**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.

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| 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.

1. 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.

1. Press Y= and enter the expression $a(x-h)^{2}+k$for Y1 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.



1. 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* =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Using this value of *a* and the values of *h* and *k* found above, write the vertex form of the quadratic function: *y* =
2. What effect does the sign (positive or negative) of *a* have on the parabola?
3. What effect does increasing the size of the absolute value of *a* have on the shape of the parabola?
4. What effect does decreasing the size of the absolute value of *a* have on the shape of the parabola?
5. How would the equation change, if at all, with a different bounce of the bouncing ball?
6. 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.
7. Find the value of *a* from the other groups of students in your class. How do these values compare to your value of *a*?
8. What conclusion can you make about the value of *a* for a quadratic function of a bouncing ball?

**Further Explorations**

1. Re-plot L1 and L6 and repeat the procedure for one of the other bounces of the original data.
2. 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.
3. 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.