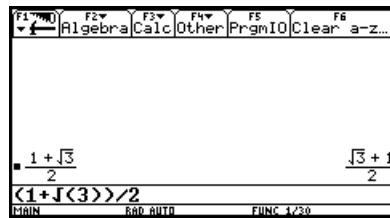


1 TI-89/92 Basics

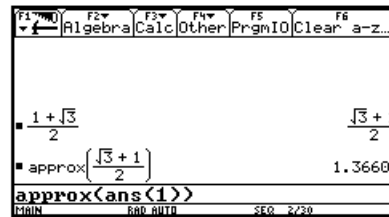
This initial chapter is a brief introduction to many of the capabilities and uses of the **TI-89/92** that will be important throughout the remainder of this manual. This is not intended to be a substitute for the **TI-89/92 Guidebook**. Always keep your **TI-89/92 Guidebook** handy for reference. In particular, you should work carefully through Chapters 1 and 2 and make at least a cursory pass through Chapters 3–6 of the **TI-92 Guidebook** or Chapters 3, 5, 6, and 13 of the **TI-89 Guidebook** before proceeding any further in this manual.

1.1 The Home screen

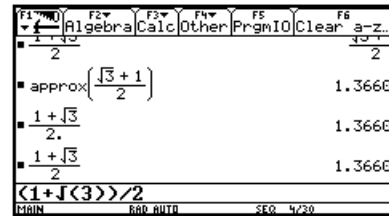
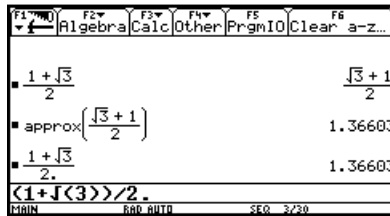
The Home screen is the starting point for both symbolic and numerical computation on the **TI-89/92**. Let's begin by clearing the Home screen (press **F1-8**) and working with a simple example. If we enter an expression such as $(1 + \sqrt{3})/2$, the **TI-89/92** does nothing to it, because it is already in its simplest exact form. (An expression such as $(4 + \sqrt{12})/\sqrt{2}$ would be simplified. Try it yourself.)



There are three ways to get a numerical value for this expression. The first is via the **approx()** function in the **Algebra** menu (**F2-5**). (Notice the use of **ans(1)** (press **[2nd]-[(-)]**) to avoid re-entering the expression.)

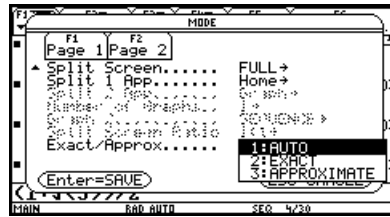


A numerical value for this expression can also be computed by placing a decimal point after any of the whole numbers in the expression. Finally, a numerical value can be found by pressing the \diamond key prior to pressing **ENTER**. (Notice the green “ \approx ” above the **ENTER** key to the right of the QWERTY keyboard.)



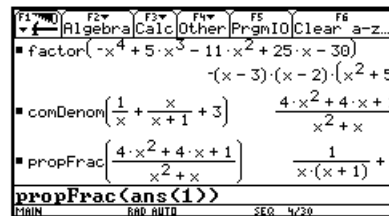
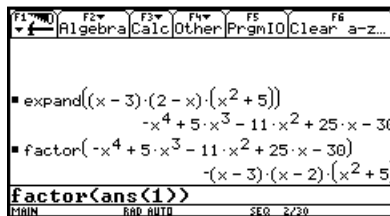
The manner in which the **TI-89/92** handles such computations can also be controlled by setting the **Exact/Approx MODE**. On **Page 2** of the **MODE** dialog box (which appears upon

pressing the **MODE** key and then **F2**) one can set **Exact/Approx** to **1:AUTO**, **2:EXACT**, or **3:APPROXIMATE**.

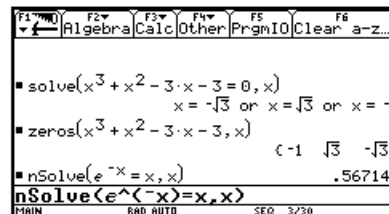
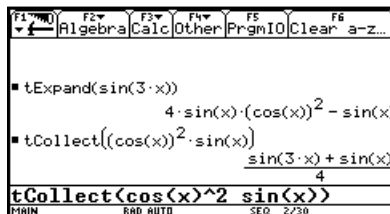


The computations above were all done with **Exact/Approx** set to **AUTO**. You should experiment with the same computations after setting **Exact/Approx** first to **EXACT** and then to **APPROXIMATE**. We recommend using **AUTO** in most circumstances.

The Algebra menu. This menu (**F2**) allows easy access to the TI-89/92's functions for doing symbolic manipulation of algebraic (and trigonometric) expressions and for solving equations. The screens shown below illustrate the algebra functions **factor()**, **expand()**, **comDenom()**, and **propFrac()**.

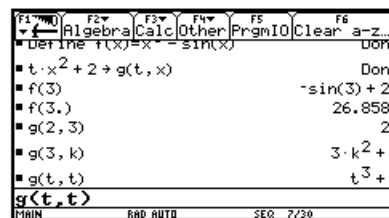
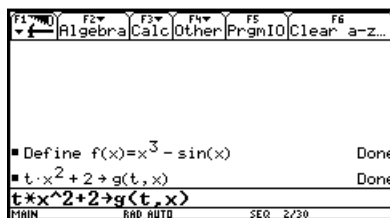


The left-hand screen that follows illustrates the functions **tExpand()** and **tCollect()**, which manipulate trigonometric expressions. (These are found in the **Trig** submenu.) The right-hand screen illustrates the **solve()**, **zeros()**, and **nSolve()** functions for solving equations.



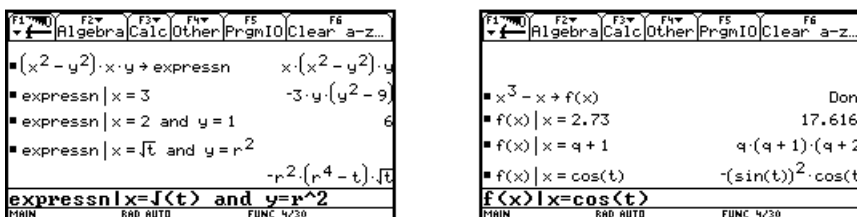
We will have more to say about **solve()**, **zeros()**, and **nSolve()**—and solving equations in general—in Section 2.3.

Defining functions. There are two ways to define a function on the Home screen. One is with the **Define** command. You can type this in or access it in the **Other** menu (**F4-1**). The second way is by using the **[STO>]** key. Once a function is defined, evaluations can be performed on the Home screen.



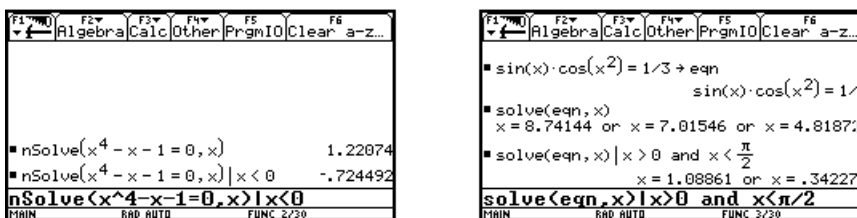
The “With” operator. Use of the “with” operator is essential to taking advantage of the TI-89/92's advanced capabilities. The “with” operator is the vertical bar (|), accessed

by pressing [2nd]-K. One use of the “with” operator is to make substitutions in expressions—including function evaluations.



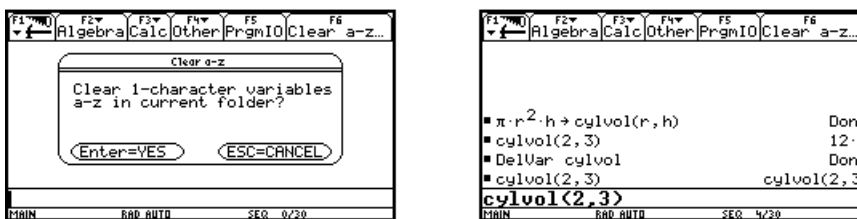
Warning: Improper use of the “with” operator can throw the **TI-89/92** into an infinite recursive loop. An infinite recursion can occur when a substituted expression involves the variable that is substituted for—for example, when entering a command such as $f(x) | x=x+1$. For more on this issue and the “with” operator in general, see page 55 of the **TI-89 Guidebook** or page 93 of the **TI-92 Guidebook**.

Another important use of the “with” operator is to restrict variable values in certain computations. For example, **nSolve()** returns a numerical approximation to one solution of an equation. If there is more than one solution, **nSolve()** needs help in order to locate them all. Also, **solve()** attempts to find *all* solutions of an equation, while many equations have more solutions than we are really interested in finding.



Clearing variables. Unexpected or erroneous results sometimes occur when one or more variables have been assigned values previously. Consider, for example, the following situation. We define the function $f(x) = x^2$ by entering $x^2 \rightarrow f(x)$. We then enter $(f(x)+1)^2$, which should result in $(x^2 + 1)^2$, but instead the calculator returns a 4! What happened? We forgot that the variable x had previously been assigned the value 1.

There are two simple ways of clearing variables. First, **Clear a-z...** (F6)—or **NewProb** on the **TI-89** and **TI-92 Plus**—clears all previously defined one-character Roman variables **a-z**. Because of the ease with which this can be done, it is a good idea always to use a one-character variable **a-z** for naming any “throwaway” variable. Other defined variables can be cleared by using the **DelVar** command from the **Other** menu (F4-4). The second screen below illustrates the use of **DelVar**.



Very important: You will find that clearing variables will cure many of the problems you encounter while using the **TI-89/92**. *Remember this!*

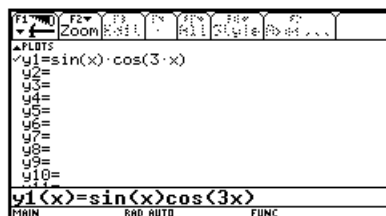
Exercises

Do each of the following with the **Exact/Approx MODE** set to **AUTO**. Before beginning, clear all variables **a–z**.

- Enter $\sin(\pi/k)$ for each of $k = 2, 3, 4, \dots, 12$. Which of these is the **TI-89/92** able to evaluate?
- Compute $\ln(e^2)$, $\ln(2e^3)$, $e^{2\ln(3)}$, and $e^{x\ln(2)}$.
- Enter **expand(ln(a*b))** and then **expand(ln(a*b))|a>0 and b>0**.
 - Enter **ln(a^x)** and then **ln(a^x)|a>0**.
- Expand each of the polynomials:
 - $(2x - 1)^2(3 - x)^3$
 - $(x - 1.23)(3.73 - x)(x + 7.77)$
- Factor each of the polynomials:
 - $6x^3 + 47x^2 + 71x - 70$
 - $3x^3 + 4x^2 + 5x - 6$
- Enter:
 - factor(180047)**;
 - factor(1234567)**;
 - factor(1235711)**;
 - factor(ssn)**, where *ssn* is your social security number.
- Define a function **cylsurf(r)** that gives the surface area of a closed, right circular cylinder with radius r inches and volume 100 cubic inches. How might the “with” operator be used in doing this?
 - Which of the radii $r = 1, 2, 3, 4$ gives the least surface area?
- The function $f(x) = 5\sin(4x) + x$ has several zeros between $x = 0$ and $x = 2\pi$. Use **solve()** and the “with” operator to find them all.

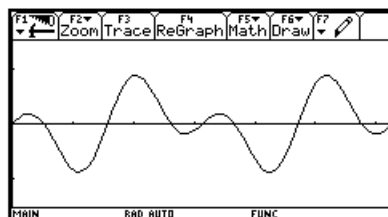
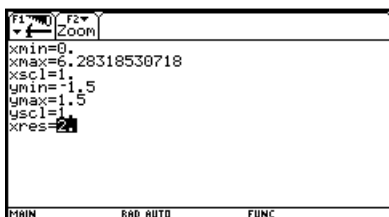
1.2 Graphs and tables

The most straightforward way to define a function for graphing is to use the **Y=** Editor. This can be accessed by pressing \diamond **Y=** or by pressing **APPS-2**. However, let’s first press the **MODE** key to bring up the **MODE** dialog box. The Graph mode should be set to **FUNCTION**. Now we’ll press \diamond **Y=** to bring up the **Y=** Editor and define the function $f(x) = \sin(x)\cos(3x)$ as **y1(x)**. Note that the variable in the function *must* be x .

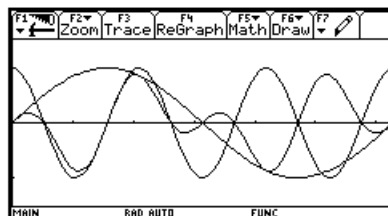
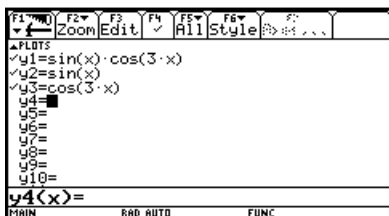


We now need to set appropriate **window variables** for the graph. This is done in the **Window Editor**, which we access by pressing \diamond **WINDOW**. Because of the nature of the particular function we’re graphing, we’ll set **xmin**, **xmax**, **ymin** and **ymax** to give us a $[0, 2\pi] \times [-1.5, 1.5]$ window. The variables **xscl** and **yscl** determine the spacing between axis tick-marks. **xres** determines the horizontal spacing between the pixels where function evaluations are done.

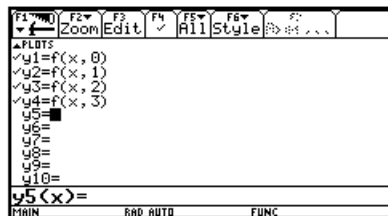
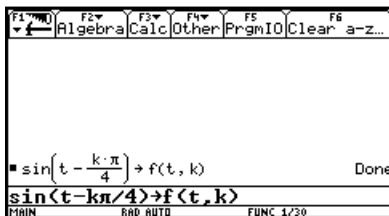
With window variables set, we then press \diamond **GRAPH** to plot the graph.



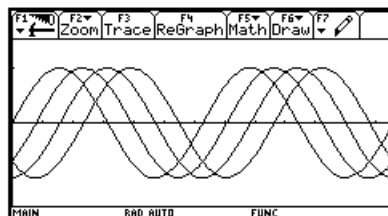
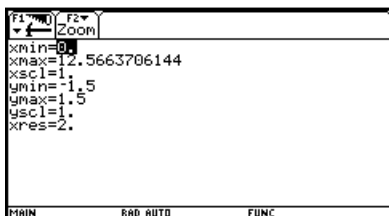
We can also plot several functions at once.



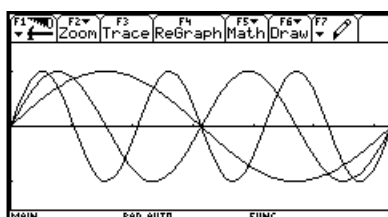
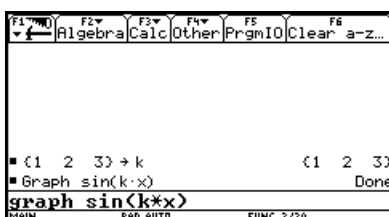
It is often convenient to define functions on the Home screen for graphing, particularly if the functions we wish to plot are each one of a family of functions. For example, let's plot $y = \sin(t - k\pi/4)$, for each of $k = 0, 1, 2$, and 3 , on the interval $0 \leq t \leq 2\pi$.



Notice that we are able to define a function on the Home screen using any variable name that we choose. Then we simply use x as the variable when entering the functions in the **Y=** Editor. Finally, we'll press \diamond **WINDOW**, set the desired window variables, and then press \diamond **GRAPH** to plot the graph.

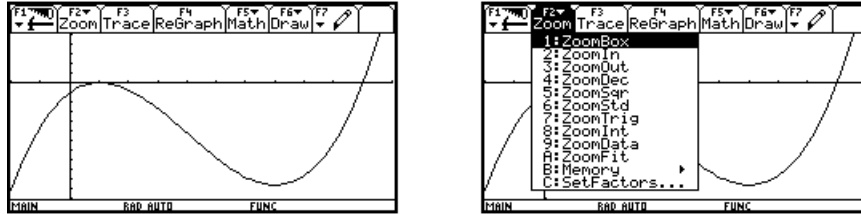


We should mention here that there is a much more convenient way of plotting several members of such a family of functions. It involves storing parameter values in a *list*. (The next section discusses lists in more detail.) The following screens illustrate this, as well as the use of the **Graph** command from the Home screen's **Other** menu (**F4-2**).

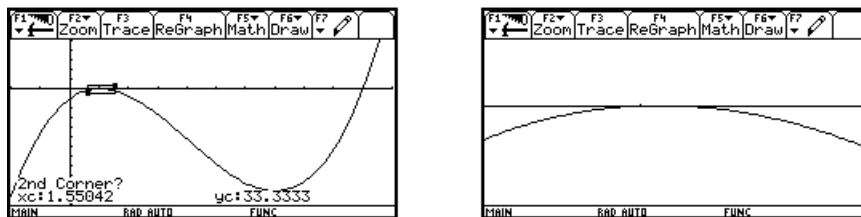


Zoom Tools. The **Zoom** menu (**F2**) is accessible from each of the **Y=** and **WINDOW** Editors as well as from the Graph screen. A variety of Zoom tools are available in this menu—see page 107 of the **TI-89 Guidebook** or page 59 of the **TI-92 Guidebook** for a complete description. Here we will only illustrate the use of the **ZoomBox** tool.

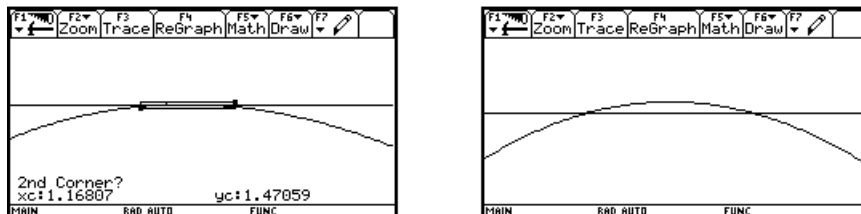
The graph of the cubic polynomial $f(x) = 10x^3 - 121x^2 + 221x - 110$ seems to indicate that f has just two real zeros. The window shown here is $[-2, 11] \times [-1200, 500]$. Let's use the **ZoomBox** tool to go to a graph that shows the behavior of the function near the first of the two apparent zeros.



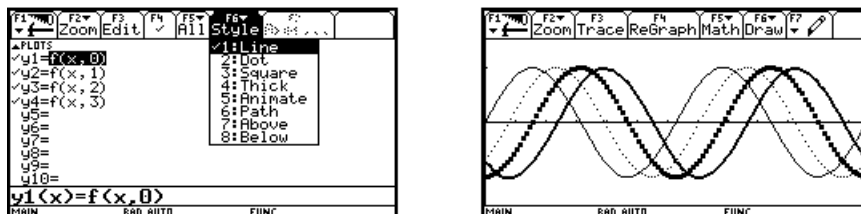
When we use the cursor pad to draw a box around the area of interest and **ENTER** the second corner point, a new graph is drawn.



Repeating the process once more finally reveals two zeros of the function that are quite close together.



Plot Styles. In the **Style** menu of the **Y=** Editor, four plot basic styles are available for graphs: **Line**, **Dot**, **Square**, and **Thick**. For illustration, let's plot the same four functions as above after choosing plot styles **Line**, **Dot**, **Square**, and **Thick** for **y1**, **y2**, and **y3**, respectively.



Tables. A table of function values is as easy to create as a graph. First enter the functions in the **Y=** Editor. Then press \diamond **TblSet** and enter the starting value **tblStart** of **x** and the stepsize Δ **tbl** between variable values. With this done, press \diamond **TABLE** to create the table.

x	u1	u2	u3	u4
0.	0.	-.7071	1.	-.7071
.1	.09983	-.633	-.995	-.7742
.2	.19867	-.5325	-.9801	-.8335
.3	.29552	-.4666	-.9553	-.8845
.4	.38942	-.3759	-.9211	-.9266
.5	.47943	-.2815	-.8776	-.9595
.6	.56464	-.1843	-.8253	-.9829
.7	.64422	-.0853	-.7648	-.9964

A shortcut for scrolling down the table is to press **[2nd]-[↓]**. This, in effect, is a “page down” command. Notice too that, from the Table screen, **F1-9** brings up a **FORMATS** dialog that allows us to set the cell width. Also, the **TABLE SETUP** dialog box can be accessed directly from the Table screen by pressing **F2**.

Exercises

- Plot $y = x^n$, for $n = 1, 2, 3, 4, 5, 8,$ and 11 in a $[-1, 1] \times [-1, 1]$ window.
- Plot $y = \sin k\pi x$, for $k = 1, 2, 3,$ and 4 in a $[0, 2] \times [-1, 1]$ window.
- Plot the function $y = \sin 2\pi x$ with **Dot Style (F6-2)** in the **Y= Editor** in the window $[0, 1] \times [-1, 1]$, first with **xres** = 10 and then with **xres** = 5, 3, 2, and 1.
- Plot $y = x \sin(x/(x^2 + .001))$ in a $[-1, 1] \times [-1, 1]$ window with **xres** = 1. Using the **ZoomIn** tool (**F2-2**) a number of times, magnify the graph to reveal the behavior of the function near $x = 0$. What are the values of the window variables for your final graph?
- Create a table of values for the function $f(x) = (1 + x)^{1/x}$, using **tblStart** = $-.02$ and **Δtbl** = $.005$. Notice the strange value of 1 shown at $x = 0$ and the warning message at the bottom of the screen. Change **tblStart** to $-.001$ and **Δtbl** to $.00025$ and recreate the table. If you had to assign $f(0)$ a value, approximately what should it be (rather than 1)?
- Plot $y = \sqrt{1 - x^2}$ and $y = -\sqrt{1 - x^2}$ in each of the windows
 $[-2, 2] \times [-1, 1];$ $[-2, 2.011] \times [-1, 1];$ $[-1.95, 1.95] \times [-1, 1].$
 Can you think of a good reason for what you’ve observed?

1.3 Lists and matrices

We have already encountered two of the **TI-89/92**’s data types: *expressions* and *functions*. Two other important data types are *lists* and *matrices*.

Lists. A list is literally a list of objects. The objects—called *elements*—in a list may be numbers, expressions, functions, or even other lists, and they need not be all of the same type. A list can be defined on the Home screen by entering the elements of the list separated by commas and enclosed by braces (**{}**). Entering *listname*[*i*] accesses the *i*th element of a list.

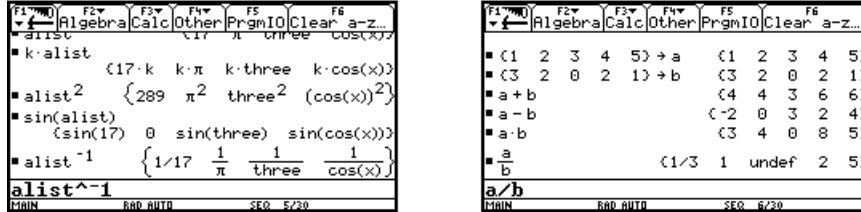
```

{17 π three cos(x)} → alist
{17 π three cos(x)}
{4 7 5.5 3 3 4 1} → blist
{4 7 5.5 3 3 4 1}
{4,7,5.5,3,3,4,1} → blist
MAIN          RAD AUTO          SEQ 2/20
  
```

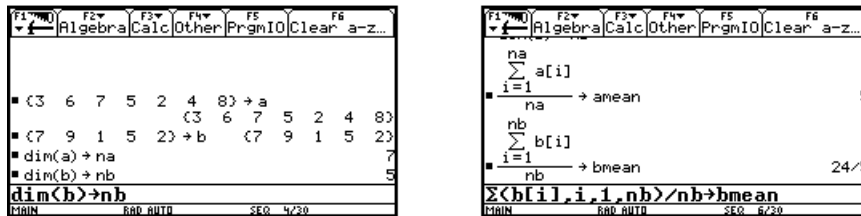
```

{17 π three cos(x)} → alist
{17 π three cos(x)}
{4 7 5.5 3 3 4 1} → blist
{4 7 5.5 3 3 4 1}
alist[3]          three
alist[4]          cos(x)
blist[3]          5.5
blist[1]          4
blist[1]
MAIN          RAD AUTO          SEQ 6/20
  
```

A list can be multiplied by an expression. It is also possible to apply various functions to a list. All such operations are done “component-wise.” Also, two lists with the same number of element can be added, subtracted, multiplied, or divided.

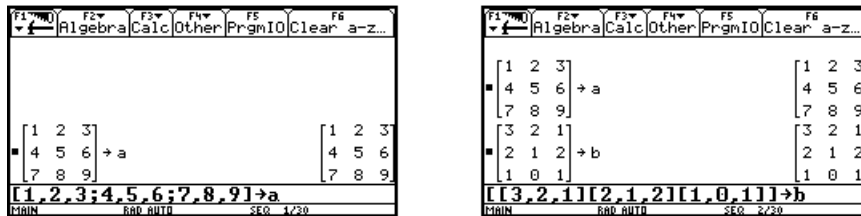


The length of a list (i.e., the number of elements in it) can be found by entering $\mathbf{dim}(\mathit{listname})$. Also, the $\Sigma()$ operator (**[2nd]-[4]**, or **F3-4**) is handy for summing the elements in a list. This makes it easy, for example, to compute the average (or mean) of a list of numbers.

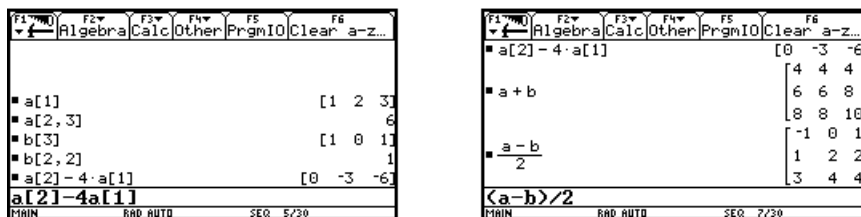


In addition to $\mathbf{dim}()$, there are numerous other built-in functions for performing operations on lists. Among these are $\mathbf{augment}()$, $\mathbf{max}()$, $\mathbf{min}()$, $\mathbf{product}()$, $\mathbf{sum}()$, $\mathbf{mean}()$, $\mathbf{median}()$, and $\mathbf{stdDev}()$. Also, there are operators for sorting lists— \mathbf{SortA} sorts a list in ascending order, and \mathbf{SortD} sorts a list in descending order. (All of these are found in either the **List** or **Statistics** submenus of the **MATH** menu.) For descriptions of these, see Appendix A of the **TI-89/92 Guidebook**.

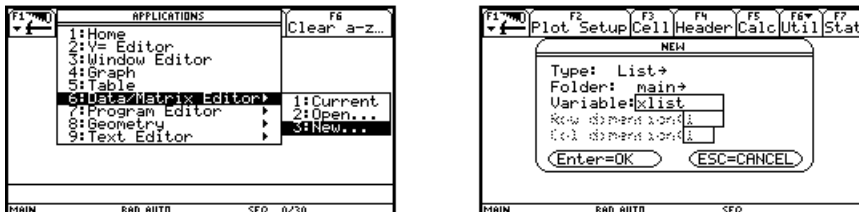
Matrices. A matrix is a rectangular array of elements. Just as braces ($\{ \}$) were used as delimiters for lists, brackets ($[]$) are the delimiters for matrices. When defining a matrix on the Home screen, elements of each row are separated by commas and rows are separated from each other either by semicolons or sets of brackets.



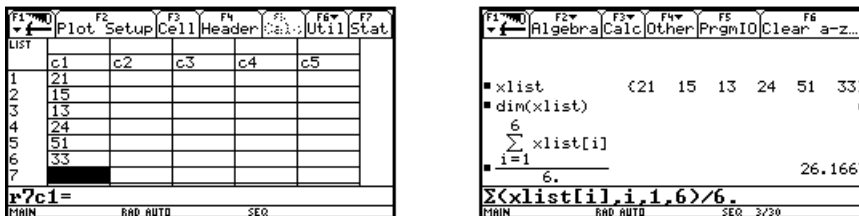
The i th row of a matrix is referenced by $\mathit{matrixname}[i]$. The element in the i th row and j th column is referenced by $\mathit{matrixname}[i,j]$. Also, the **TI-89/92** handles many algebraic operations with matrices automatically.



The Data/Matrix Editor. The TI-89/92 provides a handy editor for creating and editing lists and matrices. To create a list in the Data/Matrix Editor, we first bring up the editor by pressing the **APPS** key, and then selecting **Data/Matrix Editor** and **New...** In the resulting dialog box, we'll choose **Type: List** and **Folder: main** and then type in the name of our list.

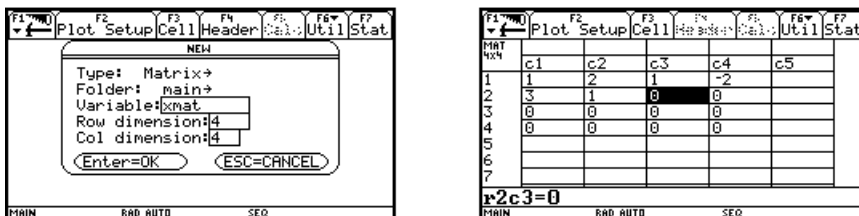


This takes us to the Data/Matrix Editor, ready to begin entering elements into the list. This is done by filling in the first column of the grid. (If items are entered into another column, the list variable is automatically converted to a data variable, which is essentially a collection of lists. Data variables are useful for doing Statistics.) After we've entered the elements of the list, we can go back to the Home screen and refer to the list we just created.

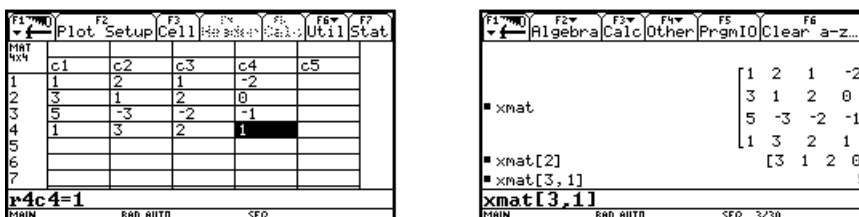


One advantage of using the Data/Matrix Editor is that it is easy to go back and add elements or otherwise modify the list. Simply press **APPS-6** and select **Current**.

Let's now use the Data/Matrix Editor to create a matrix. As before, we'll press **APPS-6-3** to bring up the **NEW** dialog box. There we choose **Type: Matrix** and **Folder: main**, name the matrix, and enter the number of rows and number of columns. This takes us to the Data/Matrix Editor, ready to begin entering elements into the matrix. Notice that the matrix is initially filled with zeros.

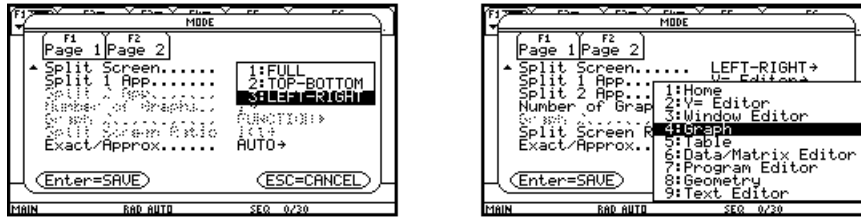


Once we've finished entering the elements of the matrix, we return to the Home screen ready to work with the matrix we've created.

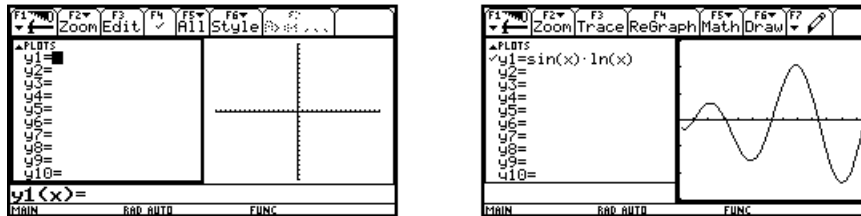


1.4 Split screens

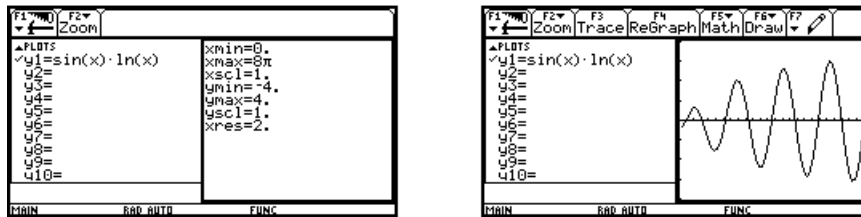
One of the most attractive and useful features of the **TI-89/92** is its Split Screen capability. To set the Split Screen Mode, press **MODE** and then **F2** to get to page 2 of the **MODE** dialog box. There we can select either **FULL**, **TOP-BOTTOM**, or **LEFT-RIGHT** as the **Split Screen MODE**. After selecting **LEFT-RIGHT**, let's then select the **Y= Editor** as the **Split 1 App**, **Graph** as the **Split 2 App**, and **1:1** as the **Split Screen Ratio**.



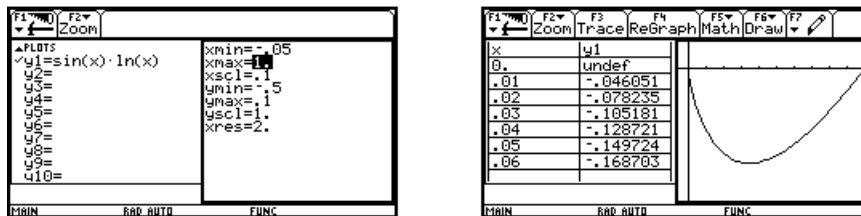
This takes us to a split screen with the **Y= Editor** active. We can then enter functions and plot them by pressing ◊ **GRAPH**.



Pressing **[2nd]-APPS** makes the inactive split screen active. The active split screen can be switched to a different screen or application in the same way as in Full Screen mode. For instance, here we might want to change window variables for the graph. So we just press ◊ **WINDOW**, enter the new window variables, and then press ◊ **GRAPH** to replot the graph.



An interesting kind of Split Screen for examining function behavior is one that shows both a table of values and a graph. Let's look closely at the function $f(x) = \sin(x) \ln(x)$ on the interval $0 \leq x \leq 1$. We'll first change the window variables for the graph. Then we press ◊ **GRAPH** to replot the graph, **[2nd]-APPS** to switch to the other split screen application, and then ◊ **Table** to create the table.



You should experiment with **TOP-BOTTOM** Split Screen **MODE** and with different **Split Screen Ratios**.

Throughout the rest of this manual, we will use Split Screens at will, often simply to convey more information in less space on the page.

1.5 Shortcuts and special characters

We have already been using a number of the **TI-89/92**'s shortcuts. For example, each of \diamond HOME, \diamond Y=, \diamond WINDOW, \diamond GRAPH, \diamond TblSet, and \diamond TABLE is a shortcut to accessing an item in the **APPS** menu. The following is a list of several other helpful shortcuts and tips.

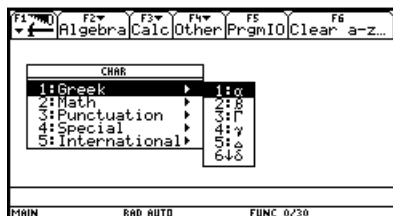
On the Home screen:

- **ans**(i) references the “answer” from the i^{th} most recent entry in the Home screen history area. Pressing **ANS** ([2nd]-[(-)]) puts **ans(1)** on the entry line. Notice also that pressing any of [+], [-], [\times], [\div], [\wedge], [x^{-1}], or [STO>] with a blank entry line automatically inserts **ans(1)**.
- **entry**(i) references the i^{th} most recent entry in the history area. Pressing **ENTRY** ([2nd]-ENTER) puts the last entry on the entry line.
- **F1-8** clears the history area of the Home screen (or the contents of the **Y=** Editor).
- Press [2nd]-[\Rightarrow] or [2nd]-[\Leftarrow] to move to the end or beginning of an entry on the entry line.
- Press \diamond ENTER to force numerical evaluation of an entry. This is equivalent to the **approx()** function (**F2-5**).
- Multiple entries, separated by colons, can be entered simultaneously.
- **Copy** and **Paste** commands in the Tools menu (**F1-5,6**) often help you avoid a lot of typing. Shortcuts for these commands are \diamond C and \diamond V, respectively.
- Press [\uparrow]-[\Rightarrow] or [\uparrow]-[\Leftarrow] to highlight characters for copying and pasting. ([\uparrow] is the “shift” key.)
- After using [\uparrow] and [\downarrow] (up and down on the cursor pad) to highlight an entry or an answer in the history area, you can press **ENTER** to place it on the entry line.

On the Graph screen:

- The **ON** key stops a plot, and the **ENTER** key pauses a plot.
- Moving the cursor about the screen with the cursor pad (in tracing or zooming) is much faster while holding down the [2nd] key.
- \diamond F brings up the Graph Formats dialog box.

Special Characters. Pressing **CHAR** ([2nd]-[+]) reveals a large collection of symbols and characters that are not seen on the standard keyboard.



Greek letters are especially useful since many Greek letters are commonly used in mathematics. Many of these letters can be accessed on the **TI-92** QWERTY keyboard by pressing

an appropriate prefix key combination first. The prefix for all Greek letters is [2nd]-G. After pressing [2nd]-G, simply press the Roman “equivalent” of the desired letter. For example, [2nd]-G-G produces γ (gamma), and [2nd]-G-A produces α (alpha). The analogous prefix key combination for the TI-89 is [2nd]-[(].

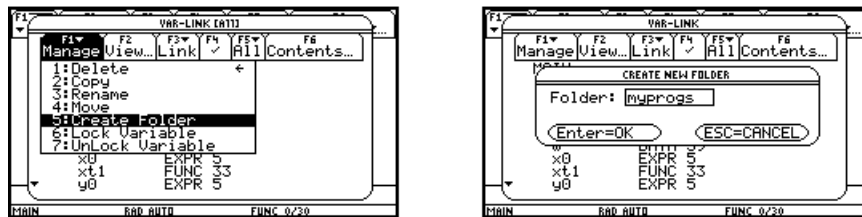
A collection of “International” characters, many of which are accented members of the standard Roman alphabet, provides an extra source of single-character variables on the TI-92. Prefixes for these accented letters are as follows.

- [2nd]-A produces the grave accent for à, è, ì, ò, ù;
- [2nd]-C produces the cedilla accent for ç;
- [2nd]-E produces the acute accent for á, é, í, ó, ú, ý;
- [2nd]-N produces the tilde accent for ñ, õ;
- [2nd]-O produces the caret, or circumflex, accent for â, ê, î, ô, û;
- [2nd]-U produces the umlaut accent for ä, ë, ï, ö, ü, ÿ.

1.6 The Program Editor

This section is an introduction to creating and running a program on the TI-89/92. However, if you’ve never had any programming experience, you should read Chapter 17 in your TI-89/92 Guidebook before going any further here.

The first thing we should do, before entering any programs, is to create a new folder to hold them. To do this, press VAR-LINK ([2nd]-[-]). In the resulting VAR-LINK dialog box, press F1 and select **Create Folder**. Then enter **myprogs** (or whatever you like) as the name of the new folder and exit VAR-LINK.



The VAR-LINK dialog box is where most memory management takes place. There we can see a listing of all defined variables (including functions and programs). We can also delete and rename variables, move a variable to a different folder, and send and receive files to and from another TI-89/92 or a computer.

Now, before getting to a somewhat more useful program, let’s first create a very simple program that does nothing more than draw random circles on the screen. To enter a new program, first press the APPS key and then select **Program Editor** and **New...**. In the subsequent dialog box select **Type: Program**, **Folder: myprogs**, and enter the name of the program, **circles**, in the box beside Variable:.

