Basketball Coach

Scott Campbell
TAMUK
campbel7@fnbnet.net

Introduction

Galileo had to use his pulse to measure time and he determined that the acceleration due to gravity was constant on the surface of the Earth. We will obtain range data from a bouncing ball and then use this data to calculate the acceleration due to the gravity of the Earth. This lab uses a CBL Motion Detector or a CBR to measure distances. The data can easily be collected in 15 to 20 minutes and distributed to the students for their analysis and conclusions. This experiment offers an excellent opportunity to explore the mathematical description of an object in free fall and then use this to verify a well known physical constant. Knowledge of Algebra is a prerequisite.

Setup

Equipment Required:

- CBL unit
- TI-89 graphics calculator with a unit-to-unit link cable
- TI CBR unit or CBL Motion Detector
- Chair or stand
- Basketball

Clamp the CBL or CBR to the back of the chair or to the stand so that it is three to four feet off the floor. Point the detector towards the floor.

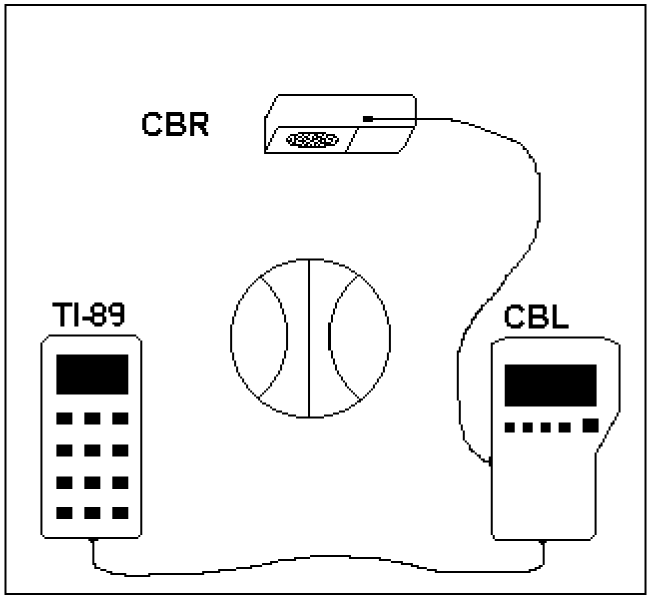

Figure 1: Equipment Setup

Equipment Setup Procedure

Connect the equipment as shown by Figure 1:

1. Connect the CBL unit to the TI-89 calculator with the unit-to-unit link cable using the I/O ports located on the bottom edge of each unit. Press the cable ends in firmly.

2. Connect the CBR unit to the motion detector channel (SONIC) on the left side of the CBL unit.

3. Attach the CBR unit to the chair back or to the stand so that it is $3\frac{1}{2}$ to 4 feet above the floor. It must be high enough for the basketball to bounce directly beneath it, but not too high or the ball will bounce out of the side range of the unit.

4. Turn on the CBL unit and the calculator.
The CBL system is now ready to receive commands from the calculator.

Program Listing

This experiment requires that you download or enter the **BOUNCE.89P** and the **CUTDATA.89P** programs listed in the appendix into your TI-89 calculator.

Collect the Data

1. One student should hold the basketball directly beneath the CBR unit.

2. Make sure the CBL is turned on. Start the program **BOUNCE** on the TI-89.

3. The program will then prompt:
 Press ENTER to collect
 data as you release
 the ball

4. The student who is releasing the basketball must try to release the ball so that it will make several bounces directly beneath the CBR unit. Several tries may be required.

5. After the data is collected, a plot of range (in ft) vs. time (in seconds) appears on the calculator screen. The plot should look similar to the one shown in Figure 2. Make a printout of this graph using TI-GRAPH LINK or save it as a PIC variable to be printed later. Attach this printout to your worksheet. Be sure to include appropriate scales and axis labels on the printout The data is saved in lists L_4 (range) and L_2 (time). It would be prudent to save these lists to lists with new names, perhaps B1 and B2, as subsequent experiments will erase L_4 and L_2.

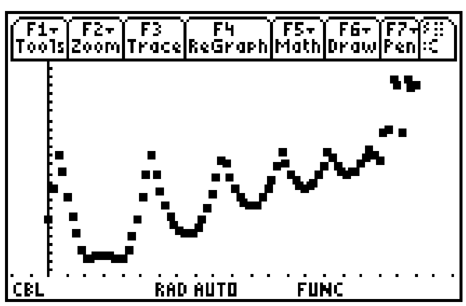

Figure 2.

6. Notice that the data seems upside down. It doesn't look like a bouncing ball because as the ball falls to the ground the distance from the detector increases. Some further work is necessary.

Analyze the data

How can we use the data gathered by the **BOUNCE** program be used to determine the acceleration due to gravity? We will use the power of the TI-89 to help us answer this question.

If the data collected is examined carefully we can see that it represents range to the ball as a function of time. From the equations of kinematics, we know that the vertical position as a function of time of a body in the Earth's gravitational field is given by:

$$y = \frac{1}{2}gt^2 + v_0t + x_0$$

Since g is a constant with an approximate value of $-32\,ft/s^2$ the graph of this equation is a parabola that opens down. We will try to match our data to the equation of a parabola and see if we can verify the value for g.

Procedure

1. We will let the calculator do some of the work for us. Run the program **CUTDATA** to convert the data. After the data is converted, a scatter plot of the (L_2, L_4) data appears on the calculator screen. The program takes two parameters, b and n. **CUTDATA**$(\boldsymbol{b}, \boldsymbol{n})$ cuts b points off the beginning of the data set, n points off the end of the data set and flips the data vertically. A printout of one run of **CUTDATA** with $b = 15$ and $n = 8$ (from our example) is shown in figure 3.

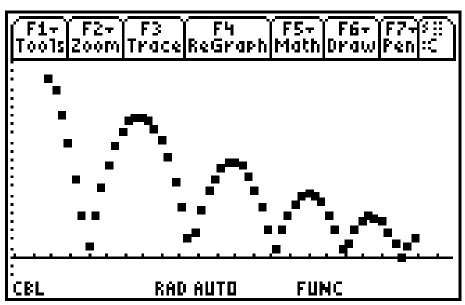

Figure 3.

2. Carefully use **CUTDATA** repeatedly to cut out one of the parabolas in the graph. You must use it an even number of times to maintain the vertical orientation. If you just want to flip the data vertically then run **CUTDATA** with $b = 0$ and $n = 0$. Continue until you have a graph resembling figure 4.

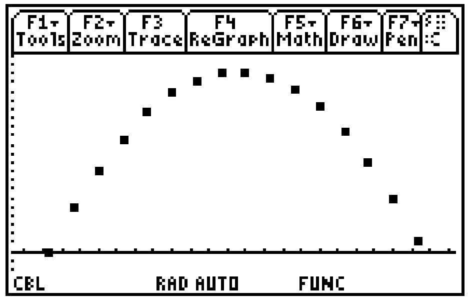

Figure 4.

3. Make a printout of this graph using TI-GRAPH LINK or save it as a PIC variable to be printed later. Attach this printout to your worksheet. Be sure to include appropriate scales and axis labels on the printout The data is saved in lists L_2 and L_4. It would be prudent to save these lists to lists with new names, perhaps B3 and B4, as subsequent manipulations or experiments will erase L_2 and L_4.

Analysis and Conclusion

1. Can we find the equation of a parabola that best fits this data? We will use the built in curve fitting capability of the calculator to answer this question.

2. Perform the regression calculation.

– From a screen that looks like figure 4 press $[APPS]$ $6 : Data\text{-}Matrix$ $Editor$ $2 : Open$ and select $Variable : stat$. The $stat$ data variable was already filled with the latest L_2 and L_4 lists each time **CUTDATA** was run. Your screen should look like figure 5.

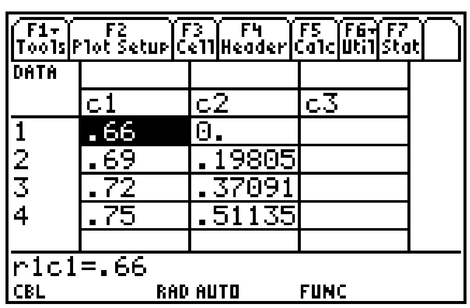

Figure 5.

– Press [F5-*CALC*] to do a calculation based on the data.

– For a quadratic regression press the right arrow once to reveal the menu of regression choices and then scroll down to $9 : QuadReg$. Press [ENTER].

– Now select the x and y variables by putting $c1$ in the x space and $c2$ in the y space.

– Now select $Store\ RegEQ\ to \rightarrow y1(x)$.
– When the screen looks like this:

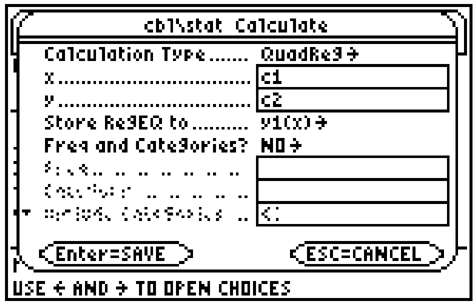

Figure 6.

Press [ENTER] and the regression results will appear like this:

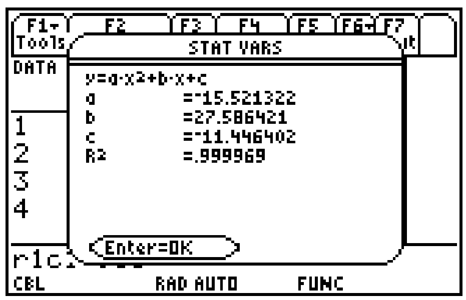

Figure 7.

– Note the value of a. It should be a number very close to -16 since this is the value $\frac{1}{2}g$ in our corresponding kinematics equation.
– We don't need to copy down the equation because we stored it in $y1(x)$ for easy access.
– We can graph the parabola over our data to visually check the fit of the equation. Press $[ENTER]$ and then $GreenDiamond + [GRAPH]$. Your screen should appear as figure 8.

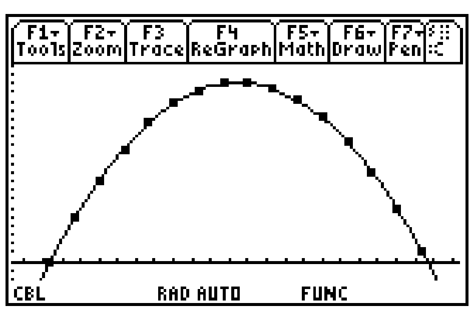

Figure 8.

BOUNCE

```
Prgm
80»n
.03»i
{3,i,n,0}»l1
ClrHome
ClrDraw
ClrIO
Send {6,0}
Send {1,0}
Send {1,11,3}
newList(n)»l2
newList(n)»l4
Disp "Press ENTER to collect"
Disp "data as you release"
Disp "the ball"
Pause
Send l1
For x,1,n
(x-1)*i»l2[x]
EndFor
Get l4
NewData stat,l2,l4
NewPlot 1,1,l2,l4,,,,4
ZoomData
DelVar l1,x,n,i
EndPrgm
```

CUTDATA

```
Prgm
(b,n)
Prgm
Local i,dd,l3,l5
dim(l2)-b-n»dd
newList(dd)»l3
newList(dd)»l5
For i,1,dd
l2[i+b]»l3[i]
l4[i+b]»l5[i]
EndFor
l3»l2
l5»l4
max(l4)-l4»l4
NewData stat,l2,l4
NewPlot 1,1,l2,l4,,,,4
ZoomData
EndPrgm
```