

“How-To”
With Your TI-84 Plus CE
Graphing Calculator
Part 3

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This handout and related accessories (programs, image files, graphical databases) can be downloaded at <http://users.pfw.edu/lamaster/technology> if you scroll to the presentation *Create Silent Movies to Model the Real World*, 29th Annual T³ International Conference, Chicago, IL, March 11, 2017. On this page you can also get links to Part 1 and 2 of this Webinar Series.

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Lights! Camera! Action! – Three Ways to Produce Movies on the TI-84 Plus Family Calculator

1. Live Action

Using parametric mode, many classical story problems from traditional algebra and precalculus textbooks can be brought to life by entering the settings in four menus: Mode, Format, Y=, and Window. In the activities *Harry and Sally* and *Batman and the Joker*, the teacher directs the activity from the display calculator live before the class (with some prior setup). Students mathematize the problem to tell the teacher what value of T_{max} will stop the movie to show when the main characters meet. The activity *Ditch Diggers* is similar. The student activity *Alexander Hamilton and Aaron Burr* is designed so the settings could be entered by the students to create the movie.

2. Function Transformations and Graph Styles saved with a Graphical Database (GDB)

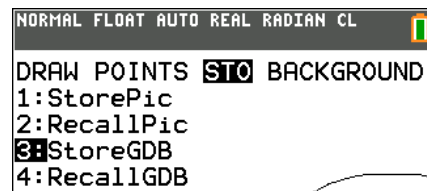
A graph database (GDB) stores the set of elements that defines a particular graph. You can recreate the graph from these elements. You can store up to 10 GDBs in variables GDB0 through GDB9 and recall them to recreate graphs.

A GDB stores five elements of a graph

- Graphing mode
- Window variables
- Format settings
- All functions in the Y= editor and the selection status of each
- Graph style for each Y= function

GDBs do not contain drawn items (created from the Draw Menu) or stat plot definitions.

Use 2nd Draw and press the right arrow to the STO menu to enter the command **StoreGDB 1** on the Home Screen to store GDB 1. To recall it, enter the command **RecallGDB 1**.



Some disadvantages with GDB's:

- Limited to 10 GDB's. However, you can store them in a group file, and there is no limit to the number of group files you may have (up to calculator memory).
- It is easy to accidentally overwrite a GDB by storing a new one over an existing one.
- Cannot be given descriptive names so it is difficult to know what is in it.
TIP: When you store them onto a computer, you can rename the file.
You can assign a name to each GDB and then create a program to index them.
- While GDBs store most Mode and Format settings, it does not store Degree vs Radian Mode. Some examples using GDB's are *Bus Chase*, *Falling Objects on Different Planets*, *Home Run?* and *Roller Coaster*.

3. Use a program

There is no limit to the number of programs you may have (up to calculator memory) and these can be given somewhat descriptive names. Much more control is possible, in particular, setting mode to Degree or Radians, computer generated imagery (CGI) such as random animated fireworks and flashing lights (*Math 99 Animated Movie*) or replaying automatically using an infinite loop (*Math 99 Animated Movie* and *Spotlight Crawling on a Wall*).

Harry and Sally

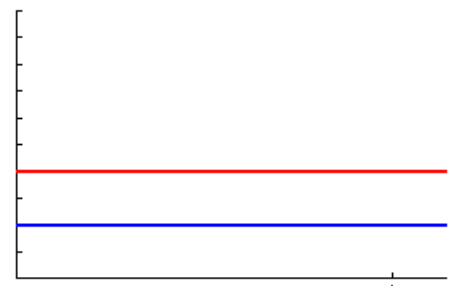
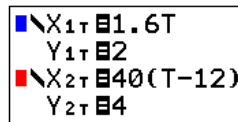
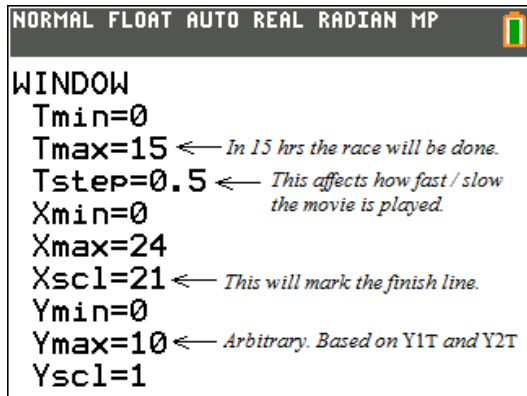
Adapted from an Algebra 1 Textbook: Harry the Hare and Sally the Tortoise have a race. Sally travels at a slow but steady speed of 1.6 mph. Harry travels at constant speed of 40 mph, but gives Sally a 12 hour head start. If the finish line is 21 miles away, who will win the race?

We will make a silent movie of this scenario to bring this iconic fable to life. Let Harry travel along the line $y = 4$ and Sally travel along the line $y = 2$.

- Press MODE.
Highlight parametric mode and simultaneous graphing.



- Press WINDOW and enter these settings. Press Y= and enter these equations. Press GRAPH.



Use the 21 mile marker for the finish line.

A Look Behind the Scenes: What is happening?

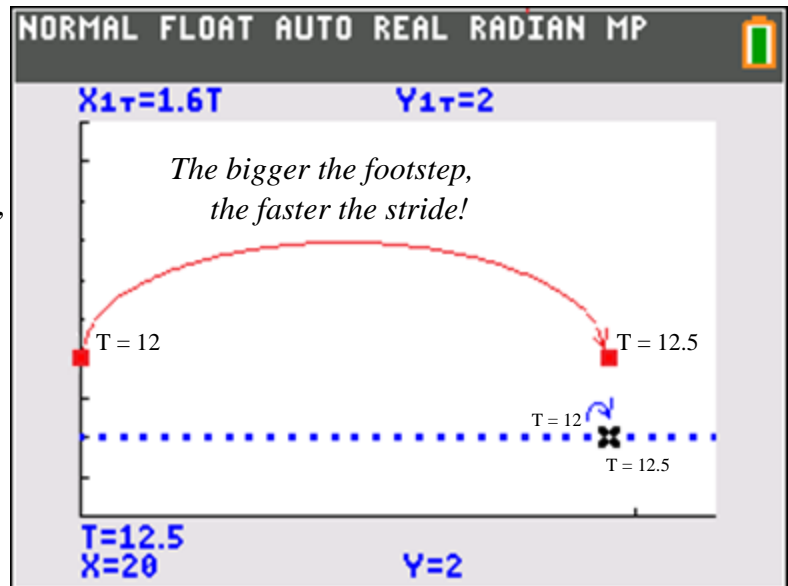
Press MODE, highlight DOT-THICK.

Press GRAPH. Press TRACE and >.
Type 12 to jump to T = 12 hours.

Press ; to move between graphs.
In THICK (or CONNECTED) Graphing, the TI-84 connects these dots with lines.

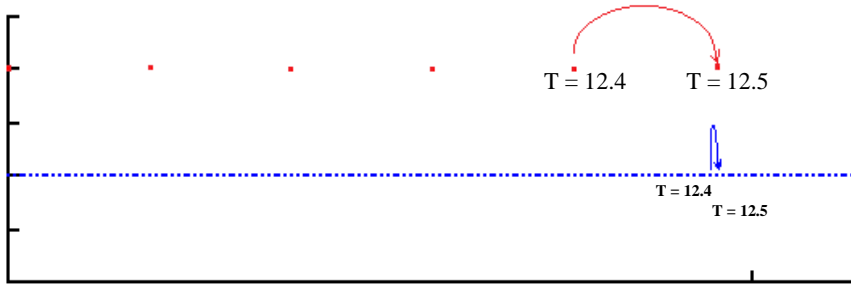
Footsteps for each graph are connected simultaneously, so Harry will graph remarkably faster than Sally.

Lowering Tstep adds more footprints.
This will slow down the action.



In Dot mode, TRACE from T = 12 to T = 12.5 with TStep = 0.5. Compare the leaps between footprints for the Hare and the Tortoise.

Set Tstep = 0.1. The distance between footprints is smaller and more footprints appear.



In Dot mode, TRACE from T = 12.4 to T = 12.5 in steps of TStep = 0.1.

Class Activity: Use the movie to heighten student engagement

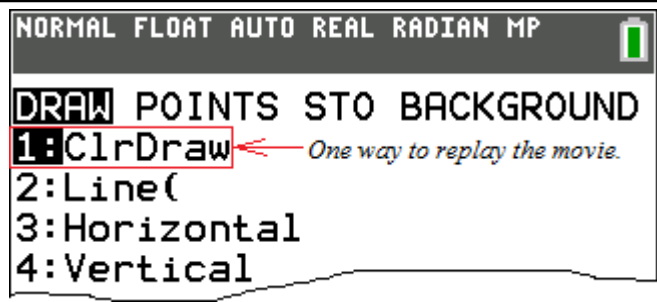
Set up your calculator as in Step 2 (with THICK or CONNECTED and Tstep = 0.5).

Present the problem to students. Display to the class the movie on your calculator.

(Students are not using their calculator in this activity to create the movie.)

TIP: To replay the movie without disclosing the formulas in the Y= Editor

1. Press GRAPH
(if not already on the Graph Screen).
2. Press DRAW.
3. Press 1:ClrDraw.



- Who won? Set Tstep = 0.05 to slow down the movie. Press GRAPH.
- Find when they meet, i.e., *When Harry met Sally* 😊
Replay and ask the class to tell you when to pause the action when they meet (by pressing ENTER).
(This usually is not easy without Jedi skills.)

Easier: Have the class write formulas for each racer and solve equations algebraically:

$$1.6t = 40(t - 12)$$

$$1.6t = 40t - 480$$

$$38.4t = 480$$

$$t = \frac{480}{38.4} = 12.5$$

Assign Tmax = 12.5, Tstep = 0.5, and press GRAPH.

- *Optional:* ask the class to generate additional questions.

- At what mile marker did they meet?

Answer: 20 miles

- How long did it take each to cross the finish line?

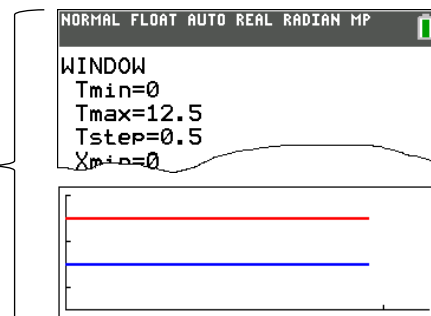
Answer: Sally took 13.125 hr = 13 hr, 7.5 min;

Harry took 12.525 hr = 12 hr, 31.5 min

- What are the values of t for which Harry is in the lead? How many seconds is this?

Answer: From $t = 12.5$ to $t = 12.525$.

This was the last 0.025 hr = 1.5 min = 90 seconds of the race!



Batman and the Joker

This problem is similar to the Harry and Sally problem in that you can direct it from the Teacher Calculator while engaging students in the discussion.

Batman is traveling 200 mph due East when he sees the Joker coming directly toward him 27 miles away, traveling at 70 mph West. How long until they meet?

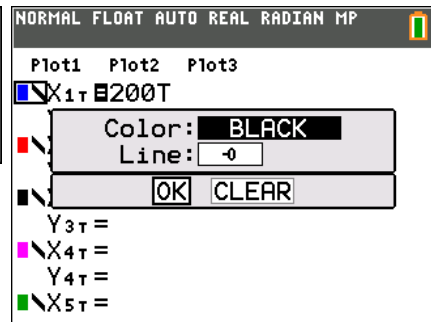
1. Set up your TI-84CE.
Highlight parametric mode and simultaneous mode.

2. Press Y= and enter these equations:

```

-0X1T B200T
Y1T B4
-0X2T B27-70T
Y2T B4
    
```

Optional: Use the spinner to change graph color (Black/Magenta) and graph style (Path).



3. Set the window.

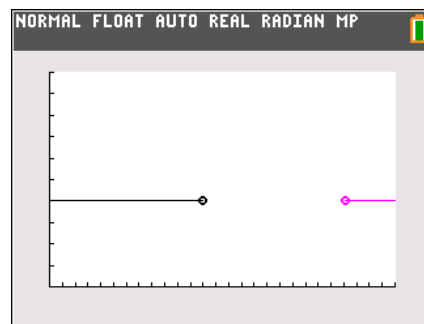
```

Tmin=0
Tmax=0.2 (Set Tmax to be the length of time, in hours, you want to see them driving)
Tstep=0.005 (adjust Tstep to taste; the higher the Tstep, the faster the movie.)
Xmin=0
Xmax=27 (set Xmax to be the initial distance they are apart.)
Xscl=1
Ymin=0
Ymax=10
Yscl=1
    
```

Change the above movie to play for Tmax = 0.05 hours (or consider using 60ths of an hour) Show the class that the movie stopped too soon. Bummer.

4. Now ask, “When shall I stop the clock so that the movie ends **exactly** when they meet?” Students set up the equation $200t = 27 - 70t$ and solve for t algebraically.

5. Once the solution $t = 0.1$ is found, change Tmax = 0.1. Press GRAPH to replay.



Here’s another one, similar to the above:

Batman’s speed is 185 mph, Joker’s speed is 55 mph and they are initially 60 miles apart.

Alexander Hamilton and Aaron Burr

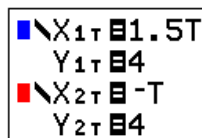
Alex and Aaron meet on the dueling ground, each holding a Super Soaker water pistol. They stand back to back and simultaneously walk until they are 20 ft apart. Alex walks 1 ft per sec West, while Aaron (a bit jittery) walks 1.5 ft per sec East. How many seconds before the distance between them is 20 ft?

First set up your TI-84CE to simulate and explore.

- Highlight parametric mode and simultaneous mode.



- Press $Y=$ to enter equations.



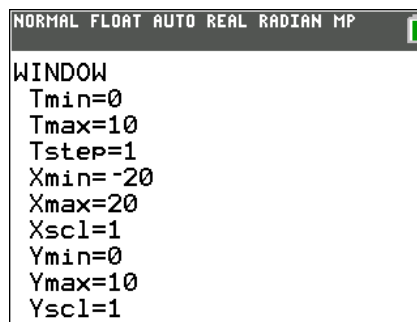
- After 10 seconds, how far apart are they? ____ ft

Aaron Burr walked _____ ft.

Alex Hamilton walked _____ ft.

Press WINDOW and use these settings.

You can confirm with TRACE or a TABLE.



- In t seconds, how far apart are they? _____ (Your answer involves t .)

Aaron Burr walked _____ ft. (Your answer involves t .)

Alex Hamilton walked _____ ft. (Your answer involves t .)

- Write an equation to determine the value of t which makes their distance apart equal to 20 ft. Solve the equation. Set T_{max} equal to this value of t and press GRAPH.

Complete:

They are 20 ft apart in $t =$ ____ seconds;

Aaron Burr walked _____ ft and Alex Hamilton walked _____ ft

Ditch Diggers

Dan Meyer incorporates video at <http://threeacts.mrmeyer> to teach with three-act math tasks. (See <http://blog.mrmeyer.com/2011/the-three-acts-of-a-mathematical-story/> for his approach.)

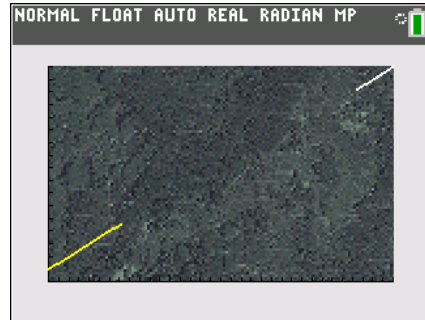
Act One:

Introduce the story/task using as few words as possible.

In this example:

Two ditch diggers start digging towards each other from opposite directions.

The three acts for this movie are available at <http://threeacts.mrmeyer.com/ditchdiggers/>; however, this movie can be simulated on the TI-84 Family calculator.



See *Dig In to the Real World with the TI-84 Plus CE* at <http://users.ipfw.edu/lamaster/technology/> from the 27th Annual T³ International Conference for details on how to incorporate the calculator into this activity.

Act Two: Coordinates are given for Digger 1 (X_{1T} , Y_{1T}) and Digger 2 (X_{2T} , Y_{2T}) for the first five days to develop the following formulas:

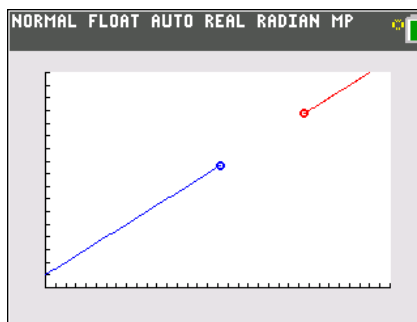
```
NORMAL FLOAT AUTO REAL RADIAN MP
Plot1 Plot2 Plot3
■ X1T 2T
  Y1T T+2
■ X2T 68-T
  Y2T 34-.5T
```

```
NORMAL FLOAT AUTO REAL RADIAN MP
WINDOW
Tmin=0
Tmax=28
Tstep=.2
Xmin=0
Xmax=68
Xscl=2
Ymin=0
Ymax=34
Yscl=2
```

Act Three: Complete the task. Set up a sequel/extension. Spoiler: The diggers do not meet.

Prequel?

```
NORMAL FLOAT AUTO REAL RADIAN MP
Plot1 Plot2 Plot3
■ X1T 2T
  Y1T T+2
■ X2T 68-T
  Y2T 36-.5T
```



Bus Chase

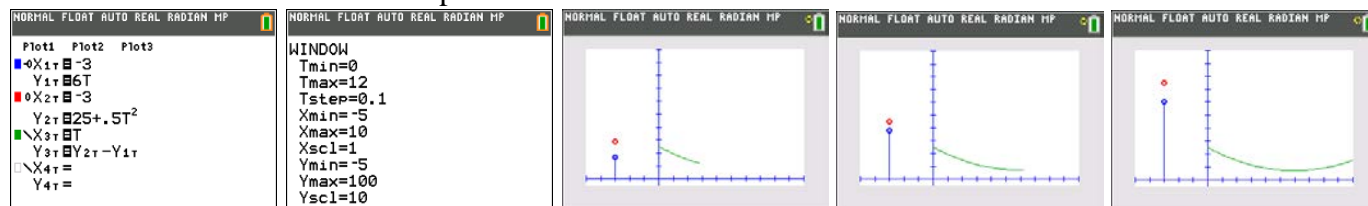
This problem was published in COMAP Consortium Number 42 in Summer 1992.

A man who is late for work is approaching a bus. When he is 25 meters from the bus it starts to pull away with an acceleration of 1.0 meter per second per second. He sees this and begins to run at 6 meters per second. Will he catch the bus? If not, how close will he come?

First we will represent the position of the man and the bus (relative to the man's starting point) on vertical lines on the screen. After t seconds the man's distance from his starting point is $6t$ and the bus's distance from the man's starting point is $25 + 0.5t^2$.

1. Use X_{1T} and Y_{1T} to represent the man's motion and X_{2T} and Y_{2T} to represent the bus's motion. Make the man and the bus move on the vertical line $x = -3$. Set the equations and the window to do this. Use SIMUL mode. Use O Line Style for the bus and dotted line style for the man.
2. Trace to see if he catches the bus.
3. Graph the distance between the bus and the man versus time t . To do this let $X_{3T} = T$ and $Y_{3T} = Y_{1T} - Y_{2T}$. Keep the window set so that you can see the vertical motions and the plot of Y_{3T} .

Screenshots from the **Bus Chase** problem:



Falling Objects on Different Planets

Teacher: "Three balls will be dropped from a height of 100 meters on each of the planets, Mars, Earth, and Jupiter."

Show the TI-84 movie of the balls dropping. Do not show formulas yet.

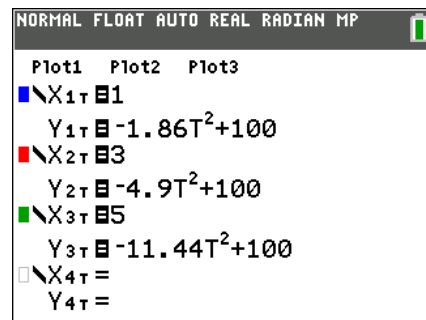
"Discuss in your groups:

What is similar about each? What is different?

Which planet goes with which graph?"

Prior to class set up the calculator using the screens to the right.

A GDB is an excellent way to have this ready to go for class.



Students may bring up the following similarities:

- Each has the same initial height.
- As they fall, they move faster and faster.

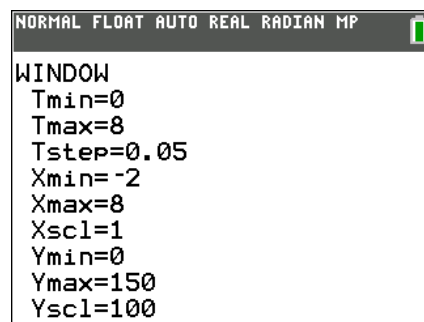
Students may bring up the following differences:

- Length of time to drop.
- Rate of acceleration.

Match:

The slowest is Jupiter, fastest is Mars, and Earth is in between.

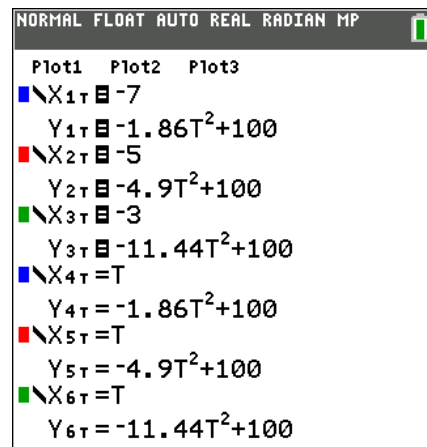
The larger the planet's mass, the larger the acceleration due to gravity.



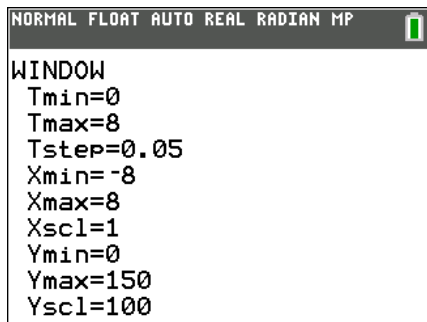
Optional (based on the level of your students): Help students construct the formulas for each.

Falling Objects on Different Planets (Alternative)

Based on students' level, interest, or available class time, the previous activity can be extended. Instead of setting up the calculator with only the three balls dropping, use the screens to the right, where the last three graphs are deselected (not highlighted) and use the more expanded viewing window $-8 \leq x \leq 8$.



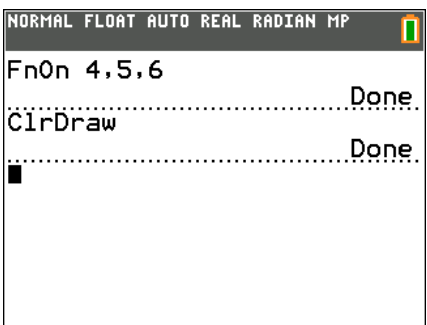
As before, play the movie while asking students to find similarities, differences, and to match the planet with the graph.



Enter the command **FnOn 4,5,6** to turn on the last three functions without disclosing their formulas in the Y= Editor.

(Use VARS Y-VARS 4:On/Off to paste the FnOn command on the home screen.)

Press DRAW 1:ClrDraw to refresh the movie and press GRAPH.



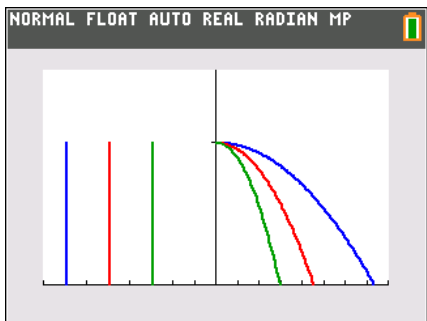
Production Tip: If you select ClrDraw immediately from leaving the Graph Screen it will immediately redraw. If you select it from any other menu, the command is pasted on the Home Screen and you must then press GRAPH to refresh the screen.

Provide these three formulas: $a(t) = -1.86t^2 + 100$,

$$b(t) = -4.9t^2 + 100,$$

$$c(t) = -11.44t^2 + 100$$

Now ask students to match the formula to the planet and explain their reasoning. Students may connect the planet with the time it takes for the ball to hit the ground (which now you can ask them to find, if class time permits). Other students may point out the leading coefficient has vertically stretched or compressed the graph and affects the rate at which the ball is falling.



Yet even another approach: Instead of providing the formulas, ask students to construct a formula for $h(t)$, the height of the ball above ground in t seconds for each planet if $h(t) = \frac{1}{2}gt^2 + h_0$, where g is the acceleration due to gravity and h_0 is the initial height. For Mars, Earth, and Jupiter, $g = -3.72, -9.8,$ and -22.88 meters per sec^2 , respectively.

Home Run?

Adapted from a problem by Mike Koehler published in the Fall 1993 issue of *Eightysomething!*

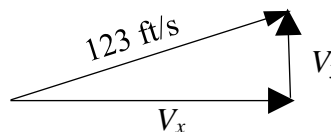
The “Green Monster,” the left field wall in Fenway Park in Boston is 37 feet high. Its distance from home plate is 379 feet. A baseball is hit by a Boston Red Sox player when it is 3 feet from the ground with an initial velocity of 123 feet per sec at an angle of elevation of 32° .

A wind of 3 mph (4.4 ft per sec) is blowing towards the batter. The ball is on a path that will take it to the deepest part of the Green Monster, 379 feet away. Is it a home run?

The initial force is resolved into horizontal (x) and vertical (y) components using trigonometry.

$$V_x = 123\cos 32^\circ$$

$$V_y = 123\sin 32^\circ$$



The horizontal parametric equation is $X(t) = V_x T + W$, where V_x is the horizontal component of the initial velocity, T is the time, and W is the other horizontal forces working, such as the wind.

The vertical parametric equation is $Y(t) = -16T^2 + V_y T + S_0$, where V_y is the vertical component of the initial velocity, T is the time, and S_0 is the starting height.

Enter the equations:

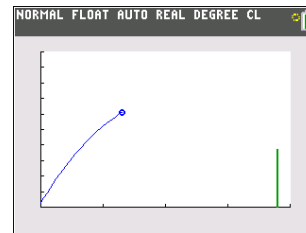
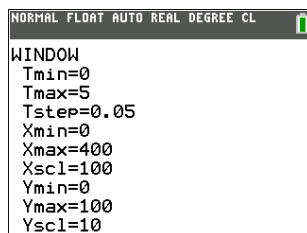
The ball: $X_1 T = 123\cos(32^\circ)T - 4.4T$
 $Y_1 T = (-16T^2 + (123\sin(32^\circ)T + 3)) / (T < 3.85)$

The wall: $X_2 T = 379$
 $Y_2 T = 37T (T \leq 1)$

The quantity $(T < 3.85)$ is 1 if true, 0 if false.
 A division by 0 occurs for $t \geq 3.85$, so the domain is restricted to $t < 3.85$.

The quantity $(T \leq 1)$ is 1 if true, 0 if false.
 The wall will rise from the ground until, when $t = 1$, its height is 37 ft. and thereafter rise no more.
 For $t > 1$ the height of the wall is 0.
 The multiplication of $(T \leq 1)$ creates a line connecting $(379, 37)$ to $(379, 0)$ when $t = 1$.

Press WINDOW. Use the settings shown.
 Press GRAPH.



The graph of $Y_3 T$ has a restricted domain of $t > 3.8$. After playing the movie, you can see what it does!

$X_3 T = (758 - X_1 T) / (T \geq 3.80)$
 $Y_3 T = (-16T^2 + (123\sin(32^\circ)T + 3)) / (T \geq 3.80)$

The graph of $Y_4 T$ is just for fun. Position your cursor over the = sign, press ENTER to highlight it, and press GRAPH.

$X_4 T = 14\cos((2880T)^\circ) + \{500, 325, 015, 030, 115, 075\}$
 $Y_4 T = 7\sin((2880T)^\circ) + \{88, 85, 85, 70, 87, 72\}$

Store this into a GDB to recall later.

Roller Coaster

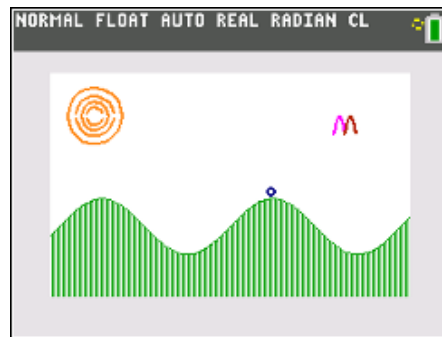
Animations can be done using Graph Styles and transformations of functions. The GraphStyle in Y6 creates a ball that has been raised to sit just above the “rollercoaster” sinusoidal path. The ball floats above the roller coaster track because the sine curve in Y3 has been translated vertically.

Note also that the sun and the bird are done with lists and restricted domains so that multiple transformations can be done as one graph. This gives the student the ability to graph more than 10 functions at a time.

```
NORMAL FLOAT AUTO REAL RADIAN CL
Plot1 Plot2 Plot3
Y1((4.2,1,.4)-(X+10)^2)+5
Y2-√((4.2,1,.4)-(X+10)^2)+5
Y32sin(.5X)-3
Y4(-8(X-8)^2+5)/(X≤8.4 and X≥7.6)
Y5(-8(X-8.8)^2+5)/(X≥8.4 and X≤9.2)
```

```
NORMAL FLOAT AUTO REAL RADIAN CL
WINDOW
Xmin=-13.2
Xmax=13.2
Xscl=1
Ymin=-8
Ymax=8
Yscl=1
Xres=1
ΔX=0.1
TraceStep=0.2
```

```
NORMAL FLOAT AUTO REAL RADIAN CL
Plot1 Plot2 Plot3
Y4(-8(X-8)^2+5)/(X≤8.4 and X≥7.6)
Y5(-8(X-8.8)^2+5)/(X≥8.4 and X≤9.2)
Y62sin(.5X)-2.5
Y7=
Y8=
Y9=
Y0=
```



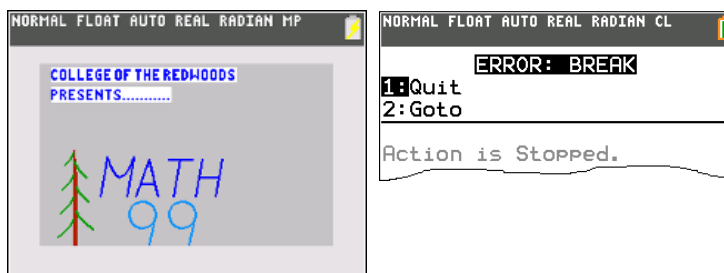
Math 99 Animated Movie

The program shown below was created for an Advanced Calculator Topics course (numbered MATH 99). It contains animated features such as fireworks and flashing lights to highlight the kind of CGI movies possible using a program.

These fireworks randomly appear on the screen:



After the title MATH 99 unveils, the animation automatically repeats indefinitely. Press the ON key to interrupt the program. Then press **1:Quit**.



After running a program, you may wish to Reset Defaults. Press 2nd MEM 7 2 2.

Below is the code for the program MATH99.

It can be downloaded on the Website listed on the cover of this handout.

```

0001 Radian
0002 FnOff :PlotsOff :AxesOff
0003 ClrDraw
0004 BackgroundOn 22
0005 Ø→Xmin
0006 94→Xmax
0007 Ø→Xsc1
0008 Ø→Ymin
0009 62→Ymax
0010 Ø→Ysc1
0011 Lbl 1
0012
0013 For (P,1,5,1)
0014   ClrDraw
0015   Text(2,1Ø,"COLLEGE OF THE REDWOODS")
0016   Text(2Ø,1Ø,"PRESENTS.....")
0017   randInt(35,6Ø)→J
0018   randInt(1Ø,3Ø)→K
0019
0020   For(Q,1,9,1)
0021     randInt(1Ø,21)→L
0022     Line(J,K,randInt(3Ø,65),randInt(5,45),1,L)
0023   End
0024
0025 End
0026 ClrDraw
0027 Text(2,1Ø,"COLLEGE OF THE REDWOODS")
0028 Text(2Ø,1Ø,"PRESENTS.....")
0029 Line(15,Ø,15,43,1,16,2)
0030 Line(15.5,Ø,15.5,39,1,16,2)
0031 Line(16,Ø,16,33,1,16,2)
0032 DrawF e^(X/Ø6)/((X≥Ø8)(X≤15)),14
0033 DrawF e^(X/Ø6)/((X≥Ø9)(X≤15))+1Ø,14
0034 DrawF e^(X/Ø6)/((X≥1Ø)(X≤15))+2Ø,14
0035 DrawF e^(X/Ø6)/((X≥11)(X≤15))+3Ø,14
0036 DrawF e^((-X+3Ø)/6)/((X≥16)(X≤24))+5,14
0037 DrawF e^((-X+3Ø)/6)/((X≥16)(X≤22))+16,14
0038 DrawF e^((-X+3Ø)/6)/((X≥15)(X≤21))+26,14
0039 Line(3Ø,39,27,22)
0040 DrawF (.25(X-36)^2+31)/((X≥3Ø)(X≤42))
0041 Line(42,39,39,22)
0042 Line(49,39,43,22)
0043 Line(49,39,53,22)
0044 Line(46,28,51,28)
0045 Line(58,39,69,39)
0046 Line(63,39,6Ø,22)
0047 Line(73,39,7Ø,22)
0048 Line(82,39,79,22)
0049 Line(72,31,81,31)
0050 For(I,1,Ø2,1)
0051   StorePic 7
0052   ClrDraw
0053   seq(X,X,1,ØØ1,1)→L5
0054   RecallPic 7
0055   seq(X,X,1,ØØ1,1)→L5
0056 End
0057 Circle(46,14,6,18)
0058 Circle(64,14,6,18)
0059 Line(52,14,49,Ø,1,18)
0060 Line(7Ø,14,67,Ø,1,18)
0061 seq(X,X,1,475,1)→L5
0062 ClrDraw
0063 Text(1Ø,Ø8,"ADV. CALCULATOR TOPICS")
0064 Text(5Ø,2Ø,"WEDNESDAYS 1-3 PM")
0065 Text(3Ø,12,"STUART MOSKOWITZ")
0066 DrawF (Ø8sin(.2X)+15)/((X≥1Ø)(X≤84))
0067 seq(X,X,1,ØØ2,1)
0068 Goto 1

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