The Bounce Factor

Student Activity

7 8 **9** **10** 11 12

TI-Nspire™ CBR2™ Investigation Student 50 min

Introduction

The motion of a bouncing ball can be modelled using a parabola. In this activity you will collect position and time data using a CBR2 (Calculator Based Ranger) as a ball bounces beneath the detector. Things you need to keep in mind while completing this activity:

- The data is real, so it won't be 'perfect'. Real world data can be messy! The idea of developing equations is to model the motion and evaluate the appropriateness and accuracy of the equations.
- It takes less than a minute to collect the data, if you're not happy with your first data set, generate a new one!
- Keep the motion sensor at the same height throughout the data collection period. It can be moved side to side to track the bouncing ball, but the height cannot be changed.
- Collect data for approximately 4 to 5 bounces.
- Images in this activity include sample data.

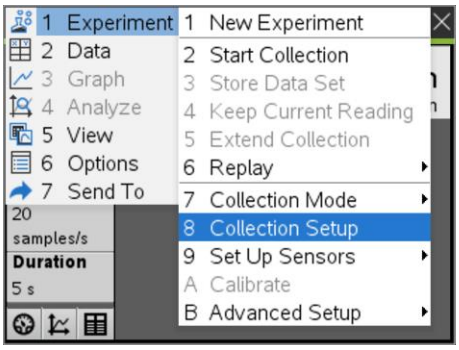
Set up

Start a new TI-Nspire document, insert a Calculator Application and then connect the CBR to the calculator using the USB cable.

The Vernier DataQuest Application will launch automatically.

Once the Application has launched **Collection**:

Menu > Experiment > Collection Setup

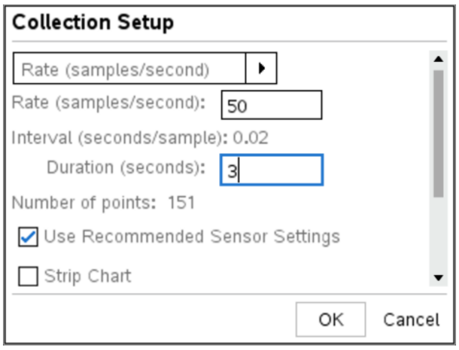


The data collection rate and duration depend on the type of ball and the height from which the ball is released. Try the following:

Rate: 50 (Samples per second)

Duration: 3 (Seconds)

This menu also provides the option for remote data collection. If you are collecting the sample by yourself, check the box for remote collection so you can disconnect the CBR and use the Trigger button to initiate data collection.



> A basketball bouncing on a level concrete surface makes an excellent target. If the ball is well inflated and released from a height of approximately 1m, the set up shown will produce 3 to 5 bounces.

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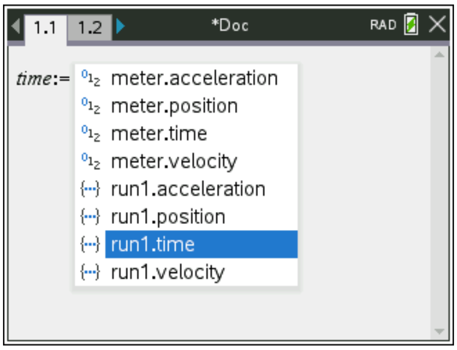
Navigate to the Calculator Application and assign the following variables:

time:= run1.time [Available from the VAR menu]

temp:= run1.position [Available from the VAR menu]

height:= max(temp) - temp

Note: If you collected and saved multiple data sets, select your best run set. run#.time



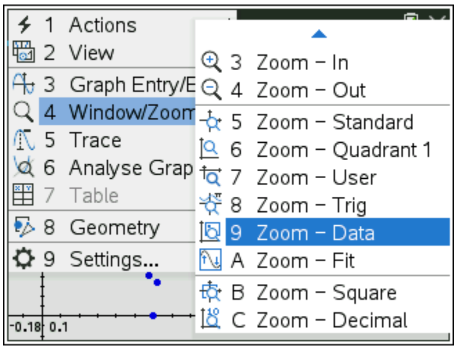
Navigate to the Graph Application and set up a **Scatter Plot** using the **Graph Entry/Edit** menu.

Set Scatter Plot 1 (S1) such that:

x = time

y = height

Use the Window / Zoom option to zoom in on the data. Make sure the x and y axis are visible, if not, adjust the window settings accordingly.



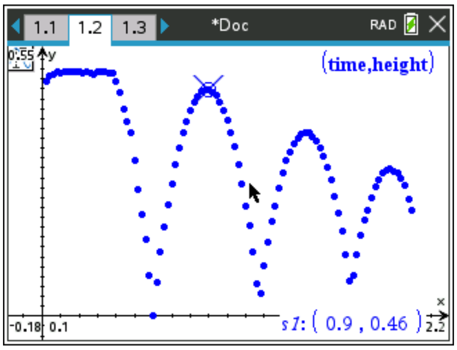
Question: 1

What is the purpose of the instruction: height := max (temp) – temp ?

Modelling Motion: Translations

Use the **Trace** > **Graph Trace** command to move the cursor across the data set. Navigate to the top of the first ball bounce and record the time and height of the ball.

Note: Each data set is different. Do NOT use the values shown opposite.



Question: 2

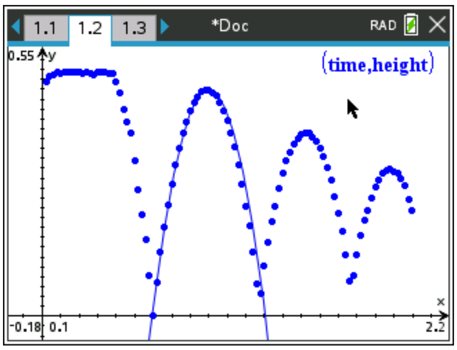
Use the translational form of a parabola: $f(x) = a(x-h)^2 + k$ to determine appropriate values for the corresponding parameters.

Question: 3

Graph your function and experiment with the value of a so that your parabola models the first ball bounce.
Note: You may choose to experiment with h and k to create a better fit.

The graph shown opposite illustrates how well the parabola can model the bouncing ball. Further experimentation with the parameters in this equation could produce an even better fit.

Note: The data shown opposite includes a 'flat' spot at the start of the data collection. The flat spot corresponds to the ball being held after the CBR has started data collection.



Question: 4

Model the remaining ball bounces using the Trace command and the technique outlined in Questions 2 and 3.

Question: 5

What similarities do each of the parabolic equations share?

Question: 6

Thinking about transformations and your current equation; suggest and test another way to generate equations for the remaining ball bounces.

If each equation is defined as $f(x)$ then subsequent equations can be defined as $af(x-h)+k$ or even $f(x-h)+k$ since the dilation for each is approximately -4.9.

Save your document! The data you have collected is unique, so too are your equations.

The accuracy of your equations is easy to check by using each of the graphs.

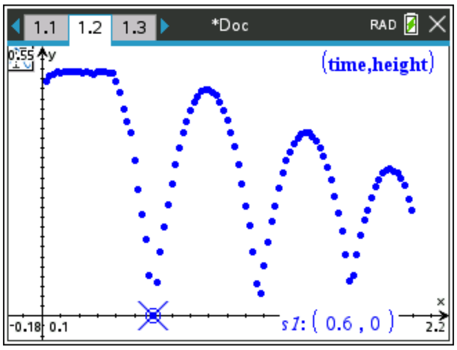
Modelling Motion: Impact Points

Another way to generate an appropriate equation is to consider *when* the ball hit the ground.

Switch the current equations OFF (don't delete them) so that you don't get confused between equations.

Use the **Trace** > **Graph Trace** commands to locate the closest point to *when* the ball struck the ground.

In the example shown here the first point is actually on the axis, the second point is not. The second point can be estimated using the proximity of neighbouring points.



Question: 7

Use the intercept form of a parabola: $f(x)=a(x-m)(x-n)$, determine appropriate values for the parameters m and n.

Answers will vary as each student has their own data.

Note that students will need to estimate the intercepts (times where the ball hit the ground). Students may also be asked to explore if a pattern exists between consecutive times. (Extension opportunity)

Question: 8

Graph your function and experiment with the value of a so that your parabola models the first ball bounce.
Note: You may choose to experiment with m and n to create a better fit.

While answers will vary, students should get an answer of approximately a ≈ -4.9. Students should also be encouraged to reflect upon why this value is the same for this representation of the parabola.

$$a(x-m)(x-n)\approx a(x-h)^2+k$$
$$ax^2-mx-nx+mn\approx ax^2-2ahx+ah^2+k$$

As the two quadratic equations are modelling the same data set the coefficient of x^2 should be approximately the same in each.

Question: 9

Explain why changing the value of a has no effect on the axis intercepts.

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Null factor law: $a(x-m)(x-n)=0$ has the same solutions regardless of the value of a.

Question: 10

Model the remaining ball bounces using this technique and record your results. [Save your document]

Answers will vary as each student has their own data.

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