Experiments with the TI-92 and CBR

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Experiment One: What Goes Up

1. Form in groups. Connect the Calculator-Based Ranger (CBR) to the TI-92 with the unit-to-unit link cable. Push in the cable firmly at both ends. Make sure the TI-92 is on the home screen. Open the pivoting head on the CBR and press the oval program-transfer button labeled TI-92 to transfer the RANGER program . If you were successful, you will hear a beep from the CBR and see it flash a green light.

2. Run the RANGER program. Follow the directions to get to the MAIN MENU screen. Choose SETUP/SAMPLE. For this experiment the settings should be:

Realtime:	No
Time (S):	2
Display:	Distance
Begin On:	[ENTER] Key
Smoothing:	Light
Units:	Meters

3. Once the settings are correct, choose START NOW and press ENTER for the next screen of directions. Drop an object on top of the CBR (an open box dropped upside-down works well) to produce a plot such as in Figure 1-1. Give a countdown so that the object is released at the same time the ENTER button is pressed. Once satisfied with your plot, exit the program. Press Graph and store the current Window settings in the Zoom memory using **ZoomSto**.

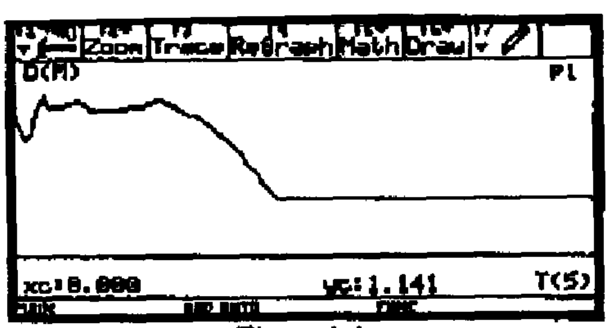


Figure 1-1

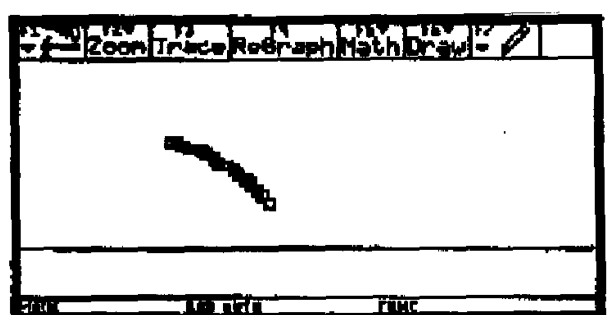


Figure 1-2

4. Run RANGER again, choosing *1:Distance-Time* to view the plot. Press ENTER and choose the *4:Plot Tools* to *1:Select Domain* to isolate only the quadratic portion of the graph. (Note that RANGER then changes the window.) Press ENTER, choose *7:Quit* and perform a **ZoomRcl**. Revise Plot1 from the Y= menu so that the Plot Type is *Scatter* and the Mark is *Box*. You will now have a plot similar to Figure 1-2.

5. Go to the home screen. Enter **QuadReg** L1,L2 to find the best-fitting parabola through the points. Enter **ShowStat** to see the results. Then dump the contents of *Regeq*(*x*) into *y1*(*x*) using 2nd [RCL]. Press Graph to see something like Figure 1-3.

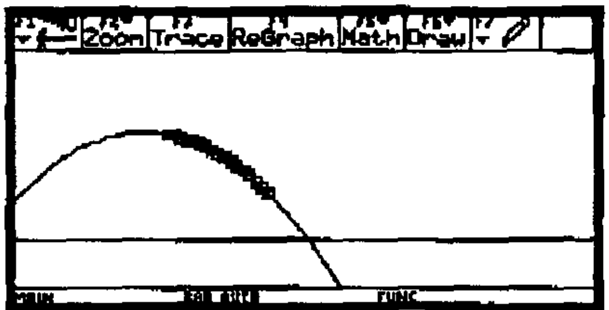


Figure 1-3

6. We want to make a transformation so that at time $x = 0$ the object is at its maximum height. We will do this in two ways and then compare results. If $a = regCoef[1]$, $b = regCoef[2]$, and $h = -b/(2a)$, then h is the x-coordinate of the vertex of the best-fitting parabola in Figure 1-3. We must shift the data in Figures 1-2 and 1-3 h units to the left.

7. **Method 1:** ***Using NewPlot and Regression*** For the plot in Figure 1-2, time data is stored in L1, distance in L2. We create a new list *Ltime*, where *Ltime* = L1– *h*, plot a second Distance-Time graph using *Ltime* and L2 (see Figure 1-4) using the **NewPlot** command. We then find the best-fitting parabola through the translated data (see Figure 1-5) as in Step 5, and store its equation in *y2*(*x*). Discuss the similarities and differences between *y1*(*x*) and *y2*(*x*). Why would you expect *y2*(*x*) to have no *x* term? Discuss the coefficients of determination for each regression.

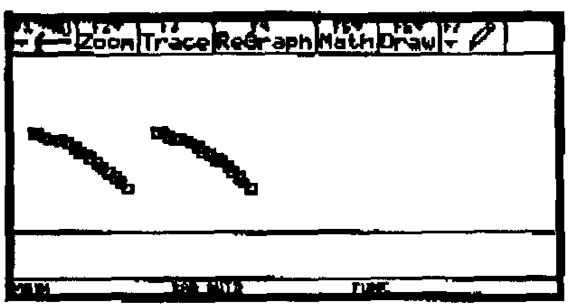


Figure 1-4

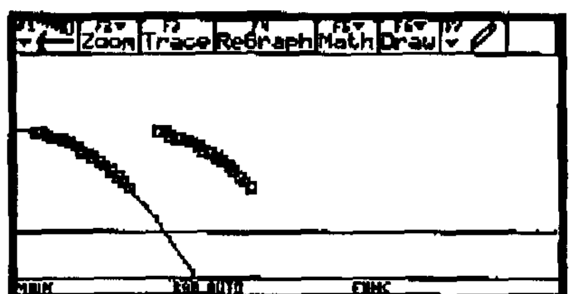


Figure 1-5

8. **Method 2:** ***Using the Y= Editor and CAS*** Secondly, use the CAS of the TI-92 to expand *y1*(*x*+*h*) and then store this in *y3*(*x*). (Why *y1*(*x*+*h*) as opposed to *y1*(*x*–*h*)?) What do you observe about *y2* and *y3*? Clear your variables and expand the right side of $y = a(x + h)^2 + b(x + h) + c$, followed by a replacement of h by $-b/(2a)$. Voila! Does this look familiar? Use **comDenom**(to manipulate the form of this expression and set it equal to zero for a pleasant result.

EXTENSION: If possible, save the series of earlier commands to a script and repeat, this time dropping the object away from the CBR and comparing the nature of the coefficients. You may wish to set the CBR to begin on Trigger when dropping an object away from it. This experiment helps relate Newton's position equation with the concept of transformations and the meaning of the quadratic formula.

Experiment Two: Ball Bounce

1. Again work in teams, dropping a ball under the CBR to produce a graph such as in Figure 2-1. Run RANGER, choosing *3:Applications, 1:Feet*, or *2:Meters* and *3:Ball Bounce*. Position the CBR at least 1.5 feet above the highest bounce to get good data. (Observe that the Ball Bounce application flips the data.)

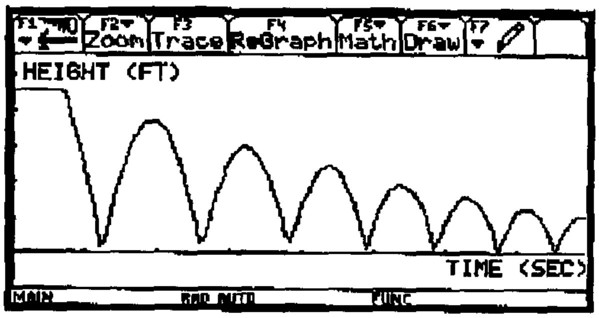


Figure 2-1

2. Use Trace to capture the x- and y-coordinates of the vertices of the parabolas and store them in the lists *tball*, *hball*, respectively. See Figure 2-2. We have labeled the bounces #0 - #6. Create a scatter plot of these vertices as in the figure.

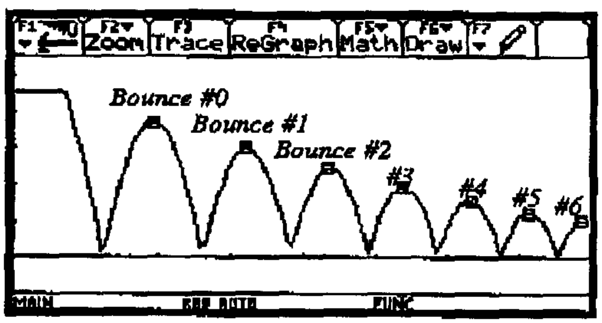
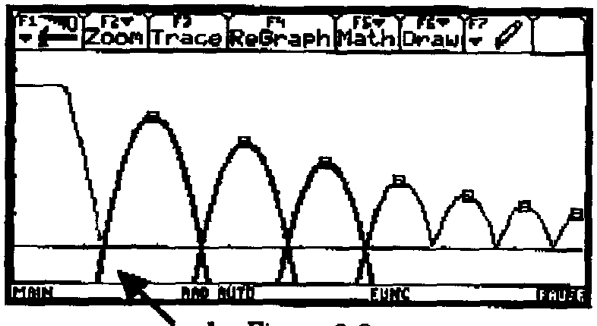


Figure 2-2

3. Draw the graph of $y1(x) = -16(x\text{-}tball)^2 + hball$ on top of the plot as in Figure 2-3. Using the unique features of the TI-92, we will find the equation for the path of *Bounce#–1* or *Bounce #7*. First, find the leftmost zero *r1* of the parabola for *Bounce #0* (see Figure 2-3) using the command: **zeros**$(-16(x\text{-}tball[1])^2 + hball[1],x)$.

Contents



r1 Figure 2-3

4. Meanwhile another team member uses their TI-92 to find the maximum height, *kneg1*, of *Bounce #–1* by running an exponential regression on a plot of Bounce Height vs Bounce #. (See Figure 2-4). Since *r1* and *kneg1* are determined and, theoretically, the parabolas of Figure 2-3 intersect at their zeros, we can easily find the x-coordinate hneg1 of the vertex for *Bounce #–1* using the solve command: **solve**$(-16(r1\text{-}hneg1)^2 + kneg1=0, hneg1)$.

Figure 2-4

5. We now have the equation for *Bounce #–1*, namely $y2(x)=-16(x\text{-}hneg1)^2 + kneg1$ (See Figure 2-5). Similarly, you can save this session to a script and repeat to find the equations and graphs for Bounce #7, 8, ... or Bounce #–2, –3, ..., adjusting the viewing window accordingly.

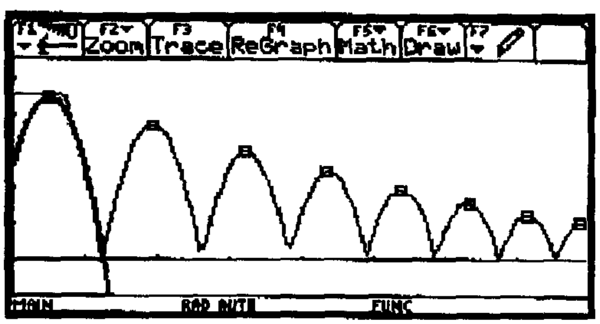


Figure 2-5

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Students and teachers alike have thoroughly enjoyed both of these experiments, which involve some rich mathematics easily made possible by the TI-92.