Connecticut Common Core Algebra 1 Curriculum

Professional Development Materials

Technology Handbook

Unit 2

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TI-83 or TI-84: Graph Feature
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TI-84 or TI-84: Drawing a Scatterplot
TI-84 or TI-84: Calculating and Drawing a Regression Line
TI-84 or TI-84: Evaluating a Function
TI-84 or TI-84: Solving an Equation
TI-84 or TI-84: Setting up Lists

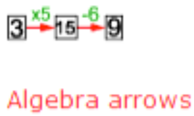
Unit 8

TI-84 and CBR: Rolling Ball
TI-84 and CBR: Bouncing Ball
TI-Inspire and CBR: Bouncing Ball

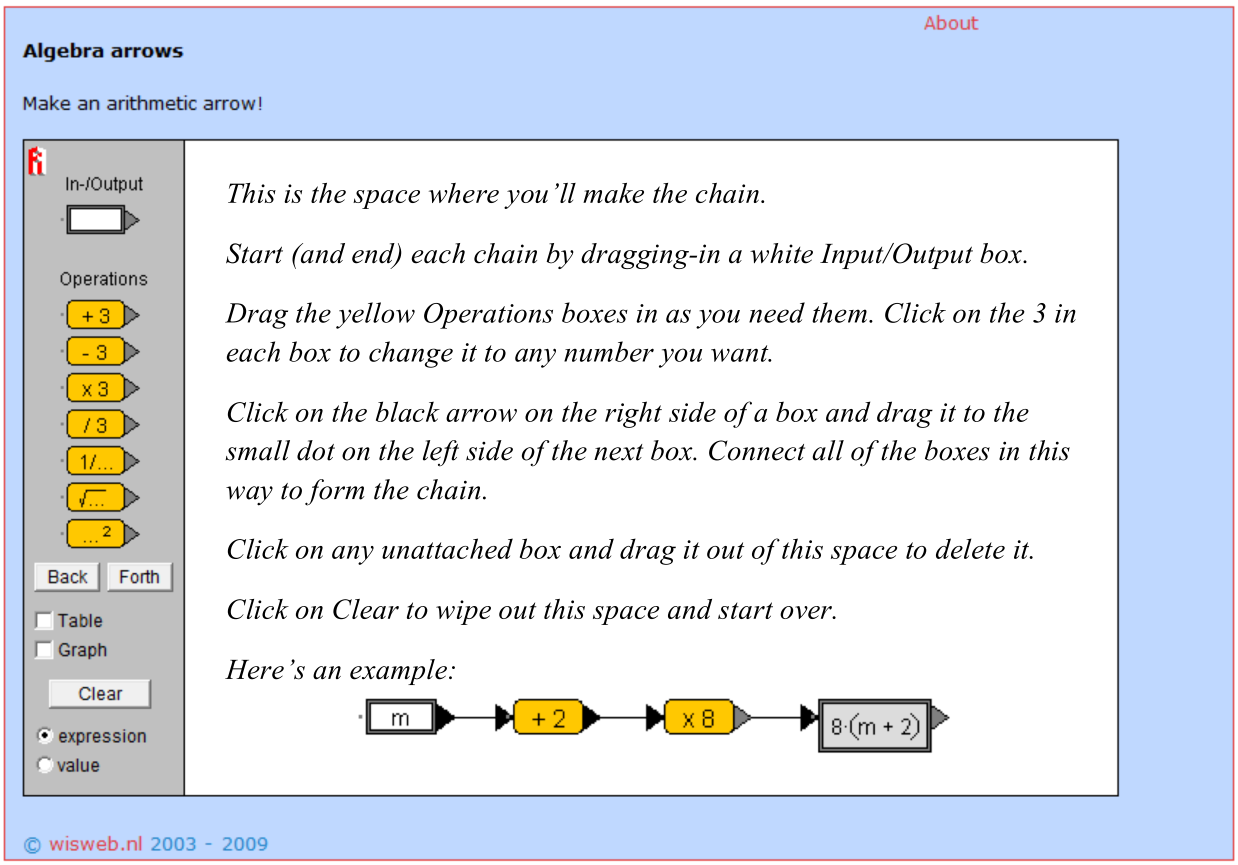
Algebra Arrows (Wisweb)

Go to: http://www.fi.uu.nl/wisweb/en/ and select the menu item **applets** across the top

Click on this icon:



You will see a screen like this. Read the notes below that describe the process of making a chain.

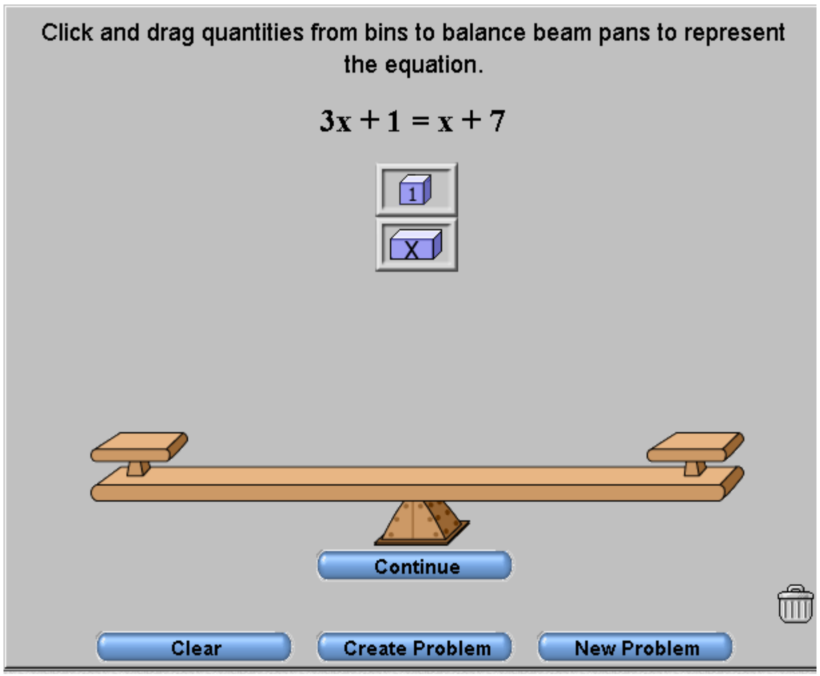


Notice that Algebra Arrows builds chains from left to right, so you need to consider order of operations carefully before building a chain.

Algebra Balance Scales

Go to:
http://nlvm.usu.edu/en/NAV/frames_asid_201_g_4_t_2.html?open=instructions&from=category_g_4_t_2.html (positive coefficients) or
http://nlvm.usu.edu/en/nav/frames_asid_324_g_4_t_2.html?open=instructions&from=category_g_4_t_2.html. (negative coefficients).

You can close the information block on the right and you will see what is below.

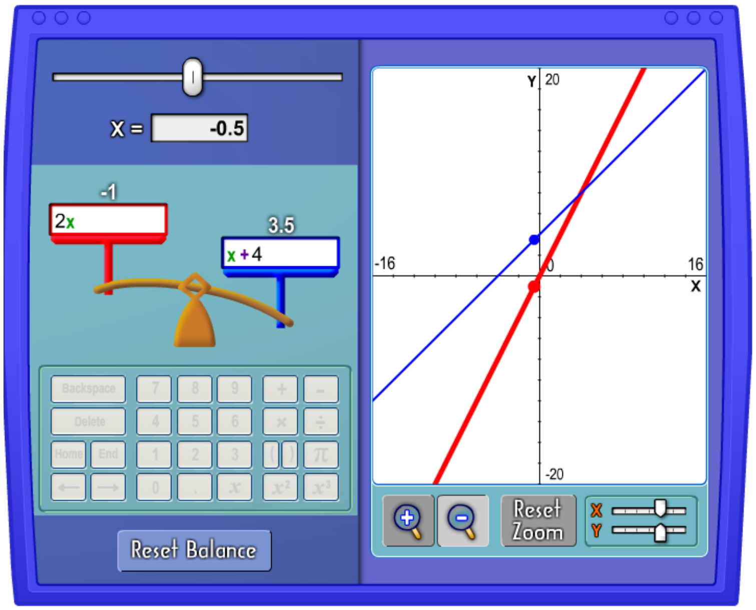


1. Click "Create Problem".
2. Enter the coefficients and constants for each side of the equation.
3. Click "Begin".
4. Drag quantities from bins to balance beam pans to represent the equation.
5. Click "Continue".
6. Click the operation you want to use (+, -, x, ÷).
7. Enter the term you want to add, subtract, multiply or divide by.
8. Click "Go".
9. Repeat steps 6 – 8 until the equation is solved.
10. Click "Create Problem" if you want to enter another problem or "New Problem" if you want to practice problems generated by the applet.

Note: When using this software, if you have no solution or a fractional/decimal answer you will get the error message: "This equation doesn't have an integer value for its solution, so it cannot be solved using this manipulative."

Pan Balance Applet

Go to: http://illuminations.nctm.org/ActivityDetail.aspx?id=10



Place an algebraic expression in each of the red and blue pans. These expressions may or may not include the variable *x*. Enter a value for *x*, or adjust the value of *x* by moving the slider.

As the value of *x* changes, the results will be graphed. Use the Zoom In and Zoom Out buttons, or adjust the values for the *x*- and *y*-axes with the sliders, to change the portion of the graph that is displayed.

The Reset Balance button removes the expressions from the pans and clears the graph.

Exploration

Explore algebraic equivalence with the following investigation.

1. Enter the expression $2x$ into the red pan, and enter the expression $x + 4$ into the blue pan.
2. Enter the value $x = –5$ into the box near the top. What happens? Change the value of *x* to 0 and then to 5. How does this change the relationship between the pans?
3. Find a value of *x* such that the red pan equals 0. Where is the red dot when the red pan has a value of 0?
4. Find a value of *x* such that the blue pan equals 0. Where is the blue dot when the blue pan has a value of 0?
5. Move the slider to adjust the value of *x*. For what value of *x* do the red and blue pans have equal values? What happens in the graph when the values of the pans are equal?
6. What other observations can you make about the relationship between the values of the pans and the graph?

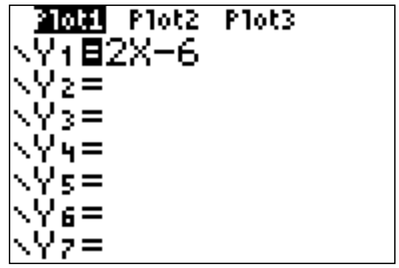
The TABLE Feature – TI 83 or TI 84

You can explore tables by using three main keys, **Y=**, **TBLSET**, and **TABLE**.

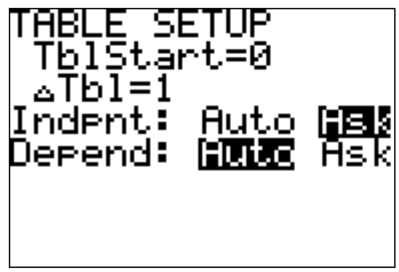
Table Feature: User is Prompted for Inputs

1. Press **Y=**. Type in an expression (rule). Press **ENTER**.

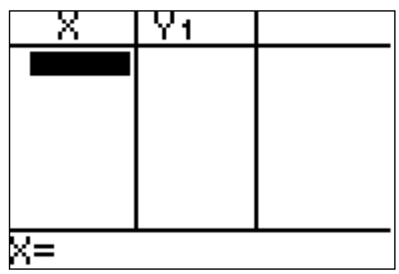
For example: Below we entered the equation $y = 2x - 6$



2. Press **2nd TBLSET**, move the cursor using the arrow keys, place the cursor on **ASK** (for independent), and hit **ENTER**.



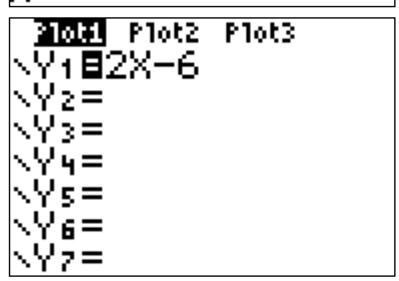
3. You are ready to create a table. Press **2nd TABLE**. At the bottom of the screen, the X = is waiting for you to type in an input. After typing in the input, hit the **ENTER** key.



4. You should see your input and its corresponding output in the table. Continue to enter your inputs, one at a time. *Note*: after 7 inputs, the eighth input will replace the 7^{th} and so on.

Table Feature: Table is Automatically Created

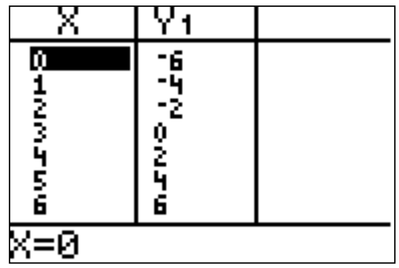
1. Press **Y=**. Type in an expression (rule). Press **ENTER**.



2. Press **2nd TBLSET**, move the cursor down, enter in your starting input (TblStart) for the table, then set ΔTbl to a certain increment. Move the cursor using arrow keys, place the cursor on **AUTO** (for independent), and hit **ENTER**.

3. You are ready to create a table. Press **2nd TABLE**.

4. Your completed table should be on the screen. Use your *up* and *down arrows* to scroll to other values.

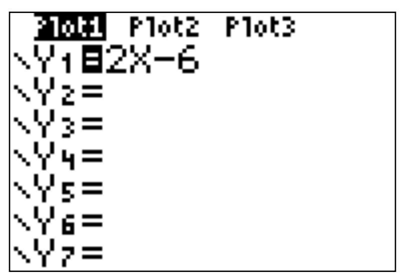


The GRAPH Feature – TI 83 or TI 84

You can explore graphs with three main keys, **Y=**, **WINDOW**, **ZOOM**, **TRACE**, and **GRAPH,** and **CALC** (above **TRACE**).

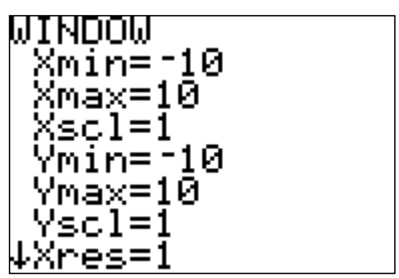
1. Press **Y=** and enter each rule. Remember that the variable is imputed using the k ***X,T,n,θ*** key. Make sure the equal sign is darkened.

For example: Below we entered the equation $y = 2x - 6$

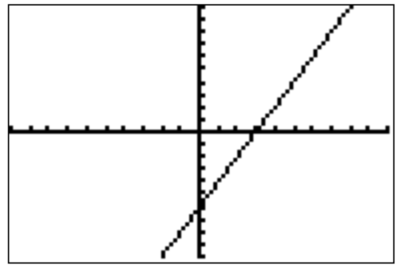


2. Now you will need to set the window. This specified the viewing window and the increments shown on the axes.

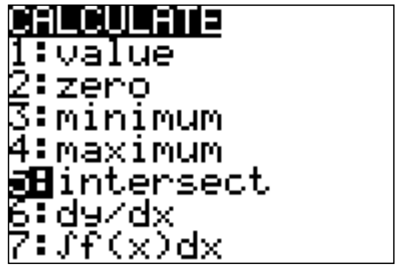
3. Press **WINDOW.** Enter the following:
   Xmin = -10, Xmax = 10, Xscale = 1,
   Ymin = -10, Ymax = 10, Yscl = 1, Xres = 1



4. Now press **GRAPH**.



5. If you graph two equations, to calculate the exact intersection point, press **2nd CALC**. Scroll down to "5: intersect" using the arrow key and press **ENTER**.



6. Press **ENTER** three times in a row. At the bottom of your screen, you will see the coordinates of the intersection point.

Linking TI's to Transfer Programs and Data

A. Use the black link chord and place each end in a calculator (I/O). Be sure you push in far enough.

For the calculator that will receive the programs, data list etc.

1. Hit the **2nd** key and the **x,T,e,n** key = **Link key**
2. On the screen use your **right arrow** to highlight RECEIVE and then hit **ENTER.**
3. The screen should say *Waiting*

Meanwhile for the calculator that has the program, list, etc. and is to share it

1. Hit the **2nd** key and the **x,T, e, n** key = **Link key**
2. Use the down arrow to move down to 3 for programs if you wish to share a program or 4 for sharing lists. Then hit **ENTER** (or you could just hit the 3 or the 4 key)
3. The screen then will display the names of available programs or lists that may be shared.
4. Use the down arrow to move to the row that contains the desired name and hit **ENTER.** You will see the cursor changes its look indicating the program or list has been selected**.**
5. Now use the **right arrow** to highlight **TRANSMIT** and hit **ENTER**
6. Wait for the screen to say *done*. Disconnect the link cord. You are set. If you get an error message most common reason is that the link cord has not been pushed in far enough. In this case, go to step A above.

NOTE: If you are linking to an old calculator the operating system might need updating. You can do this by going to the TI Education site.

TI Programming Instructions

Activity from Unit 2 Investigation 5 Overview Teaching Strategy VII

The instructions below show how to create a program to find the perimeter of a rectangle given its length and width. Programming the TI-83 or TI-84 is an optional activity outlined in the Unit 2 Investigation 5 Overview.

1. Hit the **PRGM** Key
2. Use right arrow to slide to *NEW*
3. Hit **ENTER**
4. Use **2nd** key and **ALPHA** key = **A-LOCK** and type in the name of the program for our example, PERIM
5. Then Hit the **PRGM** Key
6. Use **right arrow** key to highlight *I/O* and select 2: PROMPT
7. Type in the letter L using the alpha key and hit **ENTER**
8. Then Hit the **PRGM** Key
9. Use **right arrow** key to highlight *I/O* and select 2: PROMPT
10. Type in W using the alpha key and hit **ENTER**
11. Type 2L + 2W using the alpha keys for the letters. Press the **STO►** key to get the arrow (→) and type P. Hit **ENTER**
12. Hit the **PRGM** Key
13. Use **right arrow** key to highlight *I/O* and select 3: DISP. To get the quotes use **Alpha +** then type P. To get the equal sign, hit the **2nd MATH** key **f**or **TEST** and select **1** followed by **Alpha +** to obtain another quote sign. Hit **ENTER**
14. Hit the **PRGM** Key
15. Use **right arrow** key to highlight *I/O* and select 3: DISP and type P

Your program should look like:

```
:Prompt L
:Prompt W
:2L + 2W → P
:Disp "P ="
:Disp P
```

To use the program, press **2nd** key and **MODE** = **QUIT**, hit **PRGM** and under **EXECUTE**, select the number of the program and follow the screen prompts.

LINEQUA PROGRAM

Activity from Unit 2 Investigation 6 Overview – Teaching Strategy V

This activity doesn't have an Activity sheet, but is referenced in the Investigation 6 Overview under Teaching Strategy V:

> The TI-84 program LINEQUA allows students to represent inequalities by tables and graphs on their graphing calculators. The program is supported by teacher notes and student activity sheets. In order for students to use the program LINEQUA, it must be downloaded onto their graphing calculators. Program and website can be found at:
>
> http://education.ti.com/calculators/products/US/home/
>
> (Type 8773 or LINEQUA into the search box.)

Download the LINEQUA program from the TI website or copy it from another calculator. Then use this program to complete the LINEQUA student activity sheet.

Using the CBR as a motion detector.

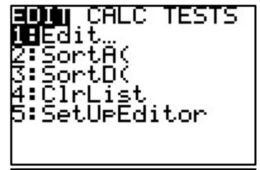
Instructions to go with Unit 4 Investigation 1

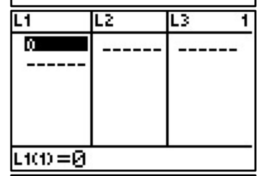
Graphing Calculator Instructions

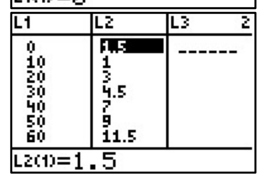
This document contains TI-83 and TI-84 calculator instructions for:

- Entering in a data set or multiple data sets
- Clearing an entire list in the List Editor
- Setting up the List Editor
- Calculating single-variable statistics on a data set
- Creating a scatterplot
- Calculating the slope and intercept of a linear regression line and the correlation coefficient
- Evaluating a function
- Solving an equation

Entering Data into Lists





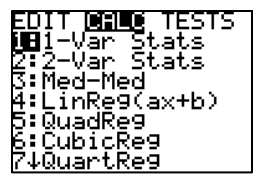


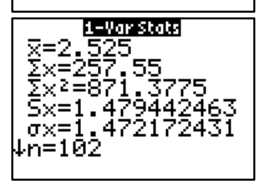
a. Press **STAT** and select **1:Edit** to go to the list editor.
b. Move the cursor to the list that you wish to edit. Type in a number. Press **ENTER**.
c. Continue entering numbers into a list. Press **ENTER** after typing in each number.
d. Then (if necessary) enter another data set into another list.
e. You can amend each single entry with the **DEL** key.

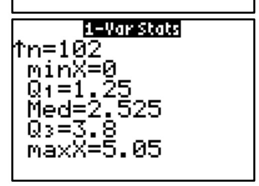
You can sort a list that you entered by using the **SortA** command. Press **STAT**, and select **2:SortA**. **SortA(** will appear on the home screen. Then enter the name of the list you want sorted (by pressing **2nd 1** (for L_1)), and press **ENTER**.

If you enter in two lists containing paired data, be sure that the lengths (also called *dimensions*) of the two lists are the same. Otherwise, you will get the *Dimension Mismatch* error message when you try to graph the data or perform regression.

Calculating Single-Variable Statistics on a Data Set



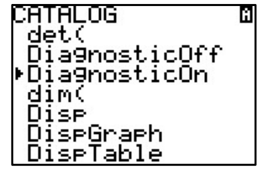




a. You must have a list entered into L_1.
b. Start at the home screen. Clear the home screen.
c. Press **STAT**, move the cursor to the right to highlight **CALC**.
d. Select **1:1-Var Stats**.
e. On the home screen you will see the **1-Var Stats** command. You must assign this command a list.
f. Press **2nd 1 (L_1)** to place the list name L_1 next to the command.
g. Press **ENTER**.

You will see the output of the **1-Var Stats** command on the home screen. The output contains several statistics. The statistics include the mean, population standard deviation, sample standard deviation, sample (or population) size, minimum value, first quartile, median, third quartile, and maximum value.

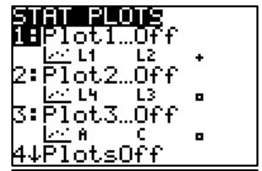
Turning on the Diagnostics to Obtain the Correlation Coefficient *r*



a. Clear the home screen.
b. Press **2nd 0 (CATALOG)** and scroll down to **DiagnosticOn** then press **ENTER**.
c. Home screen now shows **DiagnosticOn**. Press **ENTER**.
d. Home screen shows **Done**.

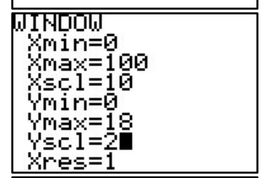
If the Diagnostic is turned off, the **LinReg(ax+b)** command (discussed below) will not output the correlation coefficient.

Drawing a Scatterplot

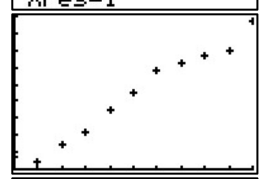


a. You must have two lists with the same dimension in L_1 and L_2.
b. Press **2nd Y= (STAT PLOT)**
c. Select **Plot 1** by highlighting **Plot 1** and pressing **ENTER**.
d. Set up the STAT PLOT by selecting **On**, selecting the first **Type** (the first type is a scatter plot), making the **Xlist** equal to $\mathbf{L_1}$, making the **Ylist** equal to $\mathbf{L_2}$, and selecting the **Mark** you wish to use.

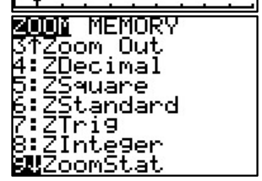
e. Choose an appropriate window to view the scatterplot based on the minimum and maximum values of the data in the two lists. Press **WINDOW** and enter the minimum and maximum values for *x* and *y*. Choose a scale for each axis using **Xscl** and **Yscl**. Set **Xres** = 1 for the screen resolution.



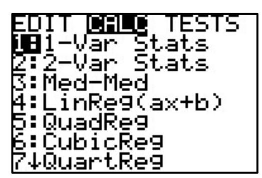
f. Press **GRAPH** to see the scatterplot.



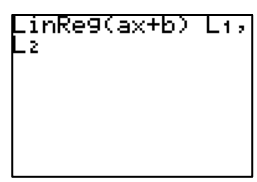
The calculator can create a window which contains the entire scatterplot automatically. Instead of manually defining the window manually, press **ZOOM**, then select **9**:**ZoomStat. ZoomStat** automatically sets a window that captures all data points in the scatterplot.



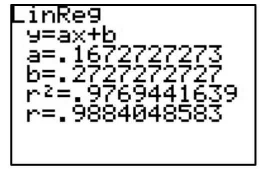
Calculating the Slope and Intercept of a Linear Regression Line and the Correlation Coefficient



a. You must two lists with the same dimension in L_1 and L_2.
b. Start at the home screen. Clear the home screen.
c. Press **STAT**, move the cursor to the right to highlight **CALC**.
d. Select **4:LinReg(ax+b)**.
e. On the home screen will be the command **LinReg(ax+b)**.
f. Press **2nd 1 ($\mathbf{L_1}$)** to get the list, L_1, that contains the independent variable.
g. Press **,** (the comma key), which is to the right of the x^2 key.
h. Press **2nd 2 ($\mathbf{L_2}$)** to get the list, L_2, that contains the dependent variable.
i. Press **ENTER**.



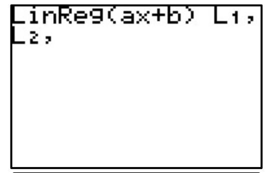
You will see the slope, *a*, and the *y*-intercept, *b*, of the regression line. You also will see the correlation coefficient, *r*, and the coefficient of determination, r^2, if you have turned the **Diagnostic** on. (See **Turning on the Diagnostic to Obtain the Correlation Coefficient *r***)

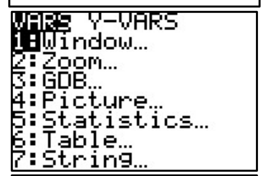


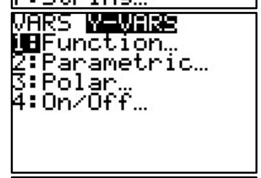
Graphing a Regression Line and Scatterplot in the Same Window

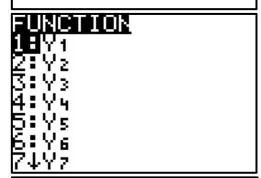
a. You can store the regression line into a function in the calculator by running the **LinReg(ax+b)** command. Select the command **LinReg(ax+b)**.
b. Type in **L_1 ,** (comma) **L_2 ,** (comma) .
c. You now must enter in a function name (such as Y_1 or Y_2). To enter the function name Y_1, press **VARS**, move the cursor right to **Y-VARS**, select **1:Function**, then select **1:Y_1**.
d. The home screen should now show the command **LinReg(ax+b) L_1, L_2, Y_1** which will calculate the regression line and store the regression line into Y_1.
e. Press **ENTER** to execute the command.
f. Press **Y=** key to verify that the regression line is indeed pasted into Y_1. Make sure that **Plot 1** at the top is highlighted. This specifies that the scatterplot in STAT PLOT 1 and the regression line in Y_1 will be plotted simultaneously. You can remove the highlight from **Plot 1** if you want to only show the regression line.
g. Press **GRAPH**.

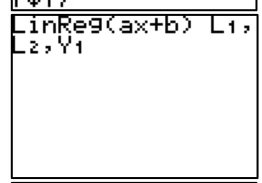
You can also enter the regression line in for Y_1 by hand. Press **Y=** and type in the regression equation which the calculator obtained.

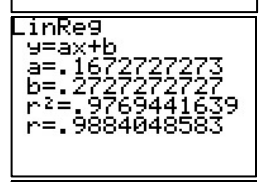


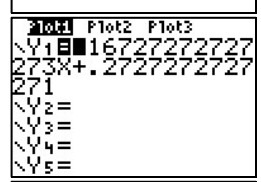


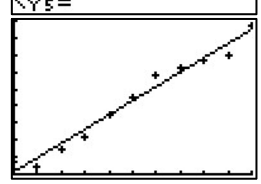




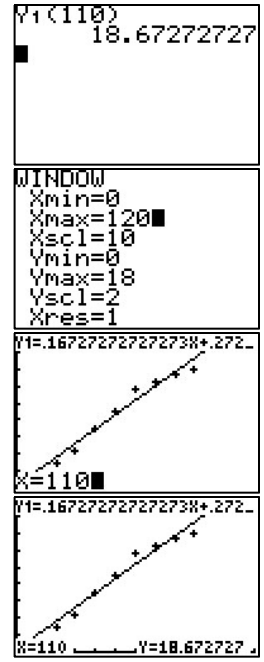






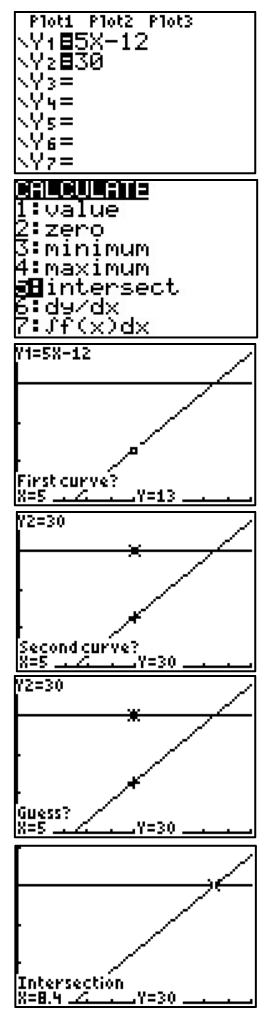


Evaluating a Function



a. To evaluate a function, store a function $y = f(x)$ in Y_1.
b. To evaluate Y_1, you must bring the function name Y_1 to the home screen.
c. Press **VARS**, move to cursor to the right to **Y-VARS**, then select **1:Function**, then select **1: Y_1**. This will make **Y_1** show up on the home screen.
d. Then enter **(110)** to evaluate $Y_1(110)$.
e. Press **ENTER**.
f. You can also use the table or graph feature to evaluate a function.
   - **Table feature**: You may want to choose "ask" mode for the independent variable. This mode lets you choose any input. When you press **TABLE** a blank table will appear. Enter in any value you want for the independent variable, press **ENTER**, and the corresponding dependent variable will appear.
   - **Graph feature**: When the function is graphed, press **2nd Trace (CALC)**. In the Calculate menu, select **1: value**. Enter a value for *x* and press **ENTER**. Make sure that you are in a graphing window which includes the input value which you want to use.

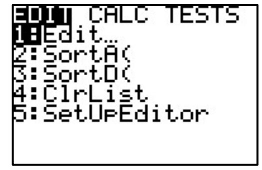
Solving an Equation



Consider the equation $5x - 12 = 30$. To solve this equation using the graphing calculator you must treat each side of the equation as a function. Then you can find the intersection point (if it exists) of the two functions.

a. Enter the expression $5x - 12$ into Y_1 and enter 30 into Y_2.
b. You must set a window that contains the intersection point of the two functions.
c. Press **GRAPH**.
d. Press **2nd TRACE (CALC)**.
e. Select **5: intersect**.
f. The calculator asks you to select the first curve. One of the functions will be highlighted. Press **ENTER**.
g. The calculator asks you to select the second curve. The other function will be highlighted. Press **ENTER**.
h. You are asked for a guess. You can leave this prompt blank. Press **ENTER**.
i. The intersection point (solution of the equation) is displayed at the bottom of the screen.

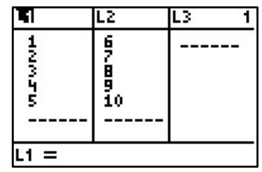
Setting Up the Lists in the Editor



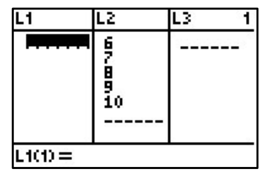
a. Press **STAT**.
b. Select **5:SetUpEditor** and press **ENTER**.
c. The home screen will show **SetUpEditor**.
d. Press **ENTER**.
e. The home screen will show **Done**.

You only need to run SetUpEditor if you are missing a list in the List Editor or if your lists are out of order. You do not need to do this every time.

Clearing an Entire List in the Editor



a. Press **STAT** and select **1:Edit**.
b. Place the cursor over the list name at the top so the list name is highlighted.
c. Press **CLEAR** and then press **ENTER** to clear an entire list. *Note*: you must highlight the list name at the top, not the first entry.



You can replace entries in a list with new data by simply typing over the existing data in the list.

Rolling Ball – TI-84 + and CBR-2

In this activity you will roll a ball down a ramp and examine a graph that results from the data collection.

Equipment & Materials

- CBR-2 unit
- TI-84 + calculator and Standard-B to Mini-A USB cable (square end and small trapezoidal end)
- Two 1 by 2 boards at least 8 feet long
- Smooth ball (approximately 8” in diameter - play balls from Stop & Shop work well)

CBR Setup

1. With the calculator turned off, connect the CBR-2 to the calculator using the link cable. The square plug goes into the side of the CBR-2, and the trapezoidal plug goes into the top of the calculator.

2. The Tic-Tic-Tic sound and light indicates that there is a connection but data are not being collected.

3. The EasyData app is already installed in TI-84 calculators. The calculator may turn on and automatically launch the program when the CBR-2 motion detector is connected. If the calculator doesn’t turn on, turn it on, find the key marked APPS and select #6 – Easy Data. The CBR-2 will be flashing.

4. From the MAIN MENU, select SETUP by pushing the WINDOW button. Choose Time Graph by pressing 2. Then push the ZOOM button to edit the Time Graph Settings.

5. Set the sample interval to .02. Push ZOOM to get to the Number of Samples window. Set the number of samples to collect to 100.

6. Push ZOOM to see the final settings. Note that the experiment length will be 2 seconds (the number of samples multiplied by the sample interval). Note the flashing light and the ticking only indicate the CBR-2 is ready to collect data. It is not collecting data.

7. Select OK by pressing the GRAPH key. Respond START by pressing Zoom. The CBR-2 will stop ticking.

A Data Deletion window will appear reminding you that the selected function will overwrite any prior data collection. Be prepared to collect the data before pressing GRAPH. **The device will start collecting the data as soon as you press the GRAPH button to respond OK.**

So you can see how it works you will collect some data just for a trial. Put the CBR-2 data collector facing up and the calculator on a table next to it. Hold one of your hands over the data collector screen, press GRAPH and move your hand up and down slowly. After a while the CBR-2 will stop collecting data, transfer the data to the calculator and show you a graph.

To use the app again after you see a graph press TRACE to select the Main menu and then ZOOM to select Start.

Create a Ramp and Set up the Experiment

Find a low step with space in front of it. Create a ramp by placing the boards parallel to each other about 4" inches apart with one end of each board on the step. Place the ball at the top of the ramp and release it to test how smoothly it rolls.

Place the CBR-2 at the bottom of the ramp hinged at approximately 90° to the ramp.
In this activity, you will roll a ball down the ramp and record its motion with the CBR-2.

1. Have one person at the top to let go of the ball and another at the bottom with the calculator and CBR-2.

2. Have the person with the calculator count down to release the ball at the same time he or she presses GRAPH to start collecting the data.

3. When the CBR-2 stops collecting the data, it will transfer it to the calculator and display a graph.

4. When you have a satisfactory graph, press TRACE to select the Main menu and select GRAPH to quit the app. Disconnect the cable from the calculator.

Modeling the Data with a Quadratic Function

You are going to use the collected data that are stored in L1 and L6. There are data in L7 and L8 that you will ignore for this experiment.

Press 2nd Y= to be certain that your Plot1 is turned on and that it is showing the data in L1 and L6.

Press STAT, select CALC, and 5: QuadReg. Scroll down to Xlist and Ylist making sure that entries are L1 and L6 respectively. Scroll down to Store RegEQ: enter VARS, Y-VARS, 1: Function and 1:Y1. Scroll down to CALCULATE and hit ENTER.

When the QuadReg appears, the parameters for the quadratic function are shown. Now go to Y=, Y1 will now contain the quadratic function from the quadratic regression formula in your calculator. Scroll left until you reach the column before Y1. Hit enter until you see –O. Press ZOOM and 9 for StatPlot.

Ball Bounce – TI-84+ and CBR-2

(Adapted from Texas Instruments EasyData Activity 12)

Objectives:
In this activity you will:
- Graph the height of a bouncing ball over time
- Graph and interpret quadratic functions
- Apply the vertex form of a quadratic function
- Determine the equation of a quadratic function that models data
- Examine the role of the parameter a in a quadratic function.

Overview
A bouncing ball is a real-world example of a quadratic function. This activity investigates how the quadratic equation, $y = a(x - h)^2 + k$, can be used to model the behavior of a bouncing ball and how the parameter a impacts the graph of a quadratic function.

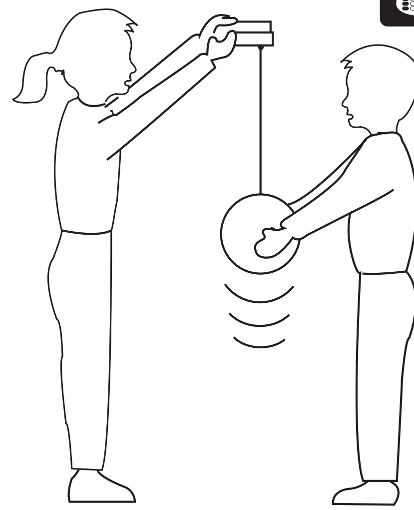
Materials
- CBR-2 unit
- TI-84 + calculator
- Standard-B to Mini-A USB cable
- A firm bouncing ball with a smooth surface (a tennis ball will absorb the pulses from the CBR-2).

Setup
1. 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.
2. Set the sensitivity on the CBR-2 to Normal under the data sensor with the person and the ball icon.

CBR Setup
1. Connect the CBR-2 to the calculator using the link cable. The “square” plug goes into the side of the CBR-2, and the trapezoidal plug goes into the top of the calculator.
2. The Tic-Tic-Tic and flashing light indicate that there is a connection but not that data are being collected.
3. Turn on your calculator. The EasyData app is already installed in TI-84+ calculators. It may automatically launch when the CBR-2 motion detector is connected. If it doesn’t launch, find the key marked APP and select #6 – Easy Data. The CBR-2 will be flashing to indicate it is connected.
4. From the MAIN MENU, select SETUP by pushing the WINDOW button.
5. Press 5: Ball Bounce.
6. Press ZOOM to start the activity.

The Data Deletion screen will state, “The selected function will overwrite the latest run.” Respond OK by pressing the GRAPH button.

You will see the Ball Bounce menu "Hold the ball at least half a meter below the motion detector. Choose next to continue."



Press ZOOM to go Next.

The Ball Bounce window appears with the message "If desired, disconnect the calculator. To start data collections, press TRIGGER [on the CBR-2]. If necessary, reconnect the calculator, then choose next." Stand far away from the CBR-2 so that your body will not interfere with the data collection. It seems to work best if you do disconnect the calculator.

Press the TRIGGER to start the collection of data (it will stop automatically). Then reconnect the calculator and press ZOOM for next. It will respond "Please Wait" as it transfers data. The next thing you will see is a graph of your data.

The Ball Bounce selection on the CBR-2 automatically sets the units to meters and collects data for 5 seconds every .05 seconds. The time data is stored in List1 (L1) and the distance data in L6. There are data in L7 and L8 that you will ignore for this experiment. Press TRACE to go to Main. Press GRAPH to Quit out of the program. It will respond with Ready to Quit. With STAT PLOT 1 on, you can trace your graph.

In this experiment, you will collect the height vs. time data of a bouncing ball by using the CNR-2 and the EasyData App. When you see the Easy Data App graph the ball data, complete the questions below.

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

2. What are the units?

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

4. What are the units?

5. What does the highest point on the plot represent?

6. What does the lowest point represent?

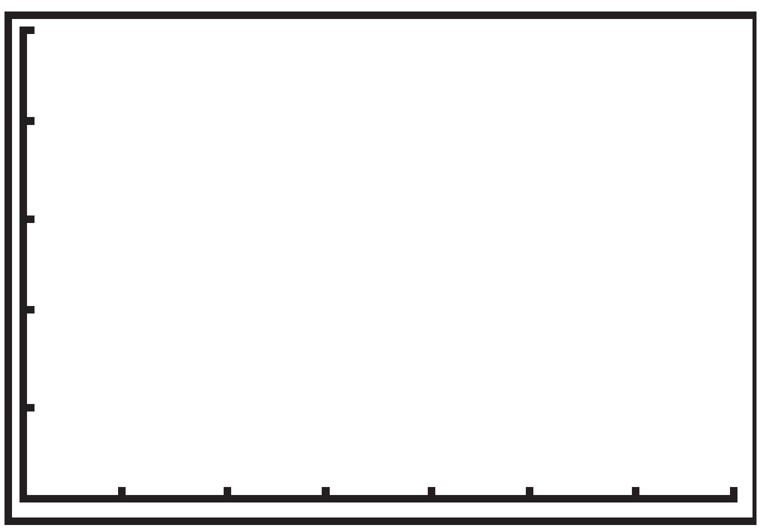
7. Why does the plot look like the ball bounced across the floor?

After exiting the App, with the graph showing use the Select feature (go to 2nd LIST, OPS and choose Select (8) and enter L2 (2nd 2) and L3 (2nd 3) as the parameters, your graph will reappear and you will be able to select the left and right boundaries), on your calculator to isolate any one bounce you choose. For any one bounce, a plot of height vs. time has a parabolic shape. The equation that describes this motion is quadratic: $y = a(x-h)^2 + k$ where *a* affects the width of the *parabola* and (*h,k*) is the *vertex* of the parabola.

8. This equation is called the *vertex form* of a quadratic function. Trace along your height vs. time plot. Identify the vertex of the bounce you chose by going back and forth to find the highest position and record the *x*- and *y*- coordinates as *h* and *k* here.

   h= ________________ *k*=______________. Press CLEAR to exit from the graph.

9. Press Y= and enter the expression $a(x-h)^2 + k$ for Y_1 using your values for *h* and *k* and replace *a* with -1. Sketch both your selected plot and the graph of the equation when on the coordinate axes provided here. Be sure to label the axes appropriately.



10. To find the equation of the parabola, use a guess-and-check method to find the value of *a*. Adjust *a* by storing new values for *a* on the Y1= screen. For each new value of *a* that you test, be sure to press ENTER before you press GRAPH. Experiment until you find one that provides a good fit for the data. Record the value of *a* that works below.

    a =________________

11. Using this value of *a* and the values of *h* and *k* found above, write the vertex form of the quadratic function: $y =$

12. What effect does the sign (positive or negative) of *a* have on the parabola?

13. What effect does increasing the size of the absolute value of *a* have on the shape of the parabola?

14. What effect does decreasing the size of the absolute value of *a* have on the shape of the parabola?

15. How would the equation change, if at all, with a different bounce of the bouncing ball?

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

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

18. What conclusion can you make about the value of *a* for a quadratic function of a bouncing ball?

Further Explorations

19. Re-plot L1 and L6 and repeat the procedure for one of the other bounces of the original data.

20. Using what you discovered about the value of *a* in a quadratic equation for a bouncing ball, write the equation of a parabolic ball bounce with a vertex of (7,0.48). Assume the data was measured in meters.

21. 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.

Ball Bounce – TI-Nspire and CBR-2

Objectives:
In this activity you will:
- Graph the height of a bouncing ball over time
- Graph and interpret quadratic functions
- Apply the vertex form of a quadratic function
- Determine the equation of a quadratic function that models data
- Examine the role of the parameter a in a quadratic function.

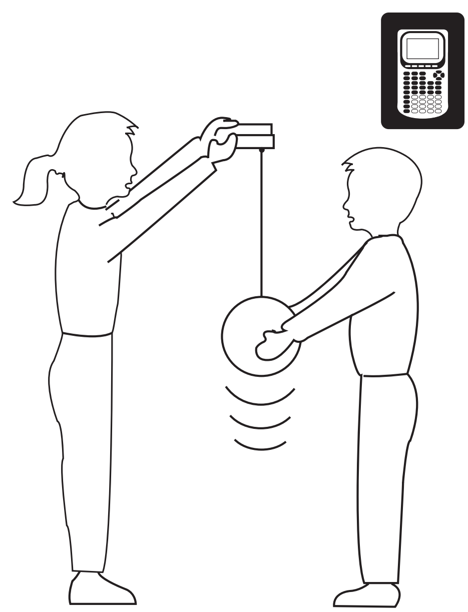
Overview
A bouncing ball is a real-world example of a quadratic function. This activity investigates how the quadratic equation, $y = a(x - h)^2 + k$, can be used to model the behavior of a bouncing ball and how the parameter a impacts the graph of a quadratic function.

You Need:
- TI-Nspire
- CBR-2
- Cable Link
- A firm bouncing ball with a smooth surface (a tennis ball will absorb the pulses from the CBR-2)
- 3 students; one to hold the CBR-2, one to release the ball, and one to run the calculator.

TI-Nspire & CBR-2 Set Up

1. Turn on the TI-Nspire. Create a new document.
2. Add Vernier Data Quest to the document.
3. Connect the CBR to the calculator using the link cable. The Tic-Tic-Tic and flashing light indicate that there is a connection. The CBR 2 will immediately begin calculating the distance between the sensor and the nearest object. This distance will be displayed on the TI-NSpire.
4. Change the Duration to 12 seconds by pressing MENU, select Experiment, select Collection Mode, select Time Based. Set Duration to 12 seconds.
5. One student will hold the CBR in the air as shown in the previous figure.
6. Identify the distance from the CBR to the ground. This distance will be used to transform the data.

   Distance from CBR to Ground, D = ___________________



7. One student will hold the ball halfway between the CBR and the floor.

Data Collection

1. At the same time, one student will drop the ball and the student holding the calculator will click on the Start Collection link (green arrow) to begin collecting data on the ball's movement. (Another way to begin collecting data is to press MENU, select Experiment, and then select Start Collection).
2. The distance between the ball and the sensor will be plotted on a graph. The data will be labeled *run1*. Store the data by clicking on the Store Latest Data Set link. (Another way to store the data is to press MENU, select Experiment, and then select Store Data Set). If the run1 data is not visible, click on the run button and select run1.
3. Disconnect the CBR to the calculator by unplugging the link cable.

Data Analysis

To analyze the movement of the bouncing ball, you will copy the time and position data into a spreadsheet.

1. Add a spreadsheet to your document. Press doc, select Insert, select Lists & Spreadsheets.
2. Label column A by selecting the top cell in column A. Type in "time".
3. Import the time data into column A by selecting the gray cell below the label. Type in "run1." and then select time from the drop down menu. Hit enter and the run1.time data will populate column A.
4. Label column B by selecting the top cell in column B. Type in "pos".
5. Import the position data into column B by selecting the gray cell below the label. Type in "run1." and then select position from the drop down menu. Hit enter and the run1.position data will populate column B.

   The CBR measured the distance from the sensor to the ball as the ball traveled away from and towards the sensor. To approximate the height of the ball above the ground, you will calculate a new variable called h, using the formula

$$h = D - pos$$

6. Label column C by selecting the top cell in column C. Type in "h".
7. Select the gray cell below the label. Type in "= (value of D) – pos". Hit enter and the height data will populate column C. Column C now contains the height of the ball over time.
8. To graph the height of the ball vs. time, add a Data & Statistics sheet to your document. Press doc, select Insert, select Data & Statistics.
9. In the Data and Statistics page, set the x variable to time by clicking on the Click to add variable link at the bottom of the screen. Select time. (Or press MENU, select Plot Properties, select Add X Variable, select time).
10. Set the y variable to height by clicking on the Click to add variable link at the left side of the screen. Select height. (Or press MENU, select Plot Properties, select Add Y Variable, select height).
11. Change the window settings to zoom in on the parabolic motion. Press MENU, select Window/Zoom, then select Window Settings.

Use the graph to answer the following questions:

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

2. What are the units?

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

4. What are the units?

5. Identify the vertices of the first three complete parabolas.

6. What do these vertices represent?

7. Why does the plot look like the ball bounced across the floor?

For any one bounce, a plot of height vs. time has a parabolic shape. The equation that describes this motion is quadratic: $y = a(x-h)^2 + k$ where *a* affects the width of the *parabola* and (*h,k*) is the *vertex* of the parabola. This equation is called the *vertex form* of a quadratic function.

The goal of the next exercise is to find the quadratic function that models the highest bounce off the ground.

8. Identify the highest bounce. Find the vertex of this parabola. Record the vertex below.

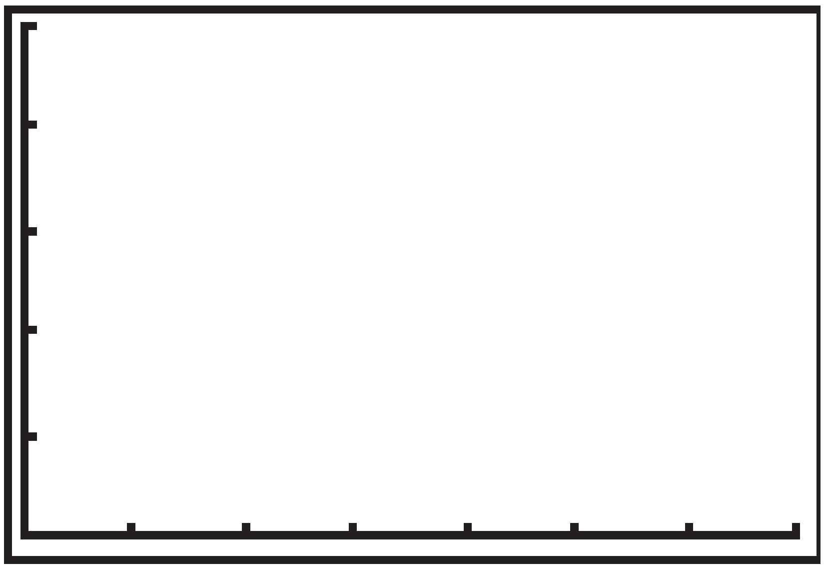
   h= ________________ *k*=______________

9. Write a quadratic function of the form $y = a(x-h)^2 + k$ by substituting in the values of *h* and *k*.

10. We will adjust the value of *a* until we have found the quadratic function which accurately models the highest bounce. Start by setting *a* = –1. Write the quadratic function when *a* = –1.

11. Plot the quadratic function you created above on the same graph with the bouncing ball ordered pairs. Press MENU, select Analyze, then select Plot Function. Enter your function as $f(x)$.

12. Sketch the points representing the highest bounce and the graph of the quadratic function when $a = -1$ on the coordinate axes below.



13. To find the equation of the parabola, use a guess-and-check method to find the value of *a*. Change the value of *a* by double-clicking on the function and typing in a new value. For each new value of *a* that you enter, view the resulting parabola. Record the value of *a* that creates a parabola which accurately fits the highest bounce.

$a =$

14. Using this value of *a,* and using the *h* and *k* values found above, write the vertex form of the quadratic function.

Use the calculator to answer the following questions:

15. What effect does the sign (positive or negative) of *a* have on the parabola?

16. What effect does increasing the size of the absolute value of *a* have on the shape of the parabola?

17. What effect does decreasing the size of the absolute value of *a* have on the shape of the parabola?

18. How would the equation change, if at all, with a different bounce of the parabola?

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

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

21. What conclusion can you make about the value of *a* for a quadratic equation of a bouncing ball?

Further Explorations

22. Find the quadratic equation that accurately models the second-highest bounce?

23. Using what you discovered about the value of *a* in a quadratic equation for a bouncing ball, write the equation of a parabolic ball bounce with a vertex of (7,0.48). Assume the data was measured in meters.

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