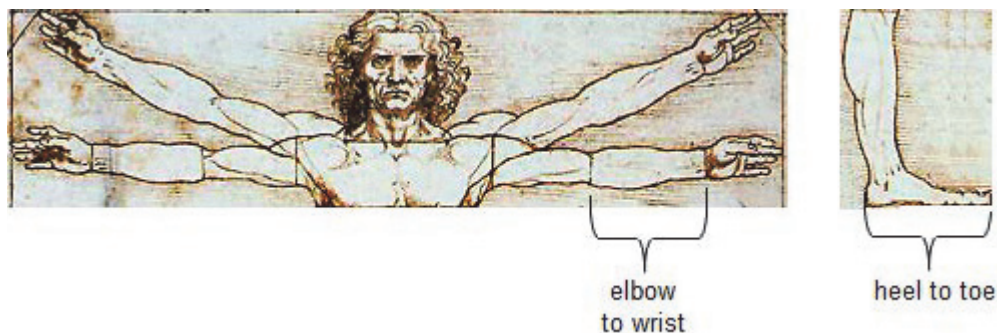
In this activity you will explore the relationship between the two lengths shown above.

> **Teacher Tip:** Shoes are kept on during this activity. The primary objective is to interpret the slope of the line as a conversion factor from the forearm length to the shoe length. Hence, students begin the activity by seeing a plot of sample data to help steer them toward the end result.

Problem - Shoe length versus forearm length

1. Measure the length of your shoe, in cm, using a tape measure or meter stick. Measure your forearm from the bend at the wrist to the elbow using the tape measure or meter stick, in cm. Record each measurement in the data table.

2. Pool the class data (forearm length, shoe length). Your goal is to create a plot and a model similar to the one shown, find a possible formula, and interpret the meaning of the slope.
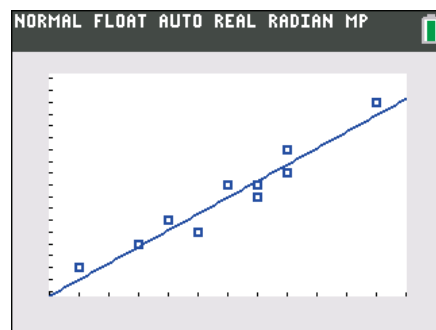
> **Teacher Tip:** Collect about 12 data points.

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Them Bones

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Use the following steps to enter your data:

3.   Press stat, and then press enter to access the Stat editor.

4.   If L1 is not empty, press ▲ to move the cursor to the top of the list, and then press clear enter to clear L1.

5.   Press ▲ to move to the top of L2, and repeat step 2 to clear L2.

6.   Move to the first position in L1 [L1 (1)], enter the first value in the forearm length column, and press enter. Continue this process until all values in the forearm length column are entered.

7.   Press ▲ to move to the first position in L2 [L2 (1)], and enter the first value in the shoe length column. Continue this process until all values in the column are entered.

8.   Press 2nd y= to access [stat plot] and press enter to access the screen shown.

   •   Adjust the settings to match those shown.

   •   Use the arrow keys to move around the screen, and press enter to select the settings.

   •   Set the viewing window and press graph to see a plot of shoe length versus forearm length.

> **Tech Tip:** The zoom **9:ZoomStat** shortcut enables you to quickly produce a viewing window, or you may wish your students to set it manually .(This shortcut does not appear on the student worksheet for you to govern if you wish to use it. If zoom **9:ZoomStat** does not change the window, press 2nd y= [stat plot] to check that Plot1 has been turned on.

Analysis

   •   Break off a piece of spaghetti approximately as long as the width of the graphing calculator screen.

   •   Then place the spaghetti on the screen of your calculator, and move it around until it best follows the pattern of your points.

   •   The spaghetti represents a graph of a line that would predict the relationship between the length of your shoe and the length of your forearm.

   •   One way to determine this line is by calculating the Manual-Fit line.

Them Bones

TI **PROFESSIONAL DEVELOPMENT**

TEACHER NOTES

Use the following steps to find the manual fit line for your data points:

- Press [stat] [▶] to get the CALC Menu on your calculator for regression calculation.

- Select option D:**Manual-Fit YmX+b**

```
NORMAL FLOAT AUTO REAL RADIAN MP
EDIT CALC TESTS
7↑QuartReg
8:LinReg(a+bx)
9:LnReg
0:ExpReg
A:PwrReg
B:Logistic
C:SinReg
D:Manual-Fit Y=mX+b
E:QuickPlot&Fit-EQ
```

- Press [alpha] [f4] to select the storage location Y1 and press [enter]. Arrow to Calculate and press [enter] again. You will be taken to the Graph Screen.

```
NORMAL FLOAT AUTO REAL RADIAN MP
            Manual-Fit
  Store EQ:
  Calculate

                    1:Y₁ 6:Y₆
                    2:Y₂ 7:Y₇
                    3:Y₃ 8:Y₈
                    4:Y₄ 9:Y₉
                    5:Y₅ 0:Y₀
 FRAC FUNC          YVAR
```

- Follow the prompts. Press the arrow keys to position the second point, press [enter] to drop the first point, then press the arrow keys to position the second point, and press [enter] to drop the second point.

- Optional: Press [graph] [STYLE] to change the color of the manual fit line.

```
NORMAL FLOAT AUTO REAL RADIAN MP
MANUAL-FIT Y=mX+b

DROP POINTS
X=28.181818      Y=41.977805  STYLE
```

- Once both points have been dropped, the slope will be highlighted. Press [enter] to manually type a number on the entry line to adjust the slope, then press [enter].

- If desired, you can also adjust the *y*-intercept: press the right arrow to highlight the *y*-intercept, press [enter] to type a number on the entry line, and press [enter].

```
NORMAL FLOAT AUTO REAL RADIAN MP
SELECT m OR b; ENTER TO EDIT OR DONE
    Y=1.5561X-1.549

m=1.5561
```

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Them Bones

TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT

- Once your line of best fit matches your raw spaghetti fit, press [graph] [DONE] to finish.

9. Report the formula of your line:

   Answer: y = 1.5x + 1.5 is one possible result for the sample data but answers will vary for each class.

10. What are the units of the slope?

    Answer: shoe length per forearm length

> **Teacher Tip:** Students may be tempted to say that the units cancel. They are partially correct. Since both are measured in cm, the *cm* cancel, but watch that they do not cancel "*them bones*."

11. What does the slope of the line tell you about the relationship between the length of one's shoe and the length of one's forearm?

    Answer: $m = \dfrac{\Delta y}{\Delta x} = \dfrac{\text{cm shoe length}}{\text{cm forearm length}} \approx 1.5$, so if both shoe length and forearm length are in the same

    units, the slope *m* converts one to the other. Cross multiply: $1.5 \text{ forearm lengths} = 1 \text{ shoe length}$.

    In other words, *m* tells us how many forearms long is the length of your shoe.

    With a slope of 1.5, we can also propose that shoe length is 50% more than forearm length. Similarly, the length of one's forearm is two thirds or about 67% of the length of one's shoe.

    Students could take off their shoe to hold next to their forearm to compare the lengths.

    Students can use proportional reasoning and equivalent fractions: 3/2 forearms = 1 shoe

    1 forearm = 2/3 shoes

    3 forearms = 2 shoes, etc.

12. When you spread your fingers, compare the maximum width of your hand to the length of your forearm. If you were to plot the date (forearm length, maximum hand length) what would be the equation of the line containing this data?

    Answer*:* *y* = *x*. Hand span length = the forearm length.

    Is this line *steeper* or *less steep* than the line containing the (forearm length, shoe length) data?
    Answer: For the sample data the line is less steep. The slope of *y* = *x* is 1 which is smaller than 1.5.
    Students can hold up their hand to their forearm to find this relationship without a meter stick. See
    http://www.craftsy.com/blog/2013/08/the-art-of-drawing-hands/ for more connections to art.

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Them Bones

TI PROFESSIONAL DEVELOPMENT

Extension: The wrist to the tip of the hand ≈ 2/3 forearm length. How many hand lengths = 1 shoe length?

Answer: 1 hand ≈ $\frac{2}{3}$ forearm so $\frac{3}{2}$ forearm = 1 hand. Use the slope as a conversion factor:

$$1 \text{ shoe} = 1 \text{ shoe} \cdot \frac{3/2 \text{ forearm}}{1 \text{ shoe}} \cdot \frac{1 \text{ hand}}{2/3 \text{ forearm}} \approx 1 \text{ shoe} \cdot \frac{3/2 \text{ forearm}}{1 \text{ shoe}} \cdot \frac{3/2 \text{ hand}}{1 \text{ forearm}} = \frac{9}{4} \text{ hands or about 2.25 hands.}$$

Teacher Tip: Students should have their hand spread apart as far as possible to check their results.

Maximum hand length when you spread your fingers
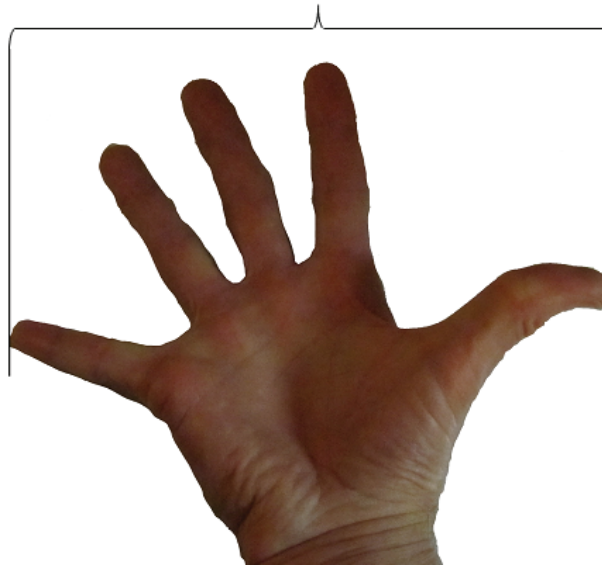
Match the Graph
Student Activity

Name _____

Class _____

Objectives
- Examine the rate of change
- Analyze and interpret the graph of a function

Materials
- CBR 2™ (Calculator-Based Ranger 2™ data collection device) and cable
- Vernier® EasyData™ app

Compatible TI Technology
- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition (OS 2.55MP)
- TI-84 Plus (OS 2.55MP)

---

1. What physical property is represented along the *x*-axis?

2. What are the units? How far apart are the tick marks?

3. What physical property is represented along the *y*-axis?

4. What are the units? How far apart are the tick marks?

5. For one of the sample graphs your teacher displays, how far from the CBR 2 motion detector do you think the walker should stand to begin?

6. Should you walk towards the CBR2 or away from the CBR2 for a segment that slopes up? Why?

7. Should you walk towards or away for a segment that slopes down? Why?

Match the Graph
Student Activity

Name _____

Class _____

8. What should you do for a segment that is flat? Why?

9. How should you walk if the segment is steep?

10. How should you walk if the segment is not steep?

11. Can you match the graph if the segment is vertical? Why or why not?

12. Can you match the graph if it is shaped like the letter "Z"? Why or why not?

Match the Graph

**TI PROFESSIONAL DEVELOPMENT**

Activity Overview

This is designed as a teacher-led activity, with students volunteering one at a time walking to match a distance/time graph created by the CBR 2™ motion detector attached to a TI-84 Plus CE. If multiple CBR 2™ units are available, have students work in groups of 2-4 once they are familiar with the activity. This will lead to hands-on experience using the CBR 2™ motion detector and the Vernier® EasyData™ App.

Materials

- TI-84 Plus CE, TI-84 Plus C Silver Edition, TI-84 Plus Silver Edition*, or TI-84 Plus* (*OS 2.55MP)
- CBR 2™ (Calculator-Based Ranger 2™ data collection device) and USB CBR-to-calculator cable
- Vernier® EasyData™ App
- Document Camera to display the TI-84 Plus CE screen

Setting up the activity

1. Set up the activity as shown at right. Be sure there are no objects between the CBR 2™ and the student volunteer.

2. Link the CBR 2™ directly to the TI-84 Plus CE with the USB CBR-to-calculator cable. Position the TI-84 Plus CE so the document camera projects the calculator screen for the whole class to see.

3. The EasyData App should launch automatically if the USB CBR-to-calculator cable is used. If not, press `apps` and select EasyData.
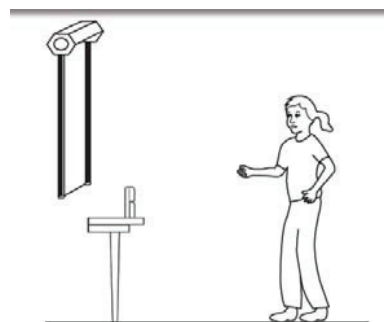
   Press `[f1]` (the `y=` key) to access the **File** menu, and select **1:New.**

   - This resets the program and clears out old data.

   - In general, the "soft keys" at the bottom of the screen are accessed by pressing the top row of keys on the calculator. While the EasyData App is running, the `alpha` key is not needed to access these soft keys.

Match the Graph

TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT
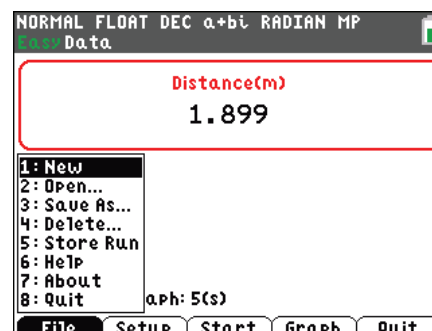
4. The default unit of measurement on the EasyData™ app is meters. Change the units to feet by doing the following:

   - Press [f2]**Setup**.

   - From the Setup menu, choose **1:Dist** by pressing [1] or [enter] (if 1 is highlighted).

5. From the [f2]Units menu, select **2:(ft)** by pressing [2], or scroll down until the 2 is highlighted and press [enter].

   Then select [f5]**OK**.

6. Change the default settings for Time Graph from 5 seconds to 10 seconds.

   Press [f2]**Setup** then select **2: Time Graph…**

7. Press [f3]**Edit.** Keep the default setting for Sample Intervals at 0.05 seconds by pressing [f3]**Next** without making any changes.

8. Change Number of Samples to 200. Press [f3]**Next**.

9. The Experiment Length should now say 10 seconds. Press [f5]**OK.**

You will be returned to the main screen of the EasyData™ App. The App senses the CBR 2™ and immediately displays the distance across the top of the screen of the closest object to the sensor.

Match the Graph

TI PROFESSIONAL DEVELOPMENT
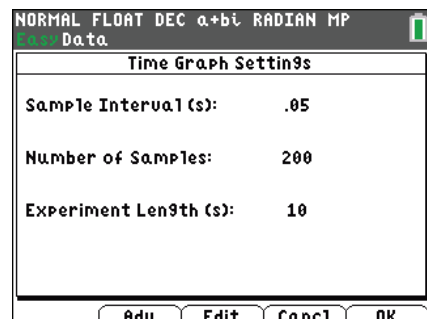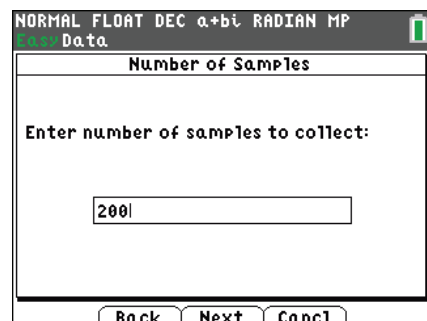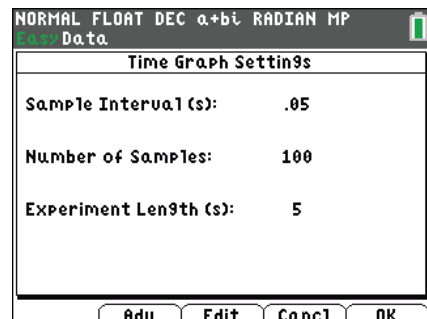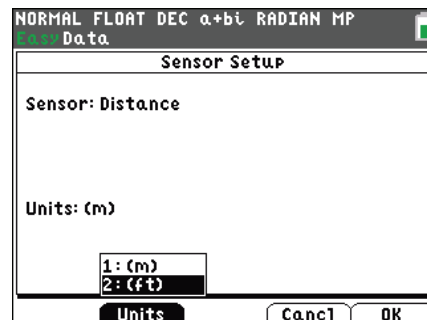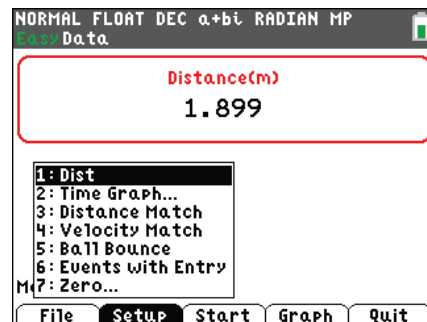
Introduction to Graphs from Motion Sensors

10. Block the class from viewing the screen projected by the document camera. Have a student volunteer choose a position approximately 10 feet from the CBR2. This is a good exercise in distance estimation. Have the class "assist" the volunteer in choosing his/her position. Display the screen for the class and let the volunteer adjust his/her position as needed.

11. Press [f3]**Start** and instruct the volunteer to walk in front of the CBR2 for 10 seconds. Direct the walker (or several walkers, one at a time) to walk at different rates and in different directions and also to stand still.

12. After each walk is finished, the time graph will be displayed. Ask questions such as:

- *What does the starting point represent?*
- *What does a fast walk look like?*
- *What does a slow walk look like?*
- *What does standing still look like?*
- *What does it look like when you walk away from the motion detector vs toward the motion detector?*
- *What would be required so the graph of a walk will be a vertical line?*
- *What would be required for a portion of the graph to be parabolic instead of linear?*

Matching the Graph

13. Select [f2]**Setup**, and choose **3:Distance Match**.
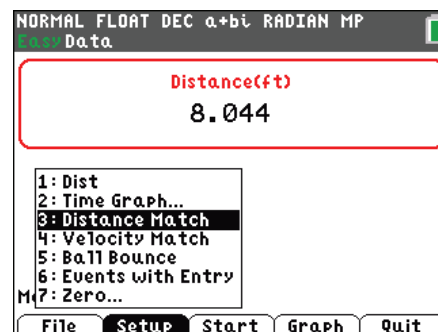
14. Press [f3]**Start**, and follow the instructions on the screen. **Distance Match** automatically takes care of window and time settings.

Match the Graph

TI PROFESSIONAL DEVELOPMENT
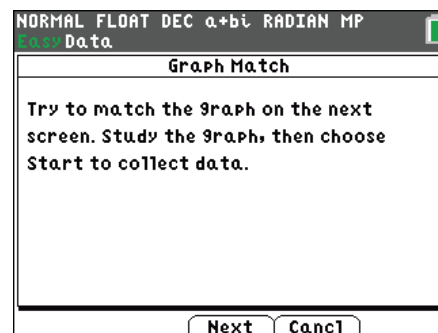
15. Press [f3] **Next** to display the first graph to be matched for this activity.

    • Take a moment to study the graph with your students.

    • Have them answer Questions 1–5 on their worksheets.
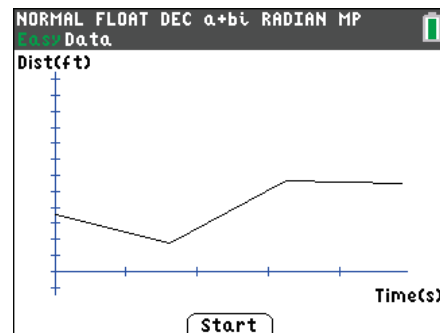
16. Have a volunteer walker stand facing the CBR 2.

    • Select [f3] **Start** to begin the activity. As the walker starts to move, a trace of the walker's path will be displayed in real time along with the original graph.

    • The goal is for the walker's path to match the given graph. A perfect (almost impossible) match is when the walker's path completely covers the given graph.

    • Initial results will vary. As students get more practice, both walking and watching, their graphs will match more closely.
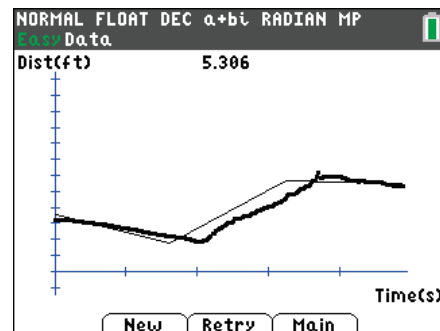
    As time permits, have as many volunteers as possible try to "match the graph."

Working in Groups

If multiple CBR 2™ units are available, have students practice in groups for 5–15 minutes.

1. One setup has the student hold the calculator and CBR 2 while pointing the CBR 2 at the wall as shown.

2. Students should take turns in their groups having each participant gain experience using the CBR 2 and walking to match the graph.

3. An alternative setup is to have one student hold and operate the TI-84 Plus CE, a second student hold the CBR2, a third student will walk when instructed, but because this student will not be able to see the calculator screen, the rest of the group will have to provide clear instructions for how to walk.
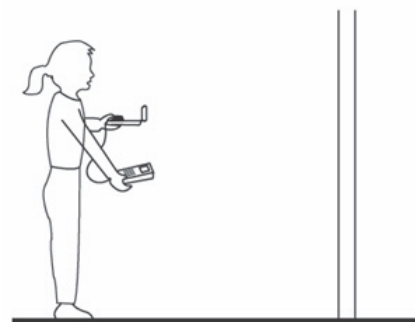
Measure Up
Student Activity

Objectives

- Create a box-and-whisker plot
- Analyze and interpret the data

Materials

- 2 meter/yard sticks or 1 measuring tape per group
- Adhesive tape

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

Overview

What is the average height of the students in your class? How does your height compare with the class average? How does your teacher's height compare? You can use statistics to answer these questions and describe the general characteristics of a set of measurements.

Data Collection

Follow your teacher's instructions for measuring the heights in inches (or centimeters) of you and your classmates. Record the heights here:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Hand Drawn Box-and-Whisker Plot

1. A special type of plot called a box-and-whisker plot shows a statistical picture of the data by graphically representing the lower extreme, lower quartile, median, upper quartile, and upper extreme. Draw a hand drawn box-and-whisker plot for the height data you collected by following these steps:

    a. Immediately below the number line, make a dot plot by plotting, with a dot, each of the heights you collected. If 2 or more people are the same height, make a dot for each of the heights.

```
  ◄──┼────┼────┼────┼────┼────┼────┼────┼────►
    48   52   56   60   64   68   72   76   80
```

Measure Up
Student Activity

Name _____

Class _____

2. Follow your teacher's instructions to find the numbers to fill in this chart.

FIVE-NUMBER SUMMARY	Your answers:
Minimum (minimum height)	
Q1 (first quartile—median of lower half)	
Median (median value)	
Q3 (third quartile—median of upper half)	
Maximum (maximum height)	

3. **Completing the Box-and-Whisker Plot by Hand**

   a. Above the number line on previous page, draw a vertical line to mark each of the five numbers in the Five-Number Summary Chart.

   b. Draw horizontal lines to complete the "box" between the lower quartile to the upper quartile, using the vertical lines through Q1 and Q3 as sides.

   c. Complete your Box Plot by drawing line segments (whiskers) from the rectangle to the extremes.

   Your Box Plot will look something like this (the lengths of the horizontal segments will vary)

Minimum   1ˢᵗ quartile   median   3ʳᵈ quartile   maximum
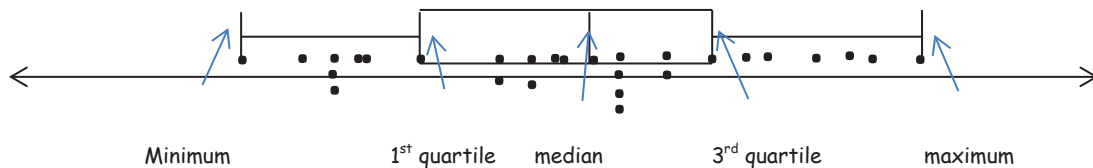
4. **Entering Data into the TI-84 Plus CE**

   1. Press [stat]. Then press [1] to select 1:Edit.
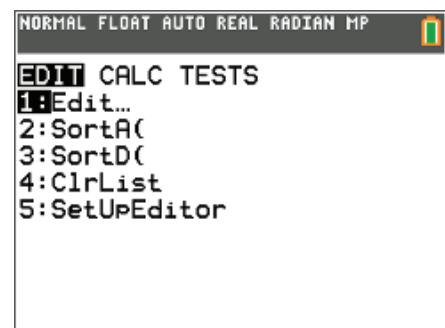
Measure Up
Student Activity

2. This opens the List Editor. If there is any data in List 1, move the cursor to the L1 header and press clear. Then press enter.

3. Type all the heights into list 1.

5. **Calculating the Five-Number Summary with the TI-84 Plus CE**

1. Return to the HOME screen by pressing 2nd [quit].

2. Press stat, then press ▶ to access the CALC menu.

3. Press 1 to choose 1-Variable Statistics. (1:1-Var Stats). This opens the 1-Var Stats Wizard. If needed, define **List** to be List 1 by pressing 2nd [L1]. Leave **Freqlist** blank, move the cursor down to **Calculate** and press enter.
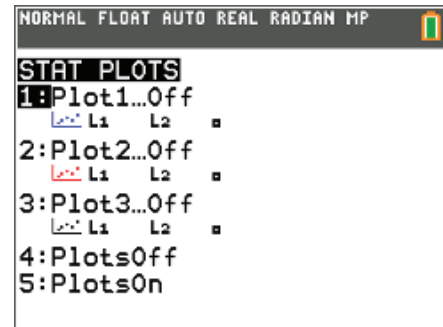
4. To display the Five-Number summary, press the down arrow repeatedly until the bottom of the list is reached. Compare these results from the TI-84 Plus CE with the results calculated one at a time previously on the first page.

Measure Up
Student Activity

Name _____

Class _____

6. **Displaying a Box-and-Whisker Plot**

1. Press [2nd] [stat plot]. Choose Plot1 by pressing [1].

```
NORMAL FLOAT AUTO REAL RADIAN MP
STAT PLOTS
1:Plot1…Off
     Lı   L2    ▪
2:Plot2…Off
     Lı   L2    ▪
3:Plot3…Off
     Lı   L2    ▪
4:PlotsOff
5:PlotsOn
```

2. Highlight On and press [enter] to select On. (A common error is to highlight it without selecting it). Select the Type.

3. Highlight ⊡·· and press [enter] to select it. This is the 2nd Box Plot option, with disconnected outliers.

4. Does your StatPlot menu look like the one at right?

```
NORMAL FLOAT AUTO REAL RADIAN MP
Plot1  Plot2  Plot3
On  Off
Type:
Xlist:Lı
Freq :1
Mark :▫  +  ·  ·
Color:   BLUE
```
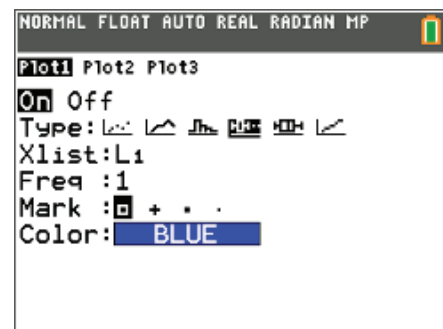
5. Press [window]. With help from your teacher, choose appropriate window parameters. Xmin should be a little less than the shortest person; Xmax should be a little more than the tallest person. Since the Box Plots are independent of the Y variable, let Ymin=0 and Ymax=10.

```
NORMAL FLOAT AUTO REAL RADIAN MP
WINDOW
 Xmin=■0
 Xmax=75
 Xscl=5
 Ymin=0
 Ymax=10
 Yscl=1
 Xres=1
 △X=.09469696969697
 TraceStep=.18939393939394
```

6. Press [graph]. Make a sketch of your Box-and-Whisker Plot here.

7. Press [trace], and use the right and left arrow keys to scroll through the plot, paying attention to the data at the bottom of the screen. Place the screen data in the appropriate place on your sketch. For easy display, round numbers to the nearest hundredth before recording this information on the screen.

```
NORMAL FLOAT AUTO REAL RADIAN MP
```
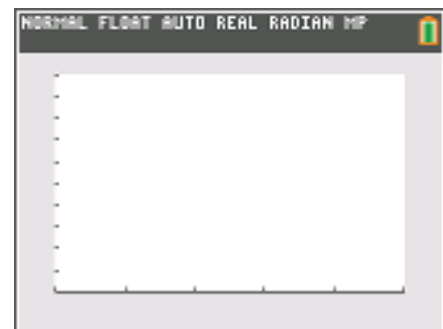
8. a. Approximately what percentage of the heights is greater than the upper quartile?_____

   b. About what percentage is less than the lower quartile? _____

9. Notice that the box part of the plot represents the middle 50 percent of the data set. The size and location of the box tell you certain things about the data. A wider box indicates that the data is spread out and a smaller box means the data is clustered. Discuss the size and location of the box part of your plot. Describe how it relates to the measured heights

10. The length of the whiskers on the box plot gives a hint as to the distribution of the data. If one whisker is significantly longer than the other, the data is skewed in the direction of the longer whisker. This means that the data is bunched together near the shorter whisker. Describe the whiskers on your plot. What do the whisker lengths tell you about the heights?

11. If the heights in this activity were measured in centimeters rather than feet, how would your box plot be affected? Explain your reasoning

Measure Up
Student Activity

Name _____

Class _____

7. **Displaying and analyzing a Histogram along with the Box-and-Whisker Plot**

1. Press 2nd [stat plot]. Choose Plot2 by pressing 2.

2. Set up a Histogram plot as shown at right.

```
NORMAL FLOAT AUTO REAL RADIAN MP
Plot1 Plot2 Plot3
On Off
Type: ⌐ ⌐ ⌐ ⌐ ⌐ ⌐
Xlist:L1
Freq :1
Color:    RED
```

3. Press graph. If your histogram doesn't fit properly on the screen, follow your teacher's instructions to adjust the window settings.

   Sketch your histogram and box plot here. Press trace. Press the left and right arrow keys to move along each graph. Press the up and down arrow keys to move between the histogram and the box plot.

```
NORMAL FLOAT AUTO REAL RADIAN MP
```
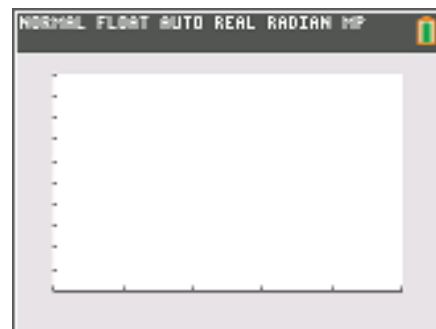
4. Trace to any bar on your histogram. At the bottom of the screen, "min", "max", and "n" are displayed. Use these 3 values to explain how to interpret this bar on your histogram.

5. The boxplot helped you analyze the data by separating it into four quarters. How does the histogram help you analyze the data?

6. Box Plots and Histograms can be distorted by outliers, data values that are significantly higher or lower than the rest of the data. Add a newborn baby (20 inches) to the data. Describe how this changes the graph. Would this have a bigger impact on the median or the mean?

Measure Up
TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, you will collect data of the heights of 12 students and the teacher in your class, create a plot showing the heights of 12 students and the teacher in your class, calculate the extreme values and median for the height data, and construct a box-and-whisker plot to summarize the height statistics.

Objectives

- Create a box-and-whisker plot
- Analyze and interpret the data

Materials

- 2 meter/yard sticks or 1 measuring tape per group
- Adhesive tape

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

Overview

What is the average height of the students in your class? How does your height compare with the class average? How does your teacher's height compare? You can use statistics to answer these questions and describe the general characteristics of a set of measurements.

Data Collection

1. Measure the height of the teacher and the heights of all the students. Record in the chart on page 1 of the student activity. Include the teacher's height because it might make a long whisker and a good topic for discussion.
2. For more consistent results, instead of holding a meter stick or measuring tape up to a student, attach the sticks or the tape to a wall and have the student stand with his/her back against the wall and the ruler. Placing a large book or other flat object on the student's head can make it easier to get a more accurate reading against the ruler.
3. This activity works best using the units that students are most familiar with. Use centimeters or inches as appropriate.
4. Each student should record all the heights on the chart on the first page of the student handout.

Five-Number Summary & Box-and-Whisker Plot, by Hand

1. Students will construct a dot plot of all the heights immediately below the number line.
2. Students will calculate the Five-Number Summary by filling in the chart at the bottom of page 1. The median is the middle number when all the data is arranged in order. When the number of data items is even, the median is the mean of the two middle values. The lower quartile, Q1, is the median of the lower half of the data; the upper quartile, Q3, is the median of the upper half.
3. Students draw the box-and-whisker plot by hand by following instructions at the top of page 2.

Measure Up

TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT
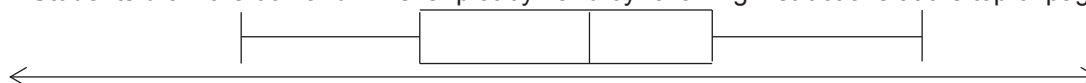
Setup the TI-84 Plus CE for a Box-and-Whisker Plot

4. Each student enters the data into List 1 of his/her TI-84 Plus CE spreadsheet by following the instructions on page 3 of the Student Activity

5. Use 1-Var Stats to have TI-84 Plus CE calculate the whole Five-Number Summary all at once.

6. Use the STAT PLOTS menu to set up a box-and-whisker plot. Follow instructions on page 3 and 4 of the Student Activity.

Note for students still needing the data entered into their own TI-84 Plus CE:

Each student needs to have this data in his/her own calculator for the data analysis.

- This is an opportunity to have the students link the data from calculator to calculator/

- If linking gets to be standard operating procedure, thirty students can link in less than three minutes. When one calculator links to one other, then two link to four, four to eight, eight to sixteen, etc., it goes very quickly. This leads to the entire class staying on task until everyone is ready.

Boxplot Explanation

A box-and-whisker plot, also called a boxplot, is a data representation that divides a data set into four regions with equal numbers of data points. The boxplot allows you to focus your attention on a few important features without the clutter that results when all data values are displayed. The median, or second quartile, separates the set into two halves. The first quartile is the median of the lower half and the third quartile is the median of the upper half. If you have an even number of data points, the median is found by calculating the average (mean) value of the two data points in the middle. One half of the data falls between the first and third quartiles.

The 1st quartile (Q1) value tells you that 25% of the values (in this case, the heights) are equal to or lower than Q1. The 3rd quartile (Q3) value is the point where 75% of the values are equal to or lower than Q3. This means that 50% of the class data is between Q1 and Q3. A shorter box means that the data is clustered and a longer box means that the data is more spread out.

When the median line is in the center of the box, the data in the middle is symmetrically distributed.

The whiskers also give you information about how the data is distributed. If you have one whisker significantly longer than the other, the data is skewed in the direction of the longer whisker. This means the data is clustered near the shorter whisker.

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Measure Up

TI PROFESSIONAL DEVELOPMENT

1. Guide the students in completing the plot on their worksheets. Your students' level of experience with box-and- whisker plots should determine how much guidance you provide. Press ⌈trace⌉, and use the right and left arrow keys to scroll through the plot.

    •   Notice the data at the bottom of the screen.

    •   Have students place the screen data in the appropriate place on the plot they sketch.

    •   For easy display, have them round numbers to the nearest hundredth before recording this information on their graph.

    •   See the images on the right.

2   Lead your students in a discussion about observations based on the length of both the whiskers and the boxes. The boxplot created by the calculator should closely match the boxplot the students sketched.

Measure Up

TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT
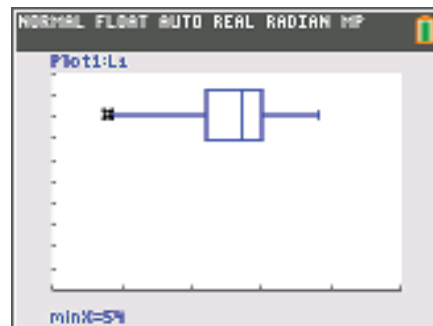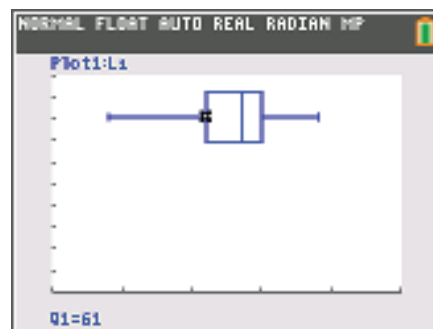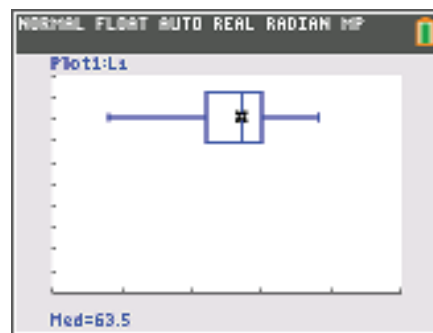
Exploration

1. Guide students in presenting the data in a histogram.

    *   Adjust the **Plot2** setting as shown here.

    *   Scroll until ⬛ is highlighted, and then press ENTER.

    *   Press graph.

2. Students often have a hard time setting up a scale for a graph. They very quickly get in the habit of relying exclusively on the **9:ZoomStat** feature, which does not adjust histogram bar widths properly. Histograms often require adjustments.

    *   The histogram at right has bar widths of 5 units each. It is too wide for the sample data set.

    *   Encourage students to adjust the window settings to allow the graph to display the data in a more useful way.

    *   The **Xscl** determines the width of each bar starting at **Xmin**.

    *   The sample Histogram at right has **Xscl=1.**
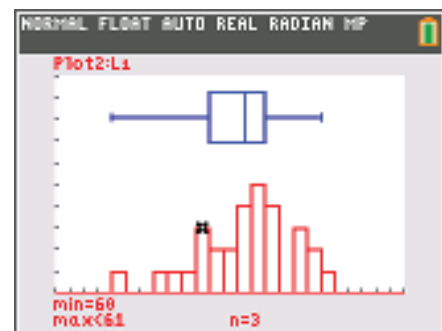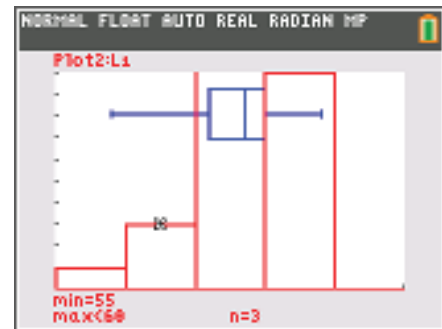
Hooke's Law
Student Activity

Name _____

Class _____

Part 1 – Introduction

In this activity, you will create a situation that produces linear behavior by observing a spring being stretched as you add candies to a cup attached to the spring.

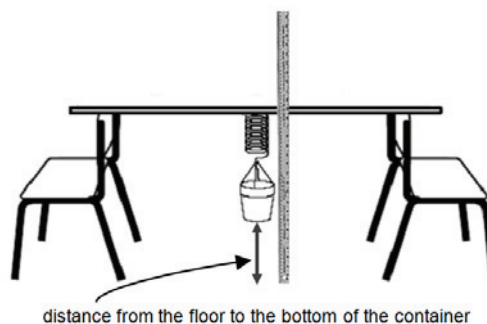You will then apply the properties of a linear function to develop a model for your motion. Finally, you will interpret the values used in your model. Work in groups of 3 or 4 to prepare the following:

- Place a meter stick or other long stick on the back of two chairs as shown in the diagram.

- Hang the spring from the meter stick.

- Attach the cup/container to the bottom of the spring. Make sure that when the cup is empty, it is at least 18–24 inches off the floor.

distance from the floor to the bottom of the container

Part 2 – Collecting the data

- Use a ruler or a second yardstick to measure the distance, in inches, from the floor to the bottom of the container. Record this measurement in the table. (Measure to the nearest ¼ -inch.)

- Slowly add 3 candies, and try to minimize the swing of the container. When the container is steady, measure the distance, in inches, from the floor to the bottom of the container. Record this measurement in the table.

- Continue for a total of 10 trials.

Number of candies	Distance from the bottom of the cup to the floor (inches)
0	
3	
6	
9	
12	
15	
18	
21	
24	
27	
30	

Part 3 – Analyzing the data

1. Enter your data values into lists with L1 = number of candies and L2 = distance from the floor to the bottom of the container.

2. Set up a scatterplot in **Plot1** with x = **L1** and y = **L2.** Sketch the graph of your data points in the space at the right. Label the graph.

Hooke's Law
Student Activity

Name _____

Class _____

3. Using your data and your understanding of linear equations, determine an equation for the line of best fit for the values in your data set.

    Write your equation below and enter it in Y1 on your calculator.

    Y1 = _____

4. Consider your trend line for the distance to the floor vs. the number of candies. Is the slope positive or negative? Why?

5. What kind of slope would you predict for an equation to model a spring that is stiffer than the one you used? Why? How would it compare to the slope of your equation?

6. Use STAT CALC to have the calculator determine the regression equation for your data in L1 and L2. Store the regression equation in Y_2 and write it in the space provided.

    Y_2 = _____

7. a. On your calculator, display the scatter plot of (L1, L2) along with the graphs of the equations in Y_1, and Y_2.

    b. Sketch the graphs in the plot to the right. Label the graphs.

8. Use your data, equations, and graphs answer the following:

    a. How far from the floor would the cup be if 10 candies were used? How do you know?

    b. How many candies are in the cup if it is 12 inches from the floor? How do you know?

    c. How many candies would it take until the container touches the floor? Explain your reasoning.

Hooke's Law
Student Activity

Name _____

Class _____

Part 4 – Understanding Slope

9. What physical property is represented along the *x*-axis of the graph?

10. What physical property is represented along the *y*-axis?

11. What is the mathematical meaning of the symbol delta, Δ?

12. Fill **L3** by using the command **ΔList(L2)**. Describe the meaning of the values in **L3** that were generated by the command **ΔList(L2).**

13. Define **L4** to be **L3** divided by 3 and then calculate the average/mean of the numbers in **L4**.

14. What does the *mean* of **L4** represent?

15. Store the *mean* of L4 to M and the initial distance (with no candies) to B.

16. Use this information from your lists to create the equation Y3 = MX + B for another line to fit the data.

17. Discuss the advantages and disadvantages of the three equations that can be used to model the data.

    Y1 = equation from question #3, determined using the data points
    Y2 = regression equation from the calculator from question #6
    Y3 = equation using the mean of the values in L4 and (0,B), where B is the first measured distance

18. For every set of three objects you put in the container, what was the change in the distance from the floor to the bottom?

19. What is the mathematical definition of slope?

20. Describe, in your own words, the meaning of slope in relation to this activity.

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Hooke's Law

TI PROFESSIONAL DEVELOPMENT

About the Lesson

In this activity, students will collect data when a spring is stretched as candies are added to a cup attached to the spring.

As a result, students will:

- Determine an equation to fit data
- Use the linear regression feature of a calculator to determine an equation to fit data
- Use list operations to determine parameters of a linear equation to fit data
- Compare techniques and linear models
- Interpret the values used in the models and apply the properties of a linear model to predict future behavior/events.

Vocabulary

- slope
- linear function
- Δ

Teacher Preparation and Notes

- Hooke's Law states that the stretch on a spring is directly proportional to the force applied to the end of the spring. In this experiment, the force is the weight of an increasing amount of candy added to a cup. This force is applied to the end of a spring.

Activity Materials

- TI-84 Plus CE graphing calculator
- Small spring cut in half (a Slinky® works well)
- Empty 4 oz plastic/paper cup (flat bottom)
- Two large paper clips or string
- Meter stick or other long stick
- Second meter/yard stick or ruler for measurements
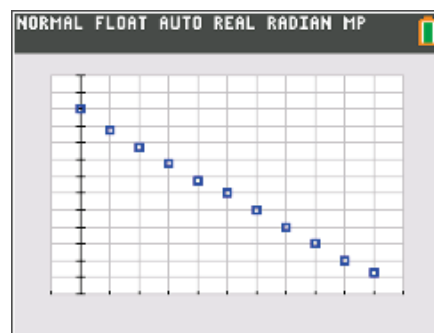- 30 candies (M&Ms® and almonds work well)

- Compatible TI Technologies:

    TI-84 Plus*

    TI-84 Plus Silver Edition*

    🌀TI-84 Plus C Silver Edition

    🌀TI-84 Plus CE

* with the latest operating system (2.55MP) featuring MathPrint™ functionality.

Tech Tips:

- This activity includes screen captures taken from the TI-84 Plus CE. It is also appropriate for use with the rest of the TI-84 Plus family. Slight variations to these directions may be required if using other calculator models.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials
- Any required calculator files can be distributed to students via handheld-to-handheld transfer.

Lesson Files:

- Hookes_Law_Student.pdf
- Hookes_Law_Student.doc

Hooke's Law

TI PROFESSIONAL DEVELOPMENT

> **Teacher Tip:** The students need to know the formula for deriving the slope when given the coordinates of two points and how to use the calculator for quicker and more accurate computations.
>
> This activity is meant to enhance the students' understanding of slope while providing supporting strategies through use of the calculator.
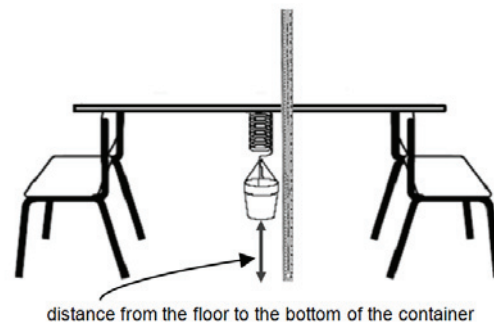
Part 1 – Introduction

In this activity, you will create a situation that produces linear behavior by observing a spring being stretched as you add candies to a cup attached to the spring.

You will then apply the properties of a linear function to develop a model for your motion. Finally, you will interpret the values used in your model

Work in groups of 3 or 4 to prepare the following:

- Place a meter stick or other long stick on the back of two chairs as shown in the diagram.

- Hang the spring from the meter stick.

- Attach the cup/container to the bottom of the spring. Make sure that when the cup is empty, it is at least 18–24 inches off the floor.

distance from the floor to the bottom of the container

Part 2 – Collecting the data

- Use a ruler or a second yardstick to measure the distance, in inches, from the floor to the bottom of the container. Record this measurement in the table. (Measure to the nearest ¼ -inch.)

- Slowly add 3 candies, and try to minimize the swing of the container. When the container is steady, measure the distance, in inches, from the floor to the bottom of the container. Record this measurement in the table.

- Continue for a total of 10 trials.
  Answer: See sample data at the right.

Number of candies	Distance from the bottom of the cup to the floor (inches)
0	18
3	16.75
6	15.75
9	14.75
12	13.75
15	13
18	12
21	11
24	10
27	9
30	8.25

Hooke's Law

TI PROFESSIONAL DEVELOPMENT

Part 3 – Analyzing the data

1. Enter your data values into lists with L1 = number of candies and L2 = distance from the floor to the bottom of the container.
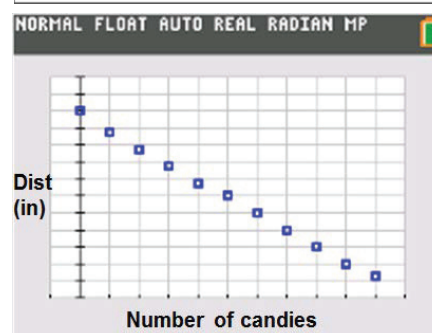
    Answer: Sample data shown at the right.

```
NORMAL FLOAT AUTO REAL RADIAN MP
L1       L2      L3      L4      L5      1
0        18      ------  ------  ------
3        16.75
6        15.75
9        14.75
12       13.75
15       13
18       12
21       11
24       10
27       9
30       8.25

L1(1)=0
```

2. Set up a scatterplot in Plot1 with x = L1 and y = L2. Sketch the graph of your data points in the plot to the right. Label the graph.

    Answer: See the graph at the right.

X[-3,33]$_3$ by Y[7,20]$_1$

Tech Tip: It is interesting select GridLine and to set Xscl = 3 when viewing the data.

3. Using your data and your understanding of linear equations, determine an equation for the line of best fit for the values in your data set.

    Answer: y-intercept = 18 and the distance decreases about 1 inch for every three candies added.

    Write your equation below and enter it in Y1 on your calculator.

    Answer: Y1 = $18 - \dfrac{1}{3}x$

4. Consider your trend line for the distance to the floor vs. the number of candies. Is the slope positive or negative? Why?

    Answer: Negative. The distance decreases about 1 inch for every three candies added

5. What kind of slope would you predict for an equation to model a spring that is stiffer than the one you used? Why? How would it compare to the slope of your equation?

    Answer: Negative because distance will decrease, but less change, so less steep

6. Use STAT CALC to have the calculator determine the regression equation for your data in L1 and L2. Store the regression equation in Y$_2$ and write it in the space provided.

    Answer: Y$_2$ = $-0.32x + 17.76$

Hooke's Law

TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT

7. a. On your calculator, display the scatter plot of (L1, L2) along with the graphs of the equations in Y_1, and Y_2.

b. Sketch the graphs in the plot to the right. Label the graphs.

Answer: See the graph at the right.
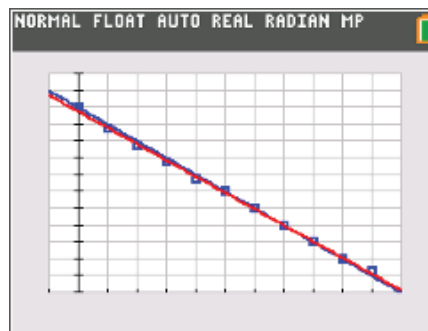
8. Use your equations and graphs answer the following:

a. How far from the floor would the cup be if 10 candies were used? How do you know?

Answer: Answers will vary depending student's spring and measurements.

Sample: About $14\frac{1}{2}$ *to* $14\frac{3}{4}$ inches

b. How many candies are in the cup if it is 12 inches from the floor? How do you know?

Answer: Answers will vary depending student's spring and measurements.

Sample: About 18 candies

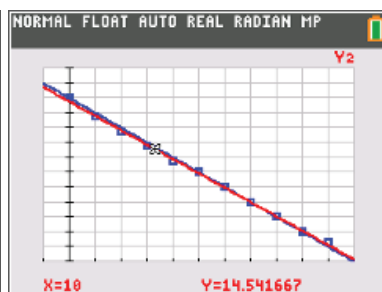c. How many candies would it take until the container touches the floor? Explain your reasoning.

Answer: Answers will vary depending student's spring and measurements. Sample**:** About 54 candies.

Note: Students can use a variety of methods to determine the answers.
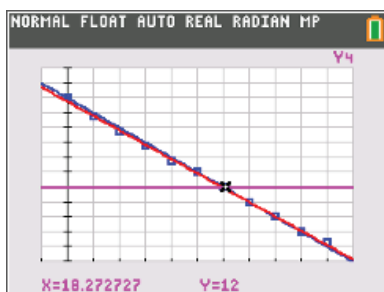
For example, they might choose to TRACE on a function, use the [Table] feature, evaluate functions, or solve equations algebraically. See the screen shots below for possible strategies.

Hooke's Law

TI PROFESSIONAL DEVELOPMENT

Part 4 – Understanding Slope

9. What physical property is represented along the *x*-axis of the graph?
    Answer: Number of candies

10. What physical property is represented along the *y*-axis?
    Answer: Distance from the floor to the bottom of the cup

11. What is the mathematical meaning of the symbol delta, Δ?
    Answer: *Difference* or *change in*

Tech Tip: The goal for this next set of calculator commands is to use the calculator to determine the differences in the y-values of the data points collected in the activity, and then use that difference to find the slope.

During this procedure, the students' knowledge of the definition of slope will be reinforced while they use technology to perform the otherwise time- consuming calculations.

---

12. Fill **L3** by using the command **ΔList(L2)**. Describe the meaning of the values in **L3** that were generated by the command **ΔList(L2).**

    Answer: The difference between two consecutive elements in L2

    - To do this, use the up arrow key to highlight **L3**.

    - Press 2nd STAT to access the [LIST] menu, and arrow over to the **OPS** menu. Select **7: ΔList**.

    - You will see this command displayed at the bottom of the Stat List Editor window.

    - Press 2nd 2 to type in **L2,** close the parentheses, and press enter

13. Define **L4** to be **L3** divided by 3 and then calculate the average/mean of the numbers in **L4**.
    Answer: mean(L4) = -0.325

14. What does the *mean* of **L4** represent?
    Answer: L3/3 calculates the slopes of each segment and the mean of the values in **L4** is a close approximation for the slope of the whole line – the change in the distance (in inches) for every 1 candy added to the cup. The distance from the floor to the cup changed about -0.325 inches for every one candy added.

Hooke's Law

TI PROFESSIONAL DEVELOPMENT

> **Teacher Tip:** Discuss with your students why these differences, although very close, are not exactly the same.
>
> This is a good time to discuss the difference between theoretical events and actual data collection and also the human error that might occur when the measurements are taken by hand with a meter/yard stick.

15. Store the *mean* of L4 to M and the initial distance (with no candies) to B.

16. Use this information from your lists to create the equation Y3 = MX + B for another line to fit the data.

17. Discuss the advantages and disadvantages of the three equations that can be used to model the data.

    Y1 = equation from question #3, determined using the data points

    Y2 = calculator regression equation from question #6

    Y3 = equation using the mean of the values in L4 and (0,B), where B is the first measured distance

15. For every set of three objects you put in the container, what was the change in the distance from the floor to the bottom?

    Answer: The distance from the floor to the cup decreased about one inch for every three candies added.

16. What is the mathematical definition of slope?

    Sample answers:

    - A number that denotes the direction and steepness of a line

    - The change in vertical position for a unit change in horizontal position along a line

17. Describe, in your own words, the meaning of slope in relation to this activity.

    Answer: The change in distance (inches) from the floor per change in number of candies

Walk the Line:
Straight-Line Distance Graphs
Student Activity

Name _____

Class _____

Objectives

- Graph linear functions

Materials

- Vernier® EasyData™ app
- CBR 2™ motion detector

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

y-intercept b	
optimized slope m	
optimized line equation	
x_1, y_1	
x_2, y_2	
regression line equation	

1. How does this value compare with the slope you found by trial and error?

2. How do the values of the slope and intercept as determined by the calculator compare to your earlier values? Would you expect them to be exactly the same?

3. Slope is defined as change in y-values divided by change in x-values. Complete the following statement about slope for the linear data set you collected.

   In this activity, slope represents a change in _____ divided by a change in _____.

4. Based on this statement, what are the units of measurement for slope in this activity?

5. The y-intercept can be interpreted as the starting position or the starting distance from the motion detector. What does the slope represent physically?

Hint: Consider the units of measurement for the slope you described in the previous question.

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Walk the Line: Straight-Line Distance Graphs

TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES

Activity Overview

In this activity, you will create straight-line, or constant-speed, distance-versus-time plots using a motion detector. You will then develop linear equations to describe these plots mathematically.

Objectives

- Graph linear functions

Materials

- Vernier® EasyData™ app
- CBR 2™ motion detector

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

When one quantity changes at a constant rate with respect to another, we say they are *linearly related*. Mathematically, we describe this relationship by defining a linear equation. In real-world applications, some quantities are linearly related and can be represented by using a straight-line graph.
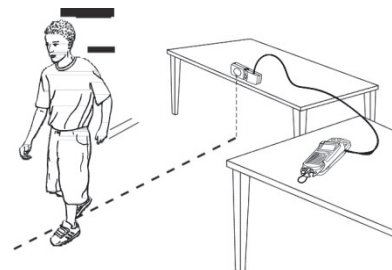
1. Set up the motion detector and calculator.

   - Open the pivoting head of the motion detector.

   - If your motion detector has a sensitivity switch, set it to Normal as shown.

   - Turn on the calculator, and make sure it is on the home screen.

   - Connect it to the motion detector. This might require the use of a data-collection interface.

2. Position the motion detector on a table or chair so that the head is pointing horizontally out into an open area where you can walk. There should be no chairs or tables nearby.

3. Set up the EasyData app for data collection.

   - Start the EasyData app, if it is not already running.

   - Select [File] from the Main screen, and then select New to reset the application.

4. Stand about a meter from the motion detector.

   - When you are ready to collect data, select [Start] from the Main screen.

   - Walk away from the motion detector at a slow and steady pace.

   - You will have five seconds to collect data.
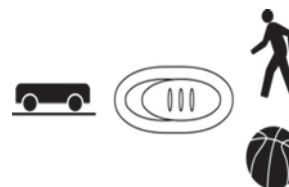
5. When data collection is complete, a graph of distance versus time will be displayed.

    *   Examine the graph. It should show a nearly linearly-increasing function with no spikes or flat regions.

    *   If you need to repeat data collection, select ⌐Main⌐ and repeat Step 4.

6. Once you are satisfied with the graph, select ⌐Main⌐ to return to the Main screen.

    *   Exit the EasyData™ app by selecting ⌐Quit⌐ from the Main screen and then selecting ⌐OK⌐.

Data Analysis

1. Redisplay the graph outside of the EasyData app.

    *   Press 2nd [STAT PLOT].

    *   Press ENTER to select Plot1, and press ENTER again to select On.

    *   Press ZOOM. Press ▼ until ZoomStat is highlighted; press ENTER to display a graph with the *x* and *y* ranges set to fill the screen with data.

    *   Press TRACE to determine the coordinates of a point on the graph using the cursor keys.

2. The slope-intercept form of a linear equation is $y = mx + b$, where *m* is the slope of the line and *b* is the *y*-intercept value.

    *   The independent variable is *x*, which represents time, and *y* is the dependent variable, which represents distance in this activity.

    *   Trace across the graph to the left edge to read the *y*-intercept.

    *   Record this value as *b* in the data table on the *Student Activity* sheet.

3. One way to determine the slope of the distance versus time graph is to guess a value and then check it by viewing a graph of the line with your data. To do this, enter an equation into the calculator, and then enter a value for the *y*-intercept and store it as variable **B**.

    *   Press Y=, and press CLEAR to remove any existing equation.

    *   Enter the equation **M*X + B** into the Y1 field.

    *   Press ◄ until the icon to the left of Y1 is blinking.

    *   Press ENTER until a bold diagonal line is shown in order to display your model with a thick line.

    *   Press 2nd [QUIT] to return to the home screen.

    *   Enter your value for the *y*-intercept, and then press STO▶ B ENTER to store the value in the variable **B**.

Walk the Line: Straight-Line Distance Graphs TEACHER NOTES
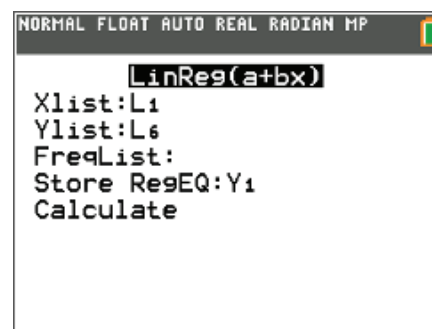## TI PROFESSIONAL DEVELOPMENT

4. Now set a value for the slope m, and then look at the resulting graph. To obtain a good fit, you will need to try several values for the slope. Use the steps below to store different values to the variable **M**. Start with M = 1. Experiment until you find one that provides a good fit.

   * Enter a value for the slope m, and press $\boxed{\text{STO}\blacktriangleright}$ M $\boxed{\text{ENTER}}$ to store the value in the variable **M**.

   * Press $\boxed{\text{GRAPH}}$ to see the data with the model graph superimposed.

   * Press $\boxed{\text{2nd}}$ [QUIT] to return to the home screen.

5. Record the optimized value for the slope in the data table on the *Student Activity* sheet. Use the values of the slope and intercept to write the equation of the line that best fits the distance versus time data.

6. Another way to determine the slope of a line to fit your data is to use two well-separated data points.

   * Use the cursor keys to move along the data points.

   * Choose two points (x1, y1) and (x2, y2) that are not close to each other, and record them in the data table on the *Student Activity* sheet.

7. Use the points in the table to compute the slope, m, of the distance versus time graph.

$$m = \frac{y_2 - y_1}{x_2 - x}$$

Calculate the slope and answer Question 1 on the *Student Activity* sheet.

8. You can also use the calculator to automatically determine an optimized slope and intercept.

   * Press $\boxed{\text{STAT}}$ and use the cursor keys to highlight CALC.

   * Press the number adjacent to LinReg(ax+b) to open the wizard. Configure as shown.

   * Press $\boxed{\text{ALPHA}}$ [F4] and select Y1and press $\boxed{\text{ENTER}}$ when asked to StoreRegEq.

   * Highlight **Calculate**, and press $\boxed{\text{ENTER}}$.

```
NORMAL FLOAT AUTO REAL RADIAN MP

        LinReg(a+bx)
Xlist:L1
Ylist:L6
FreqList:
Store RegEQ:Y1
Calculate
```

9. The linear regression model will be displayed on the home screen with parameters *a* and *b* displayed. The linear regression will be stored in Y1.

   * To see the graph of the model, press $\boxed{\text{GRAPH}}$.

   * Answer Questions 2–5 on the *Student Activity* sheet.
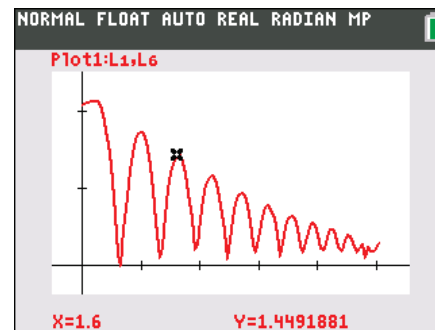
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Bouncing Ball
Student Activity

Name _____

Class _____

Introduction

After dropping a ball beneath a Calculator Based Ranger (CBR 2™), the following plot is graphed. Use a CBR 2™ to collect similar data, or obtain such data from your teacher.

Data Collection

1. The questions below refer to the graph above (or your similar plot if you collected your own data.)

    a. What physical property is represented along the horizontal axis? _____

      What are the units? _____

    b. What physical property is represented along the vertical axis? _____

      What are the units? _____

    c. What does the highest point on the plot represent? _____

      What does the lowest point represent? _____

    d. Why does the plot sometimes not touch the horizontal axis?
        Hint: Press the right & left arrow keys to trace the plot.

2. After dropping a ball beneath a Calculator Based Ranger (CBR 2™), the following plot is also graphed.

    The questions below refer to the graph (or your similar plot if you collected your own data.)
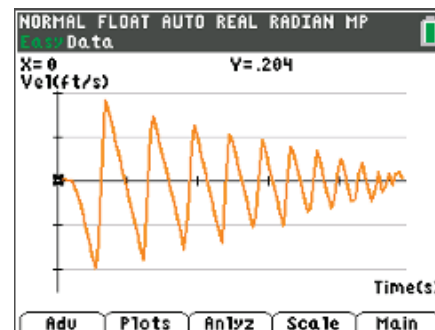
    a. What physical property is represented along the horizontal axis? _____

      What are the units? _____

    b. What physical property is represented along the vertical axis? _____

      What are the units? _____

    c. Describe what happens to the ball when the outputs of the velocity graph are positive.

    d. Describe what happens to the ball when the outputs of the velocity graph are negative.

    e. Describe what happens to the ball when the velocity outputs change from positive to negative.

    f. Describe what happens to the ball when the velocity outputs change from negative to positive.

Bouncing Ball

Student Activity

Name _____

Class _____

Data Analysis

3. For any one bounce, a plot of distance vs. time has a parabolic shape. One form of the equation that describes this motion is $y = A(x - H)^2 + K$ where (H, K) is the vertex of the parabola and A is the vertical stretch or compression factor of the graph. This equation is called the *vertex form*.

   - Trace along your height vs. time plot.

   - Identify the vertex of the bounce you chose and record the *x*- and *y*-coordinates as *H* and *K* here.

   $H =$ _____ $K =$ _____ (to 3 decimal places)

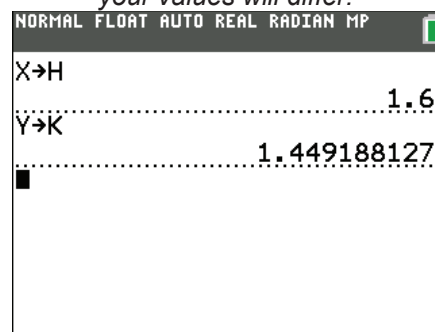4. Press [2nd] [mode] to access [QUIT], and return to the home screen.

   - Store the x-coordinate of the vertex in the variable **H**:

     [x,т,θ,n] [STO▸] [alpha] H [enter]

   - Store the y-coordinate of the vertex in the variable **K**:

     [alpha] Y [STO▸] [alpha] K [enter]

If using your own collected data, your values will differ.

```
NORMAL FLOAT AUTO REAL RADIAN MP    [ ]
X→H
                                1.6
Y→K
                        1.449188127
■
```
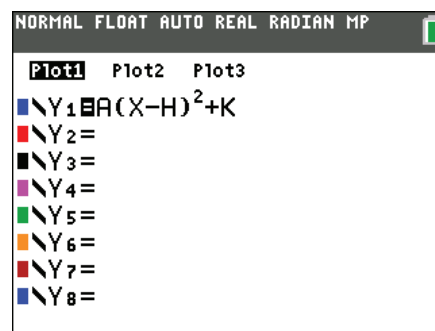
Press [y=] to enter the formula of the parabola in vertex form. Before pressing [graph], predict what you think will occur if
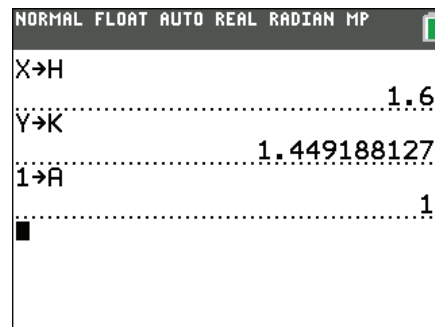
a. **A** = 1

b. **A** = 0

```
NORMAL FLOAT AUTO REAL RADIAN MP    [ ]
 Plot1   Plot2   Plot3
■\Y1■A(X-H)²+K
■\Y2=
■\Y3=
■\Y4=
■\Y5=
■\Y6=
■\Y7=
■\Y8=
```

   - Store the value 1 in the variable **A**:

     [1] [STO▸] [alpha] A [enter]

   Press [graph] to confirm your prediction.
   Similarly, confirm what occurs for *A* = 0.

```
NORMAL FLOAT AUTO REAL RADIAN MP    [ ]
X→H
                                1.6
Y→K
                        1.449188127
1→A
                                  1
■
```

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Bouncing Ball
Student Activity

5. To find the formula of the parabola, use a guess-and-check method to find the value of *A*.

   - Adjust *A* by storing new values in *A* on the home screen.
   - For each new value of *A* that you test, press graph to view the new parabola.
   - Experiment until you find one that provides a good fit for the data.
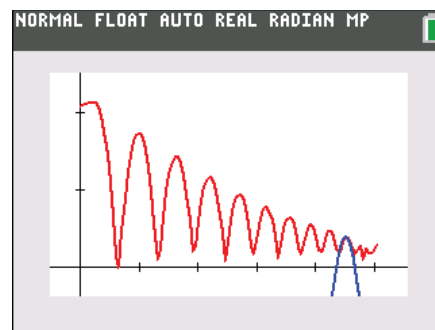
   What effect does each have on the parabola?

   a. the sign (positive or negative) of *A*?

   b. increasing the size of |*A*| ?

   c. decreasing the size of |*A*| ?

6. Record the value of *A* that works best:. *A* = _____Using this value of *A* and the *H* and *K* values you reported in Question 3, write the vertex form of the quadratic equation. *y* =_____

7. Would you expect your classmates to have the same value of *A* for their trials, or do you think the *A* value would vary? Explain your answer.

8. Find out the value of *A* from the other groups of students in your class. How do these values compare to your value of *A*?

9. If a ball that was more or less bouncy was used this time, would it affect the value of *A* in the equation? If so, describe how.

10. Repeat the activity, but this time use the last (right-most) full bounce. Identify the vertex and record the *x*- and *y*-coordinates as *H* and *K* here.

    H = _____ *K* =_____ (to 3 decimal places)

    Report the value of *A* that works best: *A* = _____

    How did *A* compare for this bounce?

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Bouncing Ball
TI PROFESSIONAL DEVELOPMENT

About the Lesson

Real-world concepts such as free-falling and bouncing objects are examples of parabolic functions. This activity investigates the values of height, time, and the coefficient A in the vertex form of the quadratic equation, $y = A(x - H)^2 + K$, which describes the behavior of a bouncing ball. As a result students will:

- Graph scatterplots.
- Create the formula of a quadratic function.
- Determine the value of the coefficient A in the vertex form of a quadratic equation
- Explore the effect of A on the shape of the graph.
- Interpret the meaning of the value of A in the context of the problem situation as one half of the acceleration due to gravity.
- Make connections between distance-time, velocity-time, and acceleration-time graphs.

Vocabulary

- Quadratic function
- Vertex
- Vertex form
- Vertical reflection, vertical stretch, and vertical compression
- Distance, velocity, and acceleration

Teacher Preparation and Notes

- Students should know have worked with translations, reflections, and vertical stretches and compressions of functions.
- This activity provides an opportunity for math-science connections.

Activity Materials

- Calculator Based Ranger (CBR 2™) and cable.
- Bouncing ball
- Vernier® EasyData™ app
- Compatible TI Technologies:
    TI-84 Plus*
    TI-84 Plus Silver Edition*
  🌐TI-84 Plus C Silver Edition
  🌐TI-84 Plus CE

* with the latest operating system (2.55MP) featuring MathPrint™ functionality.

- Recommended: TI-SmartView™ emulator software.
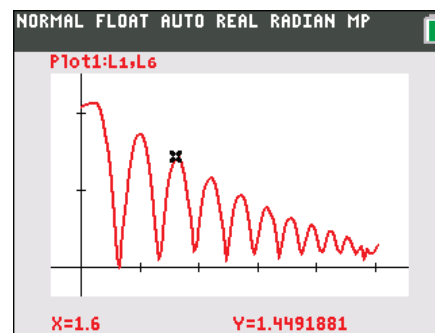
Tech Tips:
- This activity includes screen captures taken from the TI-84 Plus CE. It is also appropriate for use with the rest of the TI-84 Plus family. Slight variations to these directions may be required if using other calculator models.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials
- Any required calculator files can be distributed to students via handheld-to-handheld transfer.

Lesson Files:
- Bouncing_Ball_Student.pdf
- Bouncing_Ball_Student.doc
- It is recommended participants collect their own data; however lists L1 (time), L6 (dist) , L7 (vel), and L8 (accel) contain the sample data shown in the activity, which can be linked if needed. This is also stored in the program BALL.8XP.

Bouncing Ball

TEACHER NOTES

**TI PROFESSIONAL DEVELOPMENT**

Introduction

Demonstrate this activity using the SmartView calculator emulator so the entire class can see the process. If you only have one CBR 2™, after running the activity link the data lists to each student's calculator. If you have enough CBR 2™ devices, have students work in small groups.

Setup

1. Avoid using a soft or felt-covered ball such as a tennis ball, since pulses from the CBR 2™ tend to be absorbed by these surfaces. Racquetballs work well. If you have trouble, try using a bigger ball like a basketball or smooth playground ball.

2. This activity is best performed with at least three students: one to hold the CBR 2™, and press the trigger; one to release the ball; and one to run the calculator.

3. Lift the pivot head on the CBR 2™ and set the sensitivity on the CBR 2™ to Normal.
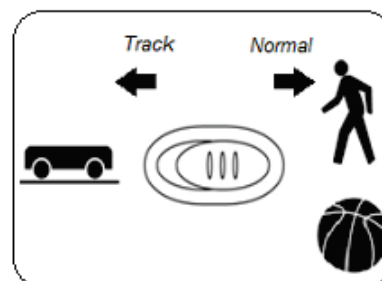
4. Link the CBR 2™ to the calculator using either the I/O unit-to-unit cable or the mini-USB cable. The EasyData® App launches automatically when you plug in a USB sensor.

5. Position the CBR 2™ motion detector at least 15 cm above the ball.

    *   Hold the sensor directly over the ball and make sure that there is nothing in the Clear Zone.

    *   Hold the sides of the ball and then quickly move your hands outward to release the ball. Drop the ball (do not throw it). Begin with a test bounce.
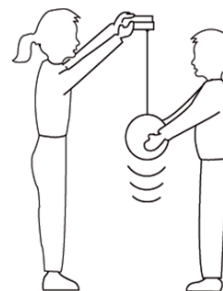
Data Collection

1. Press y= to access the **File** menu, and select **1:New** by pressing 1or since **1:New** is highlighted, you can just press enter. This resets the program and clears out old data.
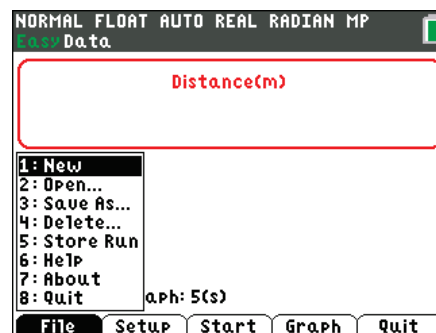
Bouncing Ball

**TEACHER NOTES**

TI PROFESSIONAL DEVELOPMENT

2. The default unit of measurement on the EasyData™ app is meters. You may want to do this activity in feet.

    - To change the units of measurement, select the **Setup** menu soft key by pressing [window] on the top row of the calculator.

    - From the **Setup** menu, choose **1:Dist** by pressing [enter].

3. You may choose to do this activity in either meters or feet. The sample data is in meters.

    - Press [window] on the top row of the calculator to access the **Units** menu.

    - From the **Units** menu, select **1:(m)** or **2:(ft**) by pressing [1] or [2] or by scrolling until your choice is highlighted and pressing [enter].

    - Then press [graph] on the top row of the calculator to select OK.

4. You will be returned to the main screen of the EasyData app.

    - From the **Setup** menu, select **5:Ball Bounce**, and then select **Start**.

    - Follow the general instructions displayed.

    - Ball Bounce automatically takes care of the window settings.

5. One person holds the CBR 2™ motion detector while another person holds the ball at least 15 centimeters beneath the sensor (50 cm if you are using an older CBR). Select **Next**.

Bouncing Ball

TI PROFESSIONAL DEVELOPMENT
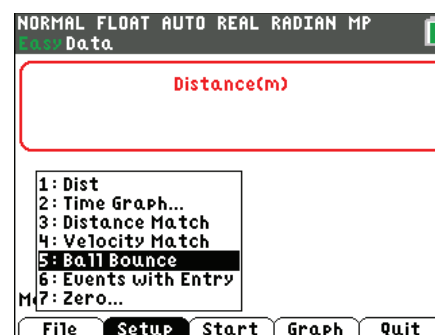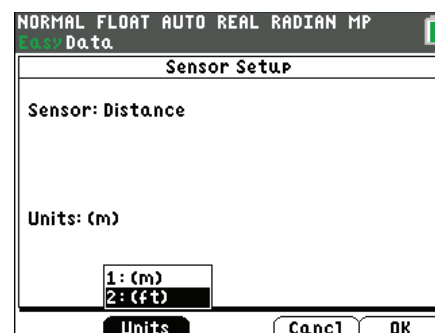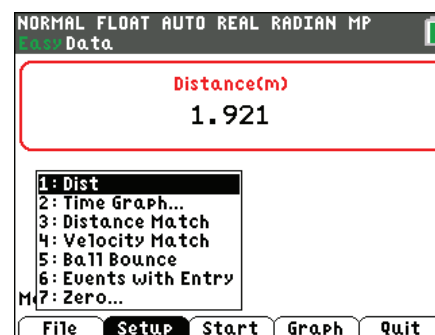
6. Follow the on-screen directions. At this time you may disconnect the CBR 2™ from the calculator or you may leave it connected.

    Whether you leave it connected or not, you will need to press the **TRIGGER** on the CBR 2™ motion detector to begin collecting data.
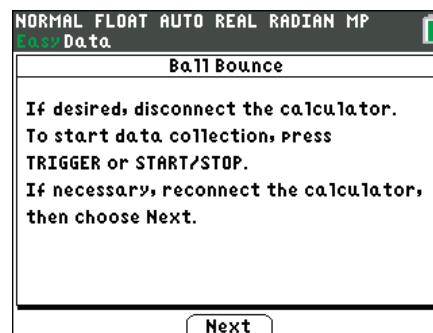
7. When the CBR 2 begins clicking, release the ball, and then step back.

    - The program will collect data every 0.05 seconds for 5 seconds.

    - If the ball bounces to the side, move to keep the CBR 2 directly above the ball, but be careful not to change the height of the CBR 2 motion detector.

    - When the clicking stops, reconnect the CBR 2 to the calculator and select **Next** on the calculator screen.

    - The collected data is transferred to the calculator. A screen displays a notice to wait as it is transferred.

8. As soon as the data is sent, the calculator displays the distance vs. time graph from within the program.

    - The plot should look like a bouncing ball.

    - If not, repeat the sample, ensuring that the CBR 2™ is aimed squarely at the ball.
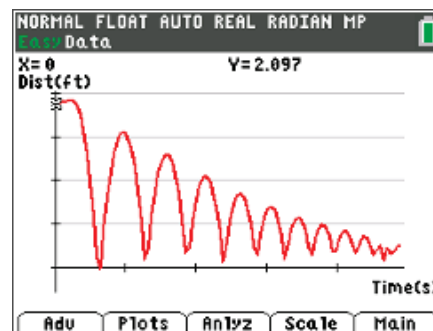
    > **Tech Tip:** The guidebook *Getting Started with CBR 2™* is available on education.ti.com, which gives hints for effective data collection and trouble shooting. It also provides a menu map for the EasyData™ app.

9. To repeat the sample, select **Main**, **Start**, and repeat the process.

    - You will get a warning screen telling you the new data will overwrite any previous data. Select **OK**.

Bouncing Ball

TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT
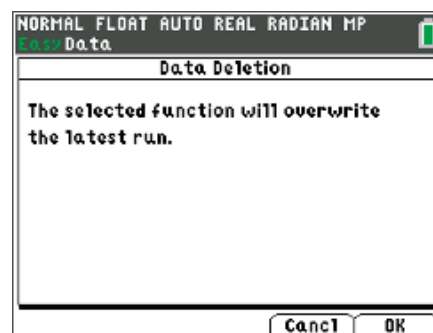
10. Guide your students in a discussion to help them realize that when the ball is at its highest point, its distance from the CBR 2 is the smallest.
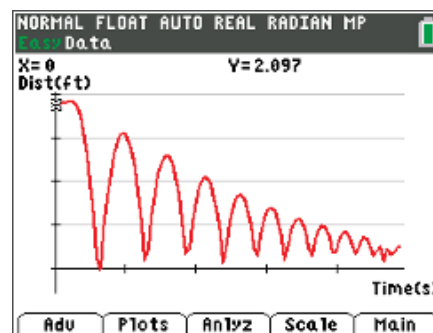
- Observe that the Ball Bounce feature automatically flipped the distance data so the graph's appearance resembles the up and down movement of the ball.

11. At this time, you can use the right and left arrow keys (not trace) to view the coordinates of the points.

- Pressing trace at this point will take you out to the Main screen of the EasyData™ app.

- If the students do that by accident, they can select **Graph** to return to the Graph screen.

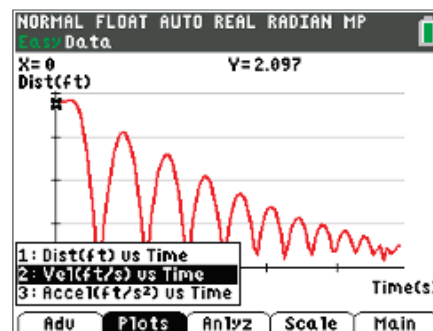- Have the students stop here, and answer the questions 1a-d below on their worksheets.

Student Questions:

1. a. What physical property is represented along the horizontal axis? **Answer:** time

   What are the units? **Answer:** seconds

   b. What physical property is represented along the vertical axis? **Answer:** distance or height

   What are the units? **Answer:** feet or meters

   c. What does the highest point on the plot represent? **Answer:** the height of the first bounce

   What does the lowest point represent? **Answer:** the floor

   d. Why does the plot sometimes not touch the horizontal axis?
   Hint: Press the right & left arrow keys to trace the plot.

   Answer: The CBR 2 collects data at regular intervals. (In fact, every 0.05 seconds.) These points are then connected with a segment. The collected point may or may not have hit the floor at the instant of sampling. Similarly, the CBR 2™ may or may not collect the maximum height of the ball at the instant of sampling.

12. From the **Plots** menu, select **2:Vel (ft/s) vs Time** by pressing 2 or by scrolling until your choice is highlighted and pressing enter.

- Guide your students in a discussion to help them realize the velocity-time graph is a series of line segments, all of which are *parallel.* The domain of each segment corresponds to the domain of each parabola.

Bouncing Ball

TI PROFESSIONAL DEVELOPMENT

13. Use the velocity-time plot to discuss with students the questions on the student worksheet.

Student Questions (Cont'd):

2. a. What physical property is represented along the horizontal axis?　　　**Answer:** time

   What are the units?　　**Answer:** seconds

   b. What physical property is represented along the vertical axis?　　　**Answer:** velocity

   What are the units?

   Answer: feet per second or meters per second

   c. Describe what happens to the ball when the outputs of the velocity graph are positive.

   Answer: when the velocity is positive the height of the ball is increasing

   d. Describe what happens to the ball when the outputs of the velocity graph are negative.

   **Answer:** when the velocity is negative the height of the ball is decreasing

   e. Describe what happens to the ball when the velocity outputs change from positive to negative.

   Answer:　The velocity of the ball is zero and the ball is stopped. The height of the ball changes from increasing to decreasing. The ball is at the peak.

   f. Describe what happens to the ball when the velocity outputs change from negative to positive.

   Answer:　The ball hits the floor. The height of the ball changes from decreasing to increasing.
   Note: the velocity is not zero. The graph actually has a discontinuous jump. The app connects the lowest point and the highest point with a segment that is not part of the graph.
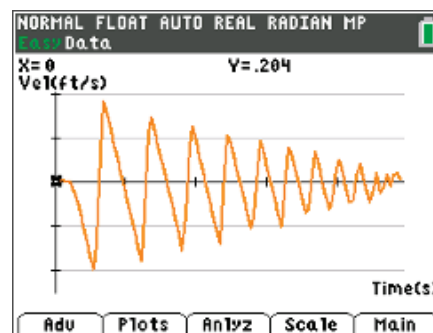
Tech Tip: The velocity (in L7) is not collected by the CBR2™, but *calculated* from the distance data (in L6) and time data (in L1) according to

$$L7_n = \frac{(L6_{n+1} + L6_n)/2 \; - \; (L6_n + L6_{n-1})/2}{L1_{n+1} - L1_n}$$

Similarly the acceleration (in L8) is calculated from the velocity. More details are found in *Getting Started with CBR 2™*.


Bouncing Ball

TI PROFESSIONAL DEVELOPMENT

14. **Optional:** From the **Plots** menu, select **3:Accel (ft/s^2) vs Time** by pressing ③ or by scrolling until your choice is highlighted and pressing enter.

- Use the left and right arrow keys to show the value of the acceleration is roughly −32 ft/s^2 or −9.8 m/s^2. Based on your students' background in physics, they may recognize this as the acceleration due to gravity, or *g*.

- The spikes of the acceleration occur at the endpoints of the domain of each segment of the velocity graph. The value of the acceleration is the slope of the parallel linear segments.

- Using SmartView software it is possible to align the screen captures in a Word processing document to show that the vertex of the parabola occurs at the zero of the velocity graph and the spikes of the acceleration graph are bounds of each bounce.

- The image to the right has been edited to show the plots without the spikes. This can be done on the calculator if the plots are not connected, but one must leave the EasyData® App to do so.

Bouncing Ball   **TEACHER NOTES**
**TI PROFESSIONAL DEVELOPMENT**
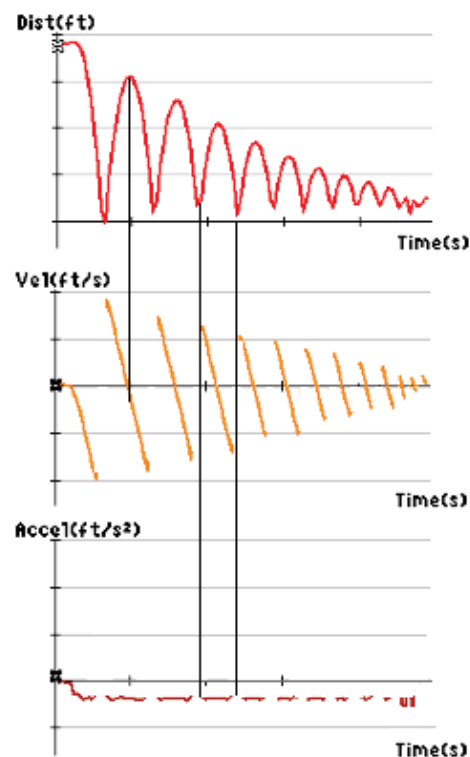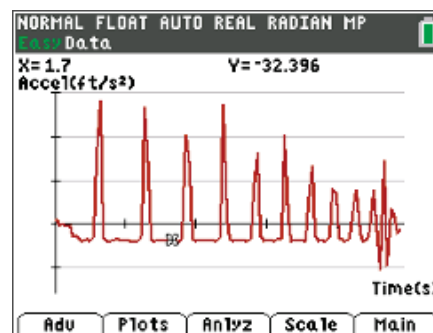
Data Analysis

1. Exit the EasyData® App by selecting **Main** and then **Quit**.

    *   The app will display a screen telling you where the data is located on the calculator. For Ball Bounce, the time is in **L1**, the distance in **L6**, velocity in **L7**, and acceleration in **L8**.

    *   You may wish to link the data to the rest of the class.

2. Press [2nd] [STAT PLOT] .Turn **Plot1** on with **L1** and **L6** in the **Xlist** and **Ylist**, respectively.
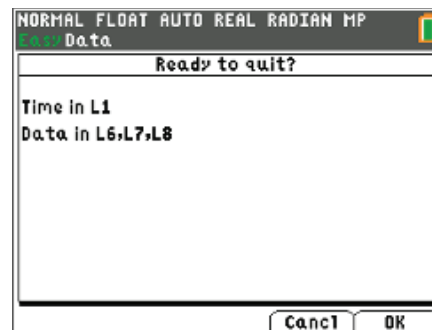
3. Press [zoom] [9] and you will see your data displayed in the same window as when it was in the app.
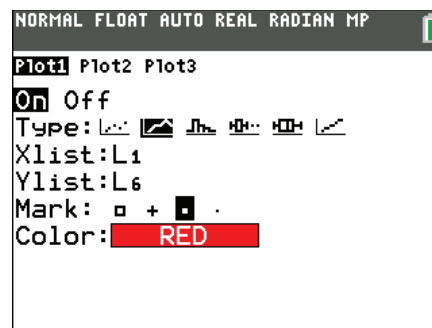
4. When the data is displayed in the graph window, press [trace] and use the arrow keys to try to reach a point as close to the vertex as possible.

    *   The *x*- and *y*-coordinates displayed at the bottom of the screen will remain in the memory of the calculator until you trace to a new point or store new values in *x* and *y*.
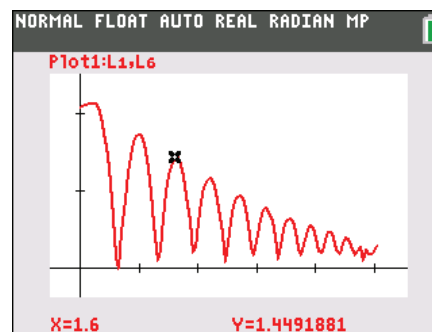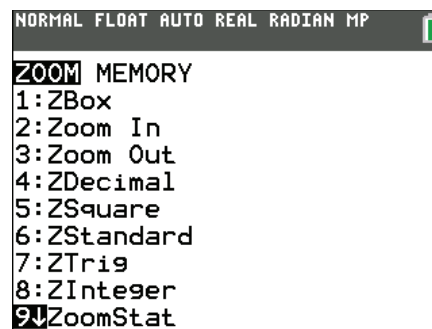
Student Questions (Cont'd):

3. Identify the vertex of the bounce you chose and record the *x*- and *y*-coordinates as *H* and *K* here.

    H = _____ *K* = _____

    Answers will vary, but for the bounce here, *H* = 1.6 and *K* ≈ 1.449

Bouncing Ball
TI PROFESSIONAL DEVELOPMENT

Tech Tip: If students ask why they may not trace exactly onto the vertex, use theTI-SmartView software to overlay a scatterplot of the distance data in Plot 2 onto the connected line graph, taking advantage of different colors. They are actually tracing on the discrete points in Plot 2.
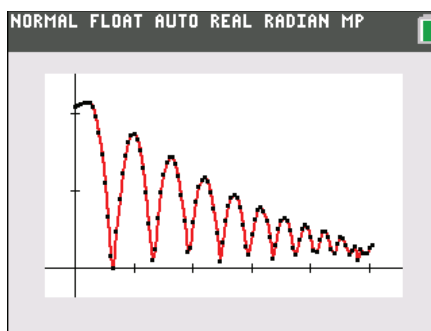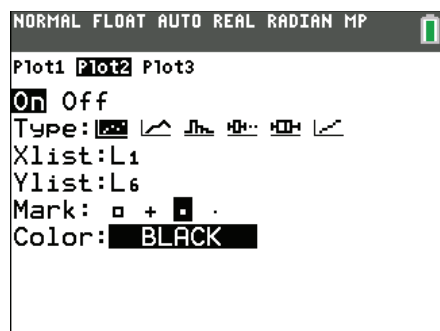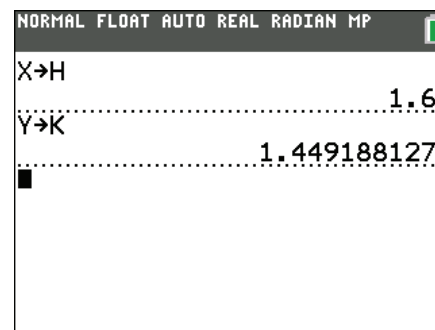
5. Press [2nd] [mode] to access [QUIT], and return to the home screen.

    * Store the x-coordinate of the vertex in the variable **H**:

    [X,T,θ,n] [STO▶] [alpha] H [enter]

    * Store the y-coordinate of the vertex in the variable **K**:

    [X,T,θ,n] [STO▶] [alpha] K [enter]

6. Press [y=] to enter the formula of the parabola in vertex form.

    Before pressing [graph], students predict on the worksheet what they think will occur if $A = 1$ or $A = 0$.

    Student Questions (Cont'd):

    4. Before pressing [graph], predict what will occur if
        a. $A = 1$

        Answer: The graph will be concave up. It needs vertically reflected and vertically stretched to match the bounce.

        After their prediction, students press [graph] to see how closely their equation fits the data. On the bright side, one point matches. This step allows students to see the vertex is in place, and just the *A*-value needs adjusting.

Bouncing Ball

TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT
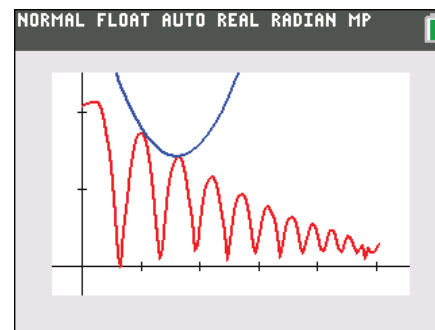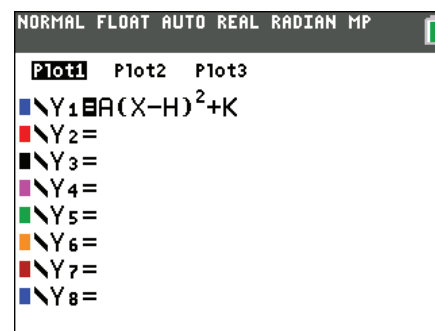
Student Questions (Cont'd):

4. Before pressing [graph], predict what will occur if

    b. **A** = 0

       Answer: The graph will be the line $y = K$.

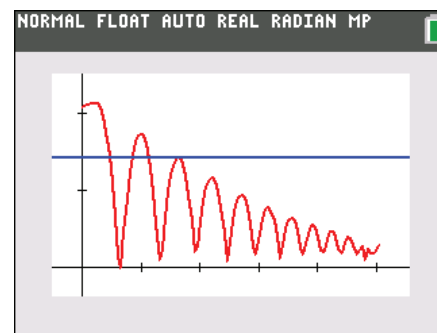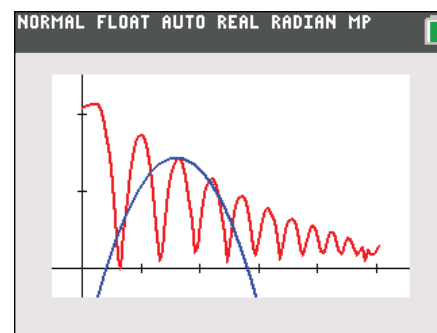7. After students try several values of *A* on their own to search for a good fit, facilitate a discussion about the value of *A*.

- If $A < 0$ the graph is concave down; if $A > 0$ the graph is concave up; if $A = 0$ the graph has no concavity.

- If $|A| = 1$ the graph is the same shape as $y = x^2$;
  if $|A| < 1$, the graph is a vertical compression of $y = x^2$;
  if $|A| > 1$, the graph is a vertical stretch of $y = x^2$.

Student Questions (Cont'd):

5. What effect does each have on the parabola?

    a. the sign (positive or negative) of *A*?
       Answer: + opens up, – opens down

    b. increasing the size of |*A*| ?
       Answer: Increasing |*A*| will make it steeper.

    c. decreasing the size of |*A*| ?
       Answer: Decreasing |A| will make it wider.

8. Lead students into a discussion about the acceleration of falling objects due to gravity.

- Remember, the ball was not thrown; it was dropped. After an object is released, it is acted upon by gravity (neglecting air resistance). So *A* depends on the acceleration due to gravity, -32 feet/second^2 or -9.8 meters/second^2.

- The negative sign indicates that the acceleration is downward.

Depending on students' knowledge of physics, decide how far you want to take this discussion.

Bouncing Ball

TI PROFESSIONAL DEVELOPMENT

9. Students find the value of *A* which best models the bounce.

    Student Questions (Cont'd):

    6. Record the value of *A* that works best:. *A* = _____

        Answer: The value of *A* is approximately one-half the acceleration due to gravity, or −16 feet/second^2.

```
NORMAL FLOAT AUTO REAL RADIAN MP
X→H
                            1.6
Y→K
                     1.449188127
-1→A
                             -1
-16→A
                            -16
```

    Using this value of *A* and the *H* and *K* values you reported in Question 3, write the vertex form of the quadratic equation. *y* =_____

    Answer: *y* = −16(*x* − 1.6)^2 + 1.449

```
NORMAL FLOAT AUTO REAL RADIAN MP
```
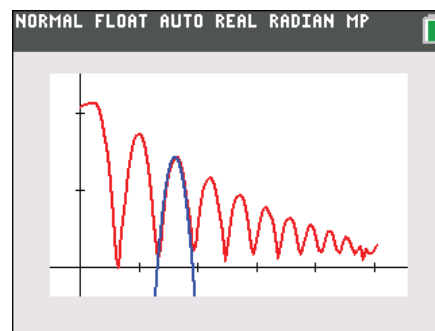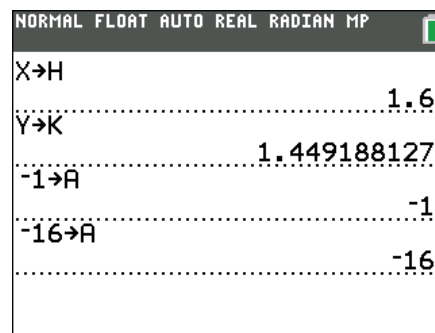
6. Would you expect your classmates to have the same value of *A* for their trials, or do you think the *A* value would vary? Explain your answer.

    Answer: Same; student explanations will vary depending on their previous experiences.

7. Find out the value of *A* from the other groups of students in your class. How do these values compare to your value of *A*?

    Answer: Same or very close.

8. If a ball that was more or less bouncy was used this time, would it affect the value of *A* in the equation? If so, describe how.

    Answer: No, it would only affect the vertices of the bounces.

10. Repeat the activity, but this time use the last full bounce.

    Student Questions (Cont'd):

    10. Identify the vertex and record the *x*- and *y*-coordinates as *H* and *K*: *H* = _____ *K* =_____

        Report the value of *A* that works best: *A* = _____

        How did *A* compare for this bounce?

```
NORMAL FLOAT AUTO REAL RADIAN MP
```
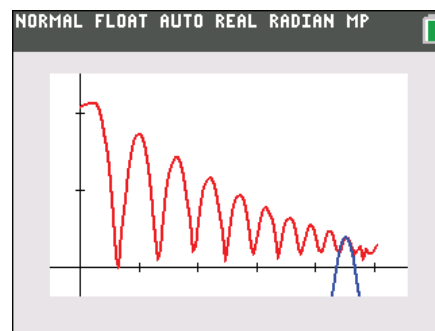
    Answer: Answers for *H* and *K* will vary, but for the bounce here, *H* = 4.5 and *K* ≈ 0.405. The coefficient *A* is the same for the previous parabola: *A* = −16 ft/sec^2 . The value of *A* depends upon the acceleration due to gravity which remains constant through all the bounces.

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Add Them Up
Student Activity

Name _____

Class _____

Objectives

- Collect data and add volts in a series
- Graph regression equations

Materials

- TI-84 Plus Silver Edition graphing calculator
- Vernier® EasyLink™
- Voltage sensor
- Vernier® EasyData™ app
- 5 same size 1.5 volt batteries (e.g., AA, AAA)

1. Record the voltage for each of the five batteries in the table below. For recording purposes, round all decimals to the nearest hundredth.

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.

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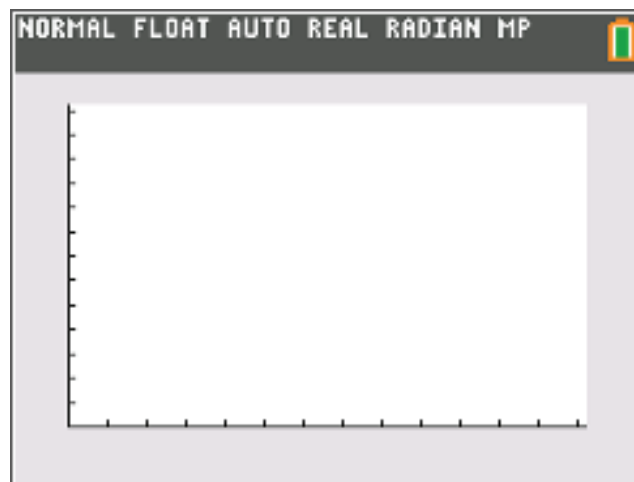
4. Press the arrow keys to trace along the data points and record your data, the voltage, in the table provided below.

# of Batteries X	Voltage Y
1	
2	
3	
4	
5	

5. What do you notice about the voltage measurements?

Add Them Up
Student Activity

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 _____.

    a. Are the calculator values of *A* and *B* the same as your values for *A* and *B*?

    b. Write a comparison explaining any differences.

11. Summarize your investigation.

    a. Write a description of the total voltage a battery-operated device will receive if several batteries are lined up in series.

    b. Include a sketch of the batteries in series below.

Add Them Up

TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, you will explore how many total volts several batteries in a series provide to a battery-operated device.

Materials

- TI-84 Plus graphing calculator
- Vernier® EasyLink™
- Voltage sensor
- Vernier® EasyData™ app
- 5 same size 1.5 volt batteries (e.g., AA, AAA)

Introduction

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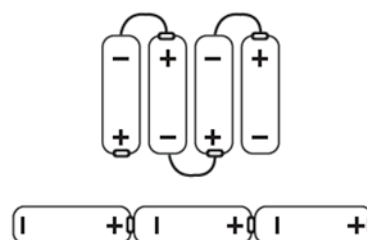
Batteries supply electrical energy to electronic devices when a circuit is created. It might help to think of a circuit as a path linking the positive terminal to the electronic device (the load) and then back to the negative terminal. This investigation will help you explore how many total volts several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

Add Them Up

**TI PROFESSIONAL DEVELOPMENT**

Setup

Briefly discuss the data collection procedure with the class.

1. Have students collect the data in groups of 3 or 4. First, have them measure the voltage of each of their five batteries.

2. Next, they need to measure the voltage of one battery, then a series of two batteries, then three batteries, and so on.

3. They should keep going until they measure the voltage of a series of five batteries.

4. 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

5. Connect the EasyLink™ to the TI-84 Plus Silver Edition using the mini-USB port.

6. Connect the voltage sensor to the other end of the EasyLink™.
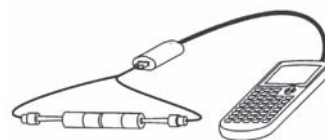
7. The EasyData™ app will launch automatically.

   - 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
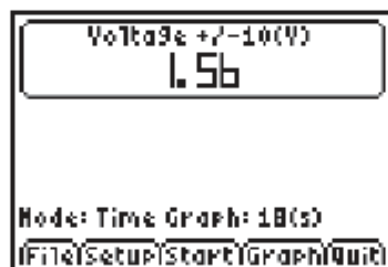
Data Collection

1. Press Y= 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.

2. 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.

Add Them Up

TI PROFESSIONAL DEVELOPMENT

3. 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 *Student Activity* sheet.

    - 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.

4. 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.

5. 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.
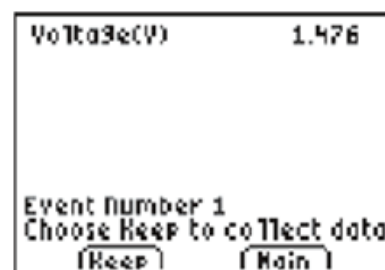
6. Line up two batteries in series.

    - 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**.
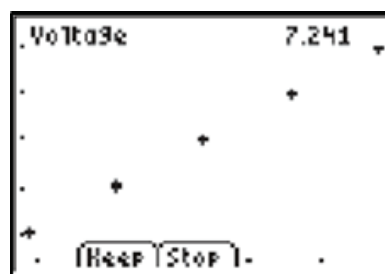
7. Continue for a total of 5 trials. With each recorded value, a new data point will be displayed on the graph.

    - You are given the option to **Keep** or **Stop** the data collection after each trial. When finished, select **Stop**.

    - A graph of data points will be displayed. Use the right and left arrow keys to view the coordinate values of the points.

Add Them Up

TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES
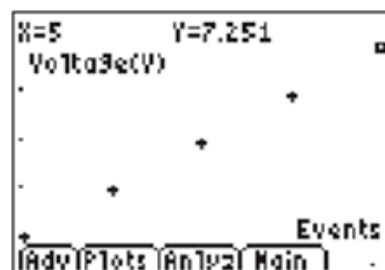
8. To confirm a description of the plots, select the **Plots** soft key.

   • 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 *Student Activity* sheet.
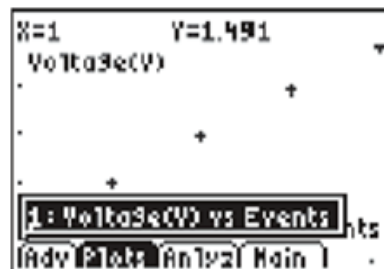
9. Select **Anlyz**, and choose **2:Linear Fit** from the menu.

10. The calculator will display an equation for the line of best fit.

    • Select **OK**.

    • Have students answer Question 8 on their *Student Activity* sheet.
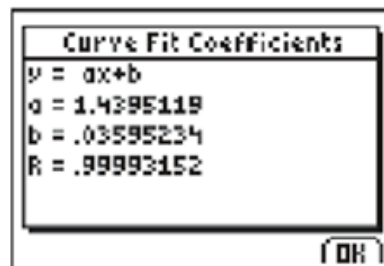
11. The data points will be connected as the regression equation is drawn on the same coordinate plane.
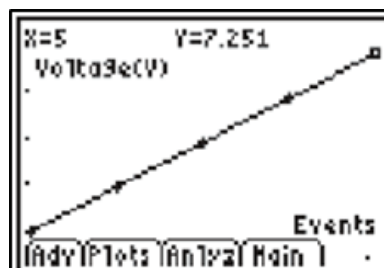
12. Select the **Main** menu, and then select **Quit**.

    • A screen will display where the data from your activity is stored.

    • Select **OK** to exit the app.

Add Them Up

TI PROFESSIONAL DEVELOPMENT

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 the *Student Activity* sheet.

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.

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

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

Add Them Up

TI PROFESSIONAL DEVELOPMENT
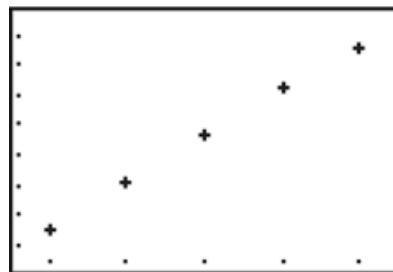
5. The line is still in the Y= window, but its equal sign is no longer highlighted. This indicates that the equation is turned off and is not being graphed.

    -   With Manual Fit, you can choose the location of your model. Putting the manual fit model in Y1 overwrites the EasyData equation.

    -   The current Y1 equation can be stored in Y2. This will allow the **Manual-Fit** line in Y1 to be compared to the regression equation.

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

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.

    -   Press ALPHA [F4] and arrow to Y1.

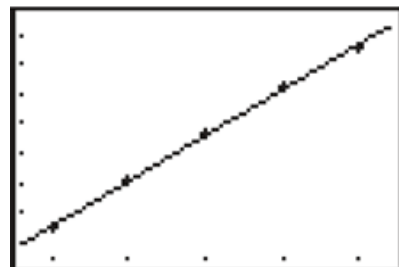8. Press ENTER to complete the command.

    -   This will paste **Y1** into **Y2**.

    -   The equal sign beside **Y2** will be highlighted. When an equal sign is highlighted, the equation is turned on and the equation will be graphed in the graph window.

9. Press GRAPH to be sure this is the regression equation.

Add Them Up

TI PROFESSIONAL DEVELOPMENT

10. Go to the $\boxed{Y=}$ window, and turn off the equal sign beside both equations.

   - To do this, position the cursor on each equal sign, and press $\boxed{ENTER}$. This is a toggle switch.

   - If the equal signs are highlighted, pressing $\boxed{ENTER}$ will turn them off. If they are not highlighted, they will be turned on.
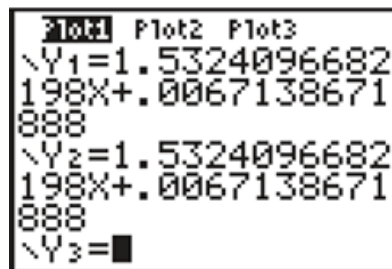
11. Press $\boxed{ENTER}$. This will move you to the graph screen.

   - Press $\boxed{STAT}$, arrow over to **CALC**, and then scroll down until **D:Manual-Fit** is highlighted.

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 $\boxed{ENTER}$. 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 $\boxed{ENTER}$. Next, move the cursor to one of the points on the right side of the screen.
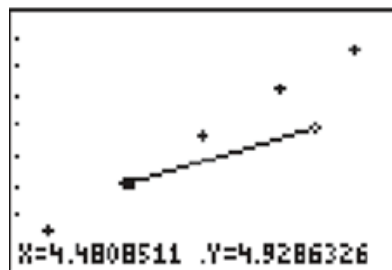
13. When satisfied with the position of the cursor, press $\boxed{ENTER}$.
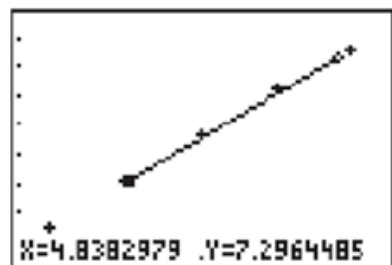
14. The entire line will fill in and its equation will be written across the top of the screen with the slope highlighted.

Add Them Up

TI PROFESSIONAL DEVELOPMENT
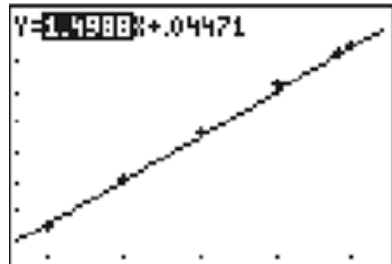
15. Round the slope to the nearest tenth. Type the rounded slope value into the calculator.

- 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 .
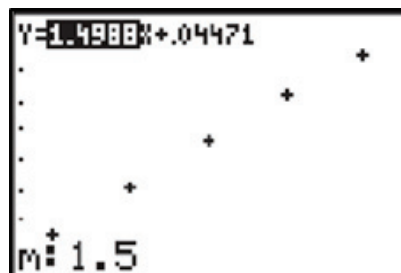
16. Press the right arrow key to highlight the *y*-intercept.

- Repeat the process above to change it.

- Zero is a good choice for the *y*-intercept because zero batteries would register no voltage.

17. Pressing Y= will take you out of the **Manual-Fit** program. Your line of best fit will stay in **Y1**.
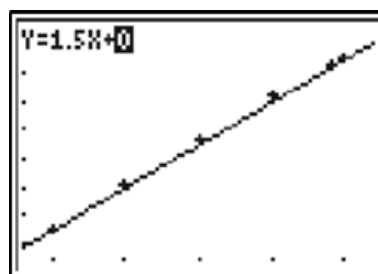
18. To compare how closely the regression equation you found matches the one the calculator found, graph them both at the same time.

- 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. This symbol has a ball with a small line to the left of the ball.

8

Add Them Up
TI PROFESSIONAL DEVELOPMENT
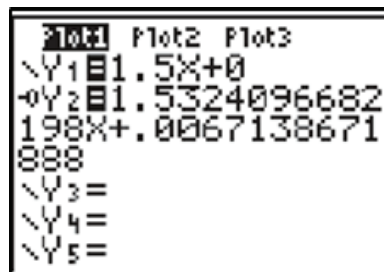
19. Press GRAPH. You will see **Y1** graphed normally.

- 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.

- Have students complete questions 9–11 on their *Student Activity* sheet.
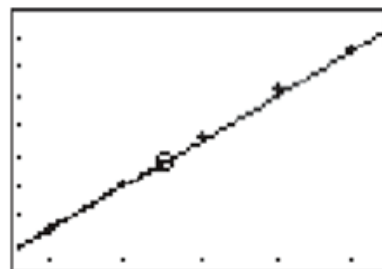
Teacher Notes

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.

Add Them Up

TEACHER NOTES

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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. $y = 1.5x$, $A = 1.5$, $B = 08$.

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.

# of Batteries	Voltage
X	Y
1	1.49
2	3.08
3	4.64
4	6.23
5	7.58
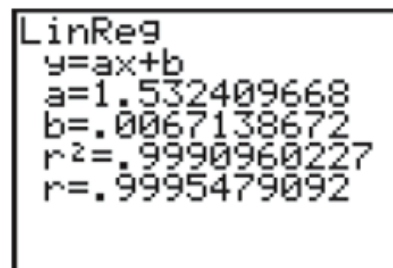
LinReg
y=ax+b
a=1.532409668
b=.0067138672
r²=.9990960227
r=.9995479092

If using TI-84 Plus C Silver Edition

Directions are the same for the TI-84 Plus C Silver Edition. StatPlots can be used with color and gridlines. Manual Fit also allows for color and line style. To exit Manual Fit you can also press the DONE soft key.
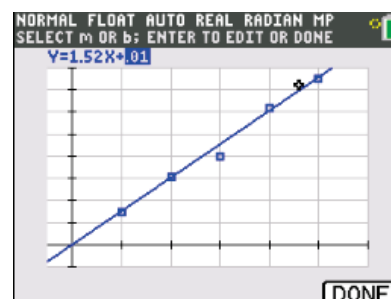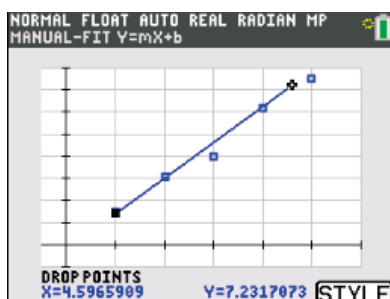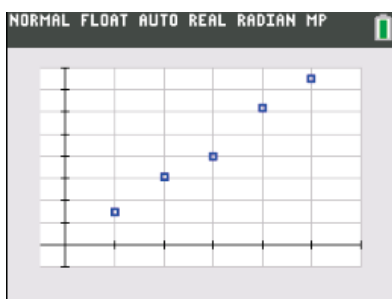
Two Hot, Two Cold
Student Activity

Name _____

Class _____

Objectives

- Graphing linear functions

Materials

- TI-84 Plus Silver Edition graphing calculator
- Vernier® EasyData™ app

In this experiment, you will collect data in both Celsius and Fahrenheit temperatures using two temperature probes in the same cups of water. Based on the data collected, you will develop and test a mathematical relationship between these two temperature scales and explore the relationship between them. Your teacher will outline the procedure for you.

1. Fill in the table with the data you collected.

Cup of Water	ºC	ºF
Air room temperature		
Tap water		
Ice water (lots of ice still		
Cool water, ice has melted		
Warm water		
Very hot/boiling water		

2. Why is the order in which you collect the data not important?

3. You put the Celsius readings in **L1** and the Fahrenheit readings in **L2**. Why did you throw away the numbers 1-6 that were originally in **L1** after running the EasyData ™ app?

4. You used two of these data points to find the slope of the regression equation. Would you get the same answer as if you used two different points? Explain.

5. How would using a brighter light bulb affect the parameters *A*, *B*, and *C* in the two models?

6. What was your regression equation?

7. The definition of the slope of a line is the change in *y* divided by the change in *x*. For this problem, that would be a change in Fahrenheit divided by the change in Celsius. Use your own words to state what that means with respect to this problem.

8. What was the regression equation the calculator found?

9. What is the reasonable explanation for why the two regression equations are different from each other and also different from the formula?

10. If your equation is in **Y1**, the formula is **Y2**, and the calculator's regression equation is in **Y3**, use the **Ask** feature on the table of the calculator, and fill in this chart for the given temperatures.

X°C	Y1	Y2	Y3
5			
15			
25			
35			
60			
85			

Two Hot, Two Cold

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Activity Overview

In this experiment, you will collect data in both Celsius and Fahrenheit temperatures using two temperature probes immersed in cups of water. Based on the data collected, you will develop an equation to convert Celsius temperatures to Fahrenheit temperatures.

Materials

- TI-84 Plus Silver Edition graphing calculator
- 2 EasyTemp™ Probes or 2 EasyLinks™ with temperature probes
- Vernier® EasyData™ app
- Several cups of water with varying temperatures
- Ice and boiling water

How do we measure temperatures? In almost all countries of the world, the Celsius scale (formerly called the centigrade scale) is used in everyday life, science, and industry. This scale sets the freezing temperature of water at 0 and the boiling temperature at 100. The distance between these two points is divided into 100 equal intervals called degrees.

The United States uses Fahrenheit scale. This scale employs a smaller degree unit than the Celsius scale, and its freezing point is set to a different temperature. For the temperatures we commonly use and observe, Celsius readings are lower than Fahrenheit readings. You have probably noticed this if you have seen a thermometer that has both Celsius and Fahrenheit markings or if you have driven by signs at banks and other businesses that display time and dual temperatures.

Setup

1. Each group will need 5 cups with water of varying temperatures.

   - One cup of water should be room temperature or fresh out of the tap.

   - One cup of water should be very cold with many solid ice cubes in the cup.

2. The order the readings are taken is not important. An efficient way to test each cup is to have a few samples in one area of the room and let students carry one or two samples at a time from that area to the area where their group is working.

   - After taking readings, the samples can be returned. This will allow you to keep the water boiling for each temperature reading.

   - Run water through a coffee pot for hot water samples, and keep ice in a small cooler for the cold water samples.

Two Hot, Two Cold TEACHER NOTES
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3. Have students work in groups of 3 or 4, and assign each group member a task. For this lab, suggest the student jobs:

- Materials/setup person who sets up the EasyTemp™ sensors and TI-84 Plus Silver Edition graphing calculators; holds probes in the samples during the activity.

- Two Tech people who each operates the EasyData™ app and a TI-84 Plus Silver Edition, one for Celsius readings and one for Fahrenheit readings.

- Data recorder who reads and records the temperature readings for each sample on the worksheet chart.

- Runner who brings samples to the group, holds the cup to avoid spillage during the activity, and returns samples after readings are taken.

4. Link two EasyTemp probes to two different TI-84 Plus Silver Editions.

- You might also use the two EasyLinks™ with two of the older temperature probes or a combination of these two setups. Refer to the figure at right.
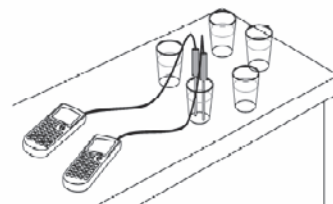
Data Collection

1. When you connect the EasyTemp probe to your TI-84 Plus Silver Edition, the EasyData app will launch automatically. Connecting the EasyLink to your TI-84 Plus Silver Edition, and connecting an older temperature sensor to an older temperature sensor to the other end of the EasyLink will work just as well.

2. The EasyData information screen is displayed for about 3 seconds followed by the main screen. The EasyData app identifies the temperature sensor.

    The main screen of the EasyData app will display the current temperature across the top of the screen in degrees Celsius.

3. Press Y= to access the **File** menu. 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.

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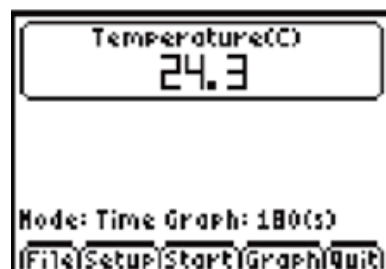
4. Leave one of the calculators with the Celsius setting but the other calculator will need to be changed to Fahrenheit.

   • Press WINDOW to select Setup, and choose 1:Temp from the menu displayed .

5. From the next screen, press WINDOW to select **Units**.

6. Select **2:(F)** from the menu to change from Celsius to Fahrenheit.
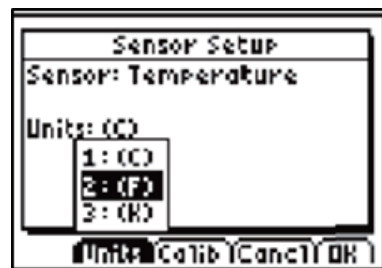
7. When the screen appears confirming that your choice has been accepted, select OK.
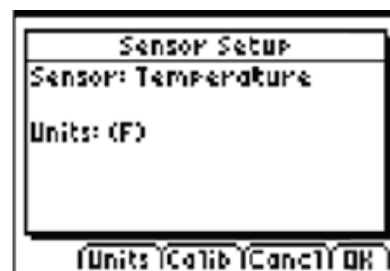
8. You will be returned to the main screen of the app. Select Setup on both calculators, and then select **4:Selected Events**.

Two Hot, Two Cold

TEACHER NOTES

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9. You will be taken to a screen that displays the temperature reading in real time at the top of the screen. See the figures on right.

```
Temperature(C)
    24.8




Mode:Selected Events
[File][Setup][Start][Graph][Quit]
```

```
Temperature(F)
    76.2




Mode:Selected Events
[File][Setup][Start][Graph][Quit]
```

10. To begin collecting data, position the two probes next to each other but not touching.

   • Select **Start**. Let the first reading be the room temperature.
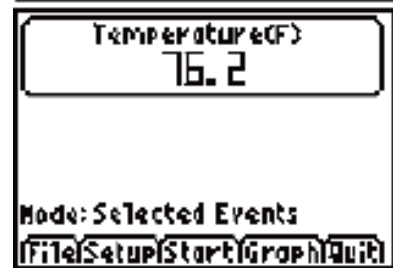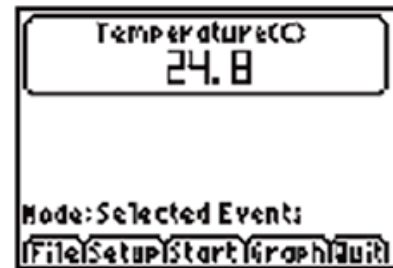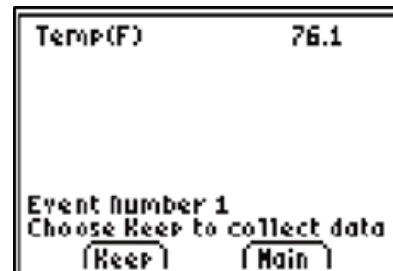
   • To record the temperature of the first reading, select **Keep**.

```
Temp(F)          76.1




Event number 1
Choose Keep to collect data
  [Keep]      [Main]
```

11. Next, place both probes in the first cup. If the first cup contains the room temperature water, the reading will probably be close to, if not the same as, the air temperature.

   • When it stabilizes, select **Keep**. The **Selected Events** feature will keep track of which reading you are on, increasing by one each time you select **Keep**.

12. Repeat the procedure until you have collected the six readings. This includes the air temperature and the five cups of water.

   • Have students record the readings in the table on their worksheet.

   • Make sure the students understand the order in which they collect the data is not important.

   • The important thing is to keep the two probes close together so they are measuring the same temperature.

   • Select **Keep** at the same time on both calculators after the temperature readings have become relatively stable.

```
Temp(F)          76.1
                        +

                    +
             +
.+
       +

  [Keep][Stop].
```

4

Two Hot, Two Cold

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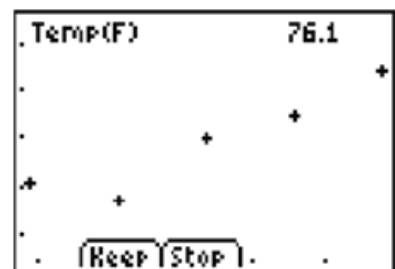
13. With each recorded value, a new data point will be displayed on the graph.

    - When finished, select **Stop**. The graph of all the data points will be displayed.

    - At this point, you can use the right and left arrow keys to view the coordinates of the points.
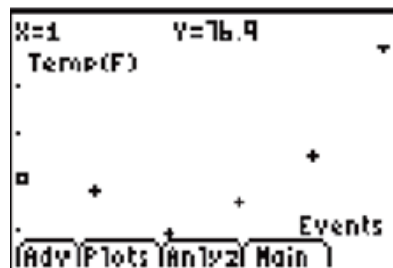
14. You will **NOT** analyze the data from within the app. Select **Main** and then Quit to exit the app.

15. The new screen informs you that your data are in lists one and two. **L1** contains the numbers 1-6. Temperatures are stored in **L2**.

    The Celsius and Fahrenheit readings are stored in **L2** on two separate calculators. The lists need to be in both calculators so that the Celsius data is in **L1** and the Fahrenheit data is in **L2**.
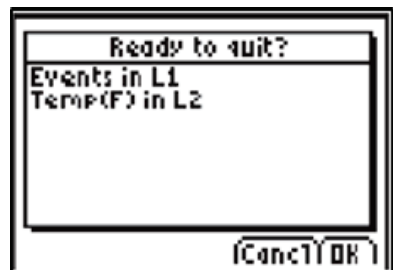
Note: The lists could be renamed CELSI and FAHRN at this point, but only a few students would get to rename the lists. If you wait until the data is linked, every student will get the experience of creating and naming a list.

16. On the calculator that took the readings in the Celsius scale, press $\boxed{\text{STAT}}$ and select **1:Edit** to see the lists displayed. We need to replace L1 with the values in L2.

17. Position the cursor so the name **L1** is highlighted.

    - Press $\boxed{\text{2nd}}$, $\boxed{2}$ to access **L2**. You will see **L2** at the bottom of the screen.

    - Press $\boxed{\text{ENTER}}$.

18. **L1** should fill in with the data from **L2** .

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19. Link the two calculators together, and pass **L1** from the Celsius calculator to the Fahrenheit calculator and then **L2** from the Fahrenheit calculator to the Celsius calculator.

     In both cases, because the receiving calculator already has data in the target list, your screen will look like the one at the right. Select **2:Overwrite**.
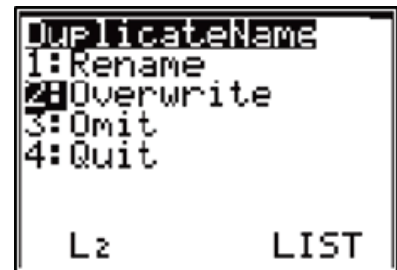
20. When the list is sent successfully, you will receive confirmation.
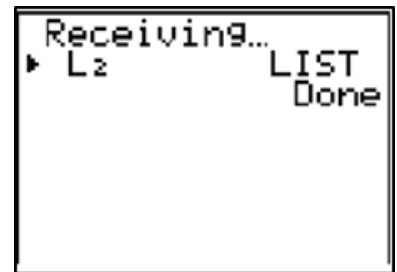
21. Press STAT, and select **1:Edit** to see the lists displayed on both calculators. Link both **L1** and **L2** to all students' calculators.

Data Analysis

1. Set up a scatterplot with temperature in degrees Celsius as the independent variable (Xlist) and the corresponding temperature in degrees Fahrenheit as the dependent variable (Ylist).

2. Press ZOOM, and select **9:ZoomStat** to see the scatterplot.

   • When TRACE is selected, you might have trouble scrolling through the points.

   • When a scatterplot is traced using the right arrow key, the points are scrolled through in the order they were entered into the data list of the independent variable.

   • Often this is the order in which they appear on the screen from the left to right, but that is not what happened in this scatterplot.

   • The right arrow will allow you to scroll through the points in the order they are listed in **L1** and **L2** regardless of where they appear on the screen.

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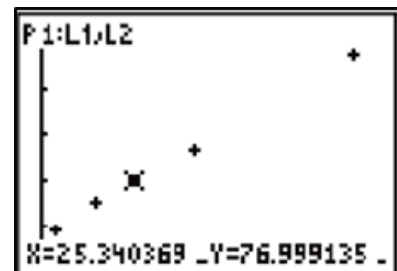
3. Sort the lists so that the data points are in order from smallest to largest. Use the calculator to sort the list for you.

- Press STAT, and select **2:SortA(** from the menu. This will sort the list in ascending order.

4. This takes you to the home screen. If you enter L1, the calculator will arrange the number in the list one in order, but it will leave the numbers in L2 alone. Because the numbers in L2 are related to the numbers in L1, the entire row needs to be carried along with the lead entry from L1.

- To do this, type **SortA(L1, L2)**.
- Press ENTER to execute the command
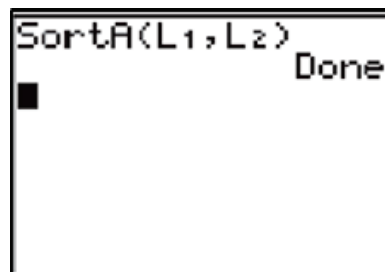
5. Press STAT, and select **1:Edit…** Your data has been sorted. Notice that the elements in L1 have been listed in ascending order, as have their corresponding values in L2.

6. Now the points can be traced in order from left to right.
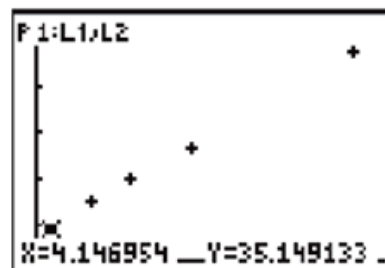
7. Next, find the trend line or the line of best fit. If your students have enough experience, you can discuss with them the different ways to find the regression equation.

- One method is to estimate the slope and *y*-intercept, and enter it into **Y1**.

- Check to see how closely it matches the points and adjust the values until you are satisfied with the fit. This can be done manually or using the **Manual-Fit** option under the STAT, ▶ **CALC** menu.

- Another method is to choose two ordered pairs on the graph and calculate the slope.

- Then, using the slope and *y*-intercept (or any other point), find the equation of the line, graph the line, and see how well it fits the data points.

- Using the built-in linear regression features of the calculator is a quick and accurate method.

Why would it be best to avoid using the built-in regression in this case? Consider the purpose of this activity. If the purpose is to find the function relating Celsius and Fahrenheit temperatures, then looking up the formula in a book is as quick and accurate as using the regression feature. Our purpose is more for the students to learn linearity, that linear data has a constant slope, and that if data has a constant slope it can be modeled with a line. Also, as students adjust the parameters to find a better fit, they cement in their minds the definitions of *m* and *b* and what effects these parameters have on the equation of a line. Learning a few keystrokes to find a regression line and calling that "the answer" limits the power of the activity to teach students about the equation of a line.

8. The calculator can help with the computation of the slope.

   • After tracing to the first point, press [2nd], [MODE] to [QUIT] and return to the Home screen.

   • Press [X,T,Θ,n], [STO▸], [ALPHA], A, [ENTER].

   • This will store the *x*-value from the point you last traced on the graph screen to the variable **A.**

   • Repeat this procedure to store the *y*-value into variable **B**.

   • Press [ALPHA], Y, [STO▸], [ALPHA], B, [ENTER].

9. Press [GRAPH], [TRACE], [▸] to move to the last point on the right. Once again, notice the *x*- and *y*-values displayed at the bottom of the screen.

10. Repeat the procedure to store these values in **C** and **D**.

   • Press [2nd], [MODE] to access [QUIT], and return to the Home screen.

   • Press [X,T,Θ,n], [STO▸], [ALPHA], C, [ENTER]. This will store the *x*-value from the last point to the variable **C**.

   • Next press [ALPHA],Y, [STO▸], [ALPHA], D, [ENTER].

11. Using the slope definition, have the calculator find the slope and store the value in **M** as shown in the screen.

   • Be sure to enclose both the numerator and denominator in parentheses.

   • The keystroke sequence is [(] [ALPHA] D [−] [ALPHA] B [)] [÷] [(] [ALPHA] C [−] [ALPHA] A [)] [STO▸] [ALPHA] M [ENTER].

Two Hot, Two Cold

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12. Go to the $\boxed{Y=}$ window, and press $\boxed{\text{ALPHA}}$ M $\boxed{\text{X,T,Θ,}n}$ to type **MX** into **Y1**.

13. Press $\boxed{\text{GRAPH}}$ to see how closely this line fits the points.

    • In the example shown, it looks like the slope is correct since the line is parallel to an imaginary line through the points.

    • The vertical position of the line needs to be moved up by adjusting the *y*-intercept.
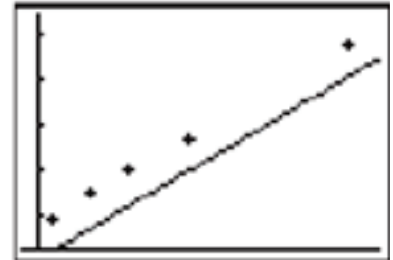
14. Determine how much your line is *below* where it needs to be.

    • This is a great opportunity to discuss the importance of the *y*-intercept.

    • Be sure your students understand that with the present equation in Y1, the *y*-intercept is 0.

    • Ask the students if anyone knows what 0 degrees Celsius would be in Fahrenheit. Although you could figure out the *y*-intercept mathematically, use this piece of general knowledge and add it to **Y1**.

15. Press $\boxed{\text{GRAPH}}$ to see how closely this fits the points. In the example shown, it looks like a great fit.
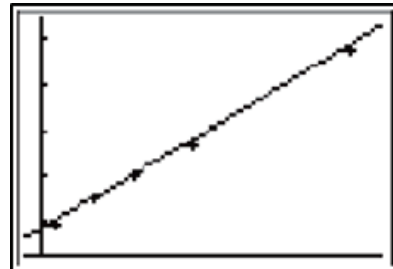
16. Look up the formula to convert Celsius to Fahrenheit, and enter it into **Y2**.

    • Use the left arrow key to highlight the slash icon in front of Y2.

    • Repeatedly press $\boxed{\text{ENTER}}$ until you see the symbol shown at the right. It is the symbol with the ball and the small line to the left of the ball.

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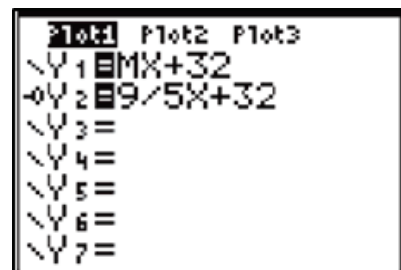
17. Press [GRAPH]. **Y1** is graphed normally.

   A circular cursor traces the leading edge of the graph of Y2 and helps emphasize how close the lines are to each other.
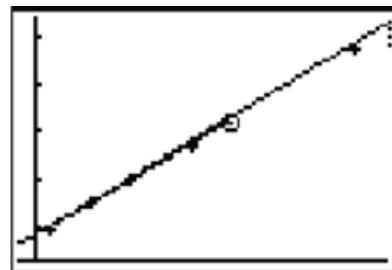
18. Pressing [2nd] [GRAPH] to access [TABLE] will allow you to see how close your regression equation is to the formula.

   A numerical comparison (rather than just the visual comparison on the graph screen) can confirm that the two lines are very close to being the same line.

19. Press [2nd] [WINDOW] to access [TBLSET].

   The defaults on the table are to start at zero, to count by one, and to automatically fill in all the values. With these settings, it could take a while to scroll and find specific values.

20. To take more control over what numbers the table displays, change the **Indpnt:** to **Ask** instead of **Auto**.

   • Leave the Depend: set on Auto.

   • Use the arrow keys to position the cursor on the word **Ask**, and press [ENTER].

21. Press [2nd] [GRAPH] to access a [TABLE]. You will be taken to a blank table.

   • Type zero (0). It will be entered beside the **X=** at the bottom of the screen.

22. Pressing [ENTER] will fill in both **Y1** and **Y2**.

   • Remind the students that they entered the *y*-intercept from their knowledge of the fact that 0 degrees Celsius is 32 degrees Fahrenheit.

   • So, this exact match is not an indicator for all points.

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23. Another common set of values is the boiling point of water. Celsius is 100 degrees and Fahrenheit is 212.

   • Have the students type in 100 beside the X=, and compare the values in Y1 to the values in Y2.

24. The goal of this lesson is to understand and highlight the algebra involved in building a mathematical model for a linear set of data.

   • Additionally, students should become more familiar with the Celsius scale. Here's a short poem that also helps: 30's hot and 20's nice: 10 is cold and 0's ice!

   • Try saying it, and then add these numbers to the *x*-values in the table to see their matching Fahrenheit values.

25. An extension to this activity it to let the calculator find a regression equation for the data, put in **Y3**, and then compare the various methods used in both the graph and the table views.

26. To accomplish this, press STAT, move over to CALC, and choose **4:LinReg(ax+b)**. You will be taken to a wizard on the home screen to enter the list names and where you want the equation pasted.

   • In the Store RegEq spot, press ALPHA [F4].

   • From the list displayed, select **3:Y3**.

27. Highlight Calculate, and press ENTER. The regression will be displayed.

28. Press Y= and use the arrow keys to highlight the slash icon in front of **Y3**.

   • Repeatedly press ENTER until you see the symbol shown at the right.

   • The symbol will look like a ball with a small line to the left of the ball.

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Two Hot, Two Cold   **TEACHER NOTES**

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29. A circular cursor traces the leading edge of the graph of **Y3**, and it helps emphasize how close the lines are.
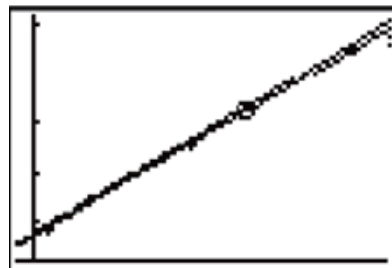
30. It is not unusual for the equation a student gets on his or her own to be closer to the actual formula than the regression equation found by the calculator. Many students think the calculator will always do a better job than they can do. This is a great chance to show them that they can be more accurate than a calculator.

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Two Hot, Two Cold

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Worksheet Answers

1. Answers will vary.

2. Because we were comparing the two temperature readings to each other.

3. They had nothing to do with how the two temperature readings were related.

4. Maybe not exactly the same but VERY close.

5. Answers will vary, but they should still be close to $y = 1.8x + 32$.

6. For every 1 degree change in Celsius, the Fahrenheit changes by 1.8 degrees.

7. Answers will vary, but they should be close to $y = 1.8x + 32$.

8. Small amounts of human error and/or calibration of temperature probes.

9. Y2 is from the formula; other answers will vary.

X°C	Y2
5	41
15	59
25	77
35	95
60	140
85	185
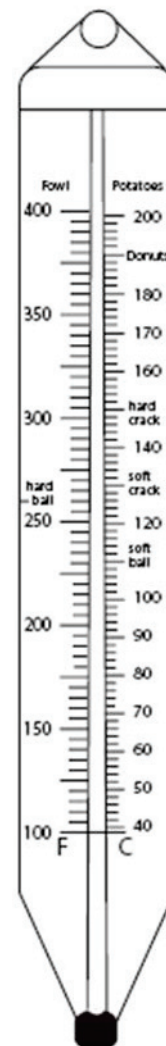
If using the TI-84 Plus C Silver Edition

Directions are the same. When graphing the different models, different colors can be used to distinguish them. In the table of values, the colors will match the equations.

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Light at a Distance:
Distance and Light Intensity
Student Activity

Name _____

Class _____

Objectives

- Explore distance and intensity of light
- Graph linear functions

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

Materials

- Vernier® EasyData™ app
- Vernier light sensor
- Vernier EasyLink™ USB interface
- Meter stick or tape measure
- DC-powered point light source

Left-most point *x*-value X_L	
Left-most point *y*-value Y_L	
Initial model parameter *C*	
Optimized inverse-square model $y = C/x^2$	
Power law model $y = ax^b$	

1. What is your prediction for the relationship between intensity and the distance to a light source?

2. Is the graph of the light intensity versus distance consistent with your earlier prediction?

3. How well does the inverse-square model $y = C/x^2$ fit the experimental data?

4. How well does the power law model fit the data? Could it fit any better than the inverse-square model? Could it fit more poorly?

5. How would using a brighter light bulb affect the parameters *A*, *B*, and *C* in the two models?

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Light at a Distance: Distance and Light Intensity

TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES

Activity Overview

In this activity, you will explore the relationship between distance and intensity for a light bulb. You will record the intensity at various distances between a light sensor and a bulb. The data can then be analyzed and modeled mathematically.

Objectives

- Explore distance and intensity of light
- Graph linear functions

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

Materials

- Vernier® EasyData™ app
- Vernier light sensor
- Vernier EasyLink™ USB interface
- Meter stick or tape measure
- DC-powered point light source

Introduction

While traveling in a car at night, you might have observed the headlights of an oncoming vehicle. The light starts as a dim glow in the distance, but as the vehicle gets closer, the brightness of the headlights increases rapidly. This is because the light spreads out as it moves away from the source. As a result, light intensity decreases as the distance from a typical light source increases. What is the relationship between distance and intensity for a simple light bulb?

Procedure

1. Arrange the equipment so that there are no obstructions between the bulb and the light sensor during data collection.

   - Remove any surfaces near the bulb, such as books, people, walls, or tables. There should be no reflective surfaces behind, beside, or below the bulb.

   - The filament and light sensor should be at the same vertical height. This makes the light bulb look more like a point source of light as seen by the light sensor.

   - While you are taking intensity readings, the light sensor must be pointed directly at the light bulb.

2. Set up the light sensor for data collection.

   - Turn on the calculator. If you are using the Vernier® Light Sensor, set it to 0–600 lux for a small light source, or 0–6000 lux for a larger light source.

   - Connect the light sensor, data-collection interface, and calculator.
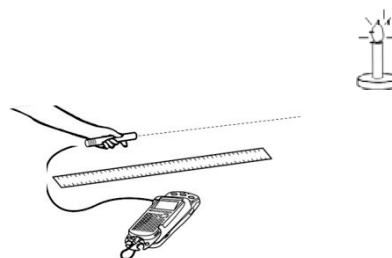
Light at a Distance: Distance and Light Intensity   TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT

3. Set up the EasyData™ app for data collection.

    *   Start the EasyData app, if it is not already running.

    *   Select ⌈File⌉ from the Main screen, and then select **New** to reset the app.

    *   Select ⌈Setup⌉ from the Main screen, and then select **Events with Entry**.

4. Dim the lights to darken the room.

    *   A very dark room is critical to obtain good results.

5. Hold the light sensor about 10 cm from the light bulb filament.

    *   Move the sensor away from the bulb, and watch the displayed intensity values on the calculator screen.

    *   Answer Question 1 on the *Student Activity* sheet.

6. To account for the particular brightness of your light source, choose a starting distance that gives a reading less than the maximum reading for your sensor (600 or 6000 lux for the Vernier® sensor, or 1 for the TI sensor), but as large as possible.

    *   However, do not get any closer than 5 cm for small (<5 mm) bulbs, or 10 cm otherwise.

    *   Choose the starting distance, and enter it as X_L in the data table on the *Student Activity* sheet.

7. Again place the light sensor at your planned starting distance from the light bulb filament.

    *   **Important**: The distance must be measured carefully.

    *   Be sure you measure from the filament of the lamp to the sensor tip on the light sensor.

8. Select ⌈Start⌉ from the Main screen to prepare for data collection.

9. Wait for the value displayed on the calculator to stabilize.

    *   Select ⌈Keep⌉, and then enter the distance between the light sensor and the light source in meters on the calculator.

    *   Select ⌈OK⌉ to store the data pair.

10. Move the light sensor 1 cm farther away from the light source, and repeat Step 9.

11. Continue moving the sensor in 1-cm increments until the readings fall to less than 10% of the initial reading, collecting data as before.

12. Inspect the graph of light intensity versus distance.

    *   Trace to read the *x*- and *y*-values of the left-most point, round the values to three significant figures, and record them as X_L and Y_L in the Data Table.

13. Select ⌈Main⌉ to return to the Main screen.

    *   Exit EasyData™ by selecting ⌈Quit⌉ from the Main screen, and then selecting ⌈OK⌉.

Light at a Distance: Distance and Light Intensity

TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES

Data Analysis

1. Redisplay your graph outside of the EasyData™ app.

    - Press [2nd] [STAT PLOT].

    - Press [ENTER] to select Plot1, and then press [ENTER] again to select On.

    - Press [ZOOM].

    - Press [▼] until ZoomStat is highlighted; press [ENTER] to display a graph with the *x* and *y* ranges set to fill the screen with data.

2. Inspect your graph of the light intensity versus distance.

    - Answer Question 2 on the *Student Activity* sheet.

3. One model for light intensity holds that the intensity is proportional to the inverse square of the distance from a point light source; that is, a graph would be of the form $y = C/x^2$, where C is an adjustable parameter. Does your data follow this model? You can check it out by finding an approximate value for C, and then graphing the model with the data. First, enter the model equation.

    - Press [Y=].

    - Press [CLEAR] to remove any existing equation.

    - Enter C/x^2 into the Y1 field.

    - Press [2nd] [QUIT] to return to the home screen.

4. Set a value for the parameter C, and then look at the resulting graph.

    - To obtain a good fit, you will need to try several values for C. Use the steps below to determine an initial guess for the parameter.

    - One way to find an approximate value for the parameter is to use the left-most point.

    - If you solve for C, then $C = yx^2$. Use the *x*- and *y*-values for the left-most point to calculate an initial value for C.

        o   Record this value into the data table on the *Student Activity* sheet.

   o   Enter a value for the parameter **C**.

5. If the model is systematically high or low, you might want to adjust the value of C to improve the fit.

    - As you did before, store a new value into C, and then display the graph and model.

    - Once you have optimized the model, record the complete equation in the data table.

    - Answer Question 3 on the *Student Activity* sheet.

Light at a Distance: Distance and Light Intensity   TEACHER NOTES
TI PROFESSIONAL DEVELOPMENT

6. Another model can be used to compare to your data.

    The general power law of $y = ax^b$ might provide a better fit than the inverse square function,
    especially if the light source is not small or if there are reflections from walls or other surfaces.
    The difference between this new model and the inverse square model is that the exponent is not
    fixed at –2. Instead, the exponent is now an adjustable parameter. The calculator can be used to
    automatically determine the parameters *a* and *b* in the general power law relation to the data.

    - Press STO▶ C ENTER to store the value in the variable **C**.

    - Press GRAPH to see the data with the model graph superimposed.

    - Press 2nd [QUIT] to return to the home screen.

    - Press STAT and use the cursor keys to highlight CALC.

    - Press ▾ repeatedly to scroll down to PwrReg.
      When it is highlighted, press ENTER to open up the
      regression wizard.

    - Configure as shown.

        o To access [L1] press 2nd 1; to access [L2]
           press 2nd 2; to access Y1 press ALPHA
           [F4] and highlight Y1, then press ENTER.

        o Arrow down to Calculate, and press ENTER. On the home screen, you will
           now see the power regression displayed. The resulting regression curve will
           be stored in equation variable Y1. Use the parameters *A* and *B*, rounded to
           two significant figures, to write the power law model equation in the data table.

    - Press GRAPH to see the graph of your data and the power regression function.

    - Answer Questions 4 and 5 on the *Student Activity* sheet.
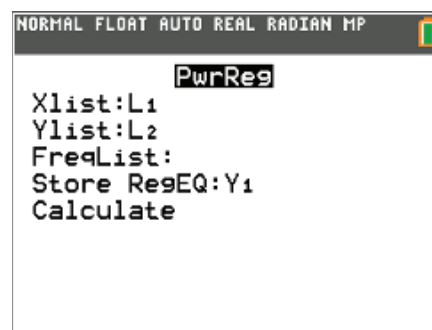
Extensions

1. Suppose that your patio is illuminated by an overhead light fixture with two bulbs. You decide to save
    on electricity by removing one of the bulbs. If the light is currently mounted 5 m off the ground, to
    what height should the light fixture be moved in order to retain the same amount of light on the patio
    with one bulb? Does your answer depend on the model you use?

2. Two identical light bulbs shine on your favorite reading chair from different locations in the room. The
    first bulb is 3 m from your chair and provides an intensity of 0.6 mW/cm^2. The second is 2 m from
    your chair. What intensity does this bulb provide? Does your answer depend on the model you use?

Sour Chemistry: Exponential pH Change
Student Activity

Name _____

Class _____

Objectives

- Graph linear functions

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

Materials

- Vernier® EasyData™ app
- Vernier EasyLink™ USB interface
- Vernier pH sensor
- Distilled water
- Lemon juice
- Eyedropper
- Effervescent antacid tablets
- Clean cup or beaker

y-intercept *C*	
pH approach value	
A	
optimized *B*	

1. Explain why the model expression from Step 4 approaches the sum of *A* + *C*.

2. How does the value of *B* affect the shape of the modeling curve?

3. a. How would adding more drops of lemon juice to the starting solution affect the resulting plot of pH versus time?

   b. Which of the parameters *A*, *B*, or *C* in the model expression would change?

   c. Explain the reasoning.

   Hint: Adding more lemon juice would make the initial solution more acidic, yielding a lower pH value at the start of data collection.

Sour Chemistry: Exponential pH Change   Name _____
Student Activity   Class _____

4. a.   How would adding two antacid tablets (instead of one) to the starting solution affect the
         resulting plot of pH versus time?

    b.   Which of the parameters *A*, *B*, and *C* in the model expression would change?

    c.   Explain the reasoning.

5. a.   How would you compare the effectiveness of two different brands of antacid tablets?

    b.   Which of the parameters *A*, B, and C in the model expression would give an indication of
         how well a tablet works?

    Hints: Which variable describes the speed of relief?

          Which variable describes the magnitude of relief?

Sour Chemistry: Exponential pH Change

TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, the conditions found in an acid stomach will be simulated using a solution of lemon juice and water. The effectiveness of an antacid remedy will be tested by monitoring the pH of the solution after an effervescent antacid tablet has been added to it. The resulting data will be modeled using a modified exponential function.

Objectives

- Graph linear functions

Compatible TI Technology

- TI-84 Plus CE
- TI-84 Plus C Silver Edition
- TI-84 Plus Silver Edition*
- TI-84 Plus* (*OS 2.55MP)

Materials

- Vernier® EasyData™ app
- Vernier EasyLink™ USB interface
- Vernier pH sensor
- Distilled water
- Lemon juice
- Eyedropper
- Effervescent antacid tablets
- Clean cup or beaker

Chemists quantify the acidity or alkalinity of a solution by measuring its pH on a scale ranging from 0 to 14. A neutral substance has a pH of 7. A pH lower than 7 suggests an acidic solution, while a pH higher than 7 indicates that a solution is basic.

Different pH levels must be maintained throughout the body in order for a person to remain healthy. Excessively high or low pH levels often result in discomfort or irritation. For example, common indigestion or upset stomach usually indicates the presence of excessive amounts of stomach acids. This condition can sometimes be alleviated by taking an antacid tablet, or by drinking a solution such as Alka- Seltzer® and water, designed to neutralize these acids and raise the pH level in the stomach.

1. Turn on the calculator. Connect the pH Sensor, data-collection interface, and calculator.
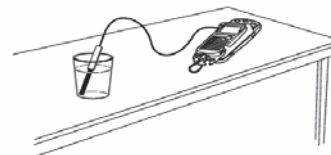
2. Set up the EasyData™ app for data collection.

   - Start the EasyData app, if it is not already running.

   - Select ⟨File⟩ from the Main screen, and then select **New** to reset the application.

   - Select ⟨Setup⟩ from the Main screen, then select **Time Graph…**

   - Select ⟨Edit⟩ on the Time Graph Settings screen.

   - Enter **0.5** as the time between samples in second, and select ⟨Next⟩.

   - Enter **100** as the number of samples, select ⟨Next⟩, and select ⟨OK⟩ to return to the Main screen.

Sour Chemistry: Exponential pH Change　　　**TEACHER NOTES**
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3. Collect pH data.

- Place about 125 mL of distilled water into a very clean cup. The cup must be clean to get good results.

- Loosen the top of the pH storage bottle, and carefully remove the bottle. Slide the top of the bottle up the shaft of the sensor so that the bottle top is out of the way. Do not remove the top from the sensor shaft.

- Rinse the tip of the pH sensor with distilled water.

- Place the pH sensor in the water, and support it so the sensor does not fall.

- Put 20 drops of lemon juice into the water. This will simulate an acid stomach. Stir gently with the sensor.

- Get ready to drop your effervescent tablet into the water.

- Select ⌈Start⌉ to begin data collection. Then, drop the tablet into the water.

- Data collection will run for 50 seconds. After collection ends, a graph of pH versus time will be shown.

- The graph should show pH values that increase rapidly at first and then level off. Select ⌈Main⌉ to return to the Main screen.

- If you want to repeat data collection, discard the solution and thoroughly rinse the cup and pH sensor in distilled water, and repeat this step.

- Once you are satisfied with the data, select ⌈Main⌉ to return to the Main screen. Exit EasyData by selecting ⌈Quit⌉, and then selecting ⌈OK⌉.

4. Use additional distilled water to rinse the pH sensor.

- Discard the solution in the cup, and rinse the cup.

- Replace the storage bottle on the pH sensor.

Data Analysis

1. To work with the data, redisplay the graph outside the EasyData™ app.

- Press ⌈2nd⌉ [STAT PLOT].

- Press ⌈ENTER⌉ to select Plot1, and then press ⌈ENTER⌉ again to select On.

- Press ⌈ZOOM⌉.

- Press ⌈▼⌉ until ZoomStat is highlighted; press ⌈ENTER⌉ to display a graph with the *x* and *y* ranges set to fill the screen with data.

- Press ⌈TRACE⌉ to determine the coordinates of a point on the graph using the cursor keys.

2. A modified exponential model can be used to model the data you have just collected.

$$y = A\left(1 - B^x\right) + C$$

- In this expression, **y** represents the pH of the solution at any time **x**. **C** represents the initial pH of the solution, which is also the *y*-intercept. **A** measures the magnitude of the pH change, while **B** is a value between 0 and 1 which measures the rate of the change.

- To fit this model to the data, first determine the *y*-intercept from your graph by tracing to the left edge of the graph.

- Round the *x* = 0 pH value to two significant digits, and record it in the data table on the *Student Activity* sheet.

3. At the other side of the graph, the pH values should approach a constant value as the curve flattens.

- Trace to the right edge of the graph to estimate the value the pH curve is approaching.

- Record this value into the data table.

4. The pH approach value you just determined is related to a sum of constants in the model equation.

- Assume that $0 < B < 1$. If *x* is large, the model expression approaches the sum *A* + *C*.

- Answer Question 1 on the *Student Activity* sheet.

5. Use the value for the approach pH and the *y*-intercept to determine a value for the parameter *A*.

- Enter the result into the data table.

6. Enter the model expression for graphing, along with values for the parameters *A* and *C*.

- Press $\boxed{Y=}$.

- Press $\boxed{CLEAR}$ to remove any existing equation.

- Enter the modified exponential model as $A*(1- B^{\wedge}x) + C$ into the Y1 field.

- Press $\boxed{2nd}$ [QUIT] to return to the home screen.

- Enter the value for the parameter **A**. Press $\boxed{STO\blacktriangleright}$ A $\boxed{ENTER}$ to store the value in the variable **A**.

- Enter the value for the parameter **C**. Press $\boxed{STO\blacktriangleright}$ C $\boxed{ENTER}$ to store the value in the variable **C**.

Sour Chemistry: Exponential pH Change   **TEACHER NOTES**
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7. Set a value for the parameter **B**, and then look at the resulting graph. To obtain a good fit, you
    will need to try several values for **B**. Use the steps below to store different values to the
    parameter **B**. Start with *B* = 0.5.

    *   Enter a value for the parameter **B**.

    *   Press [STO▶] B [ENTER] to store the value in variable **B**.

    *   Press [GRAPH] to see the data with the model graph superimposed.

    *   Press [2nd] [QUIT] to return to the home screen.

    Experiment until you find a value that provides a good fit for the data, and record the value into
    the data table.

    Answer Questions 2-5 on the *Student Activity sheet.*

Extension

The equation used in this activity $y = A(1 - Bx) + C$ is a modified version of the exponential function
$y = ab^x$. Show how $y = ab^x$ can be transformed into the model used here using reflections and shifts.

Hint: Work backwards by distributing *A* and regrouping.

Beverage Tests
Student Activity

Name _____

Class _____

Objectives

- Become familiar with the pH scale
- Determine the pH of a liquid
- Create graphs comparing pH levels
- Compare the same data displayed as a scatterplot, a boxplot, a histogram, and a bar graph

Materials

- TI-84 Plus Silver Edition graphing calculator
- Vernier® EasyLink™ & pH probe
- Vernier® EasyData™ app
- Distilled water for rinsing sensor
- Beaker or container for rinse water
- Beverage samples

1. Are most of the beverages you drink each day acids, neutral, or bases?

2. Before testing, complete the table below.

   - Write acid, neutral, or base to categorize each beverage.

   - Use your current knowledge of pH to predict the rank of each in order of pH
   (1 = most acidic = lowest pH value).

Beverages	Predicted pH description (acid, neutral, or base)	Rank (1 = most acidic)

Beverage Tests
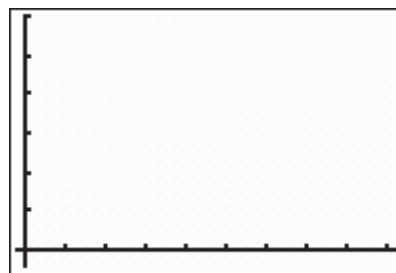**Student Activity**

Name _____

Class _____

3. After you test the beverages, use the displayed scatterplot to fill in the pH values on the table below.

    • Then, label each beverage as an acid, a neutral, or a base, and rank them in order of pH
      (1 = most acidic). (Round all numbers to the nearest hundredth.)

Sample Number	Beverages	Actual pH	Actual pH description (acid, neutral, or base)	Rank (1 = most acidic)
1				
2				
3				
4				
5				
6				
7				
8				

4. Set up a scatter plot on Plot1 to display the pH data.

    • Go to the Y= window, and graph a horizontal line at 7.

    • Press GRAPH, and print it out on a computer and
      attach it to this page, or sketch it in the plot to the right.

    • Discuss the meaning of the location of the points relative
      to the horizontal line at pH = 7.
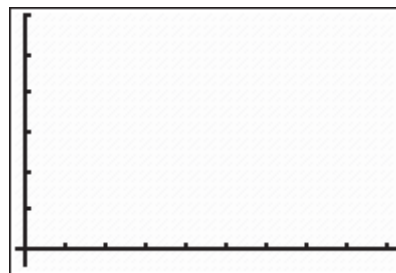
5. Go to the Y= window, and clear the Y= line.

    • Draw a boxplot to display the pH data, print it out on a
      computer, and attach it to this page. Alternately, sketch it
      in the plot to the right.

Beverage Tests
Student Activity

Name _____

Class _____

Use your data and graphs to answer the following questions:

6. Compare the actual pH rankings to your predictions. Discuss any surprises or differences you find.

7. Match each description to a tested beverage:

    a. Most Acidic

    b. Most Basic

    c. Closest to neutral

    d. Median beverage

8. What is the range in the pH readings?

9. Find the mean pH.

10. Find the median pH.

11. How does the mean compare to the median?

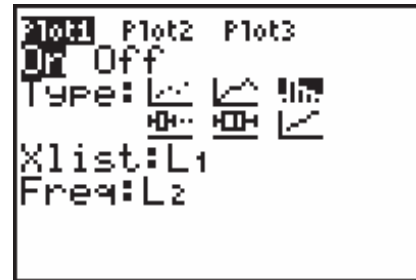12. Which measure would best describe the average beverage?

13. Where do most of the beverages cluster on the graph?

14. What does this reveal about most of the beverages you drink?

Beverage Tests
Student Activity

Name _____

Class _____

Exploration

1. Set up a histogram in Plot1 to display the pH data with the settings as shown in the figure to the right.

   • Follow your teacher's directions to adjust the window settings so the histogram will display a bar graph where each bar represents one of the liquids measured.

   • Record your window settings below:
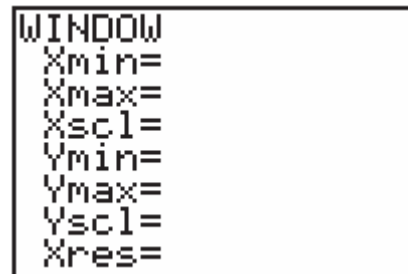
2. Press GRAPH, and use the TI Connect™ software to take a screen shot, print it out on a computer, and attach it to this page. Alternately, sketch it in the plot to the right.

   • Follow your teacher's directions to label your graph and save it as a picture. Add these labels to the sketch.
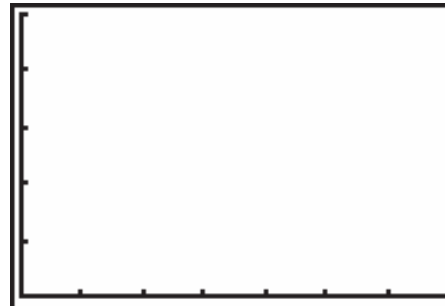
3. What is/are the advantage(s) of being able to write on the graph and save it as a picture?

4. What is/are the disadvantage(s) of saving the graph as a picture?

Beverage Tests
TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, you will pour samples of common beverages/liquids into sample cups, and use the EasyLink™ with a pH sensor and the EasyData™ app to test their pH levels. Then you will choose a graph that will compare the liquids by their pH readings.

Materials

- TI-84 Plus graphing calculator
- Vernier® EasyLink™ & pH probe
- Vernier® EasyData™ app

- Distilled water for rinsing sensor
- Beaker or container for rinse water
- Beverage samples

Introduction

Scientists use a pH scale to measure the acidity or alkalinity of various solutions such as swimming pool water, lakes and rivers, and even our blood. This lesson is an entry level lesson to help students get more of an understanding of this scale. The pH scale is a measure from 0 to 14. A pH lower than 7 is an acid solution, and a pH greater than 7 is basic or alkaline. A pH of 7 is considered neutral.

In this activity, you will pour samples of common beverages/liquids into sample cups, and use the EasyLink™ with a pH sensor and the EasyData™ app to test their pH levels. Then you will choose a graph that will compare the liquids by their pH readings.

Problem: Are most of the beverages you drink each day acids, neutral, or bases?

Hypothesis: Before testing, have students answer questions 1 and 2 on their worksheet to predict the pH of some common beverages. Have students fill in the chart with the items you decide to use.

Setup

1. Briefly discuss the data collection procedure with the class. Demo the activity using the overhead calculator so the entire class can see the process. If you only have one EasyLink and pH sensor, link the data lists to the class after running the activity.

2. If you have enough equipment, have the students work in small groups. Use small plastic or waxed paper cups for the beverage samples. Provide a variety of popular beverages to test. Suggestions for liquids to test are tap water, milk, orange juice, lemonade, tea, soda, and coffee.

3. As a hypothesis, students can rank beverages from least to greatest by acidity or they could predict acid, neutral, or base for each sample. They could also predict both. It is a good idea to have at least one sample of something you would not drink. In the example, the last sample is ammonia.

   CAUTION: Be sure to consider that some students may be allergic to some beverages.

4. Provide at least 125 ml of distilled water for rinsing the pH sensor between trials. Crook-necked bottles work well. Be sure all containers are very clean.

Beverage Tests   TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT

5. Each group should have its own water for rinsing between samples. Since the order the readings are taken is not important, have a few clearly marked samples of each liquid in one area of the room.

6. Students can carry one or two samples at a time from that area to the area where their group is working. After taking those readings, the samples can be returned.

Suggest these student jobs for this lab:

- Materials/setup person (sets up EasyLink™, pH sensor, and TI-84 Plus: holds probe in sample during activity, rinses probe in water between samples)

- Tech person (operates the TI-84 Plus Silver Edition and EasyData™ app)

- Data recorder (reads and records the pH readings for each sample on the worksheet chart).

- Runner (brings samples to group, holds cup to avoid spillage during activity, and returns samples after readings are taken)

NOTE: The pH sensor must remain in buffer solution bottle (packaged with the sensor) when not in use. The sensor will stop working if it becomes completely dry.

Data Collection

1. Connect the EasyLink™ to your TI-84 Plus Silver Edition using the mini-USB port.

2. Connect the pH sensor to the other end of the EasyLink.

3. The EasyData™ app will launch automatically.

- The EasyData information screen is displayed for about 3 seconds followed by the main screen.

- The app identifies the pH sensor.

- The main screen of the EasyData app is shown.

4. Press $\boxed{Y=}$ to access the **File** menu, and select **1:New** by pressing $\boxed{1}$ or, since **1:New** is highlighted, you can press $\boxed{ENTER}$. This resets the program and clears out old data.

Beverage Tests
TEACHER NOTES
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5. Press **Setup**, and choose **4:Selected Events**. This setting will allow you to control when readings are taken.

```
1: PH
2: Time Graph...
3: Events with Entry
4: Selected Events
5: Single Point
6: Rate...
Mode 7↓Zero...
[File][Setup][Start][Graph][Quit]
```
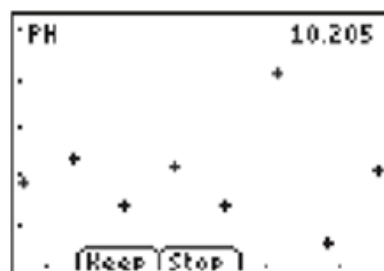
6. Unscrew the cap from the pH sensor's storage bottle. Slide the cap up the probe so it is out of the way, but do NOT remove it from the probe's shaft.

   • Rinse the probe in the distilled water. Select **Start** to begin collecting data.

   • You will see the current pH in the upper right corner of the screen. Let the water be your first reading.

   • Wait for the pH reading to be stable, and then select **Keep** to take the reading. Be sure to record it on your worksheet.

```
PH                    6.277



Event number 1
Choose Keep to collect data
  [Keep]        [Main]
```
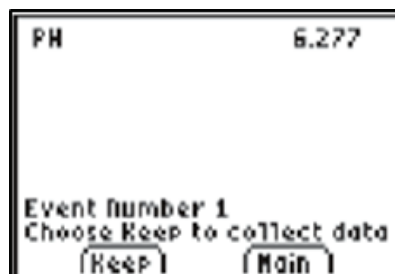
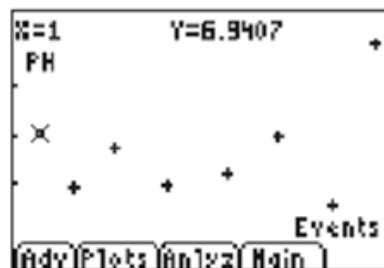7. Insert the probe into the second sample, and wait for the reading to become stable.

   • Select **Keep** to collect the pH reading. Continue for a total of 8 trials (or the number of samples you have).

   • With each recorded value, a new data point is displayed on the graph with the option to **Keep** or **Stop** the data collection.

   • The **Selected Events** feature will keep track of which reading you are on, increasing it by one each time you select **Keep**.

```
·PH                  10.205
                        +
.
.
.                +        +
.
.        +      +
.
      [Keep][Stop] .       +
.                 .    .
```

Note: After each reading, the pH sensor should be rinsed in the distilled water before being used for the next reading. The recorder should be filling in the chart on the worksheet with each beverage and its pH reading.

8. When all samples have been measured, select **Stop**.

   • A graph of your data points will be displayed.

   • At this time, you can use the right and left arrow keys to view the values of the coordinates of the points.

   • Have students double-check these values with what was recorded in the chart.

```
X=1        Y=6.9407      +
 PH

 X       +        +
        +      +      +
                        +
                     Events
[Adv][Plots][Anlyz][Main]
```

Beverage Tests
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9. To confirm a description of the plots, select the **Plots** soft key.

- You should see a confirmation that the points graphed are the pH values vs. the Events number.

- Be sure your students identify the Events number as the independent variable and the pH reading as the dependent variable.
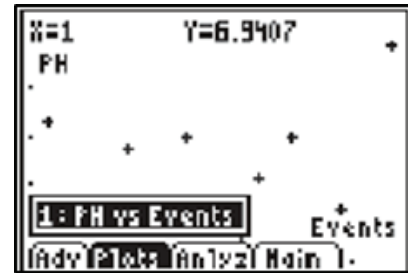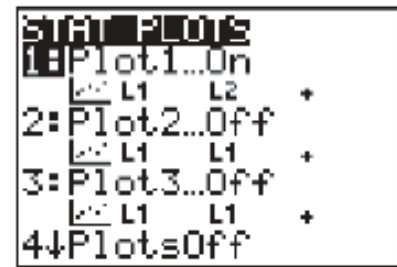
10. Select **Main**, and then select **Quit**. A screen displays where the data from your activity is being stored. Select **OK** to exit the app.

Data Analysis

1. Press [2nd] [Y=] to access the [STAT PLOT] menu; you will see that **Plot1** is turned on with the **L1** and **L2** data.

2. Press [GRAPH], and you will see the same graph that was displayed before you left the app.

- At this point, have students link the data lists so each student has **L1** and **L2** from the activity in his/her own calculator for the data analysis.
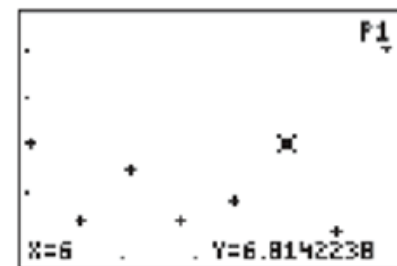
3. Have each student set up the same scatterplot on **Plot1** to display the pH data.

- Go to the [Y=] window, and graph a horizontal line at 7.

- Press [ZOOM], and choose **9:ZoomStat** to view the graph.

- Have students sketch the scatterplot in the space provided on their worksheet. Discuss the meaning of the location of the points relative to the horizontal line at pH = 7.

**Beverage Tests**

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TEACHER NOTES

4. Have students trace through the points, and discuss the meaning of the fact that most points are below the line y = 7.

- Discuss the meaning of any points that are significantly different from the others.

5. Guide students in viewing the data as a box-and- whisker plot.

- First, go to the [Y=] window and clear **Y1**.

- Go back to **Plot 1**, select the box-and-whisker icon, enter **L2** for the **Xlist**, and 1 for **Freq:**.

- Press [ZOOM] and choose **9:ZoomStat** to view the new graph.

- Have students sketch the box-and-whisker plot in the space provided on their worksheet.

- Have them trace the plot and move from one part of the plot to another, paying attention to the data at the bottom of the screen.

- Have students place the screen data in the appropriate place on the plot they are sketching on the worksheet.

6. Lead your students in a discussion about observations that are easily made based on the length of both the whiskers and the boxes.

Beverage Tests

**TI PROFESSIONAL DEVELOPMENT**
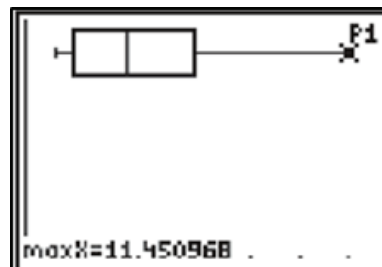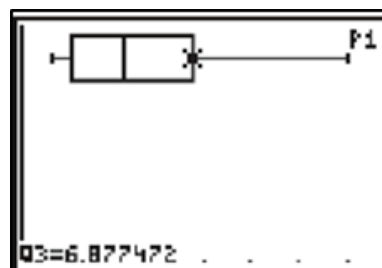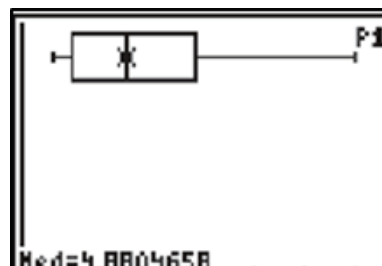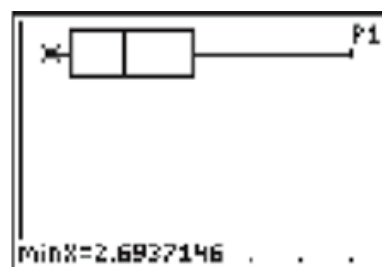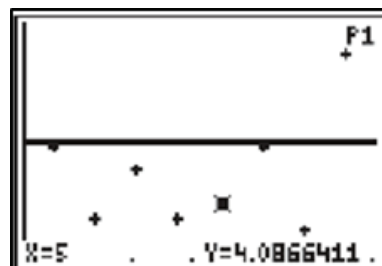
Exploration

1. Guide students in presenting the data in a histogram.

   • Adjust the **Plot1** setting to select a histogram rather than the boxplot just used.

   • Then press ZOOM , and choose **9:ZoomStat** to view the new graph.

2. Press the right and left arrow keys to scroll through the bars. Discuss which graph they think gives more information about the data.

   • Trace the data and make sure they see that the *n* at the bottom of the window is the number of items in the bar marked by the cursor.

   • In the example here, 4 of the 8 data collected were between 2.69 and 4.88.Encourage students to adjust the window settings that will allow the graph to display the data in a more useful way.

3. Before leaving this problem, show students how to display data to look like a bar graph by making a few adjustments to the histogram feature.

   • In the [STAT PLOT] menu, go into **Plot1** and adjust the settings from above by entering **L1** for the **XList** and **L2** for the Freq.

4. Press WINDOW , and select appropriate settings. In the sample, 8 items were measured.

   • By setting the **Xs** from 1 to 9 with a scale of one, there will be 8 bars generated, one for each item.

   • The pH readings can only go from 0–14. In the sample, the highest reading was 11.45.

   • The **Ymax** needs to be at least that high. The -3 for the **Ymin** will give space below the graph.

   • When the graph is traced, the numbers can be viewed without blocking part of the graph.
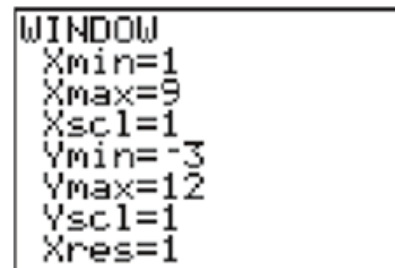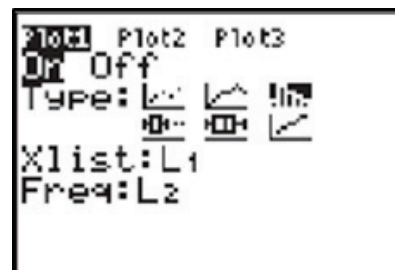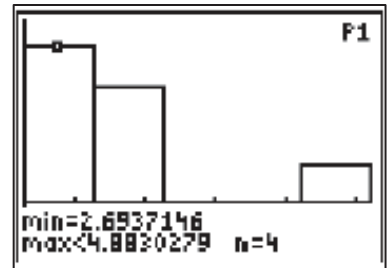
5. Press [GRAPH], and then [TRACE] to see that each bar represents one sample with the pH value being displayed beside the n at the bottom of the window.
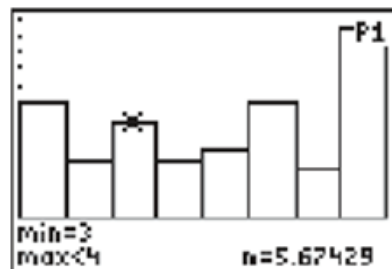
6. Pressing [GRAPH] again erases the data displayed at the bottom of the screen. The goal is now to label this graph and save it as a picture in the calculator.
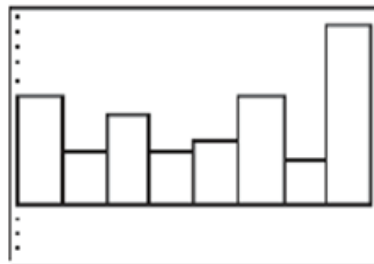
7. Press [2nd][PRGM] to access the [DRAW] menu, and arrow down until **0:Text(** is highlighted.

   • Press [ENTER], and you will be taken to the graph screen. Remember, most menus are wrap-around menus, so you could also press the up arrow key twice to get to **0:Text**.
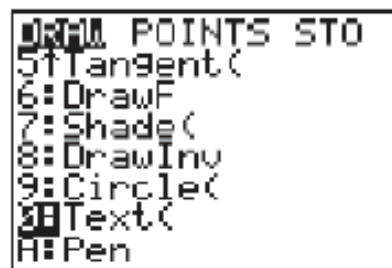
8. Your cursor is most likely near the center of the screen. Do NOT press [TRACE].

   • Use the arrow keys to position the cursor to the upper left corner of the screen, and then press [2nd][ALPHA] to access the [A-LOCK], Alpha Lock, command.

   • This will lock the calculator in Alpha mode so you can continuously type text across the screen. Notice the **A** in the upper right corner.

Beverage Tests

**TEACHER NOTES**

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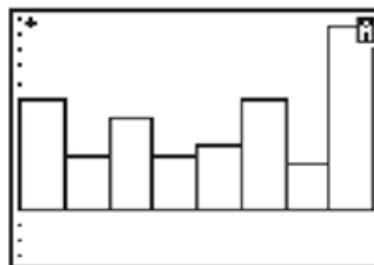
9. When you begin to type, you will notice that the text falls below and to the right of where the cursor is positioned.

- Give the graph a title. This example is titled, "PH VS COMMON LIQUIDS."

- Only uppercase letters can be used. For spaces, use _ (above the zero key).

- If you make a mistake and need to erase something, arrow back to the left of what you need to erase and press the zero key again. Anything you type will overwrite anything that is written below it. To erase, type blank spaces over the error.
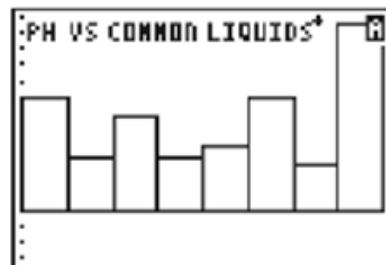
10. After the title is complete, use the arrow keys again to position the cursor below the first bar.

- You don't have much space, so use the first one or two letters as descriptors for the individual bars as demonstrated in the example, e.g., W for Water, V for Vinegar.
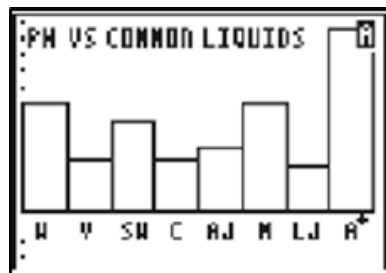
11. When finished, press [2nd] [MODE] to [QUIT], and return to the home screen.

- You are going to store this picture in the calculator.

- There are 10 locations in which to save a picture.

- If there is already something in the location you choose, it will be overwritten with no warning.

- It is a good idea to first take a look at where pictures are stored.

12. Press [2nd][+] to access the [MEM] menu.

- Select **2:Mem Mgmt/Del**, and press [ENTER].

- Scroll down until **8:Pic** is highlighted, and press [ENTER].

- You will see a list of locations that are already filled with pictures. If you do not see any **Pics** listed, then there are no pictures stored in your calculator.

- The example shown here indicates that **Pics** 1, 4, 5, 6, and 7 are all available.

- The * in front of **Pic9** means it is archived.

Beverage Tests

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13. Press [2nd][MODE] to [QUIT] and return to the home screen.

   • Press [2nd][PRGM] to access the [DRAW] menu, and arrow over to **STO**.

   • **1:StorePic** is highlighted.

14. Press [ENTER] to select it, and then type the number of the **Pic** where you want to store your picture. In the sample it will be stored in **Pic1**.

15. Pressing [ENTER] again will complete the command and return you to the graph screen.

   • You could now delete all your data in the lists and/or turn off **Plot1**, and this picture would remain intact. However, it is a stagnant picture. You will no longer be able to adjust the size of the window or trace the graph to view the coordinates.
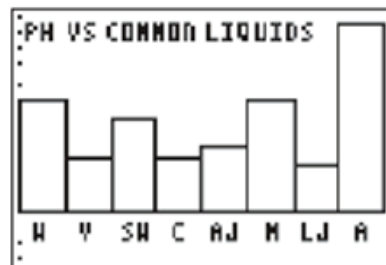
Note: When you make a change to anything in the [Y=] or the [STAT PLOT] window, the drawing will be cleared from the display. To view it again, press [2nd][PRGM] to access the [DRAW] menu, and arrow over to **STO**. Select **2:RecallPic** followed by the number of the picture that was stored.

16. After saving the picture, have students see if they can add to the drawing by putting in the pH values at the top of each bar. The process is the same as for adding letters to a drawing.
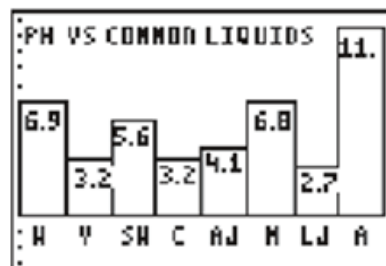
17. After adding the numbers, store the picture either in the same location as before or in a new location.

   • Caution them to remember to press [2nd][MODE] to [QUIT], and return to the home screen before trying to store the picture.

   • If they forget that step, they could end up with the **StorePic** command in the middle of their picture as shown here. Unfortunately there is no "undo" command for this error.

Beverage Tests

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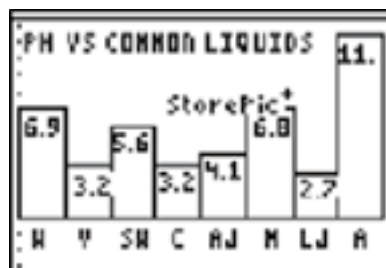
Worksheet Answers

You can use any beverages/liquids you choose. Here is an example.

Sample Number	Beverages	Actual pH	Actual pH description (acid, neutral, or base)	Rank (1= most acidic)
1	Water	6.94	Neutral	7
2	Vinegar	3.2	Acid	2
3	Salt water	5.67	Acid	6
4	Soda	3.26	Acid	3
5	Apple Juice	4.09	Acid	4
6	Milk	6.81	Neutral	6
7	Lemon Juice	2.69	Acid	1
8	Ammonia	11.45	Base	8

Other answers are either addressed in the directions, or will vary depending upon the data collected.

If using TI-84 Plus C Silver Edition

The directions are the same for the TI-84 Plus C Silver Edition graphing calculator.

On the StatPlot screen, there are additional choices for color and Mark Style. On the Text screen, you will also be able to add color. When tracing on the boxplot or histogram, the values are displayed in the bottom border of the screen.

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education.ti.com

Getting Started with the TI Connect™ CE Software

TI PROFESSIONAL DEVELOPMENT

Activity Overview

Teachers and students need a way to back up their graphing calculators, take screen captures, transfer files, and easily update the operating system. The TI Connect™ CE software application makes exchanging information between the TI-84 graphing calculator family and your computer quick and easy. You can use TI Connect™ CE to send files to multiple connected calculators at once, quickly take and manage screen captures, create background images, and create and edit TI Basic programs. The TI Connect™ CE software includes three workspaces – Screen Capture, Calculator Explorer, and Program Editor. In this activity, you will explore the basic features of the TI Connect™ CE software.

Materials

- TI Connect™ CE software, which is available for free at education.ti.com
- TI-84 Plus CE graphing calculator
- Standard-A to mini-B USB cable

Note: Although this activity references the TI-84 Plus CE graphing calculator, most functions work with the TI-84 Plus C Silver Edition, TI-84 Plus Silver Edition, and TI-84 Plus graphing calculators.

Part One – Introduction to the Software

To use the TI Connect™ CE software:

- Connect the TI-84 Plus CE to the computer using the standard-A to mini-B USB cable.
- Turn on the graphing calculator.
- Launch the TI Connect™ CE software on your computer.

Getting Started with the TI Connect™ CE Software
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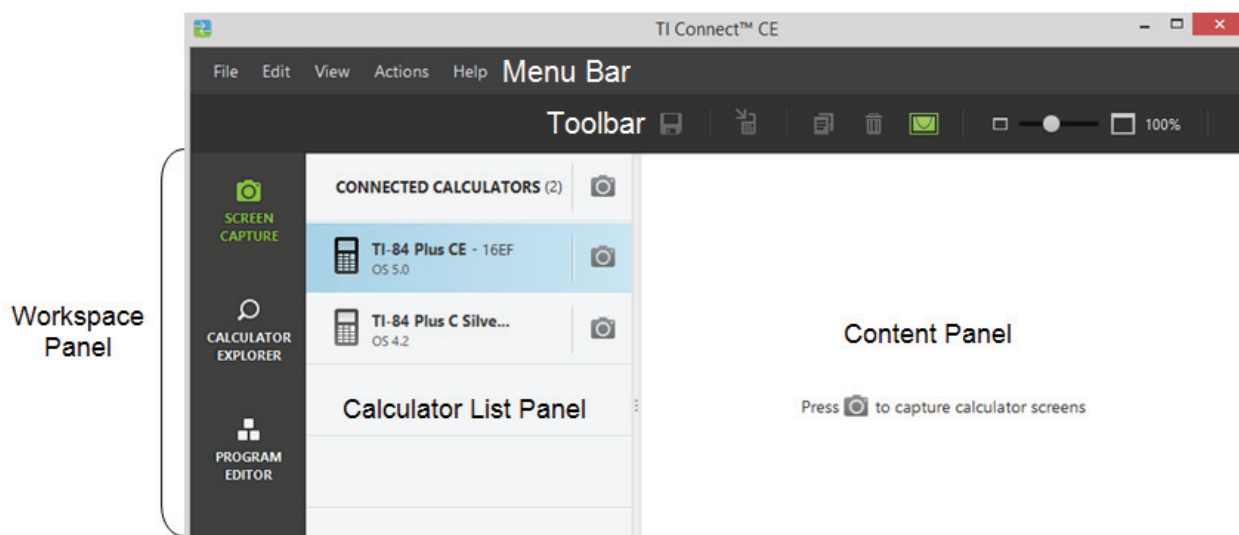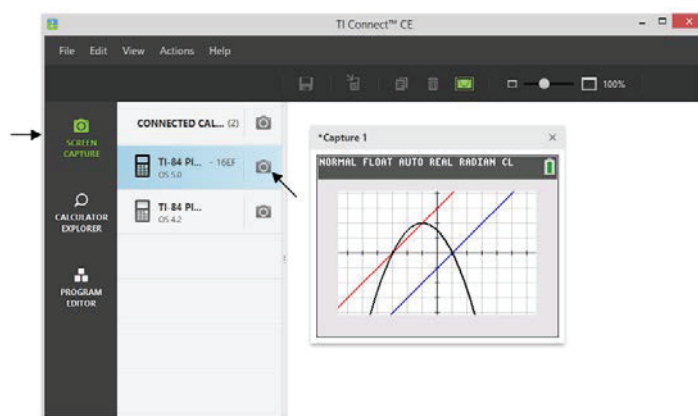
Part Two – Using the Screen Capture Workspace

The Screen Capture feature gives the teacher or student an easy way to take and manage screen captures from the connected graphing calculator quickly and simply.

Capturing Screen Images from the Calculator
With the calculator connected, select the **Screen Capture** Workspace in the TI Connect™ CE software.

To Capture Calculator Screens
1. Display the screen on your calculator that you want to capture.
2. Click the camera icon 📷 next to the desired calculator in the Calculator List.

- You can drag and drop captured images from the Screen Capture workspace into many computer applications.
- Captured calculator images in the Screen Capture workspace can be saved to your computer as a PNG file.

Part Three – Using the Calculator Explorer Workspace

The **Calculator Explorer** workspace allows the teacher or student an easy way to work with the files on the TI-84 Plus family of graphing calculators. The Calculator Explorer key features related to files are:
- Viewing the contents of the graphing calculator
- Copying calculator files to your computer
- Copying computer files to the connected graphing calculators
- Deleting calculator files
- Backing up and restoring calculator files
- Updating calculator files

You can copy most data, files, and programs from your calculator to your computer as a content backup, to send to others, or to free up calculator memory.
- The **Calculator Explorer** workspace also enables you to convert images to be used as a background on your calculator.
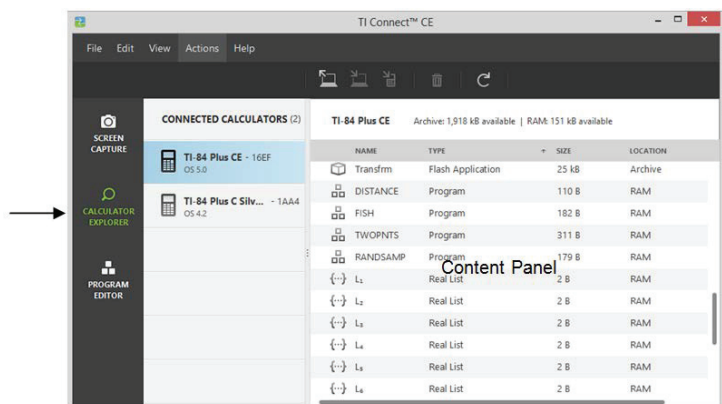
Getting Started with the TI Connect™ CE Software
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A. Exploring the calculator contents

With the calculator connected, select the **Calculator Explorer** workspace in the TI Connect™ CE software.

Make sure that the contents of the connected calculator appear in the Content Panel.

B. Using "drag and drop" to copy a file from the calculator to the computer

1. Click on the file name to select it.
2. Drag and drop the file into a folder on your computer or onto your desktop.

C. Using "drag and drop" to copy a file from the computer to the calculator(s)

1. Navigate to the desired file on your computer.
2. Drag the file to the Calculator List Panel and hover over the desired calculator.
3. Release the mouse button when you see ➕ Copy
4. Select a file name from the drop-down menu. This will be the name of the program on your calculator.
5. Click Send.
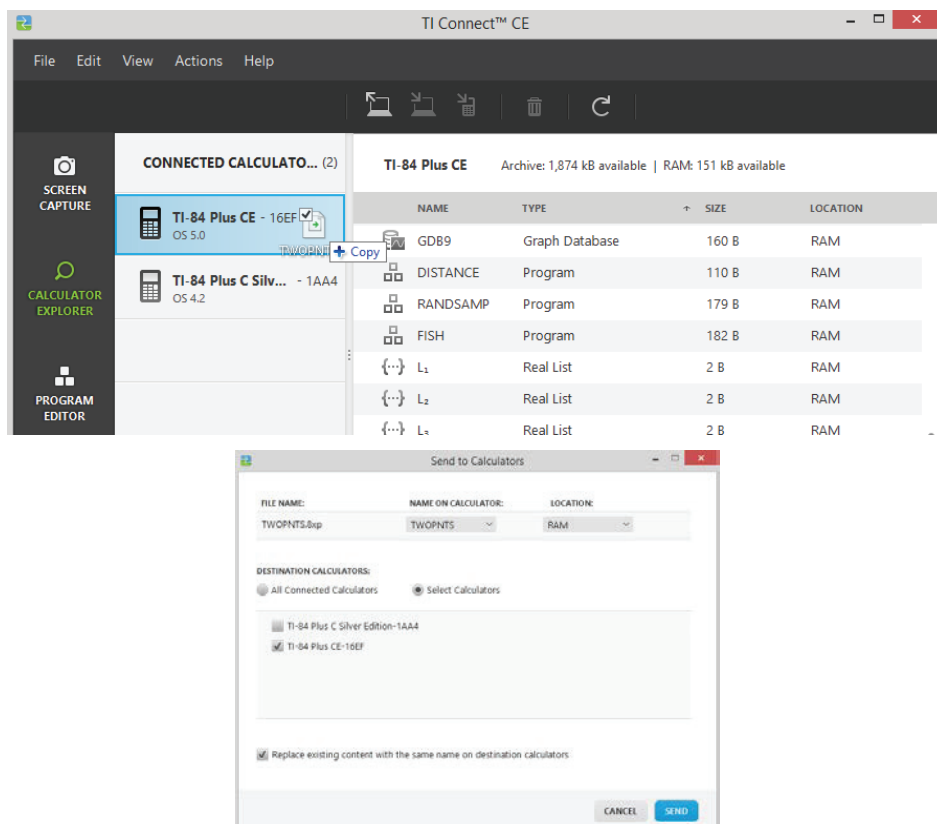
Getting Started with the TI Connect™ CE Software
TI PROFESSIONAL DEVELOPMENT

- Options for copying and sending files can be found under Actions on the Menu bar.
- Alternatively, they are also on the Toolbar.
- **Do not disconnect the cable during a transfer.**

D. Sending a Background Image to a Connected Calculator

Calculator Explorer workspace also enables you to convert images to be used as a background on your calculator

With the calculator connected, select the **Calculator Explorer** workspace in the TI Connect™ CE software. Make sure that the contents of the connected calculator appear in the Content Panel.
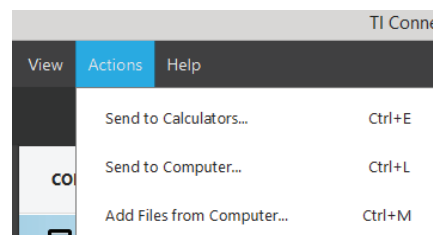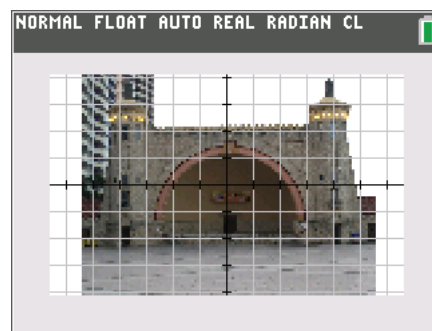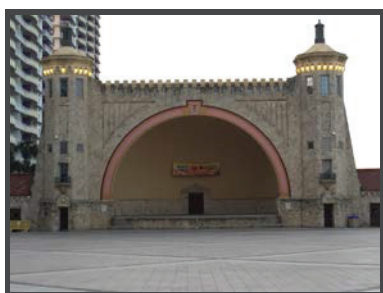
1. Choose the image file on your computer that you want to convert to a calculator background.
2. Drag the file to the Calculator List Panel and hover over the desired calculator.
3. Release the mouse button when you see + Copy
4. Select an image# name from the drop-down menu (Image0 – Image9). This will be the name of the image on your calculator.
5. Click Send.

Keep in Mind:

- Sending files lets you share your files with others and still maintain a copy on both your computer and your own graphing calculator.
- If multiple calculators are connected to the computer, you can choose to send the file to all connected calculators, or just selected calculators (from a check list).
- Background images are converted and sent from the **Calculator Explorer** workspace.
- **Do not disconnect the cable during a transfer.**

4

Getting Started with the TI Connect™ CE Software
TI PROFESSIONAL DEVELOPMENT

Part Four – Using the Program Editor Workspace

The **Program Editor** workspace can be used to create and edit calculator TI Basic programs. Additionally, you can quickly send programs directly to your connected calculator(s).

- Use the **Program Editor** workspace to write a program.
- Name and save the program on your computer, and then send the program to your calculator. (A sample program for computing the distance between two points in the coordinate plane is shown below.)
- **Do not disconnect the cable during a transfer.**

Optional: Checking the box next to the lock icon before saving and sending will protect the program from being edited on the handheld.

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Getting Started with the TI-SmartView™ CE Emulator Software
TI PROFESSIONAL DEVELOPMENT

Activity Overview

You will explore features of the TI-SmartView™ CE emulator software for the TI-84 Plus Family. The TI-SmartView software gives you the complete functionality of the TI-84 Plus CE, the TI-84 Plus C Silver Edition, and the TI-84 Plus graphing calculators on your computer. The software contains additional functionality that can be used to enhance presentations and classroom demonstrations.

Materials

- TI-SmartView™ CE emulator software

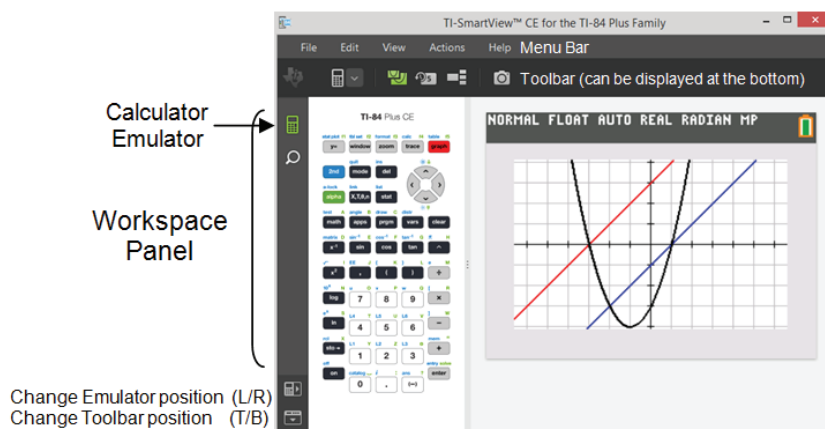**Note:**   Although the TI-84 Plus CE is used throughout this activity, the TI-SmartView CE software contains three emulators: TI-84 Plus CE, TI-84 Plus C, and TI-84 Plus.

Part One – Introduction to the software

- Launch the TI-SmartView™ CE software on your computer.
- Locate the Menu Bar, the Toolbar, and the Workspace Panel.

Calculator Emulator Workspace

Emulator Explorer Workspace
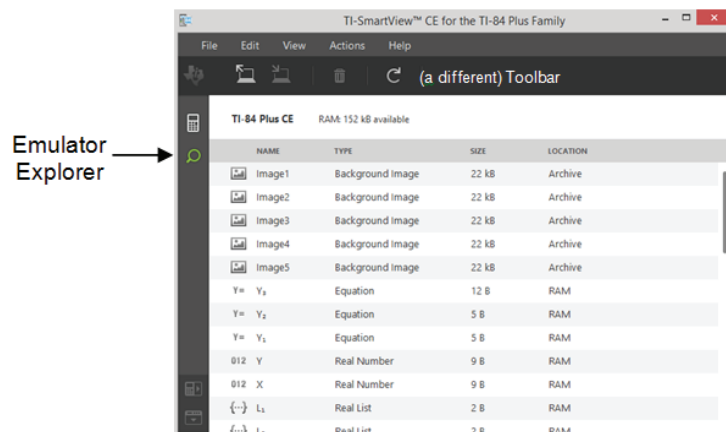
Getting Started with the TI-SmartView™ CE Emulator Software
TI PROFESSIONAL DEVELOPMENT

Part Two – Using the Calculator Emulator Workspace

- Select the Calculator Emulator workspace from the Workspace Panel

A. Exploring the Calculator Emulator Toolbar

- Explore each item in the Calculator Emulator Toolbar. Click on the icon. What happens? What happens if you click it again?

- Use the space below to record information about the toolbar items and their functions.

B. Exploring the Menu

- Explore each category in the Menu Bar and notice the options that are available.

  | File | Edit | View | Actions | Help |
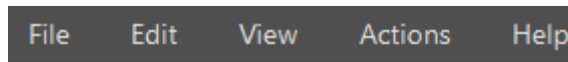
  (Most of the items in the Menu Bar can be completed by clicking icons in the toolbar.)

- What is something that *cannot* be completed by clicking an icon in the toolbar?

- From the Help option, choose "TI-SmartView CE Help" and browse the document. If possible, save the PDF file to your computer.

C. Match the Screen

Use the Calculator Emulator workspace to graph:

$Y_1 = X-1$

$Y_2 = X+3$

$Y_3 = (X-1)(X+3)$

Use your calculator and software skills to make your TI-SmartView CE screen look like the one shown at the right.
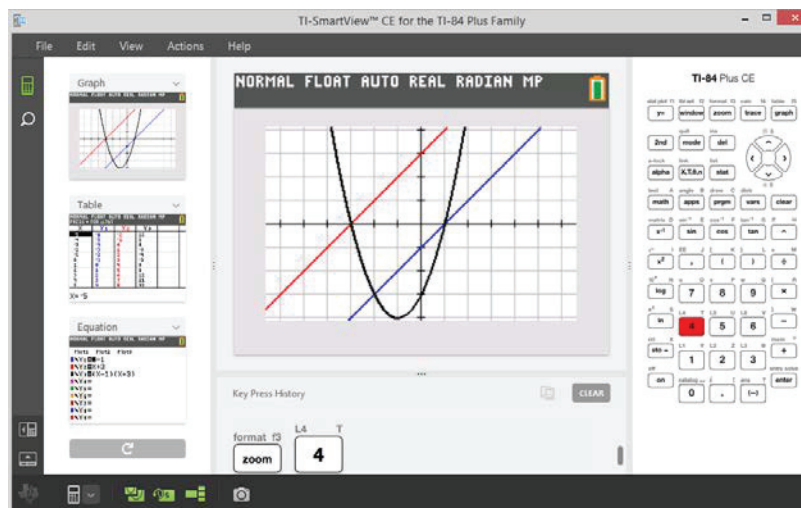
Getting Started with the TI-SmartView™ CE Emulator Software

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Part Three – Using the Calculator Emulator Workspace for Screen Captures

TI-SmartView™ CE Screen Capture allows the teacher to capture the current image displayed on the TI-SmartView™ emulator. When you capture a screen, the Screen Capture window is displayed. In this window, you can view, manipulate, and save screen images.

- Select the Calculator Emulator workspace from the Workspace Panel

- Create a screen image that you wish to capture. (home screen computations, data in lists, window settings, functions in Y=, a graph, …)
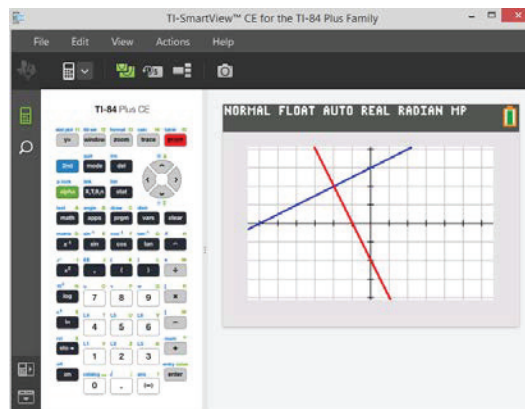
Method 1: Using the Screen Capture tool

- Click [icon] on the toolbar (or choose *Capture Screen* from the Actions menu).
- Note: Ctrl T is a computer keyboard shortcut for a Screen Capture
- Explore the Menu and the Toolbar options in the TI-SmartView CE Screen Capture window.
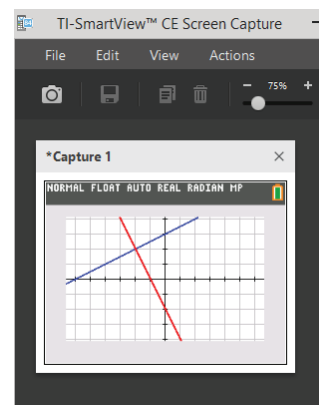
Method 2: Dragging and Dropping a Screen to Another Application

- You can drag and drop and paste any TI-SmartView™ CE screen into another application.

✓ Practice getting Screen Captures from the Calculator Emulator workspace.
✓ Try copy/pasting or dragging into another application such as Microsoft® Word.
✓ Read more about TI-SmartView™ CE Screen Captures in the TI-SmartView™ CE Help Guidebook.

Notes:

- Screenshots are saved in .png file format.
- Screenshots can be copied and pasted into a variety of other applications.
- Screenshots can be dragged and dropped into a variety of other applications.
- Screenshots can be resized using the slider in the screen capture window.
- A border is automatically added to each image when you capture it, but you can remove the border by clicking **View > Hide Screen Capture Borders**.
- The screen capture window can be used as a record of the steps in a lesson.

Getting Started with the TI-SmartView™ CE Emulator Software

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Part Four – Using the Emulator Explorer Workspace

Emulator Explorer workspace allows you to manage emulator files, add content from your computer to your emulator, and send selected content to your computer.

- Select the Emulator Explorer workspace from the Workspace Panel.

A. Exploring the Emulator Explorer Toolbar

- Explore each item in the Emulator Explorer Toolbar.
- Use the space below to record information about the toolbar items and their functions.

⬆	
⬇	
🗑	
↻	

B. Exploring the Menu

- Explore each category in the Menu Bar and notice the options that are available.

C. Practicing with files in the Emulator Explorer

1. Copy (or drag) a file from the emulator to your computer.
2. Copy (or drag) a file from your computer to the emulator.
3. Drag an image (.jpg, .png, etc) from your computer onto the Emulator Explorer. This will convert the image to a calculator/emulator background.

✓ Read more about using the TI-SmartView CE Emulator Explorer Workspace in the TI-SmartView CE Help Guidebook

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Getting Started with the TI-SmartView™ CE Emulator Software
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Part Five– Connecting a Calculator as a Remote Keypad

The SmartPad™ CE App is available for the TI-84 Plus CE. To use the TI-84 Plus CE as a remote keypad for TI-SmartView™ CE:

1. Load the SmartPad™ CE App on your TI-84 Plus CE.
2. Connect your TI-84 Plus CE to your computer using a USB Computer cable which came with your calculator.
3. Launch TI-SmartView™ CE. Make sure the TI-SmartView™ CE window is in focus by clicking on the TI-SmartView™ CE window.
4. Run the SmartPad™ CE App on your TI-84 Plus CE. Press [apps] and select SmartPad™ CE from the Apps menu. Read the information on the splash screen.

5. Press keys on the calculator keypad.
6. Disconnect the USB cable from the calculator to stop the App and the remote keypad feature.
7. Reconnecting the USB cable and running the app again may be needed if the remote keypad connectivity is no longer responding.

Notes:

- SmartPad™ CE App running on the TI-84 Plus CE will remotely press emulator keys for the TI-84 Plus CE, TI-84 Plus C and TI-84 Plus emulators in TI-SmartView™ CE.
- TI-SmartView™ CE does not support any other version of SmartPad App running on the TI-84 Plus or TI-83 Plus.
- The TI-84 Plus CE running the SmartPad™ CE app will not display the calculations or graphs. The calculator becomes a remote USB keypad for the emulator only.

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Memory Management in the TI-84 Plus Family

TI PROFESSIONAL DEVELOPMENT

Activity Overview

This activity explores memory management in the TI-84 Plus family of graphing calculators. This includes working with memory in RAM, archiving memory, and grouping files, lists, and variables for later retrieval.

Introduction

The TI-84 Plus CE is equipped with FLASH memory: special hardware that allows you to upgrade the operating system, install special software called apps, and utilize additional memory features. This extends the use life of the device and expands its functionality. This document explains two ways in which you can use the memory of the calculator for backing up your work.

Note: The TI-84 Plus CE graphing calculator is referenced throughout this activity, but the information applies to the entire TI-84 Plus graphing calculator family.

Archiving and Grouping

Memory in the TI-84 Plus CE is divided into two sections:

1. RAM (**R**andom **A**ccess **M**emory) is the "working memory" for most things that are done on the calculator. Programs, lists, matrices, functions, and other data are kept in RAM. Each "thing" in RAM is called a variable. Each variable has three properties: a name, a type, and a value.

2. ARCHIVE memory is a separate, but connected, portion of memory used for APPS, GROUPS, and "safe" storage (archiving) of your RAM variables. Memory management is important because you might need to "free up" RAM to make room for other data or programs.

Archiving protects files from intentional or inadvertent resets. **Grouping** allows you to make copies of files, such as one student's Lists, so that another student can use the calculator for the same activity.

Accessing Memory Features

1. Press [2nd] [MEM] (on the [+] key) to access the MEMORY menu.

2. Select **2:Mem Mgmt/Del**. With this option, you can delete variables or move variables between the RAM and Archive areas of memory.
   - When a variable is in RAM, it is "usable". The variable is available for general use as a "normal" variable.

Memory Management in the TI-84 Plus Family

TI PROFESSIONAL DEVELOPMENT

Archiving

1. When the variable is in Archive memory, it is not available for use generally.
   - Apps, Pic, and Image variables are stored in Archive memory and can be used.
   - Why put a variable in archive? The main reason is to free up RAM for something else without deleting any variables.
   - Programs and lists are usually put into archive because these variables take up the most memory.

2. To archive, press [2nd] [MEM]. Then select **2:Mem Mgmt/Del**.
   Next, select **1:All** to see all of the variables. The variable list screen contains a lot of information:
   - The two numbers at the top, RAM FREE and ARC FREE, are the numbers of bytes available in each portion of memory, RAM and Archive.
   - On the left side of the screen is the "selection pointer" pointing to a particular variable. Move the selection pointer down or up with the arrow keys, [▲] and [▼].

```
NORMAL FLOAT AUTO REAL RADIAN MP      ▯
RAM FREE            19687
ARC FREE            3280K
▶ HITTAR              304
  KRYPTO              306
*Image1             22256
*Image2             22256
*Image3             22256
*Image4             22256
*Image5             22256
 L1                   48
```

   - The second column (just to the left of the variable names) is the indicator that tells you whether a variable is in RAM or Archive. **A blank space indicates that it is in RAM, and an asterisk (*) indicates that it is in Archive**.
   - The number on the right of the screen is the size of the variable in bytes.

3. Press [ENTER] when the selection pointer is pointing to the variable.
   - [ENTER] switches the location of the variable.
   - "Archiving" is the act of moving a variable from RAM to Archive. "Unarchiving" is the opposite process.
   - As you move between RAM and ARCHIVE, notice the numbers at the top of the screen change to indicate new memory-free values. When you move a variable from RAM to Archive, the RAM FREE value increases and the ARC FREE value decreases by the size of the variable.
   - APPS and Pic & Image variables remain in archive and cannot be unarchived.

The Memory Management variable list screen is also used for deleting variables, although it is seldom necessary to delete variables on the TI-84 Plus CE. It is more convenient to move it into Archive memory.

4. To delete a variable, make sure the "selection pointer" is pointing to it, then press [DEL].

5. Some variables, programs, and anything in Archive memory provide you with one last chance to change your mind.
   - To finally delete the variable, select **2:Yes**. If you decide not to delete the variable, press [ENTER] or select **1:No**.

```
NORMAL FLOAT AUTO REAL RADIAN MP      ▯
Are You Sure?
1:No
2:Yes
```

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Memory Management in the TI-84 Plus Family
TI PROFESSIONAL DEVELOPMENT

When a variable is in Archive, an asterisk appears to the left of its name in the List menu ([2nd] [STAT]) too.

- The List menu shown has two archived lists: L4 and KRYPT.
- Since L4 is in Archive memory, it is not available for regular use. If you try to make a Stat Plot using L4 while it is in Archive, you get an error message. This error message will appear whenever you try to use an archived variable.
- If a program is archived, it is not available for regular use. If you try to run the program while it is in Archive, you get an error message. This error message will appear whenever you try to use an archived program.
- If you need to use an archived variable, you must move it from Archive to RAM using the Memory Management tool.

Grouping

The second useful memory management tool on the TI-84 Plus CE is the ability to "group" variables into a Group file. This is identical to the computer linking technique of grouping variables into a single file using TI Connect™ CE software (*.8xg files), but a computer is not needed here.

Grouping makes a file in the calculator containing copies of the variables that you want. Grouping does not "free up" memory. The Group file resides in Archive, so it does not use any RAM. This is a very handy tool for backing up your TI-84 Plus CE variables, especially programs and lists.

1. Select [2nd] [MEM] 8:Group.

2. Select "Create New," enter any name up to eight characters long for the GROUP file, and press [ENTER].
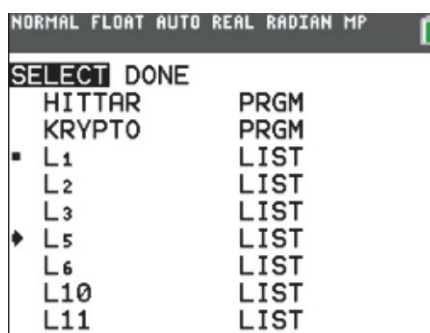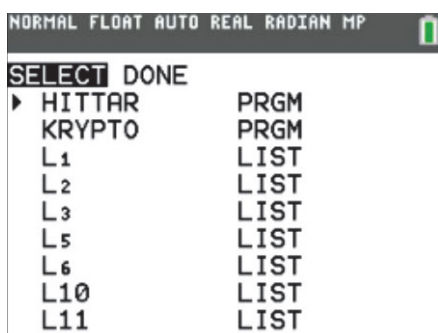   - The next screen works like the LINK-selection screen.

Memory Management in the TI-84 Plus Family
TI PROFESSIONAL DEVELOPMENT

3. Selecting 2:All gives a list of all variables in the TI-84 Plus CE (that can be put into a Group file), unselected.

```
NORMAL FLOAT AUTO REAL RADIAN MP    ▯
GROUP
1:All+…
2:All-…
3:Prgm…
4:List…
5:GDB…
6:Matrix…
7:Real…
8:Complex…
9↓Y-Vars…
```

Just as in linking, use ▲ and ▼ to point to variables and press ENTER to select (or deselect) them for copying into the Group file.

```
NORMAL FLOAT AUTO REAL RADIAN MP    ▯
SELECT DONE
▶ HITTAR        PRGM
  KRYPTO        PRGM
  L1            LIST
  L2            LIST
  L3            LIST
  L5            LIST
  L6            LIST
  L10           LIST
  L11           LIST
```

```
NORMAL FLOAT AUTO REAL RADIAN MP    ▯
SELECT DONE
  HITTAR        PRGM
  KRYPTO        PRGM
▪ L1            LIST
  L2            LIST
  L3            LIST
▶ L5            LIST
  L6            LIST
  L10           LIST
  L11           LIST
```

- The two lists, L1 and L5, have been "selected" for this Group file (note the square mark).
- You might choose mixed data types as well. For instance, choose some lists, some programs, and some matrices.
- Pic & Image variables cannot be grouped.
- When you have selected all your variables, press ▶ to go to the "DONE" menu, and press ENTER to finish making the Group file.
- The Home Screen displays the message: "Copying Variables to Group: yourname", and then displays "Done" on the right side of the screen.
- The key word here is "copying"— your variables are undisturbed in RAM. The Group file contains copies of the selected variables, just as linking transmits copies of your variables to another TI-84 Plus CE.

Note: You cannot have a group with just one object. Each group must contain at least two objects. The Group files reside in Archive, so a "normal" Reset, "2nd [MEM], 7:Reset, 1:AllRam, 2:Reset", will not disturb any Group files. These Group files can be linked (sent) to other TI-84 Plus CE units, and can be stored on a computer using TI Connect™ CE software.

Memory Management in the TI-84 Plus Family
TI PROFESSIONAL DEVELOPMENT

Ungrouping

"Ungrouping" is the act of putting copies of the variables in a Group file back into RAM. The Group file remains intact while the variables are copied back into RAM.

1. Select 2nd [MEM] 8:Group.

2. Press ▶ to UNGROUP, and select your Group file from the listing using ▼ and ▲ (notice the asterisks – all Group files reside in Archive).

   • Press ENTER. If any of the variables in the Group file are already in RAM, then you get a "DuplicateName" menu of choices.

   • Just as in Linking, choose 2:Overwrite to overwrite the variable with the one from the Group file.

Notes:

   • You cannot put an Archived variable into a Group file. Unarchive it first, then make the Group file.

   • Once a Group file is established, it cannot be modified, only UNGROUPED or DELETED. Thus you cannot add variables to a group file afterward.

   • When linking to a computer, you cannot make a group file on the computer containing a Group file from the TI-84 Plus CE.

Tip: Make a Group file of all your programs to prevent loss from inadvertent resets. When you add programs to the TI-84 Plus CE that you want to keep, delete the programs Group and then make it again.

   • It is convenient to Group everything on your handheld before resetting RAM. You can quickly restore everything after resetting the RAM by ungrouping the file. You can then delete that group.

Deleting A Group

1. Selecting 2nd [MEM], **2:Mem Mgmt/Del**, and **C:Groups** gives the list of Group files.

2. Press ▼ next to one of them to delete it. Press the appropriate choice at the "Are You Sure?" menu.
   • Use 2nd [MEM], **8:Group** for Grouping and Ungrouping.
   • Use 2nd [MEM], **2:Mem Mgmt/Del**, and **C:Groups** for viewing the sizes of and deleting Group files.

Tip: When the archive gets full, consider putting large Group files on a computer, and then deleting them from the TI-84 Plus CE.

Memory Management in the TI-84 Plus Family
TI PROFESSIONAL DEVELOPMENT

Summary of Memory Management

- Two sections of memory: RAM and Archive.
- Archiving/Unarchiving moves variables.
- Grouping/Ungrouping copies variables.
- Archived variables are unavailable for use, except for Pic & Image.
- Grouped variables are still available for use.
- You cannot put an archived variable into a group file.
- Archived variables and group files can be transferred to other calculators or a computer.
- Ungrouping leaves the group file intact.
- Rather than deleting to free up RAM, consider moving to Archive first.
- Normal Reset ([2nd] [MEM] **> 7:Reset > 1:AllRam > 2:Reset**) leaves archived variables and group files intact.

Memory Management Keystroke Summary

Archive/Unarchive

- [2nd] [MEM], 2:Mem Mgmt/Del.
- **1:All** (or choose your variable sub-type).
- [▼][▲] to point to a variable.
- [ENTER] to move a variable (note the * toggle).

Group

- [2nd] [MEM], 8:Group, 1:CreateNew.
- Enter a group name.
- [▼][▲] [ENTER] to select multiple variables (note the squares).
- [▶] to DONE.
- [ENTER] to execute the grouping.

Ungroup

- [2nd] [MEM], 8:Group, [▶] to UNGROUP.
- [▼][▲] to point to the desired group file.
- [ENTER] to execute the ungrouping.

Deleting Variables

- [2nd] [MEM], 2:Mem Mgmt/Del.
- **1:All** (or choose your variable sub-type).
- [▼][▲] to point to a variable.
- [DEL], possibly "Are You Sure?" will appear.

One Final Note

On the [2nd] [MEM] menu, there are two menu items, **5:Archive** and **6:UnArchive**. These are used in programs so that the program can manipulate specific variables' locations. For example, a program might contain the statement 'Archive L1, L2, L3, L4, L5, L6' which will move these six lists from RAM to Archive. You do not need to use these two commands unless you are programming.

TI-84 Plus CE Experience Survey

TI PROFESSIONAL DEVELOPMENT

Activity Overview

Review the twelve screens included in this survey. Score yourself using the scale provided depending upon your experience, and note items you have questions about. Total your score at the bottom.

---

1 for beginner	3 for average	4 for above average
2 for advanced beginner		5 for expert

WINDOW

```
NORMAL FLOAT AUTO REAL RADIAN MP
WINDOW
 Xmin=■.3
 Xmax=30.3
 Xscl=6.12
 Ymin=27.7277696
 Ymax=33.52015456
 Yscl=1.158476992
 Xres=1
 ⌂X=.11590909090909
 TraceStep=.23181818181818
```

ZOOM

```
NORMAL FLOAT AUTO REAL RADIAN MP
ZOOM MEMORY
1:ZBox
2:Zoom In
3:Zoom Out
4:ZDecimal
5:ZSquare
6:ZStandard
7:ZTrig
8:ZInteger
9↓ZoomStat
```

STAT

```
NORMAL FLOAT AUTO REAL RADIAN MP
EDIT CALC TESTS
1:Edit…
2:SortA(
3:SortD(
4:ClrList
5:SetUpEditor
```

STAT > **CALC**

```
NORMAL FLOAT AUTO REAL RADIAN MP
EDIT CALC TESTS
1:1-Var Stats
2:2-Var Stats
3:Med-Med
4:LinReg(ax+b)
5:QuadReg
6:CubicReg
7:QuartReg
8:LinReg(a+bx)
9↓LnReg
```

STAT PLOT

```
NORMAL FLOAT AUTO REAL RADIAN MP
STAT PLOTS
1:Plot1…On
   ⌐ L1   L2   .
2:Plot2…On
   ⌐ L1   L3   .
3:Plot3…Off
   ⌐ L1   L1   ▫
4:PlotsOff
5:PlotsOn
```

TBLSET

```
NORMAL FLOAT AUTO REAL RADIAN MP
TABLE SETUP
 TblStart=0
 ⌂Tbl=1
Indpnt: Auto Ask
Depend: Auto Ask
```

CALC

```
NORMAL FLOAT AUTO REAL RADIAN MP
CALCULATE
1:value
2:zero
3:minimum
4:maximum
5:intersect
6:dy/dx
7:∫f(x)dx
```

VARS

```
NORMAL FLOAT AUTO REAL RADIAN MP
VARS Y-VARS COLOR
1:Window…
2:Zoom…
3:GDB…
4:Picture & Background…
5:Statistics…
6:Table…
7:String…
```

MODE

```
NORMAL FLOAT AUTO REAL RADIAN MP
MATHPRINT CLASSIC
NORMAL SCI ENG
FLOAT 0123456789
RADIAN DEGREE
FUNCTION PARAMETRIC POLAR SEQ
THICK DOT-THICK THIN DOT-THIN
SEQUENTIAL SIMUL
REAL a+bi re^(θi)
FULL HORIZONTAL GRAPH-TABLE
FRACTION TYPE: n/d Un/d
ANSWERS: AUTO DEC FRAC-APPROX
GO TO 2ND FORMAT GRAPH: NO YES
STAT DIAGNOSTICS: OFF ON
STAT WIZARDS: ON OFF
SET CLOCK 06/24/13 7:35AM
```

DRAW

```
NORMAL FLOAT AUTO REAL RADIAN MP
DRAW POINTS STO BACKGROUND
1:ClrDraw
2:Line(
3:Horizontal
4:Vertical
5:Tangent(
6:DrawF
7:Shade(
8:DrawInv
9↓Circle(
```

FORMAT

```
NORMAL FLOAT AUTO REAL RADIAN MP
RectGC PolarGC
CoordOn CoordOff
GridOff GridDot GridLine
GridColor: MEDGRAY
Axes: BLACK
LabelOff LabelOn
ExprOn ExprOff
BorderColor:      1
Background:     Off
Detect Asymptotes: On Off
```

ALPHA[F1] - ALPHA[F4]

```
NORMAL FLOAT AUTO REAL RADIAN MP
       1:abs(
       2:summation Σ(
       3:nDeriv(
       4:fnInt(
       5:logBASE(
       6:ˣ√
       7:nPr
       8:nCr
       9:!
FRAC FUNC MTRX YVAR
```

Total Score

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TI Technology Exam Acceptance
TI PROFESSIONAL DEVELOPMENT

TI-Nspire™ Technology

Approved for Tests	TI-Nspire™ CX TI-Nspire™ w/Touchpad TI-Nspire™ w/Clickpad	TI-Nspire™ CX CAS TI-Nspire™ CAS w/Touchpad TI-Nspire™ CAS w/Clickpad
SAT*	●	●
AP*	●	●
PSAT/NMSQT*	●	●
ACT*	●	
International Baccalaureate	●	
Praxis™	●	●
Texas STAAR® Grade 8	●	
Texas STAAR® Algebra	●	

Graphing Technology

Approved for Tests	TI-84 Plus CE TI-84 Plus C Silver Edition TI-84 Plus Silver Edition TI-84 Plus, TI-83 Plus	TI-89 Titanium
SAT*	●	●
AP*	●	●
PSAT/NMSQT*	●	●
ACT*	●	
International Baccalaureate	●	
Praxis™	●	●
Texas STAAR® Grade 8	●	
Texas STAAR® Algebra	●	

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