

The TI-89 and how to use some of it for algebra, calculus, graphing, and a little bit of vector/matrix algebra

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Table of Contents

Topic	Page
Introduction	2
TI-89 picture, MODE	3
References	6
Setting up the calculator and creating a program	7
Menus	
Tools (F1)	9
Algebra menu (F2)	9
Calculus menu (F3)	13
Other menu (F4)	15
Clean Up menu (F6)	17
Apps	
Polynomial Root Finder	18
Simultaneous Eqn Solver	19
Doing Algebra	20
Graphing	20
Function graphing	21
Parametric graphing	24
Differential Equation graphing	25
Polar graphing	26
Trig	26
Vectors and Matrices	
Vectors	26
Matrices	28
Tables	30
Complex numbers	30
Assign keys 1-9 to applications	31
Unit creation and conversion	31
Bases	32
Inequalities	32
Statistics and regression	33
Tables of Contents for two TI books (\$\$)	36
Tables of Contents for MEPro, EEPro, EE200 (free)	36

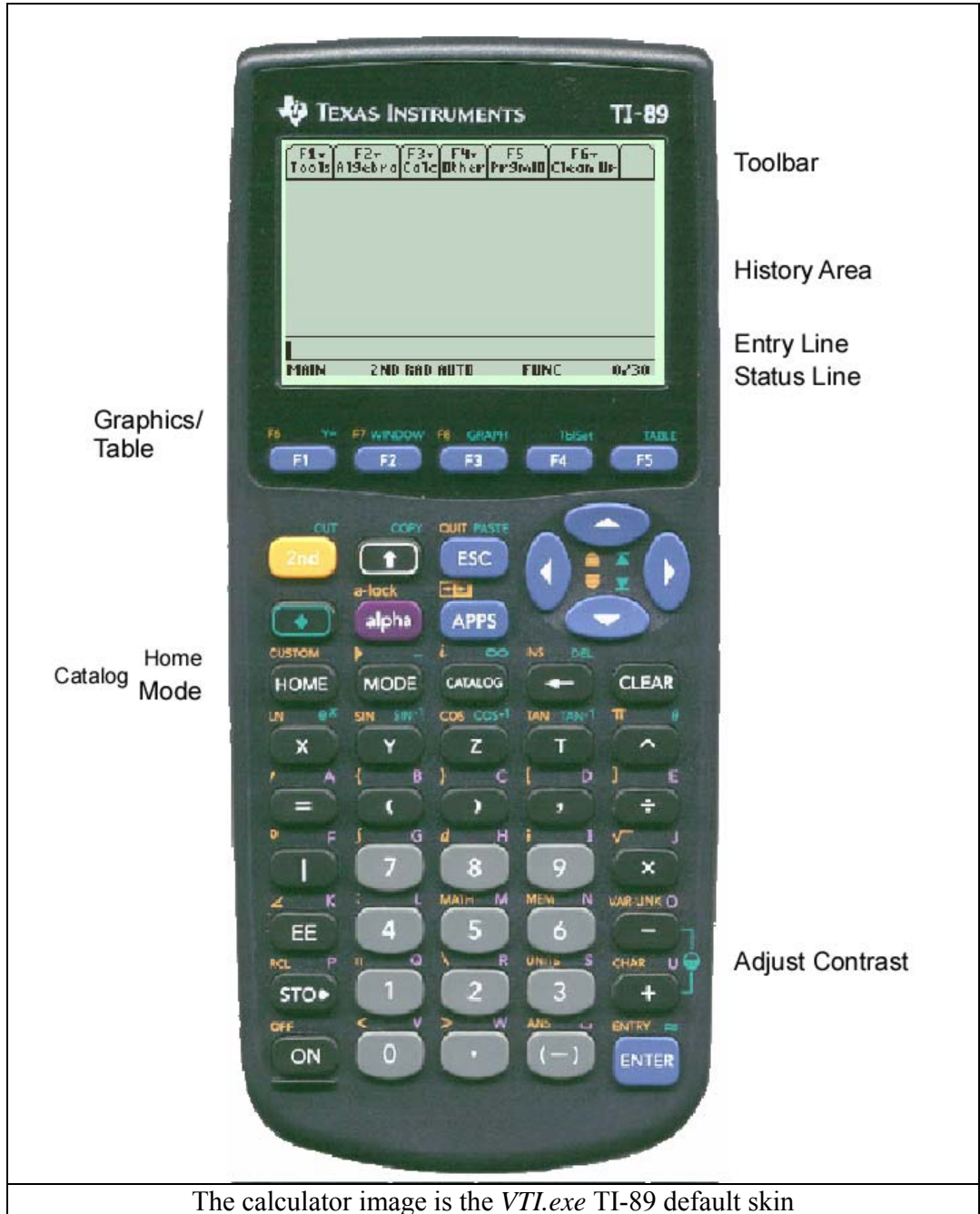
Introduction

Since so many students are using the TI-89 yet don't know much about it, I have assembled this document, which contains what I have learned about this calculator in teaching math and physics along with significant self-study. This document is intended to present examples of the different functions. Some experience with graphing calculators, such as the TI-83 or TI-86, is assumed. The question is "how does the TI-89 do it?" You will find some of the answers in this document. When all else fails, read the manual. The TI-89 is a computer algebra system (CAS) that is capable of interchanging information with the PC CAS software, *Derive*, available from TI (<http://education.ti.com/us/product/software/derive/features/features.html>). The TI-89 is programmable. Many application source files as well as executables are available from TICALC.org, <http://www.ticalc.org/>. The guidebooks for all the TI calculators are available in PDF format from the TI website, <http://education.ti.com/us/product/main.html>. More details on both sites are given in the reference section below. Please note that I am not an expert on the TI-89; I am just presenting what I use, how I do it, and where to find it.

I have written this document primarily using the technique of presenting screen shots resulting from some action. I do not give individual keystrokes. I assume you can read the screen to see what I typed. Be sure to look at the status line at the bottom of each screen to determine how my calculator is set up for the action under consideration. When giving a string of menu or button presses, I separate them by a /, e.g. MATH/Matrix/L:Vector ops. I present first the menus in the toolbar, *F1* through *F6*. After this information come sections on specific techniques such as graphing, solving simultaneous equations, regression analysis, etc. Finally, I give the table of contents for three applications and two books available from the TI website.

Where did I get my information? Most of it came from reading the printed guidebook that came with the TI-89 Titanium up to Appendix A and doing all the exercises. I actually found this guidebook to be a readable document. Some of my students have also taught me several uses of the commands.

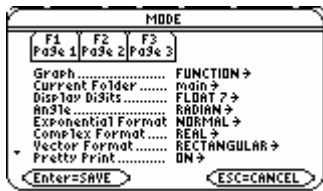
The TI-89 Calculator



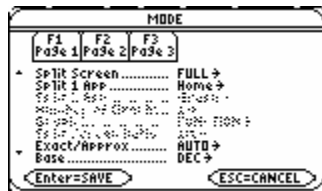
The calculator image is the *VTL.exe* TI-89 default skin

MODE

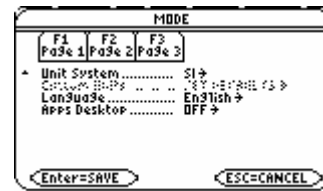
Set up the overall calculator settings by pressing the MODE button. There are three screens you need to consider.



USE ← AND → TO OPEN CHOICES



USE ← AND → TO OPEN CHOICES



USE ← AND → TO OPEN CHOICES

A few general notes:

The calculator: Titanium or not?

The TI-89 Titanium has three times the memory of the first edition and communicates with desktops by USB instead of serial port. Otherwise, as far as I know, they are functionally the same. The OS for the original TI-89 stops at version 2.09. The Titanium starts with 3.0 and will be upgradeable. TI calculators can connect to each other for program/data exchange by the supplied cable.

The interface:

On the TI-83, 86, etc., you push a button and, typically, a command is executed. On the TI-89 you typically construct a command on the entry line at the bottom of the screen by pressing buttons. Then, press ENTER to execute the command you constructed.

From MODE: Be sure to leave Pretty Print on because then when you enter an equation, it shows up in the history area looking typeset. It is therefore fairly easy to check that you typed what you meant to type. I find most students miss a parenthesis or two so having this feature available on the calculator is quite helpful.

You will also need to choose how you want your numbers to look – *approximate* (decimal) or *exact* ($\sqrt{\quad}$, \tan^{-1} , π , etc. in the result). Choosing *auto* means that, when possible, the results will be presented in *exact* form (not always a pretty sight), or *approximate* if *exact* is not possible. To force *approximate*, be sure to put a decimal point on some number.

Screen Contrast:

◆+ and ◆– make the screen darker and lighter. The ◆ symbol means “press the *Diamond* button.” It is just below the 2nd button.

Using previous expressions:

Scroll up and down in the history area. When the expression you wish to use on the entry line is highlighted, press the ENTER button. The highlighted expression is then placed on the entry line at the current cursor location.

Memory Management:

2nd – (VAR-LINK) places you in the right area. Read the Titanium Guidebook (the printed guidebook) for details. That’s what I do.

2nd 6 (MEM) displays how memory is being used.

A few notes on using some features:

- 1) *Catalog* lists all the functions as well as expected input at the bottom of the screen. The brackets, [], mean that the entry is optional.



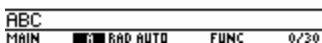
See F3/2 – \int (below for examples of the use of the integrate function with its input options.

To get to *and*, for example, in the catalog, press the CATALOG button, then press the = button to get to the beginning of the *a*'s. Cursor down once to get *and*. Using the catalog is typically much faster than using the menu system if you know the name of the command you are looking for.

- 2) Some menu items are commands and some are text that will show up on your entry line.
- 3) Press the ON button to stop a calculation in progress.
- 4) 2nd ← moves the cursor to the beginning of the entry line and 2nd → to the right end.
- 5) If you position your cursor in the middle of a line, the first *Clear* eliminates the text to the right of the cursor and the second *Clear* finishes clearing the entry line.
- 6) The HOME button brings you back to the main (HOME) screen. 2nd HOME toggles the **custom menu**. You can create your own custom menus. See the guidebooks (references #1). If your menus look weird, you probably pressed 2nd HOME. Press 2nd HOME again to get back to the original menus. Now you know how to recover the default menus.
- 7) Menu selection – you can scroll down to a menu selection, scroll up to it (good for menu items near the bottom of the list), or just press the selection's menu number on the numeric key pad.
- 8) When a menu item has an arrow (▶) to the right, press the right cursor arrow, →, to see a submenu.
- 9) “Internally, the TI-89 converts all entered trig values to radians, but it does not convert values for exponential, logarithmic, or hyperbolic functions.” [p 565 Electronic User Guide] In other words, be very careful which angle mode your calculator is in. The current mode is shown in the status line.
- 10) Spend some time looking at all the options under the MATH (2nd 5) menu. There are many options listed there that I do not cover in this document.
- 11) Typing literal characters: Keep pressing the ALPHA button. The calculator goes through a sequence of alpha-off, alpha-on for one character, then alpha-stay on. Watch the second entry in the status line. First there is nothing, then a lower case *a* then a highlighted *a*, respectively. The 2nd key is an on-off toggle. 2nd/ALPHA directly locks alpha mode. Look at the status line of the three screen shots below.



Upper case characters are created by pressing the up-arrow key just above the ALPHA key (not the up-arrow cursor key), followed by the ALPHA key. Note the *A*, versus *a*, in the status line.



REFERENCES

- 1) TI-89 Guidebooks and application software.
To download them go to the TI web site:
<http://education.ti.com/us/product/main.html>
Choose: Graphing Calculators and Accessories
Select TI-89 Titanium
 - A)
Choose: Guidebooks from the menu on the left.
Select **Printed Guidebook** (the little one that comes with the Titanium)
Filename from TI: *TI89TitaniumGuidebook_Part1_EN.pdf*
Or **Electronic Guidebook** – the full guidebook for the TI 89
Filename from TI: *TI89TitaniumGuidebook_Part2_EN.pdf*
Then Choose your language. I choose English, hence the *EN* at the of the guidebook filenames.
Then Download the PDF file.
 - B)
Choose: Apps from the menu on the left.
This is the place where you can download all the applications, most of which are free, along with their guidebooks in PDF format.
- 2) TI Calc: <http://www.ticalc.org/>
Select **Archives** to find “thousands of files for every TI graphing calculator model”
Select **Programming** to find emulators and programming help
- 3) Brendan Kelly, *Advanced Algebra with the TI-89*, Brendan Kelly Publishing, 2000.
- 4) Voltmer and Yoder, *Electrical Engineering Applications with the TI-89*, 1999.
<http://education.ti.com/us/product/book/89eea.html>
“This book is written for electrical engineering students. It is a collection of examples that show how to solve many common electrical engineering problems using the TI-89.” I find this book to be an excellent source of TI-89 information, not just information specific to electrical engineering. One chapter includes writing functions for gradient, curl, divergence, the Laplacian, etc.
- 5) Some of my students.

All screen shots in this document were taken using the original TI-89 ROM running OS 2.09 in *VTI.exe*. Unless otherwise indicated, I learned how to do everything that follows from the TI Guidebooks, reading the input information from CATALOG, and by following my instinct.

Acknowledgements. Thanks to Prof. Segal, Gale Townsend, and two of my students, Dave Johnson and Neil Patel, for proofing and editing this document. All errors are mine.

Setting up the Calculator [4, §"Do This First"]

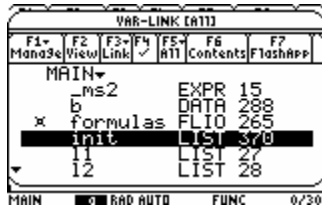
To store your current mode settings use CATALOG/getMode("all") STO►init



```

■ getMode("all") → init
  ("Graph" "FUNCTION" "►)
getMode("all")→init
MAIN          RAD AUTO    FUNC    1/30
  
```

You can look at the beginning of what is stored: VAR-LINK/init/ F6 (Contents)

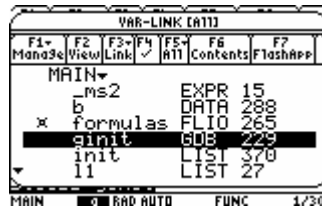


Also store the graphics settings and variables. CATALOG/StoGDB ginit.



```

■ StoGDB ginit          Done
StoGDB ginit
MAIN          RAD AUTO    FUNC    1/30
  
```



The file *ginit* is not a text file or a list so cannot be viewed.

To restore the MODE and graphics settings to those stored in *init* and *ginit*:



```

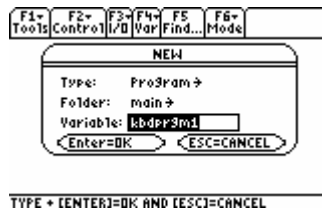
■ setMode(main\init)
  ("Apps Desktop" "OFF" ►)
setMode(main\init)
MAIN          RAD AUTO    FUNC    1/1
  
```



```

■ Rc1GDB ginit          Done
Rc1GDB ginit
MAIN          RAD AUTO    FUNC    1/30
  
```

For ease of use when starting a new problem, Voltmer and Yoder [4, p3] recommend writing the following program that restores your calculator to a desired stored mode. By naming the program *kbdprgm1* (Keyboard program #1), all you have to do is press ♦1 to run the program. To create this program, start from Apps/Program Editor



You are now presented with an empty program stub:

```

F1- F2- F3- F4- F5- F6-
Tools Control I/O Var Find... Mode
: kbdprgm1( )
: Prgm
:
: EndPrgm

```

MAIN RAD AUTO FUNC

Create the program as given below. Once you have finished typing the program, press the HOME key to exit program mode.

```

F1- F2- F3- F4- F5- F6-
Tools Control I/O Var Find... Mode
: kbdprgm1( )
: Prgm
: setMode(main\init)
: kclGDB main\ginit
: EndPrgm

```

MAIN RAD AUTO FUNC

Voltmer and Yoder recommend that before you start a new problem session

- 1) Restore the mode settings stored in *init* and *ginit* by pressing ♦1
- 2) Run HOME/F6/2:NewProb to clear out the variables used in the last problem.
- 3) Create a new folder (HOME/F4/B:newFold) to use for the new problem. Note that by using different folders for different problems, it is much easier for you to look in the folder by using VAR-LINK/F2/FolderNameOfChoice. I have not done that and now my *main* folder is so full it is very tedious to find, look at, archive, lock or delete any of my variables (VAR-LINK/Manage).

Since NewProb clears the HOME screen, you can now save the steps of the current problem only into a text file with executable lines at the end of your problem session for later reference and execution (HOME/F1/2:Save Copy As..). Note that my calculator is set to remember 99 operations. To get to the location where that number is set, execute HOME/F1/9:Format.

```

F1- F2- F3- F4- F5- F6-
Tools alpha beta Calc Other Pr3mID Clean Up
4: Cut
5: Copy
6: Paste
7: Delete
8: Clear Home
9: Format...
A: About...
B: Lock

```

MAIN RAD AUTO FUNC 0/30

```

F1- F2- F3- F4- F5- F6-
Tools alpha beta Calc Other Pr3mID Clean Up

```

FD ↑ 30

40

50

60

70

80

90

99

←Enter=SAVE →=CANCEL→

TYPE OR USE ←→↑↓ + [ENTER] OR [ESC]

You might also consider writing a few more *kbdprgm* programs. Several that come to mind are programs to toggle between radian and degree modes, toggle between approx and auto modes, and conversion between radians and degrees. For example, the appropriate commands for setting degree mode is *setMode*("angle","degree"). After this command is run, to see that it worked, run *getMode*("angle")

Menus with Examples

F1 – Tools

2 – Save copy as.

This command lets you save the history as an executable text file.

The screenshots illustrate the process of saving the calculator's history as a text file. The first image shows the calculator interface with several equations: $x + 2 \cdot y = 4$, $(x + 2 \cdot y = 4) - x$, $2 \cdot y = 4 - x$, and $y = \frac{-(x-4)}{2}$. The second image shows the 'SAVE COPY AS' dialog box where the file name is set to 'xxx'. The third image shows the 'APPLICATIONS' menu with 'v= Editor' selected. The fourth image shows the command list with 'C: (x+2*y=4)-x' selected.

The text editor is an icon under APPS if you are using the Apps Desktop. I have turned off the icon desktop (MODE/F3/Apps Desktop/OFF) so my text editor shows up in a list when I press the APPS button. The file *xxx*, above, is a text file that can be edited. The C: means the text line is a command that can be executed. Select the command, then press *F4* to execute it. The command is executed on the Home screen and then you are returned to the open text file. You can see what was executed by pressing the HOME button. This method is a nice way to save class notes. Clear the home screen before class. At the end of class save all your calculations so you can see what was done during class. Note that you can buy a full-sized keyboard from the TI web site so you can actually type notes into a text file.

3→8 **Copy, Cut, Paste, Delete, Clear Home** behave as you would expect them to. Delete is the same as the backward arrow.

9 – **Format** lets you set how many calculations are saved in the history. I use 99 so I can save a large history file.

A – **About:** gives you the operating system (OS) version and calculator serial number.

B – **Clock** (Titanium only): where you set the time and date. This information appears on the Apps Desktop.

F2 – Algebra

1 – solve(

The screenshots show the 'solve(' function being used to solve different types of equations. The first image shows solving the linear equation $x + 3 = x - (2 \cdot x - 5)$, resulting in $x = 1$. The second image shows solving a quadratic equation $a \cdot x^2 + b \cdot x + c = 0$ using the discriminant formula $x = \frac{\sqrt{b^2 - 4 \cdot a \cdot c} - b}{2 \cdot a}$ or $x = \frac{\sqrt{b^2 - 4 \cdot a \cdot c} + b}{2 \cdot a}$. The third image shows solving a quadratic equation $a \cdot x^2 + b \cdot x + c = 0$ using the quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$.

2 – factor

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ factor(1220) $2^2 \cdot 5 \cdot 61$
 ■ factor($x^2 - 4 \cdot x + 4$) $(x - 2)^2$

factor($x^2 - 4x + 4$)
 MAIN RAD AUTO FUNC 2/30

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ factor($\frac{1}{x \cdot (x^2 - 1)} + \frac{2}{x - 1}$)
 $\frac{2 \cdot x^2 + 2 \cdot x + 1}{x \cdot (x - 1) \cdot (x + 1)}$

factor($1/(x*(x^2-1))+2/(x-1)$)
 MAIN RAD AUTO FUNC 1/30

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ factor($x^2 - 4 \cdot x - 7$)
 $x^2 - 4 \cdot x - 7$
 ■ factor($x^2 - 4 \cdot x - 7, x$)
 $(x + \sqrt{11} - 2) \cdot (x - \sqrt{11} - 2)$

factor($x^2 - 4x - 7, x$)
 MAIN RAD AUTO FUNC 2/30

(I found this use of factor from a student on his exam.)

3 – expand

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ expand($(x + 5) \cdot (x - 6)$)
 $x^2 - x - 30$

expand($(x+5)*(x-6)$)
 MAIN RAD AUTO FUNC 1/30

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ expand($\frac{2 \cdot x^2 + 2 \cdot x + 1}{x \cdot (x^2 - 1)}$)
 $\frac{1}{2 \cdot (x + 1)} + \frac{5}{2 \cdot (x - 1)} - \frac{1}{x}$

expand($(2*x^2+2*x+1)/(x*(x^2-1))$)
 MAIN RAD AUTO FUNC 1/30

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ expand($\frac{y \cdot x^2 + 2 \cdot y \cdot x + 1}{x \cdot (y + 1)}$)
 $\frac{x \cdot y}{y + 1} + \frac{1}{x \cdot (y + 1)} + \frac{2 \cdot y}{y + 1}$

expand($(y*x^2+2*y*x+1)/(x*(y+1))$)
 MAIN RAD AUTO FUNC 1/30

“expand(expression1,var) returns expression expanded with respect to var. Similar powers of var are collected.” [p 184 Printed guidebook]

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ expand($\frac{y \cdot x^2 + 2 \cdot y \cdot x + 1}{x \cdot (y + 1)}, y$)
 $\frac{-(x^2 + 2 \cdot x - 1)}{(y + 1) \cdot x} + x + 2$

expand($(y^2+2*y*x+1)/(x*(y+1)), y$)
 MAIN RAD AUTO FUNC 1/30

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ expand($\frac{y \cdot x^2 + 2 \cdot y \cdot x + 1}{x \cdot (y + 1)}, x$)
 $\frac{x \cdot y}{y + 1} + \frac{1}{x \cdot (y + 1)} + \frac{2 \cdot y}{y + 1}$

expand($(y^2+2*y*x+1)/(x*(y+1)), x$)
 MAIN RAD AUTO FUNC 1/30

4 – zeros

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ expand($(x + 3) \cdot (x^2 - 1)$)
 $x^3 + 3 \cdot x^2 - x - 3$

■ zeros($x^3 + 3 \cdot x^2 - x - 3, x$)
 $(-3 \quad -1 \quad 1)$

zeros(x^3+3*x^2-x-3, x)
 MAIN RAD AUTO FUNC 2/30

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ zeros($x - 3 \cdot \tan(2 \cdot x), x$)
 $(-8.469162 \quad -3.578122 \quad \dots)$

zeros($x-3\tan(2x), x$)
 Warning: More solutions may exist

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ zeros($x - 3 \cdot \tan(2 \cdot x), x$)
 $(-1.846688 \quad 0 \quad 1.846688)$

zeros($x-3\tan(2x), x$)
 MAIN RAD AUTO SEQ 1/1

F1- Tools F2- R13eBrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ zeros($x - 3 \cdot \tan(2 \cdot x), x$)
 $(.688 \quad 3.578122 \quad 8.469162)$

zeros($x-3\tan(2x), x$)
 MAIN RAD AUTO SEQ 1/1

Graphing the function shows where these zeros are.

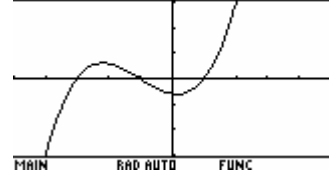
F1- Tools F2- Zoom F3- Edit F4- All F5- Style F6- Prev

*PLOTS
 $y1 = x^3 + 3 \cdot x^2 - x - 3$
 $y2 =$
 $y3 =$
 $y4 =$
 $y5 =$
 $y6 =$
 $y7 =$
 $y1(x) = x^3 + 3 \cdot x^2 - x - 3$

F1- Tools F2- Zoom

xmin=-5.
 xmax=5.
 xscl=1.
 ymin=-15.
 ymax=15.
 yscl=5.
 xres=2.

F1- Tools F2- Zoom F3- Trace F4- ReGraph F5- Math F6- Draw F7- Pen



5 – approx() returns a decimal, independent of Exact/Approx mode. Alternatively, make sure to place a decimal in one of the numbers in your calculation to be assured of getting a decimal result. You can usually use \blacklozenge ENTER to turn the previous result into a decimal as well.

6 – comDenom() (“returns a reduced ratio of a fully expanded numerator over a fully expanded denominator.” [p 161 Printed Guidebook])

7 – propFrac() (“returns the sum of proper ratios and a polynomial with respect to *var*. The degree of *var* in the denominator exceeds the degree of *var* in the numerator in each proper ratio.” [p 221 Printed Guidebook])

8 – nSolve(- finds one numerical answer (c.f. TI-86 SOLVER)

c.f. Graph both functions, then find the intersection.

9 – Trig

tExpand() and **tCollect()** (gave odd results in Radian mode)

A – Complex

cSolve(



\blacksquare cSolve($x^3 = 2, x$)
 $x = \frac{-2^{1/3}}{2} + \frac{\sqrt{3} \cdot 2^{1/3}}{2} \cdot i$ or \blacktriangleright
 cSolve($x^3=2,x$)
 MAIN DEGR AUTO FUNC 1/30



\blacksquare cSolve($x^3 = 2, x$)
 $\leftarrow \frac{\sqrt{3} \cdot 2^{1/3}}{2} \cdot i$ or $x = 2^{1/3}$
 cSolve($x^3=2,x$)
 MAIN DEGR AUTO FUNC 1/1



\blacksquare cSolve($x \cdot y + y = 3$ and $2 \cdot x$)
 $x = \frac{\sqrt{14}}{2} \cdot i$ and $y = 2/3 - \frac{\sqrt{14}}{3}$
 y+y=3 and 2x^2=-7, (x,y)
 MAIN DEGR AUTO FUNC 1/30



\blacksquare $y(0) = 1$ and $y'(0) = 0, x, y$
 $y = \frac{e^{2 \cdot x}}{3} + \frac{2 \cdot e^{-x}}{3}$
 y(0)=1 and y'(0)=0, x, y
 MAIN DEGR AUTO FUNC 1/1



\blacksquare cSolve($x^3 = 2, x$)
 $\leftarrow x = \frac{-2^{1/3}}{2} - \frac{\sqrt{3} \cdot 2^{1/3}}{2} \cdot i$ \blacktriangleright
 cSolve($x^3=2,x$)
 MAIN DEGR AUTO FUNC 1/1



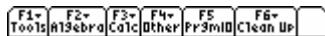
\blacksquare 3 and $2 \cdot x = \sqrt{14} \cdot i, (x, y)$
 $\leftarrow \frac{\sqrt{14}}{2} \cdot i$ and $y = 2/3 - \frac{\sqrt{14}}{3} \cdot i$
 y=3 and 2x=sqrt(14)i, (x,y)
 MAIN DEGR AUTO FUNC 1/1

cFactor(



\blacksquare cFactor($x^2 + 1$)
 $(x + -i) \cdot (x + i)$
 \blacksquare factor($x^2 + 1$) $x^2 + 1$
 factor(x^2+1)
 MAIN DEGR AUTO FUNC 2/30

cZeros(



\blacksquare zeros($x^2 + 1, x$) \emptyset
 \blacksquare cZeros($x^2 + 1, x$) $(-i \ i)$
 cZeros(x^2+1,x)
 MAIN DEGR AUTO FUNC 2/30

B – Extract

getNum(and getDenom(and left(and right(

F1- Tools F2- A13ebrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

$$\blacksquare \text{getNum}\left(\frac{x^2-1}{y+2}\right) \quad x^2-1$$

$$\blacksquare \text{getDenom}\left(\frac{x^2-1}{y+2}\right) \quad y+2$$

getDenom((x^2-1)/(y+2))
MAIN DEG AUTO FUNC 2/30

F1- Tools F2- A13ebrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

$$\blacksquare \text{left}(x^2-1=y+2) \quad x^2-1$$

$$\blacksquare \text{right}(x^2-1=y+2) \quad y+2$$

right(x^2-1=y+2)
MAIN DEG AUTO FUNC 2/30

F3 – Calc

2 – ∫ (Integrate

Note the three different input options.

F1- Tools F2- A13ebrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

$$\blacksquare \int (x^3) dx \quad \frac{x^4}{4}$$

∫(x^3,x)
MAIN RAD AUTO FUNC 1/99

F1- Tools F2- A13ebrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

$$\blacksquare \int (x^3) dx \quad \frac{x^4}{4} + c$$

∫(x^3,x,c)
MAIN RAD AUTO FUNC 2/30

F1- Tools F2- A13ebrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

$$\blacksquare \int_a^b (x^3) dx \quad \frac{b^4}{4} - \frac{a^4}{4}$$

∫_2^4(x^3)
MAIN RAD AUTO FUNC 2/30

3 – limit(

F1- Tools F2- A13ebrd F3- Calc F4- Other F5- Pr3mID F6- Clean Up

$$\blacksquare \lim_{h \rightarrow 0} \left(\frac{(x+h)^3 - x^3}{h} \right) \quad 3 \cdot x^2$$

limit((x+h)^3-x^3)/h,h,0)
MAIN RAD AUTO FUNC 1/30

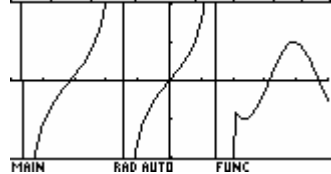
Use *when* for discontinuous functions; you can then take limits from the left and right of the discontinuity. This function was given me by a student while we were studying inequalities. The vertical lines in the graphs are artifacts of the graph being constructed by connecting points. They disappear when dots are used for the line type.

F1- Tools F2- Zoom F3- Edit F4- All F5- Style F6- P/P F7- X...

```

^PLOTS
y1=sin(2·x)
y2=tan(x)
y3={y1(x),x>2
     {y2(x),else
y4=
y5=
y6=
y3(x)=when(x>2,y1(x),y2(x...
MAIN RAD AUTO FUNC
    
```

F1- Tools F2- Zoom F3- Trace F4- Re3Graph F5- Math F6- Draw F7- Pen...



F1- Tools F2- Zoom

```

xmin=-5.
xmax=5.
xscl=1.
ymin=-2.
ymax=2.
yscl=1.
xres=2.
MAIN RAD AUTO FUNC
    
```

F1- Tools F2- Zoom F3- Trace F4- Re3Graph F5- Math F6- Draw F7- Pen...



MAIN RAD AUTO FUNC

MAIN RAD AUTO FUNC

$$\blacksquare \lim_{x \rightarrow 2^+} y3(x) \quad \sin(4)$$

limit(y3(x),x,2,1)
MAIN RAD AUTO FUNC 1/30

$$\blacksquare \lim_{x \rightarrow 2^-} y3(x) \quad \tan(2)$$

limit(y3(x),x,2,-1)
MAIN RAD AUTO FUNC 1/99

4 – \sum (sum

F1- Tools F2- Algebra F3- Calc F4- Other F5- Pr3mlD F6- Clean Up

$$\sum_{x=1}^n (x^2) = \frac{n \cdot (n+1) \cdot (2 \cdot n + 1)}{6}$$

$\Sigma(x^2, x, 1, n)$
MAIN RAD AUTO FUNC 1/30

5 – Π (product

F1- Tools F2- Algebra F3- Calc F4- Other F5- Pr3mlD F6- Clean Up

$$\prod_{x=1}^n (x^2) = (n!)^2$$

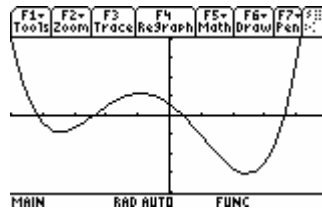
$\Pi(x^2, x, 1, n)$
MAIN RAD AUTO FUNC 1/30

6 – fmin(and 7 – fmax(and the Where operator, |

F1- Tools F2- Zoom

xmin=-5.
xmax=5.
xscl=1.
ymin=-20.
ymax=20.
yscl=5.
xres=2.

MAIN RAD AUTO FUNC



F1- Tools F2- Zoom F3- Edit F4- Rtl F5- Style F6- Pencil

DATA:
y1=sin(2·x)
y2=x+tan(3·x)
y3={y1(x), x > 2
y2(x), else
y4=.2·x⁴+ .5·x³- 3·x²- 6·x + 3

MAIN RAD AUTO FUNC

F1- Tools F2- Zoom F3- Edit F4- Rtl F5- Style F6- Pencil

Flot 1:
y1=sin(2·x)
y2=x+tan(3·x)
y3={y1(x), x > 2
y2(x), else
y4=.2·x⁴+ .5·x³- 3·x²- 6·x + 3
y4(x)=.2*x^4+.5*x^3-3*x^2-6*x+3

MAIN RAD AUTO FUNC

Note that graphs y1, y2, and y3 are deselected above so only y4 shows up on the graph.

F1- Tools F2- Algebra F3- Calc F4- Other F5- Pr3mlD F6- Clean Up

fMin(y4(x), x) x = 2.446
fMin(y4(x), x) | x < 0 x = -3.425

$fMin(y4(x), x) | x < 0$
Questionable accuracy

F1- Tools F2- Algebra F3- Calc F4- Other F5- Pr3mlD F6- Clean Up

fMax(y4(x), x) x = ∞ or x = -∞
fMax(y4(x), x) | -3 < x and x < 3 x = -.8953

$fMax(y4(x), x) | -3 < x \text{ and } x < 3$
MAIN RAD AUTO FUNC 2/30

Note the use of the “where” operator |; e.g. find the minimum value of y4(x) where x<0.

Find the same result using SOLVE and some calculus – extrema occur when $\frac{dy}{dx} = 0$.

F1- Tools F2- Algebra F3- Calc F4- Other F5- Pr3mlD F6- Clean Up

solve($\frac{d}{dx}(y4(x)) = 0, x$)
x = 2.446 or x = -.8953 or

$solve(d(y4(x), x)=0, x)$
MAIN RAD AUTO FUNC 1/30

F1- Tools F2- Algebra F3- Calc F4- Other F5- Pr3mlD F6- Clean Up

solve($\frac{d}{dx}(y4(x)) = 0, x$)
or x = -.8953 or x = -3.425

$solve(d(y4(x), x)=0, x)$
MAIN RAD AUTO FUNC 1/1

8 – arcLen(- the length of a line defined by a function.

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ arcLen(sin(x), x, -π, π)

7.64

arcLen(sin(x), x, -π, π)

MAIN RAD AUTO FUNC 1/30

9 – taylor(Performs a Taylor series.

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ taylor(sin(x), x, 8)

$$\frac{-x^7}{5040} + \frac{x^5}{120} - \frac{x^3}{6} + x$$

taylor(sin(x), x, 8)

MAIN RAD AUTO FUNC 1/30

Perform the expansion about 1: ■ taylor(sin(x), x, 8, 1)

$$\frac{\sin(1) \cdot (x-1)^8}{40320} - \frac{\cos(1) \cdot (x-1)^7}{5040}$$

taylor(sin(x), x, 8, 1)

MAIN RAD AUTO FUNC 1/30

A – nDeriv(

I don't use these.

B – nInt(

C – deSolve(

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ deSolve(y' + x = y, x, y)

$$y = @1 \cdot e^{-x} + x + 1$$

■ deSolve(y' + x = y and y(0) = 1)

$$y = -2 \cdot e^{-x} + x + 1$$

deSolve(y'+x=y and y(0)=1, x, y)

MAIN RAD AUTO FUNC 2/30

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ deSolve(y' - y = e²·x, x, y)

$$y = \frac{e^{2 \cdot x}}{3} + @6 \cdot e^{-x} + @7 \cdot e^x$$

deSolve(y'-y=e^(2x), x, y)

MAIN RAD AUTO FUNC 1/30

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ deSolve(y' - y = e²·x and y(0) = 1)

$$y = \frac{e^{2 \cdot x}}{3} + \frac{2 \cdot e^{-x}}{3}$$

deSolve(y'-y=e^(2x) and y(0)=1, x, y)

MAIN RAD AUTO FUNC 1/30

If you choose to solve for the constant @1, you can find the @ under 2nd + (the CHAR button)/Punctuation/9:

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

CHAR

1: Greek	4: \$
2: Math	5: %
3: Punctuation	6: &
4: Special	7: !
5: International	8: ?
	9: @

TYPE OR USE ←→+4 + [ENTER] OR [ESC]

F4 – Other

1 – Define

F1- Tools F2- 1/3 F3- Calc F4- Other F5- Pr3mID F6- Clean Up

■ Define z(t) = t² Done

■ $\frac{d}{dt}(z(t))$ 2·t

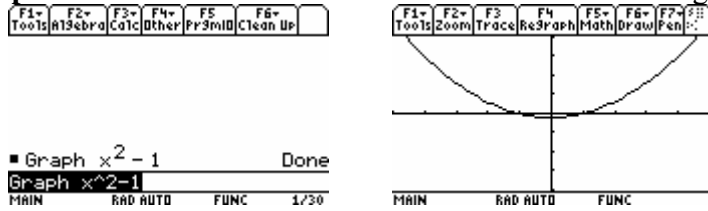
■ z(√x + 1) x + 1

z(√x+1)

MAIN RAD AUTO FUNC 3/30

2 – Graph – uses the current window.

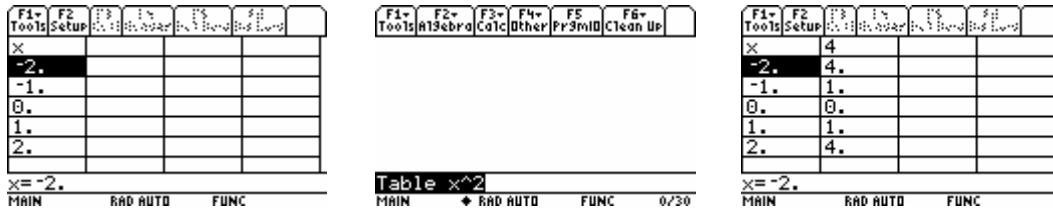
Making a selection to copy.



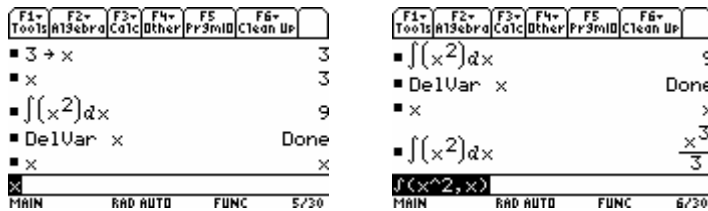
You can turn x^2-1 into a function $yn(x)=x^2-1$ by copy/paste. Select the x^2-1 : Place the cursor at the right end of the expression by using 2nd →. Press the ↑ button (just left of the ESC button). Move the cursor to the left, continuing to press the ↑ button, over the x^2-1 . Each character is selected as you cursor over it.

Copy the selection (F1/5 or ♦ ↑), go to the y= window, then paste it (F1/6 or ♦ ESC) into one of the y's.

3 – Table (use Apps/Table to see the contents of your table.)



4 – DelVar what to do when you expect a variable but get a number instead.

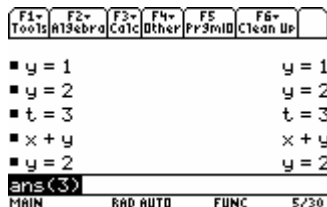


5 – ClrGraph Clear the graph screen (used in programming).

6 – ClrIO “Clear the TI-89 Program IO (input/output) screen.” (used in programming) [p 741 Electronic Guidebook]

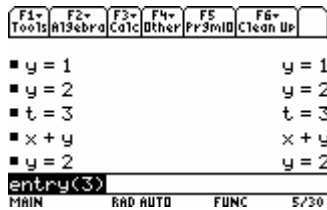
7 – FnOn/ 8 – FnOff Select/Deselect all the functions defined for the current graph mode (y=).

9 - Ans(This command allows you to use a previous result. Use 2nd (-) for Ans(1). To go further up the history chain, use F4/Ans(.



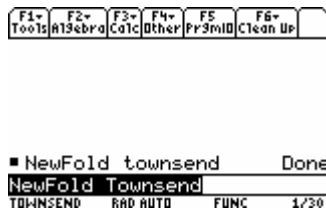
A – Entry(

This command allows you to execute a previous command. Use 2nd ENTER to edit the previous calculation. To repeat a command further up the history chain, use F4/Entry(or just cursor up until the desired entry in the history area is selected, then press ENTER



B – NewFold

Create a new folder. Since the folder name is at the bottom of your screen, you can create a folder with your name so it shows. This idea comes from one of my students. Below, I create the *Townsend* folder. The folder name appears in the status line. I then use MODE/F1 to return the folder to *main* because that is the folder I am currently using for this document. Note that in the previous screen above, we were in the *main* folder. You could create folders for each class in which to store calculations and their results (F4/B:NewFold).



F6 – Clean Up

1 – Clear a-z

“Clears (deletes) all single-character variable names in the current folder, unless the variables are locked or archived” [p 178 Electronic Guidebook]. Note that temporary variables should be stored with single characters and those you want to keep with two or more characters. Then you use this command to delete all the temporary variables. Other variables can be deleted easily using *Delvar*, as described above.

2 – NewProb

“performs a variety of operations that let you begin a new problem from a cleared state without resetting the memory” [p 178 Electronic Guidebook]. According to Voltmer and Yoder [4, p 9], “It clears all single characters, unlocked variables; turns off all functions and stat plots; and clears all errors, graphs, tables, and the program I/O and Home screens.”

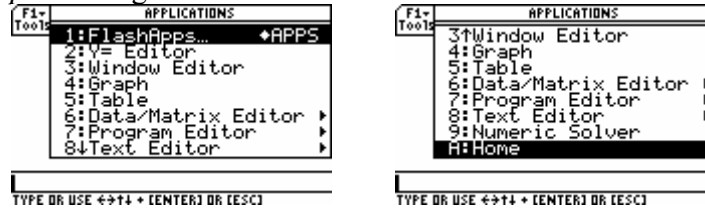
3 – Restore custom default

“If a custom menu other than the default is in effect, this command lets you restore the default” [p 178 Electronic Guidebook].

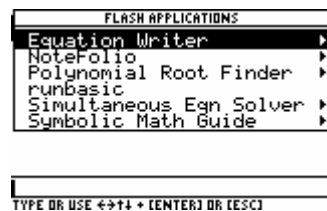
Apps and FlashApps and Other Activities

Since I have turned off the *Apps Desktop*, my screen may look different from yours. If you turn on *Apps Desktop*, all entries in *Apps* appear as icons. I felt I had too many icons to wade through to get to the application I was looking for.

Pressing the *Apps* button gives



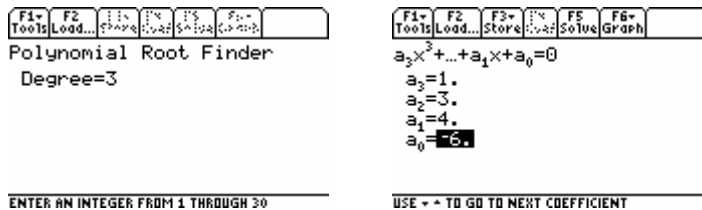
Selecting *FlashApps* gives



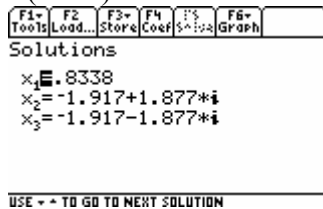
Your loaded flash apps may be different. If you do not have the *Polynomial Root Finder* and the *Simultaneous Eqn Solver*, be sure to get them from the TI web site.

Polynomial Root Finder

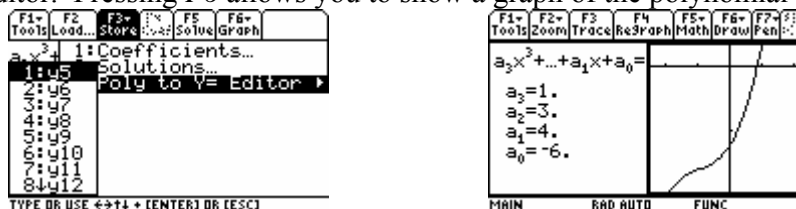
Select NEW, then find the roots of $x^3 + 3x^2 + 4x - 6$.



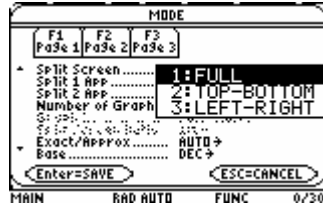
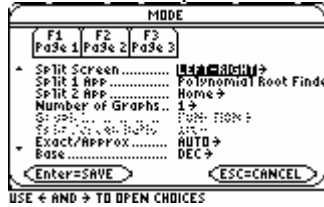
Press *F5* (solve)



Pressing *F4* returns you to the coefficient entry screen. Using *F1*, you can store or load (or use *F2*) coefficients. Pressing *F3* presents you with the option of storing your equation in the *y* editor. Pressing *F6* allows you to show a graph of the polynomial using a split screen.

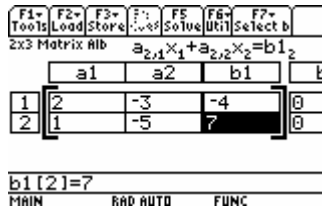
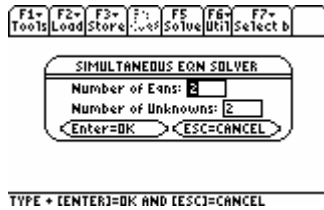


You can turn off the split screen using MODE/F2:

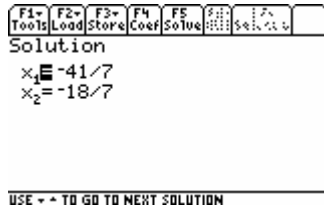


Simultaneous Eqn Solver

Select *New*, then solve $2x - 3y = -4$
 $x - 5y = 7$



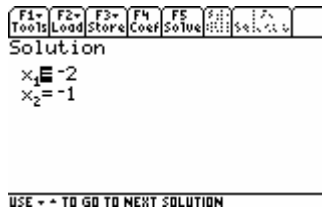
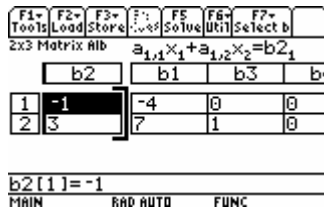
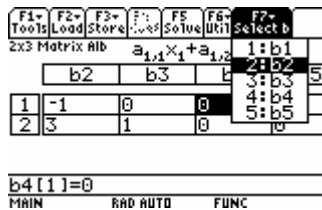
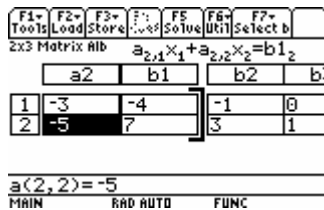
Press *F5* to solve:



Press *F4* to return to the coefficient matrix to add more equations with different right-hand sides but the same left-hand side, such as solving for currents with different voltages but the same circuit otherwise. If you don't need to save the information, just overwrite the *b* information. However, if you do wish to keep the information, you will need to add more *b*'s to the table. Now we wish to solve

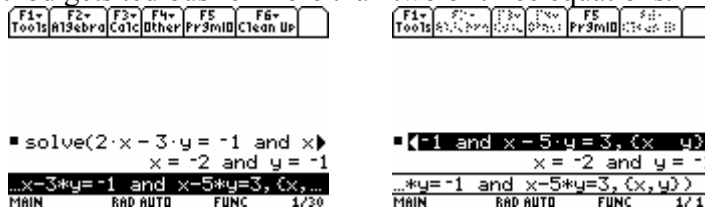
$$\begin{array}{l} 2x - 3y = -4 \\ x - 5y = 7 \end{array} \quad \text{and} \quad \begin{array}{l} 2x - 3y = -1 \\ x - 5y = 3 \end{array} \quad \text{and} \quad \begin{array}{l} 2x - 3y = 0 \\ x - 5y = 1 \end{array}$$

Using the cursor (→) gets you to the entry area for the other equations. Use *F7* to choose which right-hand side you wish to use. Press *F5* to solve.



You can use matrices to solve this type of problem. Details are presented below in the matrix section.

Note that you can also use F2/Solve(to find solutions to simultaneous equations, although this method gets tedious for more than two or three equations.

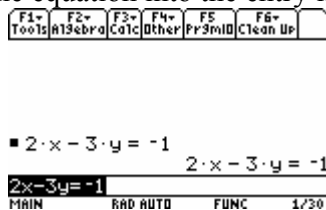


Note the brackets around x, y ; i.e. $\{x, y\}$. You are solving for both variables, not just one. Recall that *and* is in the CATALOG.

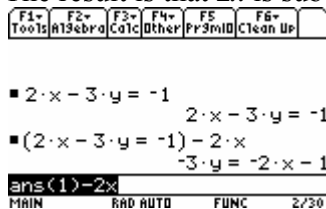
Doing Algebra

Solve $2x - 3y = -1$ for y so the equation can be graphed.

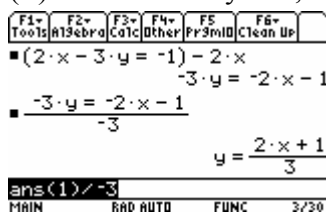
Enter the equation into the entry line, then press ENTER



Enter $-2x$ into the entry line, then press ENTER. The TI supplies the ans(1), the previous result. The result is that $2x$ is subtracted from both sides of the equation.



Enter $\div(-)3$ into the entry line, then press ENTER. The TI supplies the ans(1).



Using F2/Extract/Right, you can isolate the $\frac{2x+1}{3}$. Select, copy (F1/Copy), then paste (F1/Paste) into an empty $y=$ slot.

Be sure to peruse the MATH/Number menu. There you can find items such as mod, least common multiplier, lcm(, greatest common divisor, gcd(, etc.

Graphing

The TI-89 can generate six types of graphs. I will discuss Function, Parametric, Polar, and Diff Equations graphs.



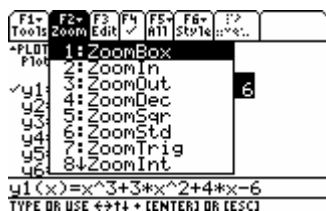
Function Graphs

In order to create a graph of a function, you need to specify the function with line type as well as what window you will use to look at it. Typically, for math problems expected to hover near the origin, I create the function first, then let the calculator create the initial grid by selecting (F2/6: ZoomStd). This command sets the graph window to $-10 \leq x \leq 10$ and $-10 \leq y \leq 10$.

Graph $x^3 + 3x^2 - x - 3$. You can get to $y=$ via the Apps menu as well as $\blacklozenge F1$.

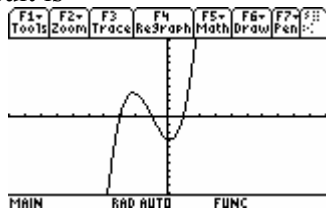


The *Zoom* (F2) menu gives the following screen, shown in two parts since there are more menu items available than will fit on one screen. Note the down arrow next to the 8th choice on the first screen. This arrow tells you to keep going, there are more options.

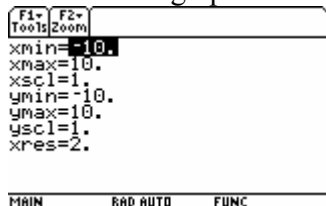


I choose *ZoomStd* as the equation should fit nicely within the $-10 \leq x \leq 10$ and $-10 \leq y \leq 10$ window.

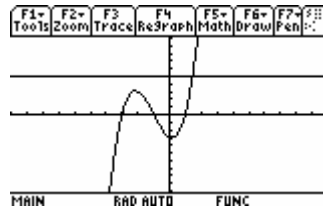
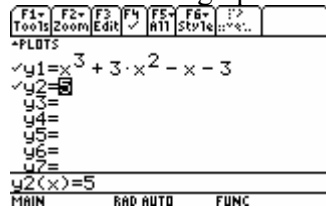
The result is



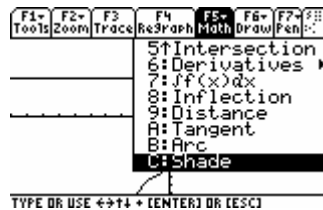
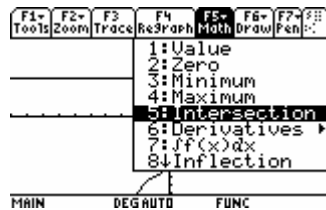
To find out what the graph limits are, press $\blacklozenge F2$.



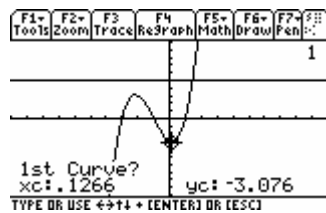
Suppose I now want to know for what value of x results in $y=5$. Set $y_2=5$, then find the intersection of the two graphs.



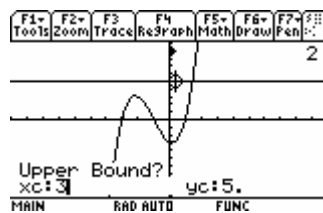
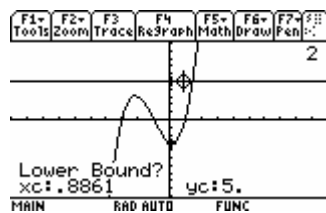
Choose *Intersection* from the current *Math* menu (*F5*). The choices for *F5* are



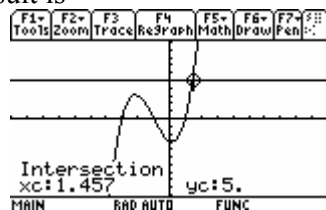
The calculator then asks which curves you want to intersect. The curve number is in the upper right-hand corner of the screen. To move among curves, use the up/down cursor arrows. Since we only have two curves, press ENTER twice.



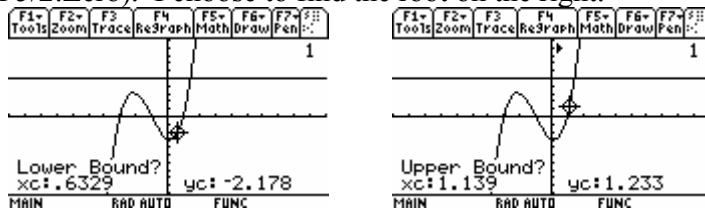
We have chosen *Intersection*, then which two curves to intersect. We are now presented with *Lower Bound?* The lower bound is any point to the left of the intersection and to the right of all other intersections to the left of the chosen one. You can move along a curve or type in a value for x . The upper bound establishes the maximum value of x that the calculator will use to find the intersection point. I moved along the curve for the lower bound and typed in 3 for the upper bound. Once I press ENTER, the calculator finds the intersection; hence, the upper bound selection does not show on the graph.



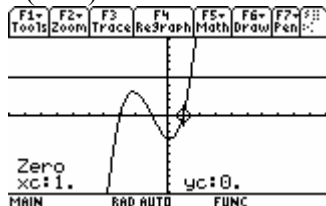
The result is



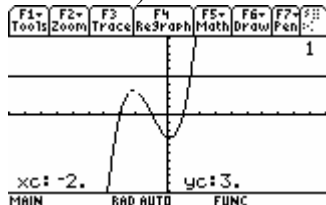
Now let's find the root of the function. Instead of *Intersection*, select *Zero* from the *Math* menu (F5/2:Zero). I choose to find the root on the right.



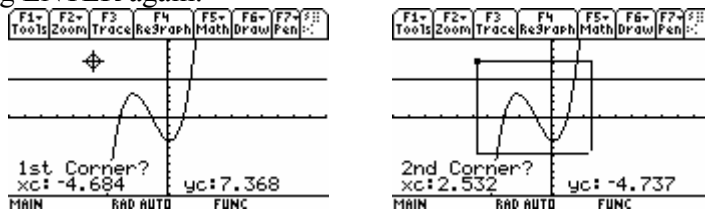
The root (zero) is found to be



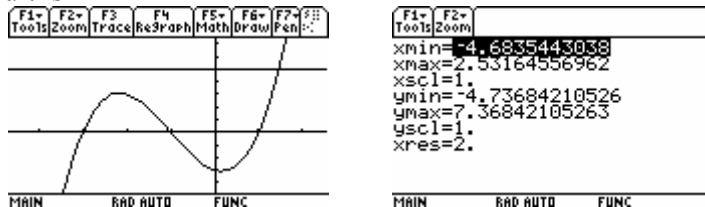
You can evaluate the function at a particular value of x by choosing *Value* from the *Math* menu (F5/1:Value). Find the value of the cubic when $x=-2$. Type -2, then press ENTER.



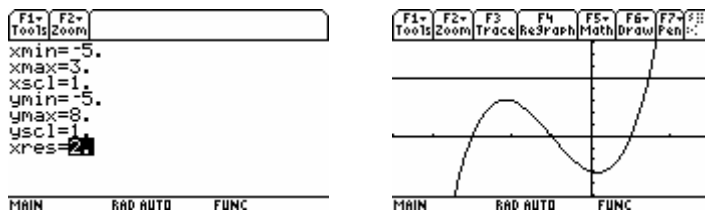
Let's now zoom in on a region. My favorite is *ZoomBox*. Select F2/1:ZoomBox. Move the cursor to the first corner, then press ENTER. Now create the box by moving the cursor, then pressing ENTER again.



The result is

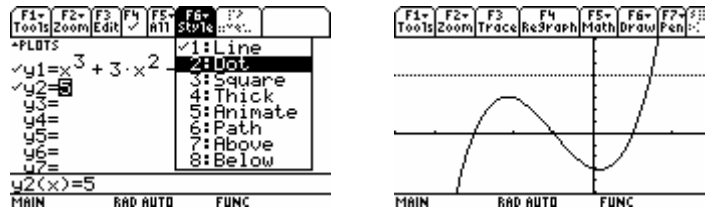


In this case we zoomed in on the intersection region. The new window coordinates are shown. If you prefer tidy graph limits, then edit the numbers in the Window screen (♦F7).



You should play with other types of zooming.

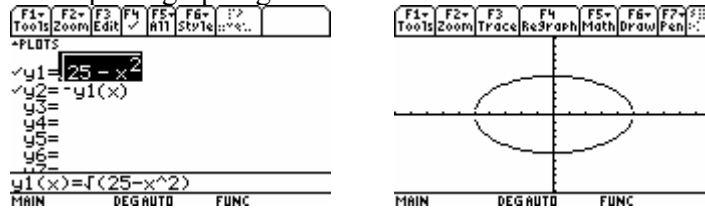
To select a line type, select the graph function in the $y=$ section. $F6$ provides a selection of line types.



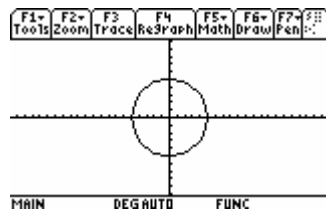
If you wish to suppress the graphing of a function but don't want to erase it, select that function, then $F4$ in the $y=$ screen. $F4$ allows you to select (\surd). i.e. you want to graph it and deselect (no \surd) a function to not graph it.

Note that you can create a complicated function on the entry line of the HOME screen, then COPY/PASTE it into one of the y 's.

Another example is graphing a circle.

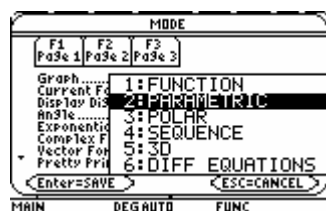


The circle looks like an ellipse due to the aspect ratio of the axes. Now use $F2/5$: ZoomSqr to correct for that effect.



To plot data points, select Plot instead of $y=$. This choice is discussed in the Statistics - Regression section below.

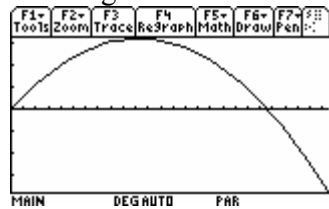
Parametric graphing



A classic case, besides Lissajous figures, is projectile motion:

<pre> F1- F2- F3- F4- F5- F6- F7- F8- Tools Zoom Edit ✓ All Style : : : : +PLOTS ✓xt1=15.·cos(32)·t ✓yt1=15.·sin(32)·t-.5·9.8·t² xt2= yt2= xt3= yt3= xt4= yt4= yt1(t)=15.·sin(32)·t-.5·9... MAIN DEG AUTO PAR </pre>	<pre> F1- F2- F3- F4- F5- F6- F7- F8- Tools Zoom Edit ✓ All Style : : : : +PLOTS ✓xt1=15.·cos(32)·t ✓yt1=15.·sin(32)·t-.5·9.8·t² xt2= yt2= xt3= yt3= xt4= yt4= yt1(t)=15.·sin(32)·t-.5·9... MAIN DEG AUTO PAR </pre>
--	--

F2/A:ZoomFit gives

<pre> F1- F2- F3- F4- F5- F6- F7- F8- Tools Zoom Trace Refresh Math Draw Pen : : MAIN DEG AUTO PAR </pre> 	<pre> F1- F2- Tools Zoom tmin=0. tmax=2. tstep=.05 xmin=0. xmax=25.4414428847 xsc1=1. ymin=-3.702422073 ymax=3.2230311708 ysc1=1. MAIN DEG AUTO PAR </pre>
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Differential equation graphing [pp 396-8 Electronic Guidebook]

```

MODE
Page 1 Page 2 Page 3
Graph: F0
Current F0: 1:FUNCTION
Display Dis: 2:PARAMETRIC
Angle: : : : 3:POLAR
Exponential: 4:SEQUENCE
Complex: F
Vector For: 5:3D
Pretty Print: 6:DIFF EQUATIONS
Enter=SAVE      <ESC=CANCEL
MAIN      DEG AUTO  FUNC
    
```

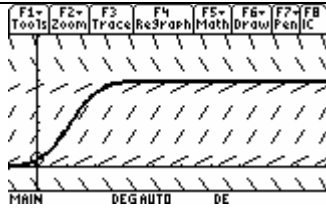
Select y= to enter the differential equation. Temporarily leave the initial condition, y_i1 , blank.

```

F1- F2- F3- F4- F5- F6- F7- F8-
Tools Zoom Edit ✓ All Style : : : :
+PLOTS
t0=0.
✓y1'=y1·(2-y1)
y11=
y21=
y12=
y31=
y13=
y11=
MAIN      DEG AUTO  DE
    
```

Select the graph formats dialog box. Make the choices indicated below.

<pre> F1- F2- F3- F4- F5- F6- F7- F8- Tools Zoom Edit ✓ All Style : : : : 2↑Save Copy As... 3: : : : 4: : : : 5: : : : 6: Paste 7: Delete 8: Clear Functions 9: Format... y11= TYPE OR USE ←↑↓+ + (ENTER) OR (ESC) </pre>	<pre> F1- F2- F3- F4- F5- F6- F7- F8- Tools Zoom Edit ✓ All Style : : : : GRAPH FORMATS +PLOT Coordinates..... RECT → Grid..... OFF → ✓y1 y2 y3 y4 y5 y6 y7 y8 y9 y10 y11 y12 y13 y14 y15 y16 y17 y18 y19 y20 y21 y22 y23 y24 y25 y26 y27 y28 y29 y30 y31 y32 y33 y34 y35 y36 y37 y38 y39 y40 y41 y42 y43 y44 y45 y46 y47 y48 y49 y50 y51 y52 y53 y54 y55 y56 y57 y58 y59 y60 y61 y62 y63 y64 y65 y66 y67 y68 y69 y70 y71 y72 y73 y74 y75 y76 y77 y78 y79 y80 y81 y82 y83 y84 y85 y86 y87 y88 y89 y90 y91 y92 y93 y94 y95 y96 y97 y98 y99 y100 y101 y102 y103 y104 y105 y106 y107 y108 y109 y110 y111 y112 y113 y114 y115 y116 y117 y118 y119 y120 y121 y122 y123 y124 y125 y126 y127 y128 y129 y130 y131 y132 y133 y134 y135 y136 y137 y138 y139 y140 y141 y142 y143 y144 y145 y146 y147 y148 y149 y150 y151 y152 y153 y154 y155 y156 y157 y158 y159 y160 y161 y162 y163 y164 y165 y166 y167 y168 y169 y170 y171 y172 y173 y174 y175 y176 y177 y178 y179 y180 y181 y182 y183 y184 y185 y186 y187 y188 y189 y190 y191 y192 y193 y194 y195 y196 y197 y198 y199 y200 y201 y202 y203 y204 y205 y206 y207 y208 y209 y210 y211 y212 y213 y214 y215 y216 y217 y218 y219 y220 y221 y222 y223 y224 y225 y226 y227 y228 y229 y230 y231 y232 y233 y234 y235 y236 y237 y238 y239 y240 y241 y242 y243 y244 y245 y246 y247 y248 y249 y250 y251 y252 y253 y254 y255 y256 y257 y258 y259 y260 y261 y262 y263 y264 y265 y266 y267 y268 y269 y270 y271 y272 y273 y274 y275 y276 y277 y278 y279 y280 y281 y282 y283 y284 y285 y286 y287 y288 y289 y290 y291 y292 y293 y294 y295 y296 y297 y298 y299 y300 y301 y302 y303 y304 y305 y306 y307 y308 y309 y310 y311 y312 y313 y314 y315 y316 y317 y318 y319 y320 y321 y322 y323 y324 y325 y326 y327 y328 y329 y330 y331 y332 y333 y334 y335 y336 y337 y338 y339 y340 y341 y342 y343 y344 y345 y346 y347 y348 y349 y350 y351 y352 y353 y354 y355 y356 y357 y358 y359 y360 y361 y362 y363 y364 y365 y366 y367 y368 y369 y370 y371 y372 y373 y374 y375 y376 y377 y378 y379 y380 y381 y382 y383 y384 y385 y386 y387 y388 y389 y390 y391 y392 y393 y394 y395 y396 y397 y398 y399 y400 y401 y402 y403 y404 y405 y406 y407 y408 y409 y410 y411 y412 y413 y414 y415 y416 y417 y418 y419 y420 y421 y422 y423 y424 y425 y426 y427 y428 y429 y430 y431 y432 y433 y434 y435 y436 y437 y438 y439 y440 y441 y442 y443 y444 y445 y446 y447 y448 y449 y450 y451 y452 y453 y454 y455 y456 y457 y458 y459 y460 y461 y462 y463 y464 y465 y466 y467 y468 y469 y470 y471 y472 y473 y474 y475 y476 y477 y478 y479 y480 y481 y482 y483 y484 y485 y486 y487 y488 y489 y490 y491 y492 y493 y494 y495 y496 y497 y498 y499 y500 y501 y502 y503 y504 y505 y506 y507 y508 y509 y510 y511 y512 y513 y514 y515 y516 y517 y518 y519 y520 y521 y522 y523 y524 y525 y526 y527 y528 y529 y530 y531 y532 y533 y534 y535 y536 y537 y538 y539 y540 y541 y542 y543 y544 y545 y546 y547 y548 y549 y550 y551 y552 y553 y554 y555 y556 y557 y558 y559 y560 y561 y562 y563 y564 y565 y566 y567 y568 y569 y570 y571 y572 y573 y574 y575 y576 y577 y578 y579 y580 y581 y582 y583 y584 y585 y586 y587 y588 y589 y590 y591 y592 y593 y594 y595 y596 y597 y598 y599 y600 y601 y602 y603 y604 y605 y606 y607 y608 y609 y610 y611 y612 y613 y614 y615 y616 y617 y618 y619 y620 y621 y622 y623 y624 y625 y626 y627 y628 y629 y630 y631 y632 y633 y634 y635 y636 y637 y638 y639 y640 y641 y642 y643 y644 y645 y646 y647 y648 y649 y650 y651 y652 y653 y654 y655 y656 y657 y658 y659 y660 y661 y662 y663 y664 y665 y666 y667 y668 y669 y670 y671 y672 y673 y674 y675 y676 y677 y678 y679 y680 y681 y682 y683 y684 y685 y686 y687 y688 y689 y690 y691 y692 y693 y694 y695 y696 y697 y698 y699 y700 y701 y702 y703 y704 y705 y706 y707 y708 y709 y710 y711 y712 y713 y714 y715 y716 y717 y718 y719 y720 y721 y722 y723 y724 y725 y726 y727 y728 y729 y730 y731 y732 y733 y734 y735 y736 y737 y738 y739 y740 y741 y742 y743 y744 y745 y746 y747 y748 y749 y750 y751 y752 y753 y754 y755 y756 y757 y758 y759 y760 y761 y762 y763 y764 y765 y766 y767 y768 y769 y770 y771 y772 y773 y774 y775 y776 y777 y778 y779 y780 y781 y782 y783 y784 y785 y786 y787 y788 y789 y790 y791 y792 y793 y794 y795 y796 y797 y798 y799 y800 y801 y802 y803 y804 y805 y806 y807 y808 y809 y810 y811 y812 y813 y814 y815 y816 y817 y818 y819 y820 y821 y822 y823 y824 y825 y826 y827 y828 y829 y830 y831 y832 y833 y834 y835 y836 y837 y838 y839 y840 y841 y842 y843 y844 y845 y846 y847 y848 y849 y850 y851 y852 y853 y854 y855 y856 y857 y858 y859 y860 y861 y862 y863 y864 y865 y866 y867 y868 y869 y870 y871 y872 y873 y874 y875 y876 y877 y878 y879 y880 y881 y882 y883 y884 y885 y886 y887 y888 y889 y890 y891 y892 y893 y894 y895 y896 y897 y898 y899 y900 y901 y902 y903 y904 y905 y906 y907 y908 y909 y910 y911 y912 y913 y914 y915 y916 y917 y918 y919 y920 y921 y922 y923 y924 y925 y926 y927 y928 y929 y930 y931 y932 y933 y934 y935 y936 y937 y938 y939 y940 y941 y942 y943 y944 y945 y946 y947 y948 y949 y950 y951 y952 y953 y954 y955 y956 y957 y958 y959 y960 y961 y962 y963 y964 y965 y966 y967 y968 y969 y970 y971 y972 y973 y974 y975 y976 y977 y978 y979 y980 y981 y982 y983 y984 y985 y986 y987 y988 y989 y990 y991 y992 y993 y994 y995 y996 y997 y998 y999 y1000 y1001 y1002 y1003 y1004 y1005 y1006 y1007 y1008 y1009 y1010 y1011 y1012 y1013 y1014 y1015 y1016 y1017 y1018 y1019 y1020 y1021 y1022 y1023 y1024 y1025 y1026 y1027 y1028 y1029 y1030 y1031 y1032 y1033 y1034 y1035 y1036 y1037 y1038 y1039 y1040 y1041 y1042 y1043 y1044 y1045 y1046 y1047 y1048 y1049 y1050 y1051 y1052 y1053 y1054 y1055 y1056 y1057 y1058 y1059 y1060 y1061 y1062 y1063 y1064 y1065 y1066 y1067 y1068 y1069 y1070 y1071 y1072 y1073 y1074 y1075 y1076 y1077 y1078 y1079 y1080 y1081 y1082 y1083 y1084 y1085 y1086 y1087 y1088 y1089 y1090 y1091 y1092 y1093 y1094 y1095 y1096 y1097 y1098 y1099 y1100 y1101 y1102 y1103 y1104 y1105 y1106 y1107 y1108 y1109 y1110 y1111 y1112 y1113 y1114 y1115 y1116 y1117 y1118 y1119 y1120 y1121 y1122 y1123 y1124 y1125 y1126 y1127 y1128 y1129 y1130 y1131 y1132 y1133 y1134 y1135 y1136 y1137 y1138 y1139 y1140 y1141 y1142 y1143 y1144 y1145 y1146 y1147 y1148 y1149 y1150 y1151 y1152 y1153 y1154 y1155 y1156 y1157 y1158 y1159 y1160 y1161 y1162 y1163 y1164 y1165 y1166 y1167 y1168 y1169 y1170 y1171 y1172 y1173 y1174 y1175 y1176 y1177 y1178 y1179 y1180 y1181 y1182 y1183 y1184 y1185 y1186 y1187 y1188 y1189 y1190 y1191 y1192 y1193 y1194 y1195 y1196 y1197 y1198 y1199 y1200 y1201 y1202 y1203 y1204 y1205 y1206 y1207 y1208 y1209 y1210 y1211 y1212 y1213 y1214 y1215 y1216 y1217 y1218 y1219 y1220 y1221 y1222 y1223 y1224 y1225 y1226 y1227 y1228 y1229 y1230 y1231 y1232 y1233 y1234 y1235 y1236 y1237 y1238 y1239 y1240 y1241 y1242 y1243 y1244 y1245 y1246 y1247 y1248 y1249 y1250 y1251 y1252 y1253 y1254 y1255 y1256 y1257 y1258 y1259 y1260 y1261 y1262 y1263 y1264 y1265 y1266 y1267 y1268 y1269 y1270 y1271 y1272 y1273 y1274 y1275 y1276 y1277 y1278 y1279 y1280 y1281 y1282 y1283 y1284 y1285 y1286 y1287 y1288 y1289 y1290 y1291 y1292 y1293 y1294 y1295 y1296 y1297 y1298 y1299 y1300 y1301 y1302 y1303 y1304 y1305 y1306 y1307 y1308 y1309 y1310 y1311 y1312 y1313 y1314 y1315 y1316 y1317 y1318 y1319 y1320 y1321 y1322 y1323 y1324 y1325 y1326 y1327 y1328 y1329 y1330 y1331 y1332 y1333 y1334 y1335 y1336 y1337 y1338 y1339 y1340 y1341 y1342 y1343 y1344 y1345 y1346 y1347 y1348 y1349 y1350 y1351 y1352 y1353 y1354 y1355 y1356 y1357 y1358 y1359 y1360 y1361 y1362 y1363 y1364 y1365 y1366 y1367 y1368 y1369 y1370 y1371 y1372 y1373 y1374 y1375 y1376 y1377 y1378 y1379 y1380 y1381 y1382 y1383 y1384 y1385 y1386 y1387 y1388 y1389 y1390 y1391 y1392 y1393 y1394 y1395 y1396 y1397 y1398 y1399 y1400 y1401 y1402 y1403 y1404 y1405 y1406 y1407 y1408 y1409 y1410 y1411 y1412 y1413 y1414 y1415 y1416 y1417 y1418 y1419 y1420 y1421 y1422 y1423 y1424 y1425 y1426 y1427 y1428 y1429 y1430 y1431 y1432 y1433 y1434 y1435 y1436 y1437 y1438 y1439 y1440 y1441 y1442 y1443 y1444 y1445 y1446 y1447 y1448 y1449 y1450 y1451 y1452 y1453 y1454 y1455 y1456 y1457 y1458 y1459 y1460 y1461 y1462 y1463 y1464 y1465 y1466 y1467 y1468 y1469 y1470 y1471 y1472 y1473 y1474 y1475 y1476 y1477 y1478 y1479 y1480 y1481 y1482 y1483 y1484 y1485 y1486 y1487 y1488 y1489 y1490 y1491 y1492 y1493 y1494 y1495 y1496 y1497 y1498 y1499 y1500 y1501 y1502 y1503 y1504 y1505 y1506 y1507 y1508 y1509 y1510 y1511 y1512 y1513 y1514 y1515 y1516 y1517 y1518 y1519 y1520 y1521 y1522 y1523 y1524 y1525 y1526 y1527 y1528 y1529 y1530 y1531 y1532 y1533 y1534 y1535 y1536 y1537 y1538 y1539 y1540 y1541 y1542 y1543 y1544 y1545 y1546 y1547 y1548 y1549 y1550 y1551 y1552 y1553 y1554 y1555 y1556 y1557 y1558 y1559 y1560 y1561 y1562 y1563 y1564 y1565 y1566 y1567 y1568 y1569 y1570 y1571 y1572 y1573 y1574 y1575 y1576 y1577 y1578 y1579 y1580 y1581 y1582 y1583 y1584 y1585 y1586 y1587 y1588 y1589 y1590 y1591 y1592 y1593 y1594 y1595 y1596 y1597 y1598 y1599 y1600 y1601 y1602 y1603 y1604 y1605 y1606 y1607 y1608 y1609 y1610 y1611 y1612 y1613 y1614 y1615 y1616 y1617 y1618 y1619 y1620 y1621 y1622 y1623 y1624 y1625 y1626 y1627 y1628 y1629 y1630 y1631 y1632 y1633 y1634 y1635 y1636 y1637 y1638 y1639 y1640 y1641 y1642 y1643 y1644 y1645 y1646 y1647 y1648 y1649 y1650 y1651 y1652 y1653 y1654 y1655 y1656 y1657 y1658 y1659 y1660 y1661 y1662 y1663 y1664 y1665 y1666 y1667 y1668 y1669 y1670 y1671 y1672 y1673 y1674 y1675 y1676 y1677 y1678 y1679 y1680 y1681 y1682 y1683 y1684 y1685 y1686 y1687 y1688 y1689 y1690 y1691 y1692 y1693 y1694 y1695 y1696 y1697 y1698 y1699 y1700 y1701 y1702 y1703 y1704 y1705 y1706 y1707 y1708 y1709 y1710 y1711 y1712 y1713 y1714 y1715 y1716 y1717 y1718 y1719 y1720 y1721 y1722 y1723 y1724 y1725 y1726 y1727 y1728 y1729 y1730 y1731 y1732 y1733 y1734 y1735 y1736 y1737 y1738 y1739 y1740 y1741 y1742 y1743 y1744 y1745 y1746 y1747 y1748 y1749 y1750 y1751 y1752 y1753 y1754 y1755 y1756 y1757 y1758 y1759 y1760 y1761 y1762 y1763 y1764 y1765 y1766 y1767 y1768 y1769 y1770 y1771 y1772 y1773 y1774 y1775 y1776 y1777 y1778 y1779 y1780 y1781 y1782 y1783 y1784 y1785 y1786 y1787 y1788 y1789 y1790 y1791 y1792 y1793 y1794 y1795 y1796 y1797 y1798 y1799 y1800 y1801 y1802 y1803 y1804 y1805 y1806 y1807 y1808 y1809 y1810 y1811 y1812 y1813 y1814 y1815 y1816 y1817 y1818 y1819 y1820 y1821 y1822 y1823 y1824 y1825 y1826 y1827 y1828 y1829 y1830 y1831 y1832 y1833 y1834 y1835 y1836 y1837 y1838 y1839 y1840 y1841 y1842 y1843 y1844 y1845 y1846 y1847 y1848 y1849 y1850 y1851 y1852 y1853 y1854 y1855 y1856 y1857 y1858 y1859 y1860 y1861 y1862 y1863 y1864 y1865 y1866 y1867 y1868 y1869 y1870 y1871 y1872 y1873 y1874 y1875 y1876 y1877 y1878 y1879 y1880 y1881 y1882 y1883 y1884 y1885 y1886 y1887 y1888 y1889 y1890 y1891 y1892 y1893 y1894 y1895 y1896 y1897 y1898 y1899 y1900 y1901 y1902 y1903 y1904 y1905 y1906 y1907 y1908 y1909 y1910 y1911 y1912 y1913 y1914 y1915 y1916 y1917 y1918 y1919 y1920 y1921 y1922 y1923 y1924 y1925 y1926 y1927 y1928 y1929 y1930 y1931 y1932 y1933 y1934 y1935 y1936 y1937 y1938 y1939 y1940 y1941 y1942 y1943 y1944 y1945 y1946 y1947 y1948 y1949 y1950 y1951 y1952 y1953 y1954 y1955 y1956 y1957 y1958 y1959 y1960 y1961 y1962 y1963 y1964 y1965 y1966 y1967 y1968 y1969 y1970 y1971 y1972 y1973 y1974 y1975 y1976 y1977 y1978 y1979 y1980 y1981 y1982 y1983 y1984 y1985 y1986 y1987 y1988 y1989 y1990 y1991 y1992 y1993 y1994 y1995 y1996 y1997 y1998 y1999 y2000 y2001 y2002 y2003 y2004 y2005 y2006 y2007 y2008 y2009 y2010 y2011 y2</pre>
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```

F1- F2- F3- F4- F5- F6- F7- F8-
Tools Zoom Edit ✓ Rtl Style :<<..

*PLOTS
t0=0.
✓y1'=y1(2-y1)
y11=.2
y2'=
y12=
y3'=
y13=
y2'(t)=
SELECT ONE 1ST-ORDER FUNCTION ONLY

```

```

F1- F2-
Tools Zoom
t0=0.
tmax=10.
tstep=.1
tplot=0.1
xmin=-1.
xmax=10.
xsc1=1.
ymin=-.5
ymax=3.
ysc1=1.
MAIN DEG AUTO DE

```

Polar graphing

```

F1- F2- F3- F4- F5- F6- F7- F8-
Tools Zoom Edit ✓ Rtl Style :<<..

*PLOTS
✓r1=8·sin(2·θ)
r2=9
r3=
r4=
r5=
r6=
r7=
r3(θ)=
MAIN RAD AUTO PDL

```

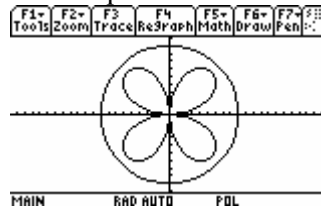
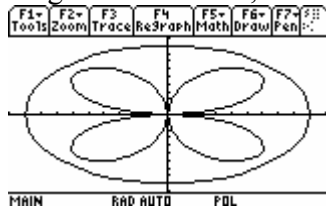
```

F1- F2-
Tools Zoom
θmin=0.
θmax=6.28318530718
θstep=.13089969389957
xmin=-10.
xmax=10.
xsc1=1.
ymin=-10.
ymax=10.
ysc1=1.
MAIN RAD AUTO PDL

```

Note that if you type 2π for $\theta_{max}=2\pi$, the TI will evaluate the expression to its numerical equivalent. You can also type trig functions, etc., on the right hand side of the Window settings.

Graph using F2/6:ZoomStd, then F2/5:ZoomSqr



Trig

The three major trig buttons with inverses (*sin*, *cos*, *tan*) are on the main keyboard above the *Y*, *Z*, *T* buttons. The other three functions with inverses as well as the hyperbolic trig functions are available in the CATALOG. They can also be found in 2nd 5 (the MATH button)/A:Trig or C:Hyperbolic.

Vectors and Matrices

The TI-89 has a full set of matrix algebra operations, such as augment, rref, diagonals, determinants, eigensystems, LU and QR decompositions, norms, row operations etc. This section discusses only those operations students typically use in many technical courses, not a full matrix algebra course like MTH 220. See the Guidebooks for more information.

Vectors

A vector is treated as a single row matrix. You can enter the vector data either using Apps/Data/matrix editor or by entering from the entry line: $[x, y, z]$. You can also enter vectors in polar form: $[2., 5.]$ or $[3., \angle 52]$. **Conversions** between the two forms are straightforward (use CATALOG or MATH/Matrix/Vector ops). Note that I use a decimal in order to not get

back the Exact form. Also note that I am in Degree mode (see the Status line).

```

F1+ F2+ F3+ F4+ F5+ F6+
Tools|Algebra|Calc|Other|Pr3mID|Clean Up

■[-2 3.]          [-2 3.]
■[-2 3.]►Polar
                [ 3.606 ∠ 123.7]
■([ 3.605551275464 ∠ 123.69)►
                [-2. 3.]
ans(1)►Rect
MAIN          DEG AUTO    FUNC    3/30
  
```

In addition, there are commands to extract the angle or radius, etc.

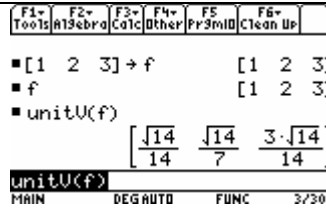
Vectors in 3D space are also straightforward to convert to cylindrical and spherical coordinates. The second conversion to cylindrical below was performed using \blacklozenge ENTER. Pressing the \blacklozenge in front of the ENTER guarantees an approximate solution, not exact. The exact result is shown in the first conversion. It is difficult to read and not too helpful unless you happen to know what the arctangent of $\frac{1}{2}$ is.

To enter the vector you wish to convert, you can either use *Ans(1)*, as above, or place the cursor at the end of the entry line before selecting the conversion operator from the catalog.

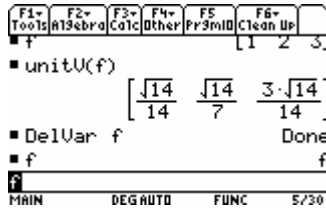
<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up ■[1 2 3.] [1 2 3.] ■[1 2 3.]►Cylind [√5 ∠ 90 - tan⁻¹(1/2) 3.] ■[1 2 3.]►Cylind [2.236 ∠ 63.43 3.] [1,2,3.]►Cylind MAIN DEG AUTO FUNC 3/30 </pre>	<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up ■[1 2 3.] [1 2 3.] ■[1 2 3.]►Sphere [3.742 ∠ 90 - tan⁻¹(1/2) ∠ 3]► ■[1 2 3.]►Sphere [3.742 ∠ 63.43 ∠ 36.7] [1,2,3.]►Sphere MAIN DEG AUTO FUNC 3/30 </pre>
<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up ■[1 2 3.]►Sphere [3.742 ∠ 90 - tan⁻¹(1/2) ∠ 3]► ■[1 2 3.]►Sphere [3.742 ∠ 63.43 ∠ 36.7] ■([3.7416573867739 ∠ 63.43)► [2.236 ∠ 63.43 3.] ans(1)►Cylind MAIN DEG AUTO FUNC 4/30 </pre>	<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up ■[1 2 3.]►Sphere [3.742 ∠ 63.43 ∠ 36.7] ■([3.7416573867739 ∠ 63.43)► [2.236 ∠ 63.43 3.] ■([2.2360679774997 ∠ 63.43)► [1. 2. 3.] ans(1)►Rect MAIN DEG AUTO FUNC 5/30 </pre>

You can perform **dot products** and **cross products** and you can make a **unit vector**. These operations are found in the CATALOG as well as MATH/Matrix/Vector ops. The **transpose** operator (T) is the first entry in MATH/Matrix. It is also the first entry under CATALOG/T. For both dot and cross products, both vectors must be either row or column vectors. You will get an error message if you mix types.

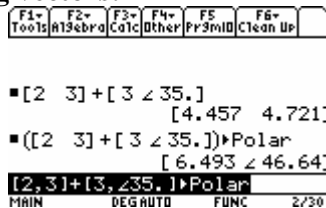
<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up ■ dotP([1 2 3],[1 0 -2]) -5 ■ dotP([1 2 3]^T,[1 0 -2]) -5 dotP([1,2,3]^T,[1,0,-2]^T) MAIN DEG AUTO FUNC 2/30 </pre>	<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up -5 ■ dotP([1 2 3]^T,[1 0 -2]) -5 ■ dotP([1 2 3]^T,[1 0 -2]) Error: Data type dotP([1,2,3]^T,[1,0,-2]^T) MAIN DEG AUTO FUNC 3/30 </pre>
<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up ■ crossP([1 2 3],[1 0 2]) [4 1 -2] [...ssP([1,2,3],[1,0,2]) MAIN DEG AUTO FUNC 1/30 </pre>	<pre> F1+ F2+ F3+ F4+ F5+ F6+ Tools Algebra Calc Other Pr3mID Clean Up [4 1 -2] ■ crossP([1 2 3]^T,[1 0 2]) [4] [1] [-2] crossP([1,2,3]^T,[1,0,2]^T) MAIN DEG AUTO FUNC 2/30 </pre>



Note that when making the unit vector, I first stored the vector as variable name, f , for future use. Use single character names for temporary variables as you can clear them all using F6/1:Clear a-z from the home screen. You can delete individual letters using *Del*var f (F4/4). I also let the format default to *Exact* instead of *Approximate* hence I got all those radical signs.

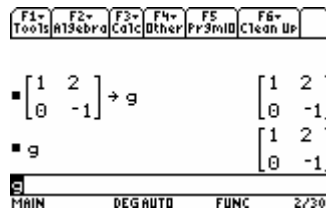
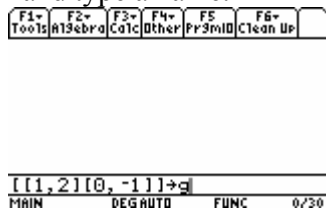


Adding vectors:



Matrices

You can enter the matrix data either using Apps/(Data/Matrix) editor or by entering from the entry line: $[[a_{11}, a_{12}, a_{13}], [a_{21}, a_{22}, a_{23}], [a_{31}, a_{32}, a_{33}]]$. For easy editing later, you might want to store matrices. After entering it from the entry line, press STO►, then press ALPHA and type a name.



When you create a matrix using the Data/Matrix editor, you are initially given three options: List, Data and Matrix. From the Electronic Guidebook [1, pp501-4]:

- “A **list** is a series of items (numbers, expressions, or character strings) that may or may not be related.”
- “A **data** variable is essentially a collection of lists that may or may not be related.” This data type looks like a spreadsheet to me.
- “A **matrix** is a rectangular array of elements.” We will discuss this one.

Once you have defined a matrix, you can perform all the MTH 220, Linear Algebra, operations on it. Let’s use **Cramer’s rule** to solve $2x - 3y = -1$ and $x - 5y = 3$. Two matrices were

defined using the Data/Matrix application (Apps/6). Once A was defined, I defined B by using F1/New to create another matrix while still in the matrix editor. The \det operator is MATH/Matrix/det(as well as CATALOG/det(. Below I calculate the y value.

```

F1+ F2+ F3+ F4+ F5+ F6+
Tools|13|ebra|Calc|Other|Pr3mID|Clean Up
■ a
  [ 1 -5 ]
■ top
  [ 2 -1 ]
  [ 1  3 ]
■ det(top)
  -1
■ det(a)
  -1
det(top)/det(a)
MAIN      DEG AUTO      FUNC      3/30
  
```

You can also solve the matrix equation $A\vec{x} = \vec{b}$ as follows. I defined A and b in Apps/6: Data/Matrix. Note the inverse operator is just raising the matrix A to the -1 .

```

F1+ F2+ F3+ F4+ F5+ F6+
Tools|13|ebra|Calc|Other|Pr3mID|Clean Up
■ a
  [ 1 -5 ]
■ b
  [ -1 ]
  [  3 ]
■ a^-1.b
  [ -2 ]
  [ -1 ]
a^-1*b
MAIN      DEG AUTO      FUNC      3/30
  
```

Another alternative is to use SIMULT (MATH/Matrix/Simult):

```

F1+ F2+ F3+ F4+ F5+ F6+
Tools|13|ebra|Calc|Other|Pr3mID|Clean Up
■ a
  [ 2 -3 ]
  [ 1 -5 ]
■ b
  [ -1 ]
  [  3 ]
simult(a,b)
simult(a,b)
MAIN      RAD AUTO      PDL      3/30
  
```

When the matrix elements are complex, you need to select your MODE settings carefully. According to [4, p 57], set Angle mode to DEGREE and ComplexFormat to POLAR. You can enter your elements in either polar ($r\angle\theta$) or rectangular $a+ib$ form. For $j = \sqrt{-1}$, use i (2nd CATALOG) to get $a+ib$. I used \blacklozenge ENTER to find the inverse as well as the solution. It takes a very long time to solve complex matrix problems in *exact* or *auto* mode.

```

F1+ F2+ F3+ F4+ F5+ F6+
Tools|13|ebra|Calc|Other|Pr3mID|Clean Up
■ acomplex
  [( 3 ∠ 30) ( 1 ∠ -120) ]
  [ 1 ( 2 ∠ -42) ]
■ bcomplex
  [( 6 ∠ 20) ]
  [( -1 ∠ -115) ]
bcomplex
MAIN      DEG AUTO      FUNC      2/99

F1+ F2+ F3+ F4+ F5+ F6+
Tools|13|ebra|Calc|Other|Pr3mID|Clean Up
■ bcomplex
  [( 6 ∠ 20) ]
  [( -1 ∠ -115) ]
■ acomplex^-1
  [( .3135 ∠ -38.57) (.1567 )
  [( .1567 ∠ -176.6) (.4702 )
acompex^-1
MAIN      DEG AUTO      FUNC      3/99

F1+ F2+ F3+ F4+ F5+ F6+
Tools|13|ebra|Calc|Other|Pr3mID|Clean Up
■ bcomplex
  [( 6 ∠ 20) ]
  [( -1 ∠ -115) ]
■ acomplex^-1.bcomplex
  [( 1.751 ∠ -15.78) ]
  [( .9362 ∠ 174.4) ]
acompex^-1*bcomplex
MAIN      DEG AUTO      FUNC      3/99
  
```

Note: On occasion, you may want to write the complex equation $A\vec{x} = \vec{b}$ as purely real. You can make the problem purely real by using the following algorithm.

Given: $(A + Bi)(x + iy) = a + ib$ A, B, a, b, x, y are all real.

Expand into two equations: $Ax - By = a$ and $Bx + Ay = b$

Write in block matrix form (the matrix elements are themselves matrices):

$$\begin{pmatrix} A & -B \\ B & A \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} a \\ b \end{pmatrix}$$

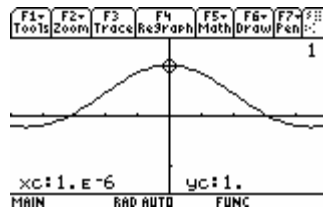
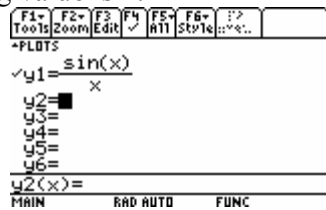
This real equation can be solved to find x and y : $\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} A & -B \\ B & A \end{pmatrix}^{-1} \begin{pmatrix} a \\ b \end{pmatrix}$.

You could use the *Simultaneous Equation Solver* or *Simult* at this point as well.

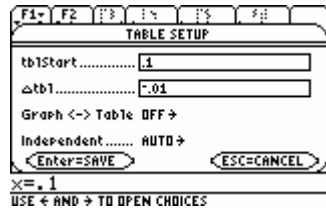
Tables

Tables are used to display a list of values for a given function.

To set one up, first create the function. We will look at $y = \frac{\sin x}{x}$ as x goes to 0. The limiting value is 1.



Now set up the initial table parameters using TblSet ($\blacklozenge F4$). $\blacklozenge F5$ displays the table generated.



x	y1		
1	.9983		
.09	.9987		
.08	.9989		
.07	.9992		
.06	.9994		

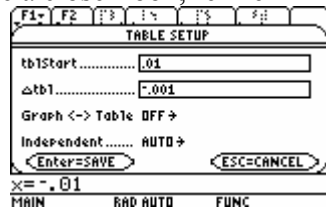
x = .1

You can scroll down the first column until the desired number is found.

x	y1		
.03	.9999		
.02	.9999		
.01	1.		
0.	undef		
-.01	1.		

x = -.01

To have a closer look, refine TBLSET.



x	y1		
.01	1.		
.009	1.		
.008	1.		
.007	1.		
.006	1.		

x = .01

Complex Numbers

There are three forms in which to write complex numbers

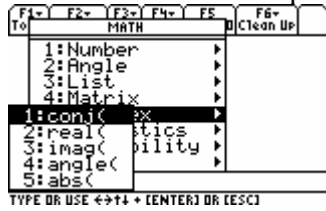
Rectangular $a + ib$ radian or degree mode

Polar $(r \angle \theta)$ radian or degree mode. *Note* - no comma - as in vectors

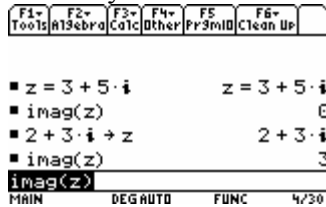
Exponential $re^{i\theta}$ radian mode only

You may enter complex numbers in any format. Depending on your choice, Rectangular ($a + ib$), real (only uses complex notation if you enter complex numbers) or polar ($r \angle \theta$), when you press ENTER, the number is converted to that format. **Note:** complex operations always work in radian mode. See note 9 at the beginning of this document. "In Degree angle mode, complex identities such as $e^{iq} = \cos(q) + i \sin(q)$ are not generally true because the values for cos and sin are converted to radians, while those for $e^{(\)}$ are not. For example, $e^{i45} = \cos(45) + i \sin(45)$ is treated internally as $e^{i45} = \cos(\pi/4) + i \sin(\pi/4)$. Complex identities are always true in Radian angle mode." [p 912 Electronic Guidebook]

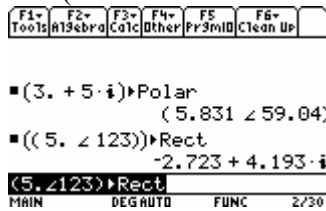
Operations in the MATH/Complex menu are



Be careful how you define a number as complex:



Conversion (note the use of a decimal point to suppress weird answers):



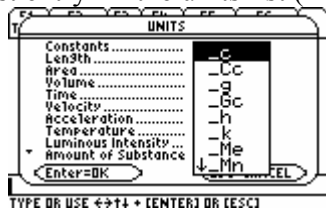
Assign keys 1-9 to applications

You can assign keys 1 through 9 to run a program, as I mentioned above. For instance, suppose you have a program called RunMe. To assign the 3 key to this program you must rename RunMe to `kbdprgm3()`. You can then run it using \blacklozenge 3. [pp 626-7 Electronic Guidebook]. Note that an example of `kbdprgm` is given on page 8 of this document.

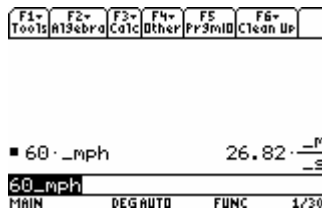
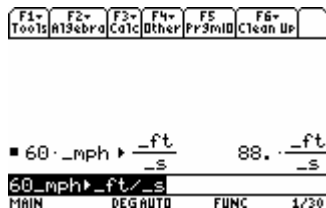
Unit creation and conversion

Unit conversion

The first entry in the units list (2nd 3) contains a bunch of built-in constants:



The TI-89 will convert units for you. The two unit operation characters, \blacktriangleright and $_$, are above the MODE key. The TI-89 converts to the default system (MODE/F3) if no final units are specified. Note that the unit ft/s is not defined in the *velocity* submenu so I had to use actual division of units.



Unit Creation [pp 52-3 Printed Guidebook]:

Create an acceleration unit called $_ms2$, then use it in $F=ma$ to find force. Remember that the character \rightarrow is what you get on the status line when you press the STO key. The result is given in *Newtons*, the SI unit of force.

Left screenshot: $\frac{-M}{s^2} \rightarrow _ms2$

Right screenshot: $5 \cdot _kg \cdot 20 \cdot _ms2 = 100 \cdot _N$

Bases

The options available under MATH/Base are

Left screenshot: MATH/Base menu with '1: Hex' selected.

Right screenshot: MATH/Base menu with '3: Dec' selected.

The default base is set in MODE/F2.

Inequalities

Solving inequalities

Solve $2x + 1 < x + 3 < 4x - 6$. The inequality must be split into two single inequalities. Try *and* first. If the answer is false, then switch to *or*.

Calculator input: $\text{solve}(2 \cdot x + 1 < x + 3 \text{ and } x > x + 3 \text{ or } x > 3 \text{ or } x < 2)$

Result: false

Graphing inequalities

Use the *When* function. The *when* function format is *When(condition, true, false)* just like the *if* function in Excel and in Word's Mail Merge. Note that I used *F6* to change the style of y^2 to dots. Using a line connects the last true point with the first false one, as shown in the graph of $y1$.

Left screenshot: $y1 = \begin{cases} 5, & 2 \cdot x + 1 < x + 3 \\ 0, & \text{else} \end{cases}$

Right screenshot: Graph of $y1$ showing a step function.

Graphing absolute values (F2/6:ZoomStd)

Left screenshot: $y1 = \begin{cases} 7, & |2 \cdot x - 3| > 5 \\ -7, & \text{else} \end{cases}$

Right screenshot: Graph of $y1$ showing a step function.

From Kelly's "Advanced Algebra with the TI-89", we wish to graph $0.5x + 0.8y \leq 13$.

Solve for y algebraically, then graph. Since it turns out $y \leq \frac{(13 - 0.5x)}{0.8}$, all values below the

line $y = \frac{(13 - 0.5x)}{0.8}$ are valid solutions so should be shaded.

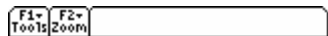


```

■ solve(.5·x + .8·y < 13, y)
  y + .625·x < 16.25
■ (y + .625·x < 16.25) - .625·x
  y < 16.25 - .625·x

```

```
ans(1) = .625·x
MAIN RAD AUTO FUNC 2/30
```



```

xmin=0.
xmax=30.
xsc1=2.5
ymin=0.
ymax=20.
ysc1=5.
xres=2.

```

```
MAIN RAD AUTO FUNC
```

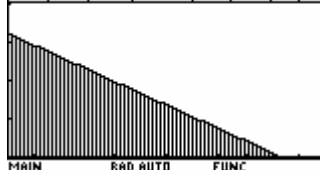
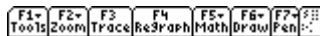


```

+PLOTS
✓y1=16.25-.625·x
y2=
y3=
y4=
y5=
y6=
y7=
y8=
1:Line
2:Dot
3:Square
4:Thick
5:Animate
6:Path
7:Above
8:Below

```

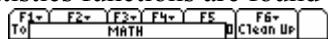
```
y1(x)=16.25-.625·x
MAIN RAD AUTO FUNC
```



This type of plot is used in Linear Programming.

Statistics – Regression [pp 917-918 Electronic Guidebook]

The statistics functions are found under MATH/Statistics.



```

1: Number
1: OneVar
2: TwoVar
3: Regressions
4: mean(
5: variance(
6: stdDev(
7: median(
8: ShowStat

```

```
MAIN DEG AUTO FUNC 0/30
```

You find the regression functions under MATH/Statistics/Regressions. The simple version is

CubicReg xlist,ylist $y = ax^3 + bx^2 + cx + d$

ExpReg xlist,ylist $y = ab^x$

LinReg xlist,ylist $y = ax + b$

LnReg xlist,ylist $y = a + b \ln(x)$

Logistic xlist,ylist $y = a / (1 + b \cdot e^{-(c \cdot x)}) + d$ i.e. $y = \frac{a}{1 + be^{cx}} + d$

PowerReg xlist,ylist $y = ax^b$

QuadReg xlist,ylist $y = ax^2 + bx + c$

QuartReg xlist,ylist $y = ax^4 + bx^3 + cx^2 + dx + e$

SinReg xlist,ylist $y = a \sin(bx + c) + d$

MedMed xlist,ylist calculates the median-median line

They can all accept more arguments. For example,

QuadReg list1, list2[, [list3] [, list4, list5]]

list1 represents **xlist**.

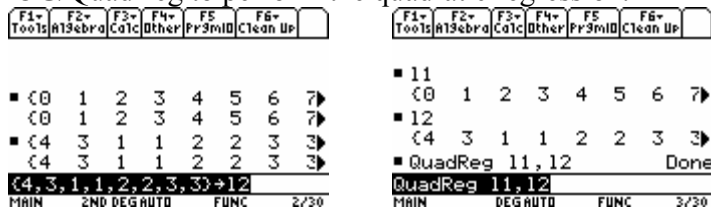
list2 represents **ylist**.

list3 represents **frequency**.

list4 represents **category codes**.

list5 represents **category include list**.

First I will use the example in the Electronic Guidebook [1], pp 832-3. Enter the two lists, $I1$ and $I2$ from the entry line using $\{ \}$. Then use MATH/Statistics/Regressions/QuadReg or CATALOG/QuadReg to perform the quadratic regression.

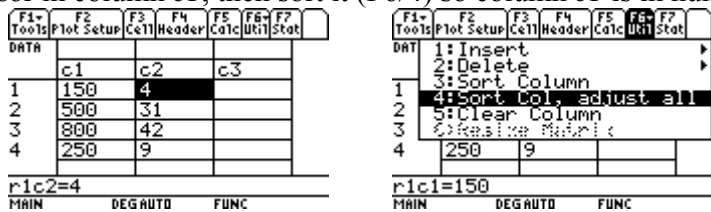


Finally, *ShowStat* (MATH/Statistics/6) to see the statistical information.

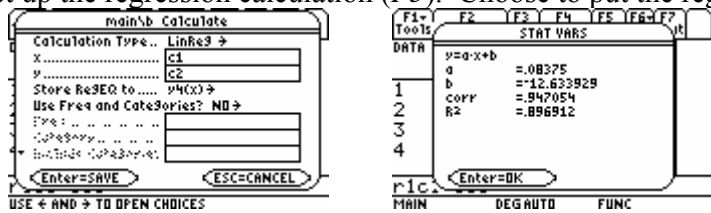


Now we want to enter data, then plot it including the regression line [pp 106-115 Electronic Guidebook].

First enter the data into the Data/Matrix Editor – Apps/6. (It's Data). Enter your data, place the cursor in column $c1$, then sort it (F6/4) so column $c1$ is in numerical order.



Now set up the regression calculation (F5). Choose to put the regression equation into $y4(x)$.



Press ENTER to close the window. Press F2 for Plot Setup. Select F1 (Define).

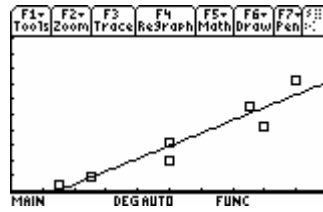
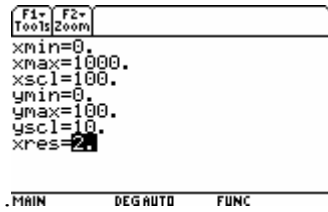


Enter to save. Select \blacklozenge F1 ($y=$)



The data will be plotted in Plot 1 and the regression curve in $y_4(x)$.

Set up the plot window based on the data (or use F2/9:ZoomData), then GRAPH (♦ F3)



If you wish to name the data columns, return to the Data/Matrix editor. Label column $c1$ by placing the cursor in the cell above the cell labeled $c1$, press ENTER. Type the title. Repeat for $c2$.

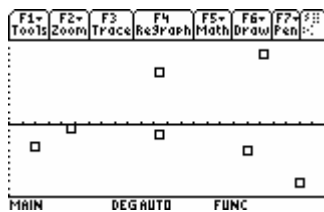
F1-Tools	F2-Plot Setup	F3-Cell	F4-Header	F5-Calc	F6-Util	F7-Stat
DATA	pop	bldgs				
	c1	c2	c3			
1	150	4				
2	250	9				
3	500	31				
4	500	20				
r1c3=						

Now we calculate the error. Move the cursor to the cell named $c3$, then type the formula. Repeat for $c4$. Label both columns so you know what they are.

F1-Tools	F2-Plot Setup	F3-Cell	F4-Header	F5-Calc	F6-Util	F7-Stat
DATA	bldgs	linfit	error			
	c2	c3	c4			
1	4	-.0714				
2	9	8.304				
3	31	29.24				
4	20	29.24				
c3=y4(c1)						

F1-Tools	F2-Plot Setup	F3-Cell	F4-Header	F5-Calc	F6-Util	F7-Stat
DATA	bldgs	linfit	error			
	c2	c3	c4			
1	4	-.0714	-4.071			
2	9	8.304	-.6964			
3	31	29.24	-1.759			
4	20	29.24	9.241			
r1c4=-4.071428571429						

Now plot the residual error. Go to $y=$ (♦ F1), and turn off (F4) y_4 so the regression line is suppressed. Select F2/9:ZoomData



If you suspect another fit may do a better job, repeat all the above, writing the new data fit to a different y function, then compare the residuals of the two data fits using Plot1 and Plot2, for example, for the residual data. You just keep creating new columns in the data table.

TI-89 Books available for sale on the TI website. http://education.ti.com/us/activity/books/collegebooks.html	
	<u>Electrical Engineering Applications with the TI-89</u> (This book is my Reference 4) by David R. Voltmer and Mark A. Yoder Table of Contents Activity 1: DC Circuit Analysis Activity 2: Transient Circuit Analysis: Symbolic Activity 3: Transient Circuit Analysis: Numeric Activity 4: Steady-State Circuit Analysis and Filter Design (147 KB)* Activity 5: Power Engineering Activity 6: Laplace Analysis: The s-domain Activity 7: The Convolution Activity 8: Fourier Series Activity 9: Vectors Activity 10: Vector Calculus Activity 11: Electromagnetics Activity 12: Transmission Lines Activity 13: Antennas Activity 14: Manipulating Lab Data: The Diode Activity 15: Financial Calculations Index
	<u>Advanced Placement Calculus with the TI-89</u> by Ray Barton and John Diehl Table of Contents Activity 1: Functions, Graphs, and Limits Activity 2: Differentiation Activity 3: Applications of the Derivative Activity 4: Integration (65 KB)* Activity 5: Riemann Sums and the Fundamental Theorem of Calculus Activity 6: Applications of Integrals (122 KB)* Activity 7: Differential Equations and Slope Fields Activity 8: Parametric, Vector, Polar, and 3D Functions Activity 9: Infinite Sequences and Series Appendix A: TI-89 Keystrokes and Menus Appendix B: Common Calculus Operations Appendix C: Creating Scripts Appendix D: Solutions to the Exercises Index

Major-Specific Applications Available for free on the TI website.	
	MEPro – see attached Table of Contents
	EEPro – see attached Table of Contents
	EE200 – see attached Table of Contents