Bouncing Ball with CBR2 and TI-Nspire

The objective in this lab is to find a functional relation between bounce height and number of bounces of a ball dropped from a certain height above the ground (i.e. the height of each subsequent bounce, after the ball is released, plotted against the bounce number) and to use this function to determine the bounciness (or "bounce-coefficient") for the ball.

Instructions for Collecting the Data

1. Find a high location (at least 2 meters) to secure the CBR2 using a clamp so that there is a clear space below it and around it for at least a radius of 0.5 meters.
2. Do a few test bounces with the large ball, releasing it about half a meter below the CBR2. The ball needs to make at least 5 bounces, staying underneath the CBR2.

Turn on your TI-Nspire and open a **New Document** with a **NOTES page** or use the *Bouncing_Ball_CBR2.tns* file.

3. Connect the TI-Nspire calculator to the CBR2 with the link cable.
    a. Choose **Data & Statistics** for the page type for the Data Collector.
4. The Data Collector should appear indicating the distance of the CBR2 from the floor (make sure there are no objects, including yourself in the range of the CBR2!):
    a. Record the height of the CBR2 from the floor (in meters) on your lab record sheet.
    b. A Data Graph should be showing behind the Data Collector with **dc01.time** on the horizontal axis and **dc01.dist1** on the vertical axis (if this is not the case, disconnect the CBR2, go to the **Home** screen and start again with a New Document and Notes page. Discard the current document.)
5. One person should hold the ball approximately half a meter below the CBR2 (the person holding the TI-nSpire should check the reading on the Data Collector—move the ball until it reads as close to 0.5 as you can get).
6. One person should press the **Enter** key on the TI-Nspire as the person holding the ball releases it by moving both hands away from the ball horizontally and stepping away from the ball. The data collector will run for 5 seconds.
7. After the CBR2 has stopped collecting data you should see a series of points on your data graph that look like a series of parabolas with the vertex point getting higher and higher. If you do not have at least 5 such parabolas before the data breaks up, then start again, discarding this document.

8. When you have a satisfactory data graph of at least 5 parabolas, TAB over on the Data Collector until you have the X selected and press Enter. The Data Collector should close. Disconnect the link cable.

Instructions for Using the Data (For plotting Bounce number against Bounce Height)

1. Insert a Lists & Spreadsheet page.
    a. Highlight the formula cell of column A and press the **VAR** key.
    b. **Link To** (select #3) **dc01.time.**
    c. Move to the formula cell of column B and press the **VAR** key.
    d. **Link To** (select #3) **dc01.dist1.**
2. Columns A and B should have been filled with the collected data at this point.
3. The following instructions are for inverting the data so as to show the height of each bounce:
    a. Tab over to the top cell in Column C and name it *lheight* for the list variable giving the height of the ball.
    b. Move down to the Formula Cell of column C and type "=" and then the height of the CBR2 from step 4a above, followed by the minus sign "-" and then press the **VAR** key to select **dc01.dist1** from the list of variables. Press enter. You should see something like the following in the formula cell of column C: **lheight:**=2.05-'**dc01.dist1** and data should appear in the column.
4. Insert a new **Graphs & Geometry** page (should be page 1.4).
    a. Change the **Graph Type** to **Scatterplot** (**Menu**->**Graph Type** (3)->**Scatter Plot** (4))
    b. For the x-variable choose **dc01.time.** For the y-variable choose **lheight**. Press enter.
5. A scatter plot showing your inverted parabolas (like a series of decreasing bounces) should appear.
    a. Adjust the viewing **WINDOW** by doing **Menu**->**Window**(4)->**Zoom Data**(9)
6. The next step is to indicate the vertex of each parabola by placing a point at the max position: press **Menu**->**Points & Lines**(6)->**Point On**(2).
7. Move your cursor to the vertex of the first parabola and click to drop a point on the vertex. Do the same for each of the first 5 or 6 parabolas. You should end up with 5 or 6

coordinates somewhere close to each of the vertices of the parabolas. You may need to move these coordinates to see each of them clearly. Make sure they are in order of height.

8. The next step is to store each of the y-coordinates of these points into a series of variables called **bh1, bh2, bh3,** etc. for bounce height 1 etc.
    a. Move your cursor over the y-coordinate of the highest point. Your cursor should change to a hand and the "text" label should appear. The y-coordinate should be flashing in faded mode.
    b. Press the **VAR** key and **Store** this value in **bh1**. The y-coordinate value should turn **bold.**
    c. Repeat a) and b) for each of the successive y-coordinates in descending height order.
9. Go back to your Lists & Spreadsheet page (page 1.3).
    a. Label column D *lbouncenum*
    b. Enter the values 1, 2, 3, 4, 5 (and 6 possibly) in the cells going down the column (these are the bounce numbers).
    c. Label column E *lbheight.*
    d. Move your cursor to cell E1 and type "=" and press the **VAR** key. Select **bh1**. The value of the height of the first bounce should appear in the cell.
    e. Repeat for each of the succeeding bounces in cells E2-E5 (and possibly E6) using the appropriate **bh** variable (i.e. **bh2-bh5** or 6).
10. Go forward to page 1.4 and insert another **Graphs & Geometry** page.
    a. Change the **Graph Type** to **Scatterplot** (**Menu**->**Graph Type** (3)->**Scatter Plot** (4))
    b. For the x-variable choose **lbouncenum.** For the y-variable choose **lbheight**. Press enter.
    c. You should see a plot of your 5 (or 6) data points.
11. Change the **Graph Type** to **Function** and try fitting a function to pass through each of these data points. You may need to change the **Window** setting to zoom into your points. You can also insert sliders for the parameters of your function. Think about the shape of the data plot and the situation. What kind of function would behave in the way your successive bounce heights behave? What would be the height of the bounce eventually? Use your fitted function to estimate the "bounce-coefficient" of the ball.