The HP 49G
Quick Start Guide

Contents

Introduction

The HP 49G is the first calculator that features both an algebraic-entry interface and the RPN (Reverse Polish Notation) interface so familiar to users of other HP calculators. With its powerful computer algebra system, the HP 49G is the most advanced scientific calculator to-date. It does all of the following (and more):

- Allows easy retrieval of previous answers and entries;
- Displays algebraic expressions in textbook format;
- Generates tables (including a ZOOM feature);
- Does dimensional analysis with units;
- Works with functions, parametric and polar equations, conic sections and inequalities;
- Solves equations;
- Does financial calculations;
- Computes and organizes statistical data;
- Does symbolic algebra and calculus;
- Operates with vectors, matrices, lists and complex numbers.

How to Use This Guide

This guide offers a quick beginning overview of the basic features of the HP 49G. It can also serve as a quick reference guide in the future, after you're already comfortable with the basics.

Presentation

Unlike a reference manual, the contents here are ordered in a sequence most useful for getting acquainted with the HP 49G; you'll learn the most basic (and most used) features of the calculator first. The first half of the guide is designed to get you quickly up-to-speed on performing computations, entering formulas, graphing functions and making tables. The second half introduces you to a variety of additional features: parametric and polar equations, equation solving, complex numbers, lists, vectors, matrices and statistics.

Conventions

In this guide, many keystrokes are indicated by labelled keys: [5], [SIN], [ENTER], etc. For shifted key functions—those appearing on the keyboard in blue or red—the notation here will include those shift keys: [←][MTH], [→][CLEAR], [→][EVAL], etc. For alphabetic characters, keystrokes will usually show the necessary [ALPHA] keystroke, too. Keystrokes corresponding to menu items are indicated as such (e.g. EDIT, ERASE, DRAW, etc.). To select a menu item, simply press the key directly beneath it (i.e. one of the keys [F1] - [F6]).

Basic Information

Physical Features

Cover

When you're ready to use the HP 49G, its translucent cover slides down off the front of the calculator. The easiest way to do this is to press with your thumbs gently on the center of the cover just under the HP logo, sliding the cover downward as you press. Then slide the cover onto the back of the machine during use. When you're done, replace the cover over the front of the keyboard for protection.

Batteries

The HP 49G uses three AAA batteries, located in the lower compartment in the back of the calculator. You should get several months of service from a set of batteries. Even when you take the batteries out, the calculator's memory will be maintained for a few minutes, allowing you to change the batteries without a loss of stored information.

Ports

The upper end of the HP 49G contains its door to the outside world. It's a 10-prong serial port for connecting your calculator to a computer, another calculator, or to an overhead device.

Contrast control

To lighten or darken the screen contrast, just hold down ON while pressing − or +, respectively.

Keys and the Keyboard

The [ON] Key

The [ON] key (lower left corner of the keyboard) not only powers up your HP 49G but also serves as a general purpose [CANCEL] key (note the label underneath). If you leave your calculator on for a few minutes without pressing any keys, it will automatically shut off to save battery power (or you can turn it off yourself via [→][OFF]). When you press [ON] again, the screen should look just as it did when you left it; the memory of the calculator is continuously maintained, even when the calculator is off.

The shift keys

Right above [ON] are three shift keys. The blue left-shift key, [←], and the red right-shift key, [→], activate the operations or menus indicated by the correspondingly colored labels directly above each key. Notice that when a shift key has been pressed so that the shift is in effect, the corresponding shift symbol appears at the top of the screen. Notice, too, that these shift keys are simple toggle switches: if you accidentally press one, just press it again to turn it off.

The third shift key is [ALPHA], which gives you access to the letters of the alphabet that appear on the lower right of most keys. When [ALPHA] has been pressed, an α appears at the top of the screen, indicating that all keys will now give their alphabetic charcaters, if any. This α mode will turn off again after one character, unless you press [ALPHA][ALPHA] to lock it on so you can type several characters in a row. Then a third press unlocks it. (Alternatively, when typing several letters in a row, you can just simply hold [ALPHA] down as you type.)

Use [ALPHA] and then [←] to get lower-case letters. To type a b rather than B, for example, you would press [ALPHA][←][B]. For Greek letters and other special symbols not on the keyboard, use the [→][CHARS] menu.

Menus

There are far more functions and operations on the HP 49G than one could ever hope to fit on the keyboard, even with multiple shift keys. The HP 49G arranges many of these additional items into menus, accessed by the six function keys F1 - F6 on the top row, just below the screen. These function keys refer to whatever menu labels you have displayed across the bottom of the screen at the time. *

Some menus contain submenus. For example, if you press MODE, you'll see that some of the menu labels have little folder tabs, each indicating another menu or screen, such as the FLAGS submenu. (To get back out of the MODE menu, just press CANCEL.)

When a menu has more than six labels—more than one "page"—you can get to the other pages via NXT and ↰PREV. Pressing NXT (or ↰PREV) repeatedly will eventually bring you back to the first page of the menu.

Scroll-down menus

Menus may also appear on screen in a scroll-down format. To select an item from such a menu, you must first highlight it by using ▲ or ▼, or by typing in the number of the item. (A partially shaded vertical bar means that there are additional items in the menu that couldn't fit on the current "page.") Once you have selected an item, press ENTER or OK to select it. If you change your mind and want to escape the menu, simply press CANCEL or CANCL.

Note that for long scroll-down menus, ↰▲ or ↰▼ will move you an entire "page" at a time; ↱▲ or ↱▼ will jump immediately to the top or bottom pages of the menu.

Other menus

The CAT key brings up a catalog of all the commands (over 700 of them) on the HP 49G. Such a menu might seem unmanageable, but it's arranged alphabetically and is ALPHA-sensitive. For example, if you press ALPHA R, the highlight bar will jump to the commands beginning with the letter R.

APPS brings up a menu of all the application environments on the HP 49G. APPS is organized by topic areas. (If you already know the name of the command you are looking for, then CAT may be the quickest access route to it. Otherwise, APPS may work best.)

**Often the menu line will remain visible even when you're not directly concerned with it—and it will continue to show the menu you most recently requested, regardless whether you're still using that menu. This is normal—just ignore the menu line. (And when such irrelevant menus appear on display screens in this Guide they may therefore show different contents from those your calculator.)*

Two other big "menus of menus" on the HP 49G are [SYMB] and [←][MTH]. [SYMB] offers menus of operations for working with symbolic expressions, including algebraic, arithmetic, calculus, trigonometric, and exponential and logarithmic expressions. [←][MTH] offers menus for working with a variety of mathematical objects—vectors, matrices, and lists—as well as special functions for real and complex numbers, different number bases, probability, fast Fourier transforms (FFT), and a directory of special mathematical constants.

Notice that, for convenience, some of the menus found in [APPS], [SYMB] and [←][MTH] have their own keys for more direct access. For example, the [ARITH] and [CMPLX] menus can be accessed directly as the [←]-shifted and [→]-shifted versions of the [1] key.

The History Screen

The history screen is the primary work area for the HP 49G. Think of it as your home base of operations. If you're not already there, pressing CANCEL once or twice will usually bring you to the history screen.

The Status Area

At the top of your history screen (above the horizontal line) is the status area, where indicators of the calculator's states and modes are displayed.*

RAD or DEG indicates that the calculator will assume Radians or Degrees for angular measure.

XYZ indicates that rectangular coordinates will be displayed for points in the Cartesian plane or space.

DEC indicates the format in which binary integers will be displayed.

R indicates that the calculator is in Real mode (for computations that may give a complex number result).

= indicates that the calculator is in Exact mode, for computations dealing with integers, as opposed to Approximate mode, indicated by ~, for computations dealing with non-integers.

'X' indicates that the current independent variable is X (instead of T or θ).

ALG indicates that the HP 49G is in Algebraic mode for computations.

HOME indicates that you are in the HOME directory of the calculator.

Whenever a little hourglass annunciator, ⧖, appears at the top of the screen, it means the HP 49G is busy with a calculation. Pressing CANCEL will stop the computation in progress.

Another annunciator, ((·)), appears when an appointment alarm comes due or when your batteries are low (in which case the calculator will also give you a Low Battery message so that you know it's not an appointment alarm.). When the battery message appears, you should change the batteries within a few days.

Above all, just bear in mind that whenever you find yourself in an unfamiliar situation or are unsure how to quit or exit, pressing CANCEL (more than once, if necessary) will bring you back to this history screen, the main calculation area for the HP 49G.

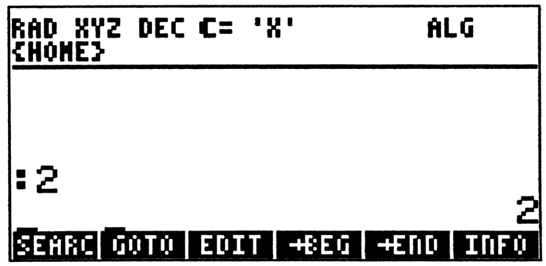
**Don't worry if your status area shows settings different than those mentioned here. Only a few are relevant for any given part in this Guide, and you'll be advised which ones to adjust for each section or exercise.*

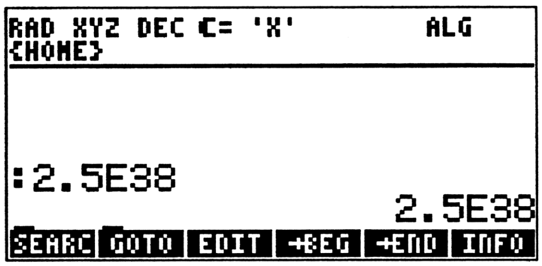
The Information Flow

Entering information

When you type, the characters appear on the Editline until you press ENTER.

For example, to enter the number 2 you would type 2 ENTER. The display will show the command on the left, then its result on the right, like this:*





To enter 2.5×10^{38}, press 2 . 5 EEX 3 8 ENTER.

Deleting and clearing

As you type, you'll see a flashing cursor arrow. (This is an insertion arrow on the history screen; it points to where the next character you type will be inserted.) If you make a mistake, ← will erase the most recent character typed. Or, if you use ▶ and ◀ to put the flashing cursor on top of a character, then pressing ↱ DEL will erase that character. To delete the current Editline entirely, just press CANCEL.

↱ CLEAR clears the history screen of all previous entries and answers.

Retrieving and editing

The ↰ ANS key echoes a special variable, ANS(1), to the Editline. The value of this variable is the most recent answer you obtained for an operation on the history screen. This lets you use a previous result in a new computation without having to type it in again.

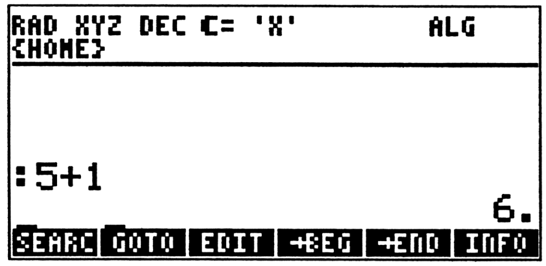
In fact, until you press ↱ CLEAR, a history of *all* your previous entries and answers is maintained on the history screen. At any time you can copy a previous entry or answer onto the Editline. Simply use the directional arrow ▲ until you've highlighted the desired item, then press ECHO. Then, to make any necessary changes, use ◀ and ▶ to move the cursor where you want it.

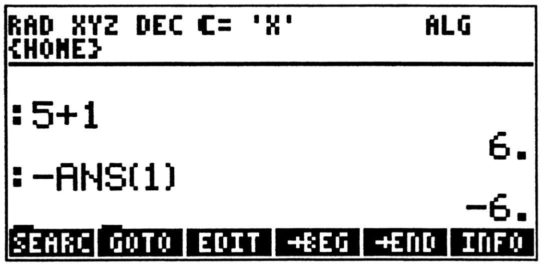
**Again, a reminder: Throughout this Guide, in these illustrative displays, you may see irrelevant differences in the menu line and/or status area. Don't worry about them.*

Any characters you type will be inserted where the cursor is pointing. (Or, pressing [↰][DEL] will delete the character underneath the flashing cursor.) After you have made the changes you want, press [ENTER].

Clear your history stack now (press [↱][CLEAR]), and try these examples:

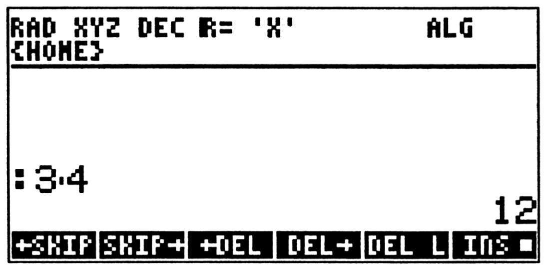
[5] [+] [1] [ENTER] should give you this resulting screen:

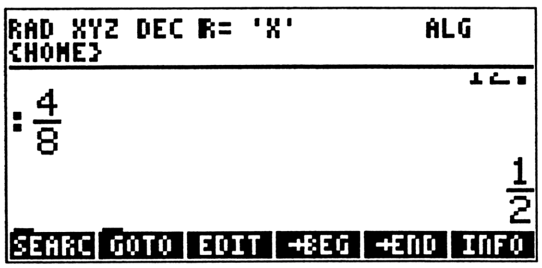




To negate the last answer: [+/−] [↰][ANS] [ENTER]

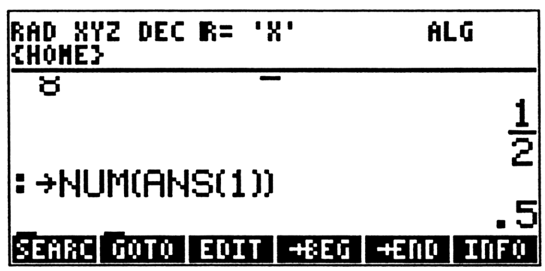
Try some multiplication: [3] [×] [4] [ENTER]





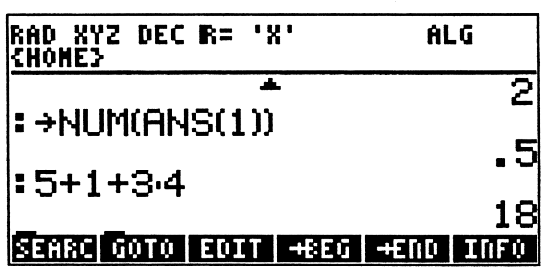
Now some division: [4] [÷] [8] [ENTER]

Notice that this result is displayed in reduced fraction form. To see the last answer as a decimal, press [↱][→NUM] [ENTER]:



Many of the computations you have entered are now out of view, but they are still on the history screen. To move up the screen to see them, press [▲] to activate the highlight bar. Then you can move up and down the home screen, using [▲] and [▼].

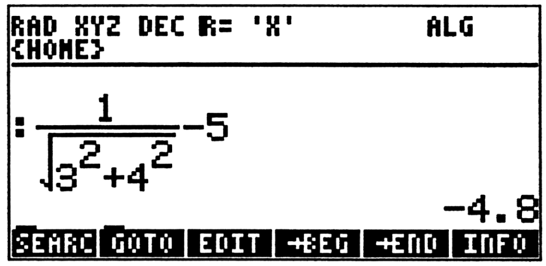
For example, to add two of the previous entries, use [▲] to move up and highlight 5+1, then press [ENTER] to send this to the Editline. Next, press [+] to build the sum. Now press [HIST] to go back to the previous entries on the history screen, and again use [▲], this time to move up and highlight 3·4. Press [ENTER] again to echo that onto the Editline. Now, if you press [ENTER] once more to do the addition, you'll see this:



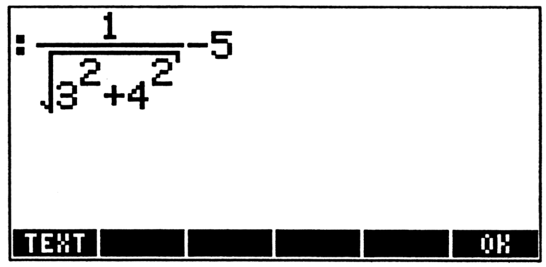
Viewing an expression

Whenever you use [▲] and [▼] to highlight a previous entry or answer on the History screen, there is another active menu key you may find useful: VIEW displays the selected item fully—and always in textbook format.

For example, suppose you do this calculation:
[1][÷][√x][↰][( )][3][y^x][2][+][4][y^x][2][▶][−][5]
[ENTER]



You get a result all right, but the original expression isn't entirely within view, and you'd like to see it.



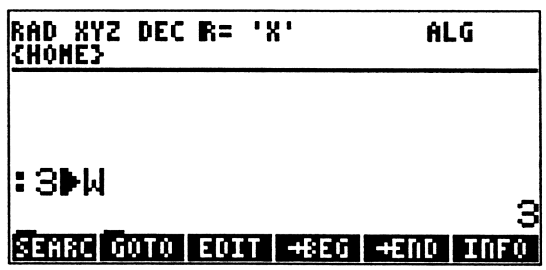
Just press [▲][▲] to highlight the expression, then VIEW to see it displayed fully, in textbook format.

When finished viewing, simply press OK.

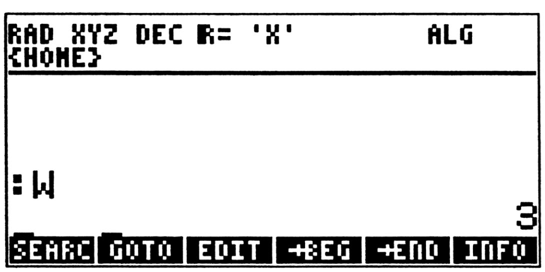
Storing objects into variables

To store a number (or any other object) into a variable name, you type in the number or object on the Editline of the history screen, press [STO▶], then type the name of the variable and press [ENTER].

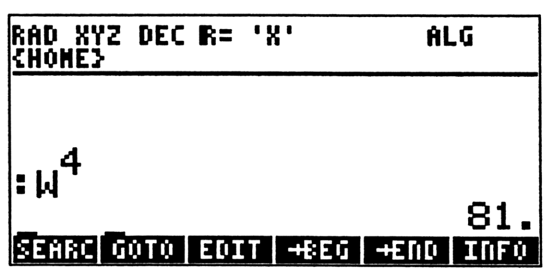
For example, to store the value 3 into the variable W, type [3][STO▶][ALPHA][W][ENTER].



That's all there is to it—the value is now stored.



Now, to recall the value, you can simply enter the variable name: [ALPHA][W][ENTER]



You can also use the name in a symbolic expression, and the stored value will be substituted: [ALPHA][W][y^x][4][ENTER]

MODES

Press the (MODE) key and you'll see a screen with a title bar, CALCULATOR MODES. These are the settings that control how the HP 49G interprets information and interacts with you—including how numbers and expressions are displayed on the history screen. You can move about this screen using the arrow keys. When an item is highlighted, the CHOOS button will show you the choices you have to fill in the blank. Take a quick tour of the (MODE) area.

The CALCULATOR MODES Screen

Operating mode

The operating mode is by far the most important setting on the HP 49G. Unless it states otherwise, this guide will assume that the HP 49G is always in *Algebraic* operating mode—where you enter numbers and expressions in algebraic format—since most users find this an easier format to work with. However, if you're an experienced HP 48G user and value the efficiency of stack arithmetic, you may prefer the *RPN* operating mode. (To set it, you'd press CHOOS, highlight RPN and press OK; or—a handy shortcut to toggle among the choices—just press (+/−).) In RPN mode, the HP 49G behaves quite similarly to the HP 48G.

Number format

The HP 49G can display up to 12 significant digits in each number (and it carries 15 digits internally for computation), but there are four formats you can CHOOS from that may alter your view of the actual value:

Standard format (Std) shows up to 12 digits (but no trailing zeroes), with a floating decimal point. For example, set Std mode (press (MODE), (▼) to the Number Format field, then CHOOS and highlight Standard and press OK OK), then type (1)(2)(3)(4)(5)(•)(6)(7)(8)(9)(ENTER). Your result is simply 12345.6789. (This display mode is probably the most useful here in this Guide.)

Fixed format (Fix) provides a fixed number of decimal places—you specify—from 0 to 11. For example, to specify 2 decimal places, press (MODE), then CHOOS Fixed for the number format and OK. Next, (▶) and CHOOS 2 decimal places. Press OK OK. The result: 12,345.68

Scientific format (Sci) uses exponential notation with one digit to the left of the decimal point and a specified number of places (0-11) to the right. For example, to specify scientific format with 2 decimal places now, press (MODE), CHOOS Sci for the number format and OK OK. The result: 1.23E4

Engineering format (Eng) is like scientific notation: the same number of significant digits, but the exponent is always a multiple of 3, so more than one digit may be to the left of the decimal point. For example, to specify engineering format with 2 decimal places now, press (MODE), CHOOS Eng for the number format and OK OK. The result: 12.3E3

FM (fraction mark)

Continuing the tour of the MODES screen, off to the right of the `Number Format` field(s) you'll notice a field called `_FM,` which offers you the option of using a comma for the decimal point—European notation. Just use `✓CHK` to check or uncheck this field as desired.

Angle measure

Next field down the screen: `Angle Measure`. What units do you wish to use for specifying angles in, say, trig calculations? There are three angle measure modes to choose from:

`Degrees`	There are 360 degrees in a full circle.
`Radians`	There are 2π radians in a full circle.
`Grads`	There are 400 grads in a full circle.

To make a selection, highlight the Angle Measure field and use either `CHOOS` or [+/-] to select the desired units. Now, when you press `OK` to confirm all your mode changes and then exit the MODES screen, you'll see the appropriate annunciator (`DEG`, `RAD` or `GRD`) up in the status area.

Coordinate system

Similarly, use the `Coord System` field to set the machine to rectangular, polar, or spherical coordinates for complex numbers and other vectors. This mode, too, is displayed in the status area of the history screen: `XYZ`, `R∠Z` or `R∠∠`, respectively. (Use polar mode, `R∠Z`, for 3-D cylindrical mode.)

To see the effect of this mode, try this: With the `Angle Measure` set to `Radians` and the `Coord System` set to `Rectangular`, press `OK` to return to the history screen and type [↰][()] [0][↱][,][1] [ENTER]. You should get this result: `(0.,1.)`.

Now, press [MODE] and change the `Coord System` to `Polar`. Press `OK` to return to the history screen and see the polar form of the value, in radians: `(1.,∠1.57079632679)` Note the status area: `RAD R∠Z`

Use [MODE] again and change the `Angle Measure` to `Degrees`. Press `OK` to go to the history screen and see the polar form of the value, this time in degrees: `(1.,∠90.)` Again, note the status area: `DEG R∠Z`

(When you're finished, use [MODE] to change back to Radians and Rectangular coordinates: `RAD XYZ`)

Making noise

Moving down the CALCULATOR MODES screen, you'll find two check fields that control the calculator's audio properties. Putting a check (via ✓CHK) into the _Beep field tells the HP 49G to beep when you make a syntax mistake or attempt an illegal operation. Recommendation: Though at first this may seem like a good idea—indeed, the default setting for _Beep is checked (on)—do yourself and the rest of the human race an enormous favor and *uncheck* it (turn it OFF). You'll still get plenty of visual feedback when you make errors.

Similarly, there's a check field called _Key Click that tells your HP 49G to click at every keystroke. The default setting is off—for good reason. (Doubtful? Go ahead—turn it on and press OK to exit MODES. Now try to use your calculator without sounding like a grocery clerk....)

Error recovery

The _Last Stack check field activates the ⟶ UNDO key, which allows you to undo the most recently performed operation, restoring the history screen to its state immediately before that operation. This can sometimes be a handy feature for recovering from keyboard goofs or fumbles, but it does take up a little memory. If you're running very low on memory, you might want to turn this mode off.

The FLAGS Menu

That about covers the CALCULATOR MODES screen itself. But notice the further resources you have for controlling other modes and settings—on the menu line. For example, press FLAGS to bring up a menu of over 70 flags that you can set or clear (i.e. check "on" or un-check "off").

To see how this works, scroll down to flag 27, which is system flag -27. (Remember that you can use ⟵ ▼ to move through a menu by pages.) Note how the description of the flag reflects its current status. If flag -27 is checked, you see 'X+Y×i' → 'X+Y×i'; if unchecked, you see 'X+Y×i' → '(X,Y)'. (This particular flag controls how symbolic complex expressions are displayed.) As usual, you use ✓CHK to toggle the setting.

A descriptive list of all the system flags and what they control are included in the pocket guide that comes with the HP 49G. Some of these flags reflect mode settings that you make in other ways. For the most part you will probably not want to fool around much with this menu.

Press CANCEL to return to the main MODES screen without disturbing the flag settings.

The CAS MODES Screen

The CAS key leads to the all-important CAS MODES screen, where the main items of interest are the check fields. (Don't worry about the Indep var or Modulo fields.) When performing a calculation where one of these modes is currently inactive but must be active for the HP 49G to complete its work, it will prompt you to change the mode, so it pays to understand these:

Numeric will substitute numerical values for special constants such as π or e in an algebraic expression.

Approx will treat all numeric values as real numbers, regardless whether they have any fractional portions—indicated by a little ~ in the status area. When Approx is not checked, the status area shows a little =, indicating Exact mode, and all values will be treated as integers; operations that would introduce non-integer values will not proceed without a change to this mode.

Complex allows computations to produce, use and carry complex numbers in their results. When this mode is checked, a little C appears in the status area; when this mode is unchecked, the little R indicates that only Real results are allowed.

Step/Step allows you to do differentiation step by step, via the [→][EVAL] key.

Incr Pow controls whether the terms of a polynomial are shown in order of increasing or decreasing powers.

Rigorous controls how rigorously the calculator will demand absolute values (i.e. not assume positive values) for variables which may not have negative values.

The DISPLAY MODES Screen

Back at the main MODES screen, pressing DISP brings up the DISPLAY MODES screen. These settings let you choose the size and/or appearance of various tools and areas in the calculator. For example, you can select a certain font size (6, 7 or 8 pixels high), and then specify whether, say, the stack or Equation Writer use that size or a small (5-pixel) size. You can also specify that expressions appear in textbook format rather than as a line of characters. And you can specify the size of the header (status area), whether a clock appears there, and in what form. Play around with these settings as you wish, using OK OK to exit MODES and observe the resulting displays.

Restoring All Modes to Default Settings

Press [MODE] [→][CLEAR] to restore all the modes to default settings.

Computational Examples

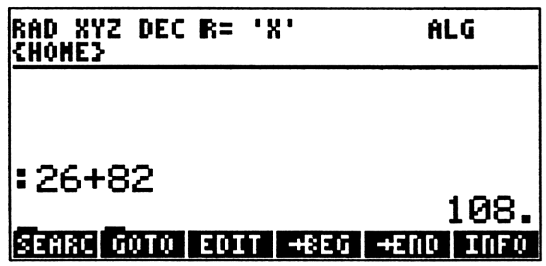
Here are some examples to demonstrate basic arithmetic and function operations of the HP 49G in `Algebraic` notation and `Standard` number format. Keystrokes are followed by a screen showing the results. (For the sake of clarity, unless otherwise noted, the history screen has been cleared via [→][CLEAR] after each example.)

Arithmetic Operations

These examples assume that the CAS modes `Numeric`, `Approx`, and `Complex` are all *off*—unchecked. (So, among the other items, your status area should show `R=`.)

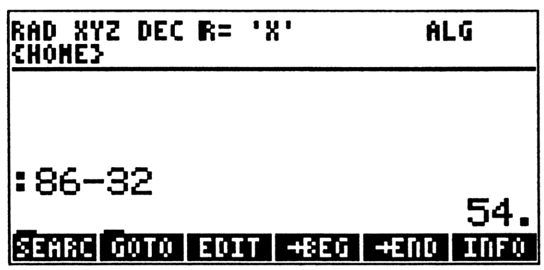
Addition

[2][6][+][8][2][ENTER]



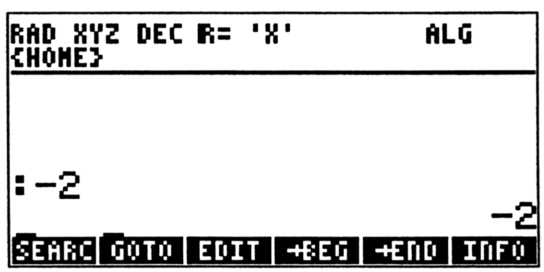
Subtraction

[8][6][−][3][2][ENTER]



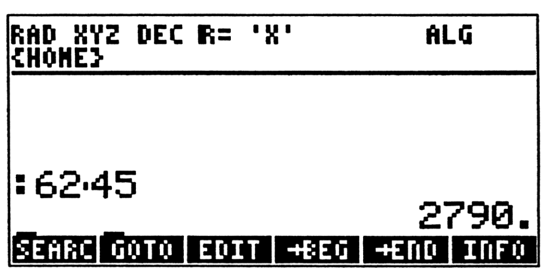
Negation

[+/−][2][ENTER]
(Either [−] or [+/−] can be used to obtain a negative sign in an expression.)



Multiplication

[6][2][×][4][5][ENTER]

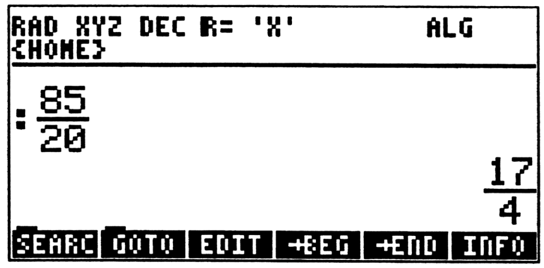


Division

[8][5][÷][2][0][ENTER]

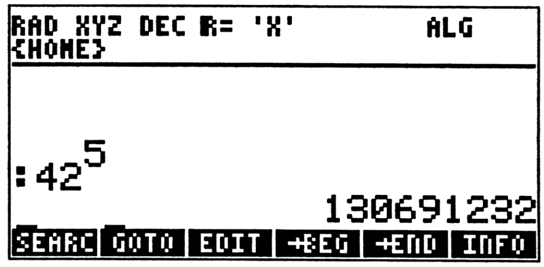
[↱][→NUM][ENTER] Result :→NUM(ANS(1))

4.25



Exponentiation

[4][2][y^x][5][ENTER]

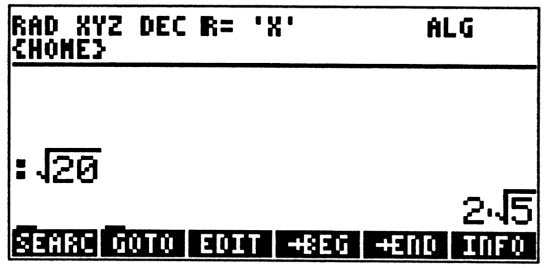


Square roots

[$\sqrt{x}$][2][0][ENTER]

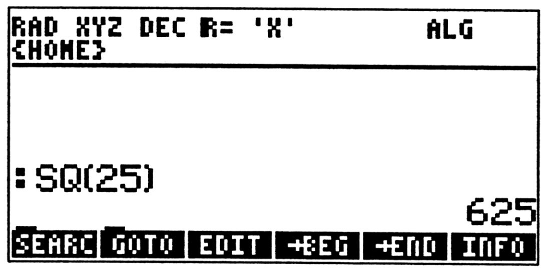
[↱][→NUM][ENTER] Result :→NUM(ANS(1))

4.472135955



Squares

[↰][x^2][2][5][ENTER]

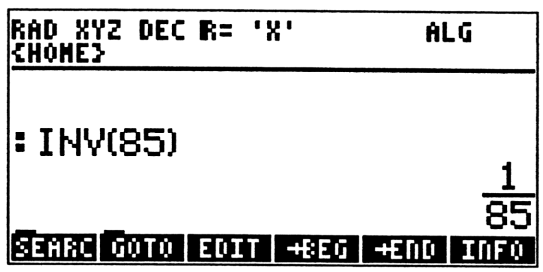


Reciprocals

[1/x][8][5][ENTER]

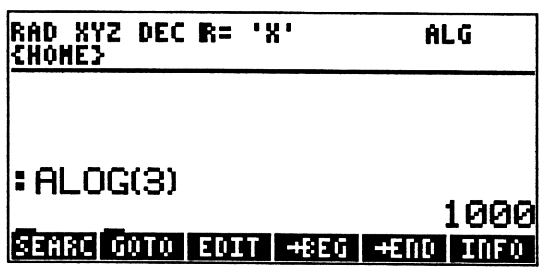
[↱][→NUM][ENTER] Result :→NUM(ANS(1))

1.17647058824E-2



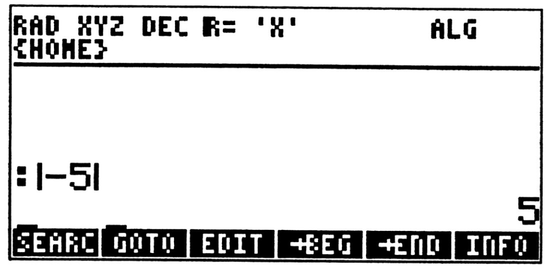
Powers of 10

[↰][10^x][3][ENTER]



Absolute value

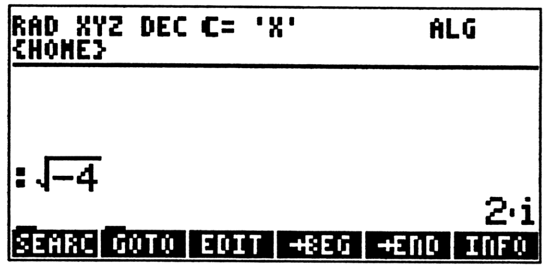
[↰][ABS] [−][5] [ENTER]



Complex Results

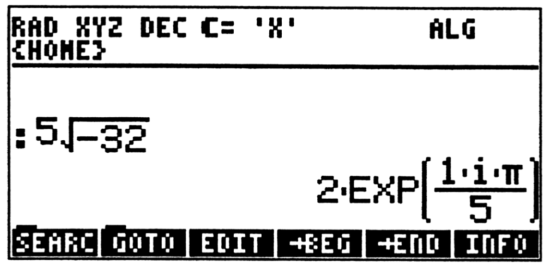
[√x] [−][4] [ENTER] (If your HP 49G is not in Complex mode, it will prompt you to set that mode now. Press [OK].)

[↱][→NUM] [ENTER] Result :→NUM(ANS(1))
(0.,2.)



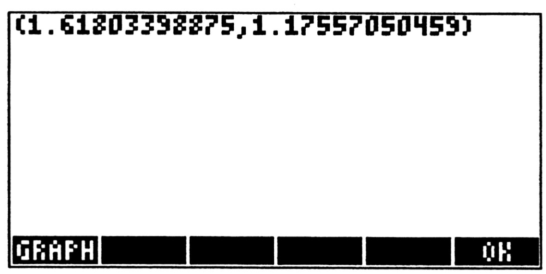
nth roots

For example, to take the fifth root of -32:
[↱][ˣ√y] [5] [↱][,] [−][3][2] [ENTER]



"What on earth is that?" It is an exponential form involving a primitive complex fifth root of unity. (*"Ah, of course."*)

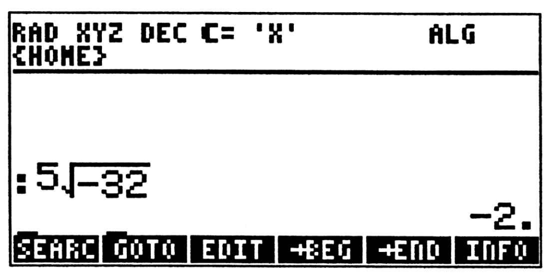
Try [↱][→NUM] [ENTER]. (To see it all press [▲] [VIEW]; press [OK] when you're done.)



This is still in complex form. Will unchecking Complex mode help? No, the HP 49G will simply prompt you to turn it back on when you attempt the calculation again.

Instead, go to [MODE] [CAS] and check Numeric. Then press [OK] [OK] to return to the history screen.

Now try it again: [↱][ˣ√y] [5] [↱][,] [−][3][2] [ENTER]



Transcendental Functions

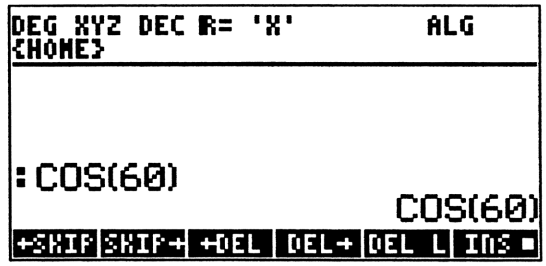
Trigonometric functions

With the angle measure set to Degrees:

[COS] [6] [0] [ENTER]

[↱] [→NUM] [ENTER] Result :→NUM(ANS(1))

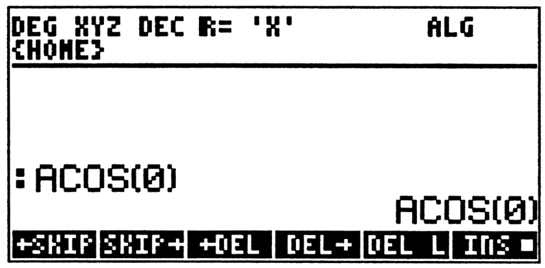
.5



[↰] [ACOS] [0] [ENTER]

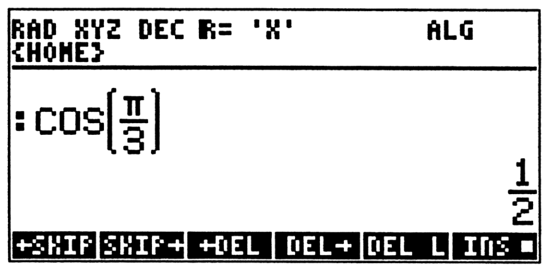
[↱] [→NUM] [ENTER] Result :→NUM(ANS(1))

90.

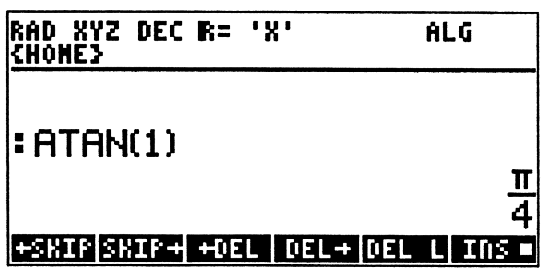


With the angle measure set to Radians:

[COS] [↰] [π] [÷] [3] [ENTER]



[↰] [ATAN] [1] [ENTER]

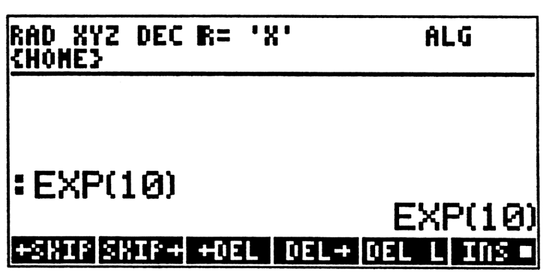


Natural exponentials

[↰] [e^x] [1] [0] [ENTER]

[↱] [→NUM] [ENTER] Result :→NUM(ANS(1))

22026.4657948



Note how function keys supply both parentheses for you.

Common (base 10) logarithms

[→][LOG] [2] [ENTER] Result :LOG(2)

.301029995664

Natural (base e) logarithms

[→][LN] [3] [ENTER] Result :LN(3)

.1.09861228867

Some Special Numbers

Certain names in the HP 49G are reserved for special mathematical constants:

[←][π] [→][→NUM] [ENTER] Result :π

3.14159265359

[ALPHA][←][E] [→][→NUM] [ENTER] Result :e

2.71828182846

[ALPHA][←][I] [→][→NUM] [ENTER] Result :i

(0.,1.)

(The machine will remind you to set complex mode here.)

Practice with these: What is $e^{i\pi}+1$? Which is larger: e^{π} or π^{e}? What is $\ln(-1)$?

Implied Multiplication

In Algebraic mode on the HP 49G, the juxtaposition of two numerical quantities (including single-character variable names) usually implies multiplication. Watch how the machine inserts the multiplication symbols:

[4] [←][()] [1] [+] [2] [▶] [y^x] [3] [ENTER] Result :4·(1+2)^3

108

[4] [ALPHA][←][C] [+] [2] [ALPHA][←][D] [ENTER] Result :4·c+2·d

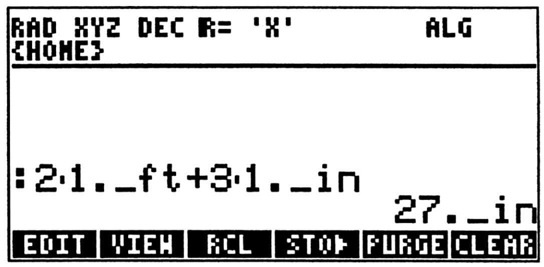
4·c+2·d

Using Units

One of the truly unique capabilities of theHP 49G is its management of units. You can attach units of measurement to numerical quantities by selecting the desired unit from the [→][UNITS] menu, using the underscore symbol ([→][_]) as the syntax. Those units will then be automatically taken care of by the HP 49G in subsequent calculations.

Press [→][UNITS] now to see how the menu is organized into different submenus: Length, Area, Volume, etc. Use [▽] to scroll down through the different categories. Highlight Area.. and press OK and another menu box will appear with various units of area. Then press [CANCEL] and try a calculation example.

Add 2 feet + 3 inches: Press [2][→][_] [→][UNITS], highlight Length.. and press OK, highlight ft and press OK; then [+]. Now [3][→][_] [→][UNITS], highlight Length.. and press OK, highlight in and press OK; then [ENTER].



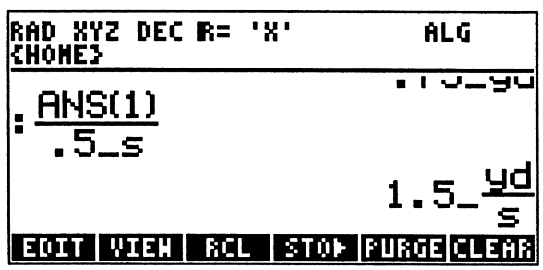
Notice that the result is expressed in the same units as the second argument.

Of course, you can simply convert from one unit to another, too—use the CONVERT command.

For example, to convert the above answer to yards, you'd press [→][UNITS], highlight Tools.. and press OK, highlight CONVERT and press OK. Now fill in the two arguments (the units to be converted and an example of the desired new units—any value): [←][ANS] [→][,] [1][→][_] [→][UNITS], then highlight Length.., OK, highlight yd, OK; then [ENTER].

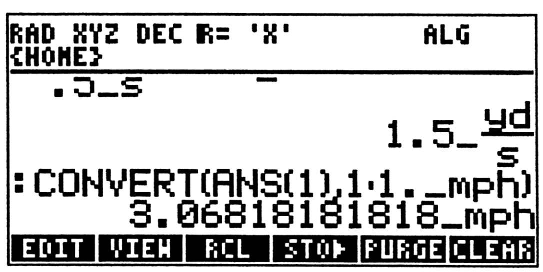
Addition and subtraction require units of like dimensions, but multiplication and division can be performed with any mix of units—compound units are formed automatically.

For example: [←][ANS] [÷] [.][5][→][_] [→][UNITS], highlight Time.., OK, highlight s, OK; then [ENTER].



Now convert this last result to miles per hour:

[→][UNITS], highlight Tools.. and press OK, highlight CONVERT and press OK. [←][ANS] [→][,] [1][→][_] [→][UNITS], then highlight Speed.., OK, highlight mph, OK; then [ENTER].



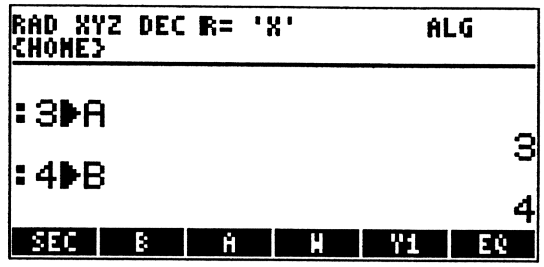
Variables

Use the [STO▶] key to store values into variable names. Try a few examples:

[3] [STO▶] [ALPHA][A] [ENTER]

[4] [STO▶] [ALPHA][B] [ENTER]

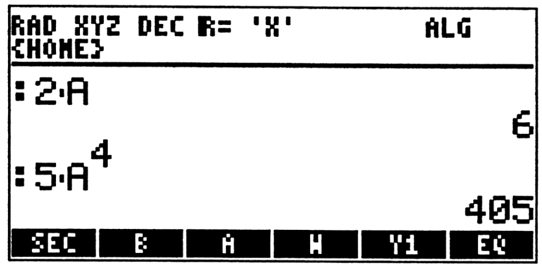
Simple commands, simple results.



[2] [ALPHA][A] [ENTER]

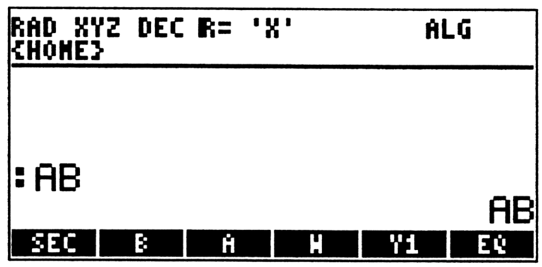
[5] [ALPHA][A] [y^x] [4] [ENTER]

Notice the use of implied multiplication between a constant and a single-character variable name.



[ALPHA][A] [ALPHA][B] [ENTER]

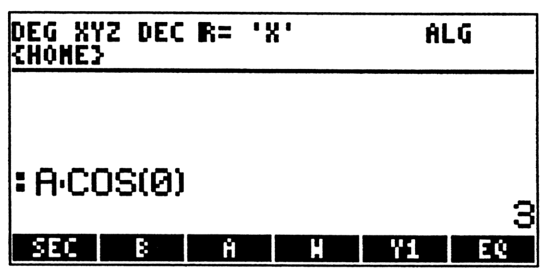
As you can see, you can't use implied multiplication between two single-character variable names; the HP 49G interprets AB as a two-character variable name rather than A · B.



Notice, too, that since there is no value stored in the variable AB, its name is simply echoed back to you. It won't simplify any further toward a numerical value; [↱][→NUM] would have no effect.

With the angle measure set to Degrees, press [ALPHA][A] [COS] [0] [ENTER]. You should see this:

The explicit multiplication symbol makes clear the meaning of the expression. But how did the machine know you didn't mean ACOS(0)—the inverse cosine of 0?



Try the above keystrokes again and watch for the space that appears on the Editline when you press [COS] immediately after typing [A]. If you delete this space before pressing [ENTER], you'll get ACOS(0), which is 90. The fact that you left the space there told the machine that you meant to multiply the variable A by COS(0).

The VAR Menu

All items that you name and store in the HP 49G will appear by name under the VAR menu. Press [VAR] now and you'll see some menu keys labeled [B], [A], etc. Pressing [B] will type its name on the Editline; then [ENTER] will show its contents.

Purging stored information from memory

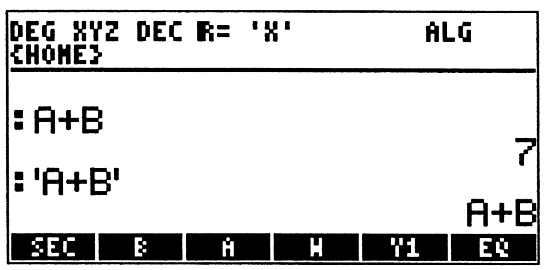
Press [TOOL] to bring up the usual menu for the history screen. You'll see a menu key labeled [PURGE], which is the command you use to erase variables you've stored. For example, store the value 12 into the name D: [1][2][STO▶][ALPHA][W][ENTER]. Notice how [D] appears on the far left of your VAR menu. Now erase the variable D from your memory: Press [PURGE] [VAR] ['] [D] [ENTER]. (Note how a menu item can act as a typing aid. You could instead have typed [ALPHA][D], but this way you saved a keystroke.) The [D] should now be gone from the VAR menu, and you get a NOVAL message to indicate that the name D now has no value stored in it.

Symbolic Algebra

You can build symbolic expressions involving variables and then perform arithmetic with these expressions just as you do with numbers.

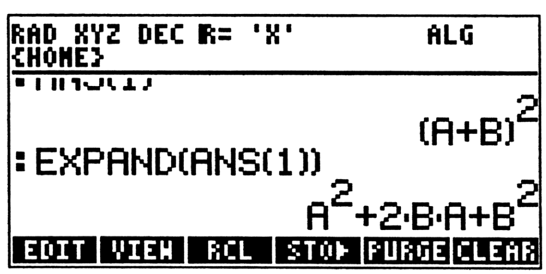
When typing expressions involving variable names on the Editline, one very important key to remember is the apostrophe key, [↱][']. (a.k.a the "tick" key). You saw it used above when you were specifying the name 'D' for purging. To see its effect in general, try an example.

Enter the expression A+B: [ALPHA][A] [+] [ALPHA][B] [ENTER].... Since A and B both have values (3 and 4, respectively), you get a numerical result immediately: 7



But now try it again, this time with "tick" marks around the expression: [↱]['] [ALPHA][A] [+] [ALPHA][B] [ENTER].... See? The tick marks suppresses evaluation of the expression. Now, square the expression: [↰][ANS] [y^x] [2] [ENTER]

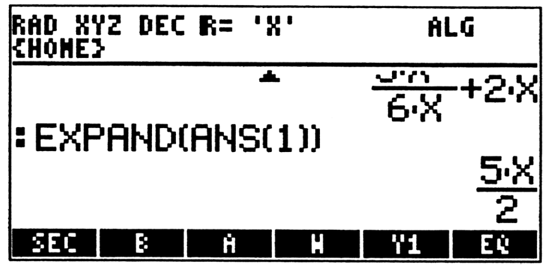
Want to expand this symbolic expression? OK—the HP 49G has tools for symbolic algebra in the [SYMB] menu—but first you have to PURGE({'A','B'}). (You'll find [PURGE] in the [TOOL] menu.)



Then press [SYMB], highlight ALGEBRA and [OK]. Highlight EXPAND and [OK]. Now [↰][ANS] [ENTER].

EXPAND also collects like terms, cancels like factors in rational expressions, and does other simplifications.

Try one more example: (→)(') (3)(X)(y^x)(2)(÷)(←)(( ))(6)(X) (▶)(+)(2)(X)(ENTER).



Now press (SYMB), highlight ALGEBRA and OK, then highlight EXPAND, OK, and then (←)(ANS) (ENTER) to see a simplification of the expression.

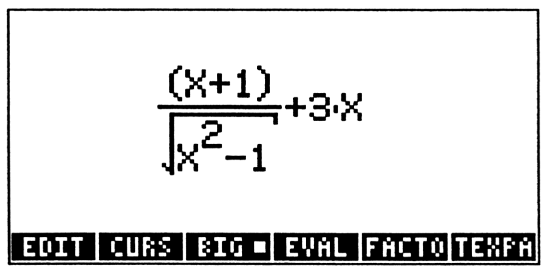
The Equation Writer

Now that you know how to key in symbolic expressions on the Editline—good for short and simple expressions—here's how to save yourself the trouble for bigger jobs: The Equation Writer uses the screen as a blackboard to write expressions in textbook format.

The important key to remember in the Equation Writer is (▶). Use it whenever you want to proceed to the next component of an expression. For example, you press (▶) whenever you wish to leave an exponent, a denominator or get outside a radical sign or an expression enclosed in parentheses.

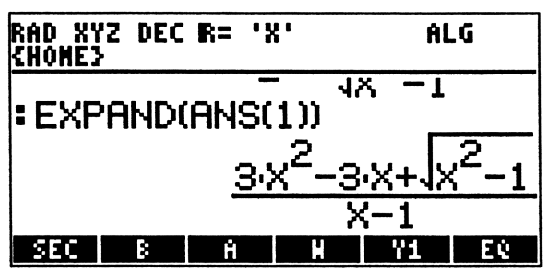
Use the Equation Writer to enter this expression (and watch your screen as you do the keystrokes):

(→)(') (EQW)(←)(( ))(X)(+)(1)(▶)(▶)
(÷)(√x)(X)(y^x)(2)(▶)
(−)(1)(▶)(▶)(▶)(▶)
(+)(3)(X)



Now press (ENTER) to send the expression to the Editline. Why use the tick marks? Because you wanted a symbolic result—suppressing any evaluation in the event that X contained a value.

Now (ENTER) again to put the result on the stack. Then press (SYMB) and highlight ALGEBRA, OK, highlight EXPAND, OK, (←)(ANS) (ENTER), to see this rational simplification:



You'll get lots more detail and practice on the Equation Writer in a later section. This was just an introduction to let you do basic symbolic calculations.

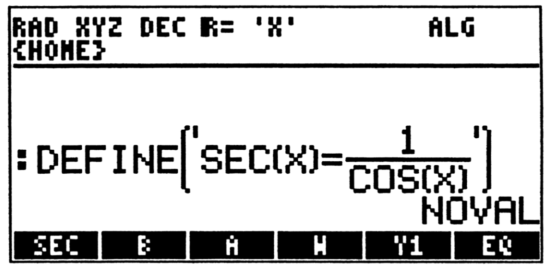
Defining Your Own Functions

Of course, you can store any sort of object into a name—and it will appear on your VAR menu just like any other name. Expressions are often very handy to store. For example, suppose you want to store the formula for secant in the name SEC. [↱]['] [1] [÷] [COS] [X] [▶] [▶] [STO▶] [ALPHA] [ALPHA] [S] [E] [C] [ENTER] would store 1/COS(X) under the variable name SEC. Then pressing [VAR] **SEC** would return the expression 1/COS(X) to the Editline.

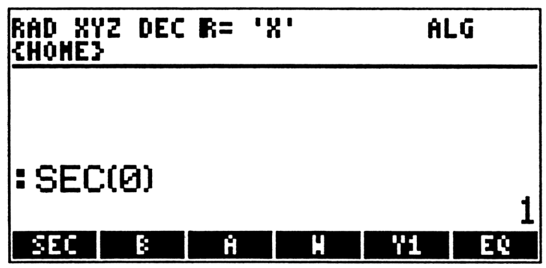
Or, you can actually define a secant *function* that will operate just like the other trigonometric function keys—accept an argument and evaluate immediately.

To do this, you define the formula as an equation, using the [↰][DEF] key, as follows:

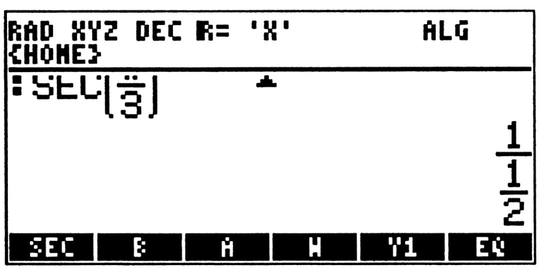
[↰][DEF] [↱]['] [ALPHA] [ALPHA] [S] [E] [C] [ALPHA] [↰][()] [X] [▶] [↱][=] [1] [÷] [COS] [X] [ENTER]



There's still a **SEC** key in the VAR menu, but now it's a function key, not an expression. Try it out:



Set Radians mode, then [VAR] **SEC** [↰][()] [0] [ENTER]

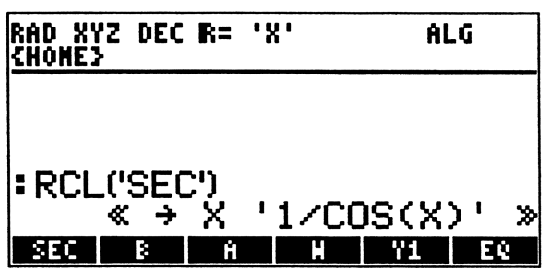


[VAR] **SEC** [↰][()] [↰][π] [÷] [3] [ENTER]

[↱][→NUM] [ENTER] Result :→NUM(ANS(1))

2

SEC is an example of a user-defined function, which actually operates like a small program. In other words, pressing **SEC** executes a program that takes a value off the stack and return a function of that value—in this case, the secant. To see what the program looks like, recall its contents: [TOOL] **RCL** [↱]['] [VAR] **SEC** [ENTER]. The « » denote a program on the HP 49G. In this case, the program takes a value off the stack (indicated by the arrow), calls it X, then evaluates and returns 1/COS(X).



You can define the other two trig functions similarly:
[↰][DEF] [↱]['] [ALPHA] [ALPHA] [C] [S] [C] [ALPHA] [↰][()] [X] [▶] [↱][=] [1] [÷] [SIN] [X] [ENTER].
And [↰][DEF] [↱]['] [ALPHA] [ALPHA] [C] [O] [T] [ALPHA] [↰][()] [X] [▶] [↱][=] [1] [÷] [TAN] [X] [ENTER].
Now you have all six trigonometric function keys for your HP 49G.

Working with Functions

The ⇦-shifted versions of the top six keys give you access to environments that work with formulas, graphs, and tables on the HP 49G. You'll probably use these keys mostly for functions of a single variable.

⇦Y= is for entering formulas, such as functions of the form $y = f(x)$.

⇦WIN is for defining a window for graphing purposes.

⇦GRAPH creates a graph.

⇦2D/3D allows you to set up the type of environment for plotting.

⇦TBLSET is for setting up a table.

⇦TABLE creates a table of values.

(NOTE: If you're experienced with other graphing calculators, you will observe that many of these correspond to similarly labeled keys on other machines. But be aware that it is not an exact correspondence. For example, on the HP 49G, you set some graphing modes via ⇦2D/3D, whereas those modes are often set in the modes menu on other calculators.)

To get to most of the basic tools for working with functions, equations, and data, use ⇦2D/3D (so called since it deals with two- and three-dimensional plotting environments). You'll see the `PLOT SETUP` screen.

Two-Dimensional Plot Types

Built into the HP 49G are 16 different plot types. The main two-dimensional plotting types are:

`Function:` For working with functions of the form $y = f(x)$.

`Parametric:` For working with parametric equations $x(t)$, $y(t)$.

`Polar:` For working with polar functions $r(\theta)$.

`Conic:` For working with quadratic equations in two variables (so the graphs are conic sections).

`Truth:` For working with inequalities in two variables (so the graphs show shaded regions of the plane).

Setting up a plot type

One of the plot types is always active, but it may not be the one you want. The default plot type is Function. To select that type, highlight the Type field and press CHOOS. This will give a complete scrolling list of all the possible plot types. Highlight Function and press OK.

Now press (⬅)(Y=), where you should see the PLOT - FUNCTION screen with a list of your function formulas. If there are no current functions activated, you'll see the message: No Equ., Press ADD. Indeed, ADD is what to press when you want to add a function to the list of active formulas for graphing or tabulating. Press it now....

You'll see Y1 (X)= appear in the Equation Writer. To enter, say, a sine function, press (SIN)(X)(ENTER). That will send you back to the Y= menu, where you'll see the function you've just added to the list.

The Y= menu

The menu keys in the Y= menu are EDIT, ADD, DEL, CHOOS, ERASE and DRAW.

EDIT sends the highlighted function back to the Equation Writer where you can edit it. Press OK or (ENTER) to enter the edited version; press (CANCEL) to restore the original.

ADD, as you've already seen, will send you to the Equation Writer and begin an entry using the next available numbered Y function.

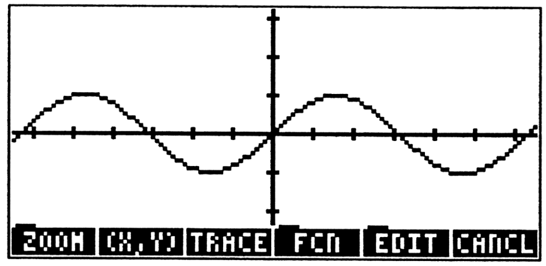
DEL deletes the highlighted function from the Y= list. Go ahead and delete Y2 (X) and Y3 (X) now.... NOTE: DEL does NOT purge the function from your calculator's memory! It merely clears it from the Y= list. The variable name and value (Y1, Y2, or whatever) will still be in your VAR menu. To purge a function, you must use PURGE('Y1') or PURGE('Y2'), etc. (PURGE is on your (TOOL) menu.)

Pressing (➡)(CLEAR) at the Y= menu is the same as using DEL to erase all the functions. The HP 49G will ask you if you really want to Delete All (and offer YES and NO options for you to respond).

ERASE and DRAW are what to press (one after the other) to see the graphs of the functions. (Press (CANCEL) to return to the Y= screen when you've finished viewing the graph.)

Plotting graphs

[⇦][2D/3D] brings you to the `FUNCTION PLOT SETUP` screen. To reset all the plot settings, press [⇨][CLEAR]. This resets the plot so that the center of the screen is at the origin, the coordinate axes are shown, each axis tick represents one unit, and each pixel is 0.1 unit.



Now press **ERASE** **DRAW** to see the graph of `Y1(X)=SIN(X)` in the default viewing window:

Making tables for functions

[⇦][TBLSET] brings you to the `TABLE SETUP` screen. This is where you set up parameters for building a table of values for a function:

`Start` is the starting value for `X`.

`Step` is the step value (increment) for `X`.

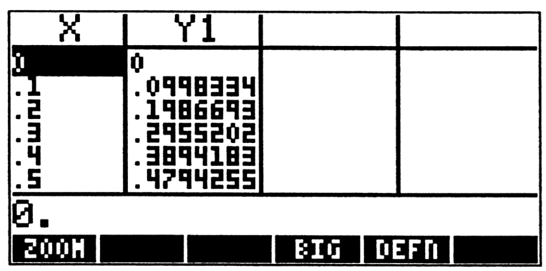
`Zoom` is the zoom factor for your table, to help you interpolate more finely between generated values.

`Small Font` lets you choose either a small or big font for the table display.

`Type` lets you **CHOOS** either `Automatic` generation of values based on regular increments of `X`, or `Build Your Own`, in which case you have to enter all the `X`-values.

For this first example, reset all the table settings by pressing [⇨][CLEAR]. This resets the table so that the starting value is 0 and values are automatically incremented in steps of 0.1.

Pressing [⇦][TABLE] will then display this table of values for `X` and `Y1`:

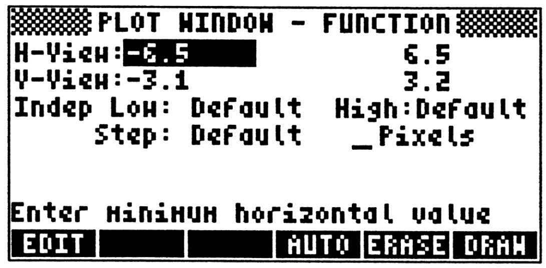


Working with Graphs

Setting Up a Graph

To set up the HP 49G for graphing, you first need to determine a window size—the viewing "domain" and "range." To do this, press [⇦][WIN] to see the PLOT WINDOW - FUNCTION screen.

As usual with such screens, you use [▲] and [▼] to highlight fields. To change a highlighted field, you either [✓CHK] the value on or off, or (if it's not a check-type field) type in the desired value, [EDIT] the current contents of a field, or, when a choice of options is available, [CHOOS] from the menu box of available choices. Pressing [DEL] resets the field to its default value. [⇨][CLEAR] resets all the fields on that screen.



H-VIEW This field specifies the left and right edges of your viewing window (the viewing "domain")

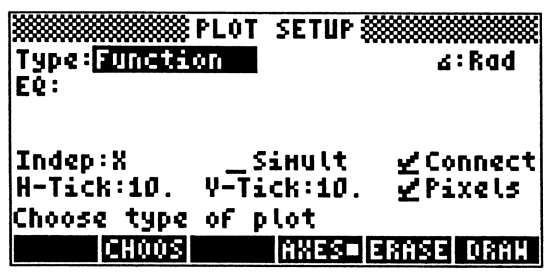
V-VIEW This field specifies the lower and upper edges of your viewing window (the viewing "range")

Indep Low and **High** These fields specify the graphing "domain," which may extend beyond your specified viewing "domain;" you can move your viewing window around on the larger graph if necessary. (Usually, though, you'll leave the default setting here, which simply matches your H-VIEW setting.)

Step This field specifies the increment or step value for the independent variable, X. The default setting is determined simply by dividing the H-VIEW length by the 131 pixels available horizontally on the screen.

Pixels If this is checked, the step size is expressed in pixels no matter what your H-VIEW happens to be. For example, if the Step is set at 2 and Pixels is checked, then every second pixel will be plotted.

The other settings for your graph are all found under the [⇦][2D/3D] (PLOT SETUP) screen.



∡ You can set the angle mode here, as well as on the main CALCULATOR MODES screen. (Be sure it's set for radians for the trigonometric function examples.)

Indep This field specifies the independent (horizontal axis) variable. For functions, this is usually X.

H-Tick This field specifies the spacing of the tick marks on the horizontal axis.

V-Tick This field specifies the spacing of the marks on the vertical axis.

`Pixels` If this field is checked, then the tick spacing is expressed in pixels rather than in units. For example, if the `H-tick` spacing is set at `10` and `Pixels` is checked, then a tick mark will appear every ten pixels along the horizontal axis. (If `Pixels` is not checked, then a tick mark will appear every 10 units, which may be represented by an entirely different number of pixels, depending on your settings in [←][WIN].)

`SIMULT` If this field is checked, the machine will plot multiple functions simultaneously. (If it's not checked, multiple functions are plotted sequentially, each on their own graph.)

`CONNECT` If this field is checked, individual plotted points will be connected on the graph.

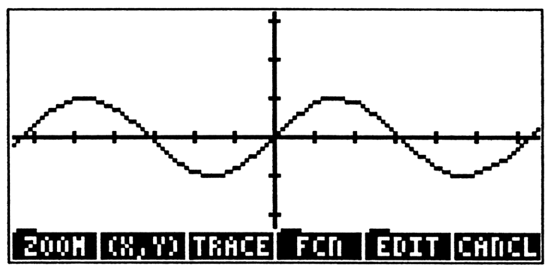
Function Graphing Examples

These examples will illustrate some of the tools available in [←][GRAPH]. All the examples are for functions, but many of the features are similar for other plot types, such as parametric, polar, and conic sections.

Press [←][2D/3D] [→][CLEAR] and make sure that the Type field is set to `Function`. Now go to [←][Y=] and check that it contains `Y1(X)=SIN(X)`.

To set the default viewing window, press [←][WIN] [→][CLEAR]. Then press **ERASE**, to clear the graphics screen. (Otherwise, the new graph will be plotted on top of the previous graph.)

Now press **DRAW** to see the graph of `Y1(X)=SIN(X)`.



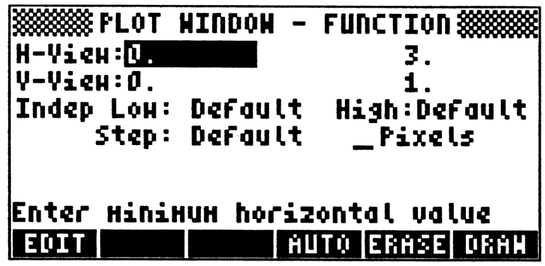
The GRAPH menu

The [←][GRAPH] menu offers these items: **ZOOM**, **(X,Y)**, **TRACE**, **FCN**, **EDIT** and **CANCL**.

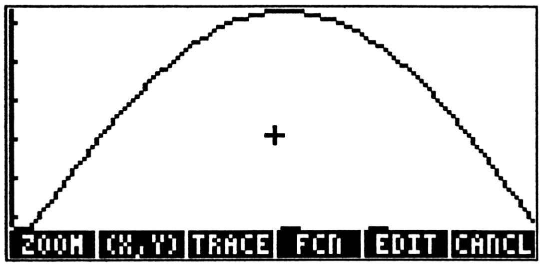
TRACE toggles the trace mode on and off. (This feature is on when a small square appears: **TRACE■**). When trace mode is on, [◄] and [►] will move a small crosshairs to trace the graph of the function. When trace mode is off (**TRACE**), the crosshairs move freely off the function graph.

(X,Y) displays the coordinates of the crosshairs at the bottom of the screen. If your graph leaves the top or bottom of the screen, the crosshairs will move along the edge of the screen, but the correct coordinates of points on the graph will continue to be read out. Press [−] to remove both the coordinates and the menu labels. Press [+] to re-activate the trace and coordinates. Press [−] (or any of the function keys) to get the menu back again.

Using the same function example as before (Y1(X)= SIN(X) with default window settings), here are several ways to rescale a function graph, both from inside and outside the graphics screen environment:

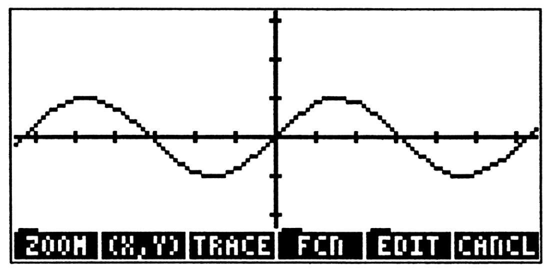


Press (CANCEL) (CANCEL) (⬅)(WIN). Set this viewing window:



Now press ERASE DRAW to see the graph shown here (left).

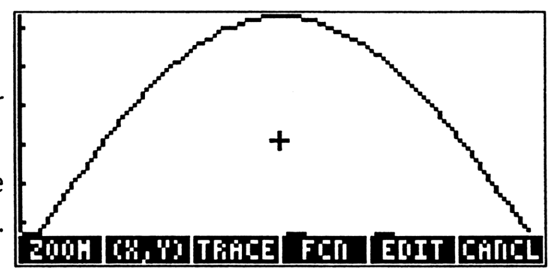
Interactive zooming features



Press (CANCEL) to return to the PLOT WINDOW screen and (NXT) RESET to Reset all OK.

Press (NXT) to return to the first page of the screen, and re-draw the graph: ERASE DRAW.

Then use the ZOOM folder key to get the ZOOM submenu:



The BOXZ key allows you to draw a box representing your new viewing window. Move the crosshairs to the point (3,1) and press ZOOM. Look familiar? You effectively reset the viewing window to [0,3] × [0,1]—without leaving the graph.

ZFACT lets you to set your horizontal and vertical zoom factors (default factor is 4), and you can also check an option to automatically recenter the screen at the location of the crosshairs.

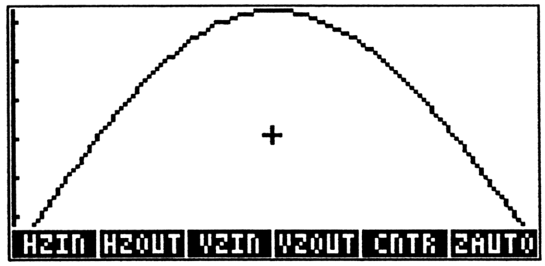
ZIN will zoom in by the designated zoom factors.

ZOUT will zoom out by the designated zoom factors.

ZSQR will "square up" the viewing window—so that 1 pixel represents the same distance horizontally and vertically—by adjusting the vertical viewing range.

ZDFLT sets the viewing window back to its default ranges: [-6.5,6.5] × [-3.1,3.2]

Press (NXT) for the second page of the ZOOM menu.



HZIN will horizontally zoom in by the current zoom factor.

HZOUT will horizontally zoom out by the current zoom factor.

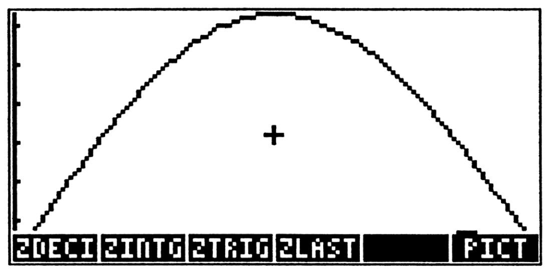
VZIN will vertically zoom in by the current zoom factor.

VZOUT will vertically zoom out by the current zoom factor.

CNTR will center the screen on the crosshairs. (The relative dimensions of the screen remain unchanged.)

ZAUTO will autoscale the vertical range by computing a sample of the values of the expression for the horizontal range, then setting the vertical range to include the extreme function values. Press ZAUTO now.

Press (NXT) for the third page of the ZOOM menu.



ZDECI sets the tick marks along the x-axis to be one unit apart. (Each pixel has a width of .1 units.)

ZINTG sets the tick marks along the x-axis to be ten units apart. (Each pixel has a width of 1 unit.)

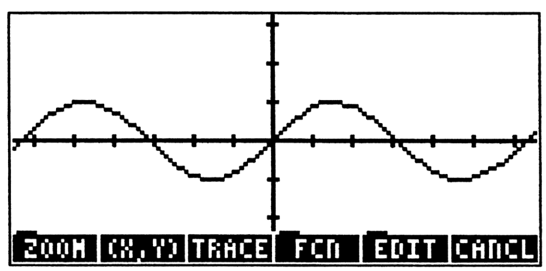
ZTRIG sets the tick marks along the x-axis to be π units apart.

ZLAST is the UNDO key for zooming. It will reset the viewing window to its most recent settings.

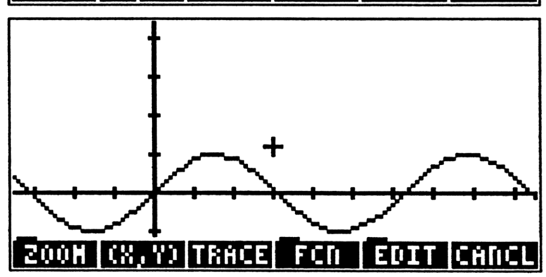
PICT will return you to the top level of the interactive graphics menu.

Try a few of the zoom features.

Press ZOOM ZDFLT to get your original sine graph back.

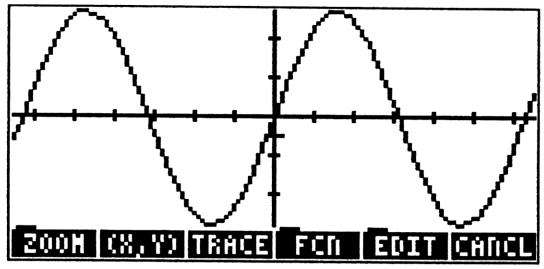


Now move the crosshairs to the point (3,1) and press ZOOM (NXT) CNTR.



Again, press **ZOOM** **ZDFLT** to restore the original sine graph.

Then press **ZOOM** [NXT] **ZAUTO**.



Try the other zoom features for yourself.

More on Graphing Functions

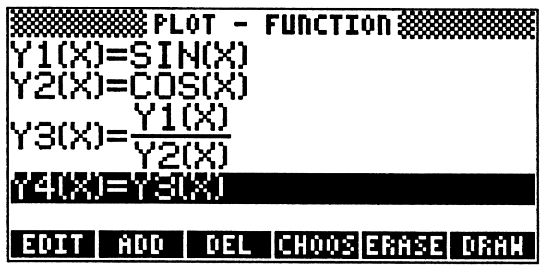
Plotting two or more functions

To add a second function for plotting, press [←] [Y=] **ADD** to see Y2(X)= appear in the Equation Writer. Type [COS] [X] [ENTER].

To add a third function, press **ADD** to see Y3(X)= appear in the Equation Writer. Type [ALPHA] [Y] [1] [←] [( )] [X] [▶] [÷] [ALPHA] [Y] [2] [←] [( )] [X] [ENTER].

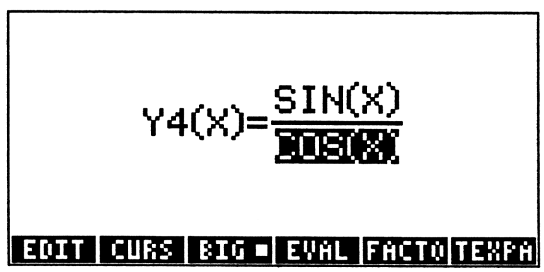
Now **ADD** one more function:
[ALPHA] [Y] [3] [←] [( )] [X] [ENTER]

You should now see this:



Before you move on, check out the following.

Highlight Y4(X) and press **EDIT** to send this expression back to the Equation Writer for editing. Press [▼] [▶] to highlight just the Y3(X) on the right side of the equation. Now press **EVAL** to see this:

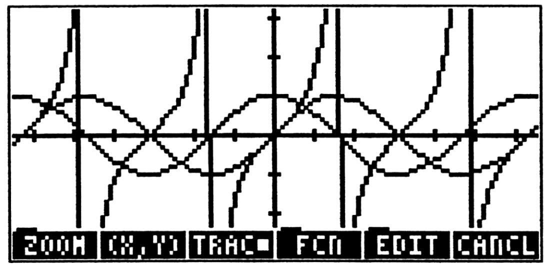


Press [ENTER]. There is now an important distinction between Y3 and Y4. The formula for Y3(X) is still in terms of Y1(X) and Y2(X); if you were to edit the formula of either or both Y1 and Y2, the definition of Y3 would be changed also. However, the formula for Y4 no longer refers to any other named function in your list, so any changes to the other functions will NOT affect Y4.

With that said, highlight Y3(X) now and delete it, using **DEL**. (Reminder: This does not erase Y3 from the memory—only PURGE can do that.)

Press [←][2D/3D] and you'll see that your three functions are listed in the EQ field. EQ is a reserved variable name on the HP 49G. This variable contains the currently active function(s) or equation(s) for graphing, tabulating, solving, etc. If Simult is not checked, these three functions will be plotted sequentially in the order they're listed in EQ.

So now you're ready to plot the sine, cosine, and tangent functions together in the default viewing window.



Press [←][WIN] [→][CLEAR] **ERASE** **DRAW** to see the plot. Turn on **TRAC■** and **(X,Y)**. Use [▲] and [▼] to switch the cross-hairs from graph to graph.

Press [←][2D/3D] and check Simult. Press **ERASE** **DRAW** again to see the same three functions graphed—but this time simultaneously. When you're done, go back to [←][2D/3D] and uncheck Simult.

Go back to [←][Y=], press [NXT], and notice the two menu items **MOVE↓** and **MOVE↑**. These allow you to manipulate the order of the functions for graphing.

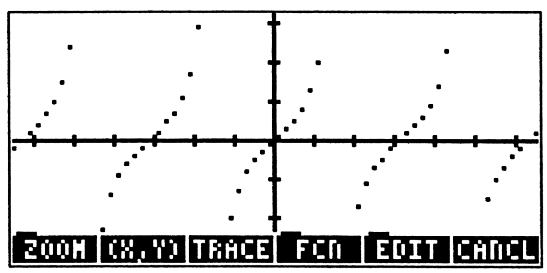
Connected versus dot modes for graphing

Go back to [←][2D/3D]. When Connect is unchecked, at most one pixel per column will be lit on a function plot. When Connect is checked, then additional pixels are lit to give the graph a continuous appearance.

To contrast the two modes, try the following example. Start with the Connect field unchecked.

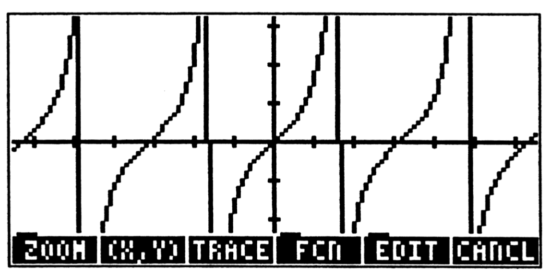
Go to [←][Y=] and delete all functions except for
Y4(X)=SIN(X)/COS(X).

Press **ERASE** **DRAW** to see the graph in dot mode:



To fill in the gaps, return to [←][2D/3D] and check the Connect field.

Now graph the function again: **ERASE** **DRAW**

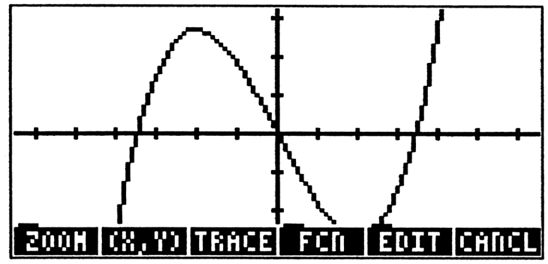


Notice how it appears that vertical asymptotes have been drawn in. This is not really the case—the HP 49G has simply connected the graph across the asymptotes. (NOTE: If a vertical asymptote or other discontinuity where the function is undefined falls exactly on the coordinate of a column of pixels, then the graph will not connect over the discontinuity, even when the HP 49G is in connected mode.)

The FCN menu for function graph analysis

When you graph a function, a FCN folder appears on the graphics menu, offering several interactive tools for working with functions directly in the graphics environment. Explore those tools with this example:

Graph X^3/6-2•X with default settings. First, go to [↰][Y=] and [↱][CLEAR] the list. Now ADD [X][y^x][3] [▶][÷][6][▶][−][2][X][ENTER].... Then ERASE and DRAW....



Now, press FCN to obtain the Function Menu (use [NXT] PICT to leave the function folder and return to the main interactive graphics menu), and look at each of the options available under the Function Menu, using the above example.

Place the crosshairs at x=3. ROOT snaps the crosshairs to the nearest root, displays its value, and records it on the history screen with the label Root. You should see Root: 3.46410161514 at the bottom of the graphics screen. (Press [−] or any menu key to get the menu labels back on screen.)

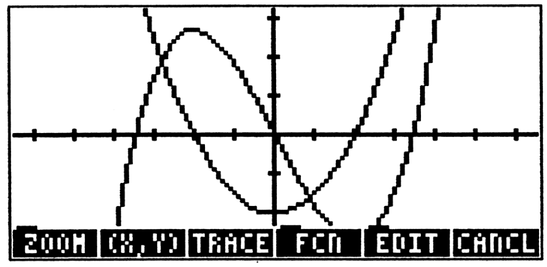
If you've plotted two functions together, INTER snaps the crosshairs to the nearest intersection point, displays its coordinates and records it on the stack, labelled Isect:. (INTER doesn't apply in this example.)

Move the crosshairs back to the origin. SLOPE calculates the derivative of the function at the x-coordinate of the crosshairs location, displays it, and records it on the stack with the label Slope:. Press SLOPE now and the calculator will compute the slope at x=0. You should see Slope: -2 at the bottom of the screen. Press [−] or any menu key to get the menu labels back on screen.

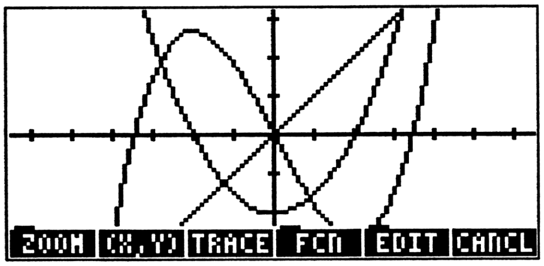
Pressing AREA marks the lower limit of integration. Press it now and you'll see a small mark at the origin. The second time you press it, it will compute the definite integral (numerically) of the function from the first mark to the current crosshairs position, then display the value and record it on the stack with the label Area:. Move the crosshairs back to x=3 and press AREA a second time. You should see Area: -5.625 at the bottom of the screen. Press [−] or any menu key to get the menu labels back on screen. (NOTE: AREA computes a definite integral, so integrating from right to left between two points will yield the opposite result from integrating from left to right.) To move the mark to a new lower limit of integration, press [X].

EXTR snaps the crosshairs to the nearest extremum, displays its coordinates, and records it on the stack with the label Extrm:. (The HP 49G uses its built-in root finder on the derivative of your function.) Move the crosshairs near the point (-2,-2) and press EXTR. You should see Extrm: (-2,2.66666666667) at the bottom of the screen. Press [−] or any menu key to get the menu labels back on screen.

Pressing NXT shows F(X), which computes the function's value at the crosshairs location, displays it, and records it on the stack with the label F(x):. Move the crosshairs to x=-3 and press F(X). You should see F(X): 1.5 at the bottom of the screen. Press − or any menu key to get the menu labels back on screen. (NOTE: If you press ENTER while in the graphics environment, the coordinates of your crosshairs will be recorded on the stack.)



F' computes the function's derivative symbolically, then graphs it, followed by the graph of the original function.



If you press F' again, the second derivativeis plotted, followed by the first derivative and the original function graph.

If more than one function is entered into EQ, then NXEQ lets you cycle through the list. Press NXEQ repeatedly now and you should see that your list of functions includes the original function and its first and second derivatives. (The function displayed at the bottom of the screen is the currently active one for the purposes of the function folder.)

Plotting split-defined functions

A split-defined function is one whose formula depends on the value of the input. Look at this example:

$$f(x) = \begin{cases} x^2 & \text{if } x \leq 1, \\ 1-x & \text{if } x > 1 \end{cases}$$

You can specify such a function on the HP 49G in two different ways.

A. `Y6(X)=(X^2)·(X≤1)+(1-X)·(X>1)`

In this expression, the inequality operators take on values of either 1 or 0 (for true or false), depending on the value of X. Since each part of the definition is multiplied by its respective inequality—and then the two parts are added—this effectively eliminates ("zeroes out") the nonapplicable portion. Very elegant.

(Try plotting this using the default viewing window. If the HP 49G is in connected mode, then the graph will connect across the jump discontinuity.

B. `Y7(X)=IFTE(X≤1,X^2,1-X)`

This expression uses the IFTE ("IF-THEN-ELSE") command, which interprets its arguments as follows: "IF X≤1, THEN evaluate X^2, otherwise (ELSE) evaluate 1-X."

Other Graph Types

Just to give you an idea of some of the other two-dimensional plot types available on the HP 49G, here are some simple examples. You select any of these other plot types are via (⇦)(2D/3D), using CHOOS at the Type field. The FCN folder is inactive for these plot types, but the other interactive re-scaling and zoom features all work.

Conic plots the solution to any quadratic relation in two variables.

Polar plots polar functions of the form $r = f(\theta)$, where θ measures the angle counterclockwise from the positive x-axis, and r is the distance from the origin.

Parametric plots parametrically defined curves, where the coordinates $x(t)$ and $y(t)$ are each functions of a parameter t.

Truth plots the solution set to any inequality in two variables.

(In all of the following examples, the screens assume that Connect mode is on.)

Polar Plotting

Press (⇦)(2D/3D) and set the Type field to Polar. Change the independent variable to θ by highlighting Indep and typing (ALPHA)(⇨)(T)(ENTER). (If you didn't know where to find the θ character, you could instead press (⇨)(CHARS) and scroll through the list of characters until you find θ and press ECHO (ENTER).) Make sure that the angle mode is set to Rad.

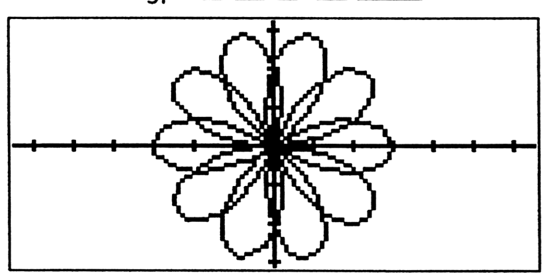
Now press (⇦)(Y=) and clear all current equations ((⇨)(CLEAR)).

Then ADD this equation: R(θ)=3·SIN(2.5·θ)

Press (⇦)(WIN) and set the Indep Low value to 0. At the Indep High field, type (4)(⇦)(π)(⇨)(→NUM).

Set the Step size to .1.

To plot this polar flower, press ERASE DRAW. With the menu labels removed (press (−)), this graph should appear:



(Keep in mind, too that you can press (⇦)(TBLSET)(⇨)(CLEAR)(⇦)(TABLE) to see a table of values generated by this polar relation—see pages 43-44 for more about Tables.)

Parametric Plotting

For parametric plotting, there is a system flag you need to uncheck (turn OFF). Press [MODE], then FLAGS and [▼] down to flag 27. Make sure it is unchecked (and therefore labelled 'X+Y×i'→'(X,Y)'). Press OK OK.

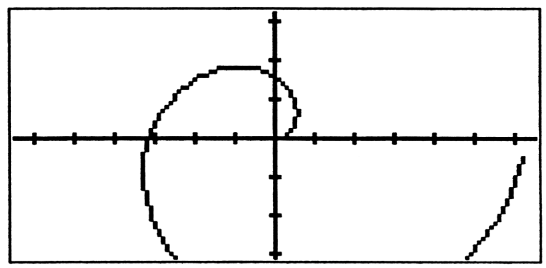
Now begin the plot by pressing [←][2D/3D] and setting the Type field to Parametric.

You want to plot x vs. y, where $x(t) = t\cos(t)$ and $y(t) = t\sin(t)$, for $0 \leq t \leq 2\pi$, so you need to change the independent variable by highlighting the Indep field and typing [ALPHA][T] [ENTER]. Also, make sure that the angle mode is set for Rad.

Next, press [←][Y=] and clear all the current equations ([→][CLEAR]). Press ADD and complete XY1(T)= by typing [ALPHA][T] [COS] [ALPHA][T] [▶] [▶] [→][,] [ALPHA][T] [SIN] [ALPHA][T] [ENTER].

Now press [←][WIN] to enter the starting and ending values for the parameter T. Enter 0 for Indep Low; for Indep High, type [2][←][π] [→][→NUM]. Enter .1 for the Step size.

Erase the graphics screen (ERASE) and draw this spiral curve (DRAW). With the menu labels removed (press [−]), the graph should look like this:

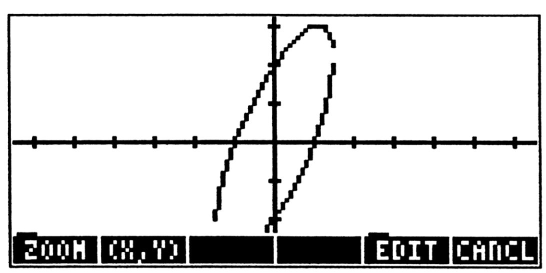


(Keep in mind, too, that you can press [←][TBLSET] [→][CLEAR] [←][TABLE] to see a table of values generated by this parametric relation—see pages 43-44 for more about Tables.)

Conic Sections

Press [←][2D/3D] [→][CLEAR], and then set Type to Conic. Press [←][Y=] and ADD to put C1(X,Y)= in the Equation Writer. Now type 4X^2-3X·Y+Y^2-4. (Note: You must type a multiplication sign between X and Y to distinguish this product from a single variable named XY.)

Now plot the ellipse at the default plot parameter settings: [←][WIN] [→][CLEAR] ERASE DRAW.... With the menu labels removed (press [−]), the graph should look like this:



Notice that the two branches are not connected to each other, so that at the extremes of the ellipse there appear to be breaks.

Inequality Plotting

Try using the Truth plot type to graph the inequality $\sin(xy) < 0.5$.

Press [←][2D/3D] and set Type to Truth. Set the Indep and Depnd fields to X and Y, respectively.

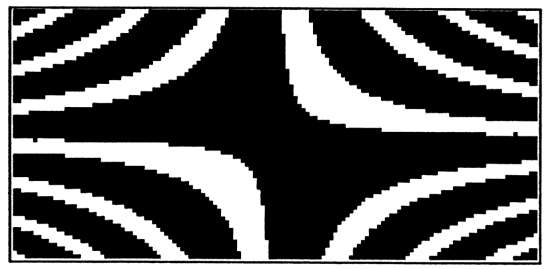
Press [←][Y=] and [→][CLEAR] all the equations. Press ADD, which will take you to the Equation Writer and offer T1 (X, Y)=. Type the following:

[SIN][X] [×] [ALPHA][Y] [▶] [▶] [ALPHA][→][X] [•][5] [ENTER]

(You must type a multiplication sign between X and Y to distinguish this product from a single variable named XY.)

Next, set the plotting parameters at their default values, by pressing [←][WIN] [→][CLEAR]. Enter 1 for Step and ✓CHK the Pixels field on.

Now press ERASE DRAW to see the shaded region. (This takes several minutes to finish.) With the menu labels removed, it should look like this:



Note that this tool offers you some interesting options for studying various functions or relations. For example, if you have a complicated equation in two variables to plot, you might consider replacing the equals sign (=) with an inequality sign (such as <) and then using the Truth plot type. The boundary of the resulting shaded region will give you some idea of the solution set to your original equation.

Cleaning Up

To set your top row tools back to Function, simply press [CANCEL] [←][2D/3D] and CHOOS Function for Type.

Then press [←][Y=] and [→][CLEAR], [←][WIN] [→][CLEAR], [ENTER].

Working with Tables

These examples will briefly illustrate some of the tools available to help you tabulate and analyze data via [←][TABLE]. All the examples are for relations of type `Function`, but many of the features are similar for `Parametric` and `Polar` types, too.

To begin, press [←][Y=], [→][CLEAR], and then enter these four functions:

```
Y1(X)=SIN(X)
Y2(X)=COS(X)
Y3(X)=SIN(X)/COS(X)
Y4(X)=COS(X)/SIN(X)
```

Press [←][TBLSET] to go to the `TABLE SETUP` screen. To reset all the numeric table settings, press [→][CLEAR]. The starting value will now be 0, and values will be incremented in steps of 0.1. Press [←][TABLE] now to see a table of values for `X` and all four functions.

X	Y1	Y2	Y3
0	0	1	0
.1	.0998334	.9950042	.1003347
.2	.1986693	.9800666	.20271
.3	.2955202	.9553365	.3093362
.4	.3894183	.921061	.4227932
.5	.4794255	.8775826	.5463025

0.

ZOOM | | | BIG | DEFN |

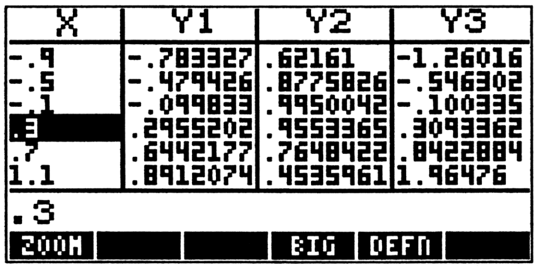
Looking at the table, notice these things:

- The arrow keys, [▲], [▼], [◀] and [▶], let you move from entry to entry of the table.
- When you are looking at a particular table entry (i.e. when it's highlighted), the full precision of that entry is displayed at the bottom of the screen.
- Not all of the columns fit on one screen, but the display scrolls when you use [▶] to move to the `Y4` column.
- New table values are generated as you scroll either up or down with [▲] and [▼].
- **BIG** is a toggle key that lets you switch between a larger and smaller font size.
- **DEFN** is a toggle key that offers you a reminder of the definition of the currently highlighted column. For example, when **DEFN■** is on, you'll see the message `Independent Variable X` appear at the bottom of the screen whenever you highlight the `X` column.

The TABLE ZOOM Menu

When you're viewing a table via ⬅TABLE, the ZOOM menu key offers you some zoom options. For example, In will zoom in by the designated zoom factor; and Out will zoom out by the designated zoom factor. You can change the designated zoom factor by pressing ⬅TBLSET and changing the value in the Zoom field. (The default zoom factor is 4.)

Try an example: Scroll down in the X column, highlight the value .3, and press ZOOM. Select Out and press OK....



X	Y1	Y2	Y3
-.9	-.783327	.62161	-1.26016
-.5	-.479426	.8775826	-.546302
-.1	-.099833	.9950042	-.100335
.3	.2955202	.9553365	.3093362
.7	.6442177	.7648422	.8422884
1.1	.8912074	.4535961	1.96476

See what happens? The table is recomputed. .3 is still highlighted, but now the step size is .4 instead of .1.

Notice, too, these other options you have when you ZOOM:

Decimal sets the Start value to 0 and the Step size to .1 units. (These are the default settings.)

Integer sets the Start value to 0 and the Step size to 1 unit.

Trig sets the Start value to 0 and the Step size to (approximately) $\pi/24$ units. (If the angle measure mode is degrees, then this Step size is 7.5 degrees.)

Un-zoom is an UNDO key for zooming. It will reset the table to its most recent settings.

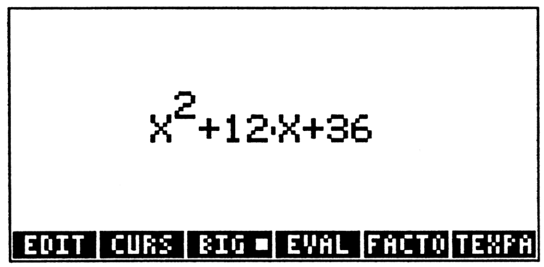
The Equation Writer

The Equation Writer is a powerful screen oriented mathematical expression editor. Expressions can be entered and/or edited while typeset as they typically appear in a textbook. Operations can be performed on expressions or sub expressions while in the Equation Writer. At any time while an expression is being edited in the Equation Writer, it must be syntactically valid. At times, the calculator will insert an empty square (□) as a place holder where an operand is expected. This can give hints about the proper form to use for various calculator commands.

Quick Overview

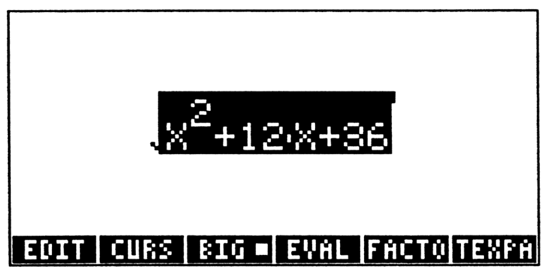
Follow the keystrokes in this quick example to get an idea of what the Equation Writer can do. From the stack screen, with the calculator in its default modes,* press [EQW] to start the Equation Writer with a blank screen. You'll enter the expression $\sqrt{x^2 + 12x + 36}$, simplify it, then recover your original expression.

Press [X] [y^x] [2] [▶] [+] [1] [2] [X] [+] [3] [6]. You should now see this screen:

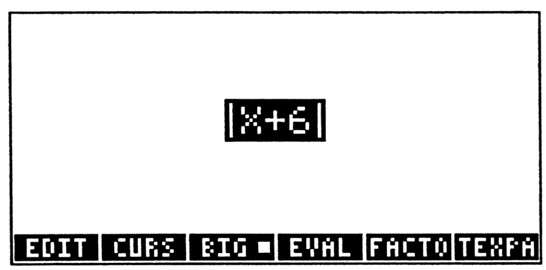


Press [▶] [▶] to highlight the entire expression, then [√x] to take its square root.

Now use [▼] to highlight the expression under the radical. You should see this screen:



Now press FACTO to factor it. Press [▲] to highlight the entire expression, and then press EVAL to simplify.



Last, press [→] [UNDO] to recover the radical expression, press [▼] to highlight the expression under the radical, then [→] [ALG] [1] [ENTER] to expand it.

**As with most areas of the HP 49G, the modes affect results significantly. This example won't work if the machine is set to approximate mode; it must be in exact mode.*

Starting the Equation Writer

The Equation Writer can be launched in several ways:

1. From either the default screen, or from within an edit line on the default screen by pressing [EQW]. This opens up a blank slate where a new expression can be entered. If the Equation Writer is started from within an edit line, the expression created during the Equation Writer session is pasted into the cursor position when the Equation Writer was started.

2. From the home screen by pressing either ▽ or [TOOL] **EDIT** with an expression or result in level 1, or by pressing **EDIT** with an expression or result highlighted during a visit to the history stack.

3. After selecting any item listed at the Y= screen, by pressing **ADD**.

4. From the home screen, by pressing [APPS] [6] [ENTER].

5. From applications where a symbolic expression is allowed to fill in the field on an input form or a cell in a matrix. Press [EQW] with the desired field highlighted.

6. From any edit line in an application—just press [EQW]. The expression entered in the Equation Writer will be patched into the position on the edit line at which the Equation Writer was launched.

Exiting the Equation Writer

The session in the Equation Writer can be terminated in either of two ways:

1. Pressing [ENTER], which takes the expression to an edit line on the home screen. Pressing [ENTER] again will cause the expression to be evaluated. If [↱] [→NUM] is pressed the second time instead of [ENTER], the expression will be evaluated numerically (in approximate mode).

2. Pressing [ON] (or [CANCEL]) will abort the session, returning you to whatever state you were in when the session began.

Operating Modes in the Equation Writer

While in the Equation Writer, there are several modes. The cursor's appearance indicates the current mode.

Entry mode

This is the default mode, which you use while entering a part of an expression. It's denoted by a cursor that is a backwards facing arrow: ◆ If you are in another mode, simply pressing a binary operator key, such as [+], [−], [×], or [÷], or the backspace key ([←]) puts you back into entry mode, where you will remain until you either enter another mode (see below) or end the Equation Writer session.

In entry mode, as new terms are typed, they are added to the end of the expression. You can use ( ) to group terms and [←] to delete the previously entered character or function. Note that the Equation Writer supplies the needed parentheses when a function is applied. Note also that the 49G understands implied multiplication. It will insert a multiplication sign (small dot) for you whenever:

a variable follows a number;	Example: `5X`
a prefix function follows a number or variable;	Examples: `2SIN(X)` or `Y√X`,
a left parenthesis follows a number or right parenthesis;	Examples: `2(X)` or `(3+7)(X+Y)`.

If you press [▲] while in entry mode, you'll go to selection mode with the current term highlighted. If you press [▶], you'll go to selection mode with the previous two terms (or term and function) highlighted.

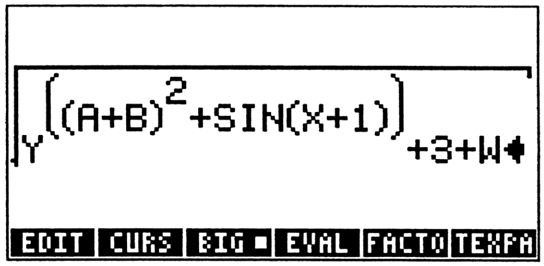
Selection Mode

Selection mode lets you operate on an expression or subexpression. In this mode, the expression appears in reverse video (white text, black background). To go into selection mode, press [▲] or [▶] from entry mode, or [ENTER] from term selection mode. To exit to entry mode, press a binary operator (or [←] at the end of the highlighted expression). To enter term selection mode, highlight a single term and press [▼].

One use for selection mode is to delete portions of an expression. To delete only the highlighted text (and go to entry mode), press [↱][CLEAR]. Or, [↰][DEL] will delete the highlighted expression and the preceding binary operator; [←] deletes the preceding unary function. (You can also use selection mode to Cut, Copy, and Paste text, just as in word processor programs. See the examples in the section on Editing Operations.)

Another use for selection mode is to alter portions of an expression. For example, pressing a function key ([SIN], [↱][EVAL], etc.) applies that function to the highlighted expression. Or, pressing a binary operator key ([+], [−], [×], [÷]) makes the highlighted expression the left operand, supplies parentheses if needed, inserts the operator, and then allows you to enter the other operand.

Moving around among terms within selection mode requires that you think about the various "levels" of an expression. (In fact, selection mode might also be called "level selection mode.") For example, consider the expression shown here:



The lowest level terms (those that will be evaluated first) are A and B. At the same level as these are X and 1. The next higher level (the terms that will be evaluated next) are `(A+B)` and its exponent, `2`. After that, `(A+B)²` and `SIN(X+1)` are evaluated. At the next level are `Y` and `(A+B)²+SIN(X+1)`. Then comes `3`, W, and `Y` to its power. The last operation performed is, of course, the square root.

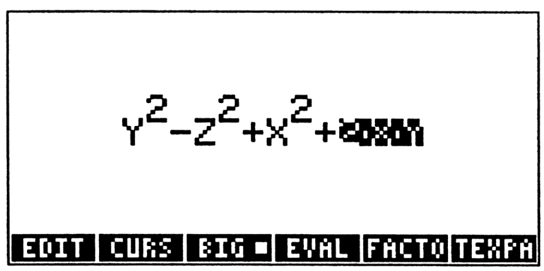
Within selection mode, pressing [▲] highlights more and more of the expression by moving you up to the next higher level of the expression, until the entire expression is highlighted. Pressing [▼] highlights less and less of the expression, by moving you down to the next lower level, until only a single term is highlighted. Pressing [▼] at that point takes you to term selection mode. [◀] and [▶] move you among terms at the same level (or, if you're already all the way at the rightmost term at that level, [▶] moves you up to the next level). Note also a couple of handy shortcuts in selection mode: Pressing [↱][▲] selects the entire expression. And pressing [↱][▼] takes you all the way down to a single term.

Practice by navigating in selection mode. First, enter the expression above: [EQW] [√x] [ALPHA][Y] [y^x] [ALPHA][A] [+] [ALPHA][B] [▶] [y^x] [2] [▶] [+] [SIN][X] [+] [1] [↱][▲] [▼] [+] [3] [+] [ALPHA][W]. Now press [▲] to highlight the `W`, then [◀] and [▶] to move among the three lowest level addends. Next, highlight just the `3` and press [▲] to select the radicand. Use [▲] once more to highlight the entire expression. Press [↱][▼] to go to term selection mode, then press [▶] and [◀] to move among all the terms.

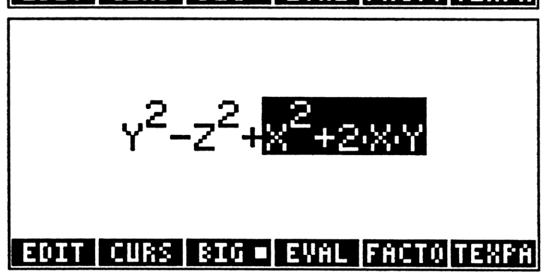
In Selection Mode, with one or more terms in a sum (or factors in a product) highlighted, pressing [↰][▶] or [↰][◀] applies the commutative property of addition (or multiplication) with the term (factor) to the right or left, respectively. This is useful for rearranging terms (or factors) in a sum (or product). [↱][▶] or [↱][◀] highlights one more term (or factor) to the right or one term (or factor) fewer, respectively.

Try an example. Enter `Y^2-Z^2+X^2+2·X·Y`

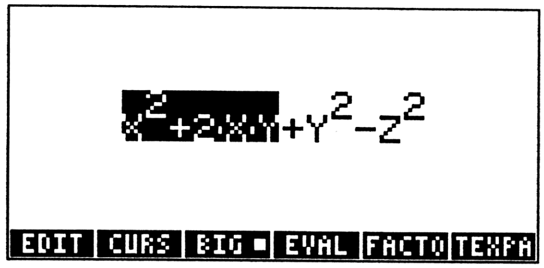
Press [EQW] [ALPHA][Y][y^x][2] [▶] [−] [ALPHA] [Z][y^x][2] [▶] [▶] [+] [X][y^x][2] [▶] [+] [2][X][X][ALPHA][Y] [▲] [▲]. You should see this screen:

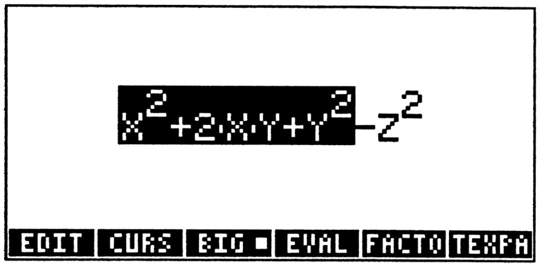


Press [↱][◀] to additionally highlight the `X^2` term:



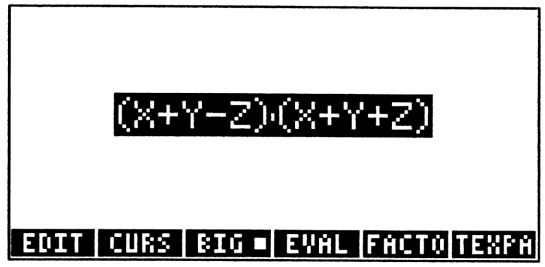
Then press [←][◄] [←][◄] to move the highlighted term to the left, shifting the other terms to the right.





Now press [→][►] to additionally highlight the Y^2 term.

Finally, press FACTO to factor the first three terms, then [▲] FACTO to factor the entire expression:



Term Selection Mode

In this mode, where the cursor appears as an outline box, you use [◄] and [►] to navigate among terms (as opposed to among levels) in an expression; any term can be selected and either replaced or operated on. You can also cut, copy, and paste from this mode. To enter term selection mode from entry mode, press [▼] and the last term entered is boxed in. From selection mode, press [▼] with a variable or number highlighted, or press [→][▼]. To exit term selection mode, you either: apply a function to the selected term (which will then take you to selection mode with the new term selected); replace the selected term by typing a new term (which takes you to entry mode); or press a binary operator, which makes the selected term the left operand, inserts the operator, and leaves you in entry mode to enter the right operand.

Cursor Mode

Screen Appearance: the cursor appears as a crosshairs; expressions are boxed.
How to Start: Press CURS or [→][►]
How to Stop: Press [ENTER] to select the boxed expression, or press [CANCEL] ([ON]) to cancel.
What it Does: Cursor mode can be used to highlight subexpressions by moving a crosshairs around within parts of the expression. Each term defines a rectangle in the expression. When the cursor is within the rectangle defined by a term, that term is included in the selection.

Press (and optionally hold down) the arrow keys to move the crosshairs to a term or subexpression you're interested in. You can press and hold down an arrow key to move just the crosshairs without redrawing the box it determines, which allows you to move around very quickly to a term or subexpression you want.

Editing Operations

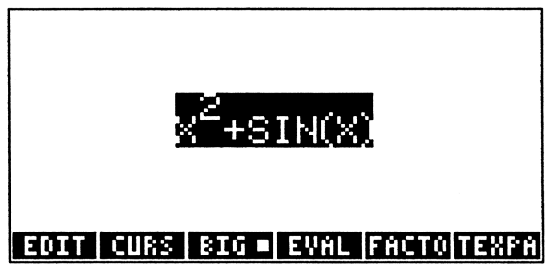
Deleting

In entry mode, [⬅] erases the character or function to the left of the cursor. In selection mode, [→][CLEAR] permanently deletes the highlighted subexpression; [→][CUT] deletes but saves the selected subexpression for later retrieval via [→][PASTE]. No deletion is allowed at all in cursor mode.

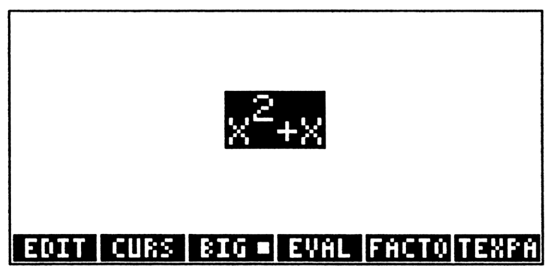
In selection mode, [←][DEL] deletes the current term and the binary operator, if any, to its immediate left. To delete a function, you have a couple of choices. First, highlight the function and its argument. Then you can press [←][DEL], which will delete the function, but leave the argument. Or, you can press **EDIT**, to bring the highlighted expression to an edit line. Then use the arrow keys to position the edit cursor appropriately, then [⬅], or [←][DEL] to delete the function.

Try this. Enter and highlight the following expression in the Equation Writer:

[EQW] [X] [y^x] [2] [▶] [+] [SIN] [X] [→] [▲]



Now, suppose you want to delete the sine function. Press [▼][▶], which will highlight SIN(X). Then press [←][DEL] [▲]. You should see this expression:



Inserting

To insert an operation and operand into an expression, just highlight the other operand and type the operation and operand you wish to insert. Similarly, if you want to apply a function to an expression, just highlight the expression and press the function. (Note that if you inadvertently apply a function to an expression, [→][UNDO] can come to your rescue—if the **Last Stack** option is selected (checked) in the **CALCULATOR MODES** screen under the [MODE] key.)

Copying and Pasting

Expressions can be cut, copied, and pasted from within the Equation Writer, from an edit line, or from the history stack. In selection mode or term selection mode, you simply highlight the term or expression to be copied and press [→][COPY]. With a target expression or term selected, pressing [→][PASTE] replaces the highlighted expression or term with whatever was previously copied.

Undoing

You can recover the contents of the Equation Writer application before the last function was applied by pressing the [→][UNDO]. Note that [→][COPY] can be used to save the current contents of the Equation Writer application. First press [→][▲] to highlight the entire expression (if it isn't highlighted already). Then press [→][COPY]. You can now go on to do any number of operations within the Equation Writer, and go back to screen that was copied by using [→][PASTE].

Step-by-Step Mode

If "step-by-step" mode (Step/Step) is selected (checked) on the CAS MODES screen, then whenever you evaluate any command that can show step-by-step calculations, that evaluation step is copied to the stack automatically. The commands that can show step-by-step evaluation are:

* Derivative
* Linear algebra problems involving row reduction, such as LINSOLVE, RREF, rref, REF and INV (of a matrix)
* Euclidean division (IDIV2 for integers and DIV2 for univariate polynomials)
* Symbolic integration with boundaries (in 2 steps)

Note that there are other commands that you can also use to show a step-by-step solving strategy, but these require your explicit intervention:

* Apply commutativity law inside the Equation Writer
* Apply a command to a subexpression inside the Equation Writer, or converting to a form that can be "solved" (e.g. by SOLVE or INTVX)
* IBP (integration by part)
* User change of variable inside an integral

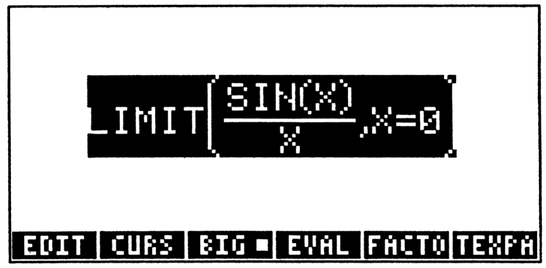
How Do I Do Calculus in the Equation Writer?

In this section, we'll cover the most common operations performed in a first year calculus course. In each example, we'll assume that we're starting from a blank screen in the Equation Writer, with default modes set. All the commands can be found in the CALC menu, or on the keyboard itself.

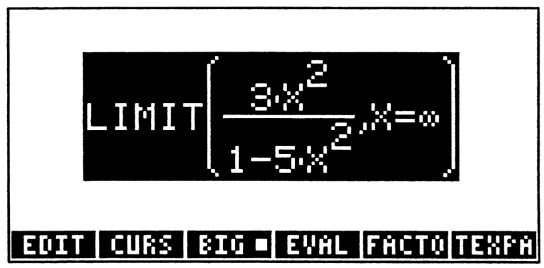
How Do I Take a Limit?

The limit command is found in the CALC menu:

[EQW] [←][CALC] [2] [ENTER] [2] [ENTER] [SIN] [X] [▲] [▲] [÷] [X] [▶] [X] [→] [=] [0] [→] [▲] will give the screen shown here. Then EVAL will evaluate it.



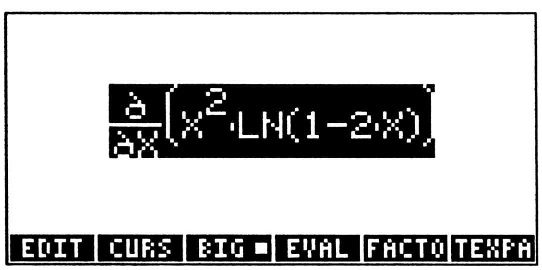
You can also take limits at infinity and apply the limit command to an existing expression. Clear the Equation Writer first by pressing [→][CLEAR], then: [3] [X] [y^x] [2] [▶] [▶] [÷] [1] [−] [5] [X] [y^x] [2] [→] [▲] [←][CALC] [2] [ENTER] [2] [ENTER] [X] [→] [=] [←] [∞] [→] [▲]. You'll get the screen shown here. Then EVAL will evaluate it.



Note: If the independent variable is the same in the limit expression as defined on the CAS MODES screen, you need not enter an equation as the second argument to the limit command. Instead, you can just enter the value. For example, if INDEP is defined as X, the command LIMIT(SIN(X)/X,0) will work.

How Do I Take a Derivative?

The command [→][∂] on the keyboard can be used to take a derivative. If you select Step/Step on the CAS MODES screen, you'll see the derivative computed step-by-step. To differentiate X^2*LN(1-2X), for example: [EQW] [X] [y^x] [2] [▶] [X] [→][LN] [1] [−] [2] [X] [→] [▲] [→] [∂] [X] [→] [▲]. Now EVAL repeatedly.

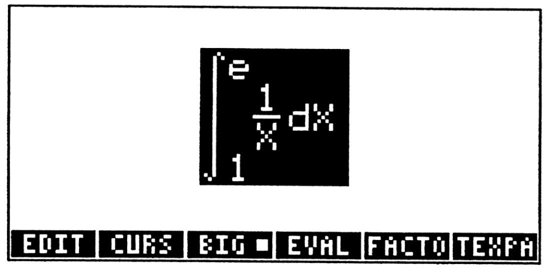


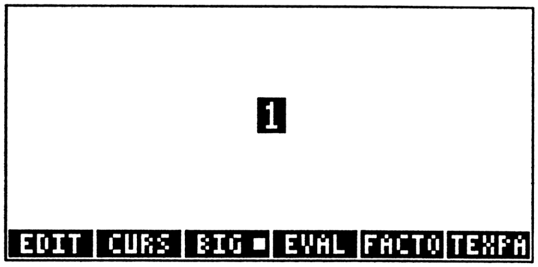
<-- This eventually becomes this. -->

Note: The DERVX command in the first menu under [←][CALC] can also be used to differentiate. It always differentiates with respect to the current independent variable. To specify a different variable of differentiation, use the DERIV command and specify that variable as the second argument.

How Do I Evaluate a Definite Integral?

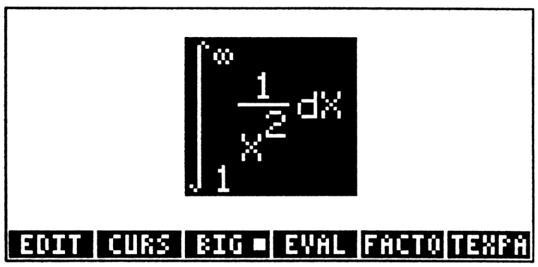
The [↱][∫] command on the keyboard can be used to evaluate an integral. Its result will be accurate to whatever number of digits is specified in Number Format on the CALCULATOR MODES screen. For example, to evaluate this integral...

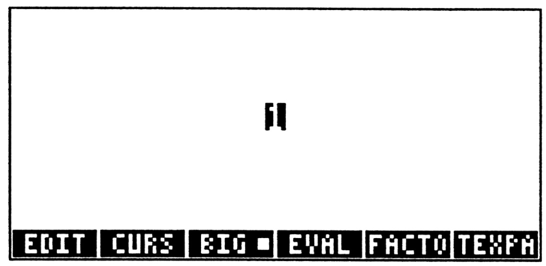




... do this: [EQW] [↱][∫] [1] [▶] [ALPHA] [↰][E] [▶] [1] [÷] [X] [▶] [X] [↱][▲] EVAL.

Note: +∞ and −∞ can be used as a limit or integration. For example, try [EQW] [↱][∫] [1] [▶] [↰][∞] [▶] [1] [÷] [X] [y^x] [2] [▶] [X] [↱][▲]... ...EVAL.

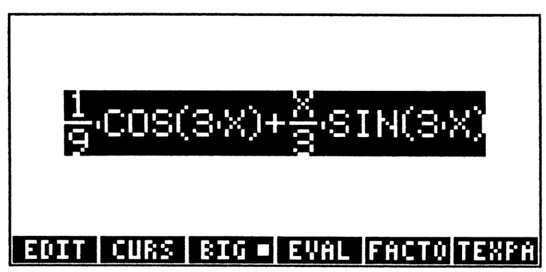




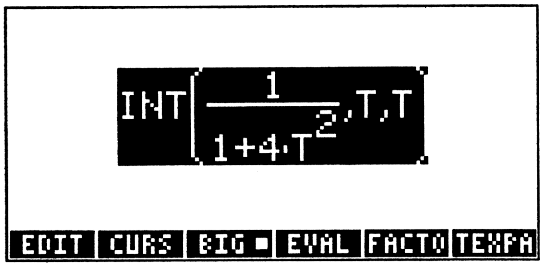
How Do I Find an Antiderivative?

There are three commands available to compute an antiderivative: INTVX, for an antiderivative with respect to the independent variable, INT, which allows you to specify the independent variable (but which you must type from the keyboard; it's not on a menu), and RISCH, which uses the Risch algorithm to compute an antiderivative.

For example, to find an antiderivative for X*COS(3X), with X the independent variable: [EQW] [X] [×] [COS] [3] [X] [↱][▲] [↰][CALC] [ENTER] [8] [ENTER]... ... EVAL.



To find an antiderivative using the INT command, you need to type INT first. For example, here's how to find an antiderivative for `1/(1+4T^2)`: [EQW] [ALPHA][ALPHA][I][N][T][ALPHA] [←][()] [1] [÷] [1] [+] [4] [ALPHA][T] [y^x] [2] [▶] [ALPHA] [T] [▶][ALPHA] [T] [→][▲]. (The third argument to INT is the variable or expression to substitute for the independent variable after the antidifferentiation.) Then **EVAL** to calculate.



Note: Instead of pressing [ALPHA][ALPHA] to lock alpha mode on (then [ALPHA] once more when you finish typing multiple characters), you could instead press and hold down [ALPHA].

How Do I Solve a Differential Equation?

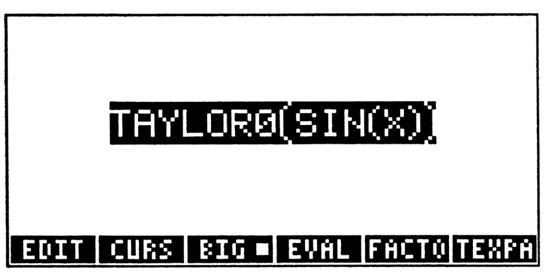
The HP 49G can find general and specific solutions to differential equations but not from within the Equation Writer. Use the home screen for this. (For more on this, see the section on the [←][CALC] menus.)

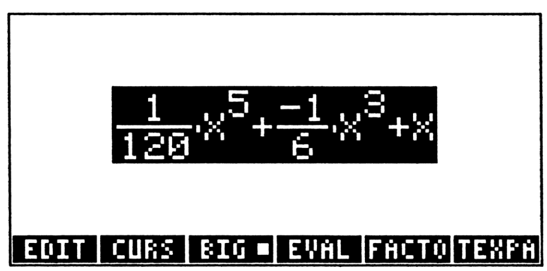
How Do I Find A Taylor Polynomial?

Within the Equation Writer, you can compute the 4th degree Taylor polynomial at $x = 0$ for a function. (To compute other Taylor polynomials or series, you need to work from the home screen. For more on this, see the section on the [←][CALC] menus.)

For example, here's how to find the Taylor polynomial for $\sin(x)$:

[EQW] [SIN][X] [→][▲] [←][CALC] [2] [ENTER] [4] [ENTER] [→][▲].... ....**EVAL**.

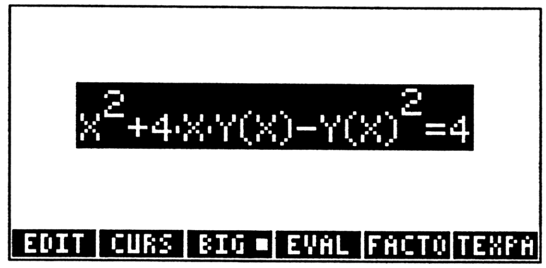


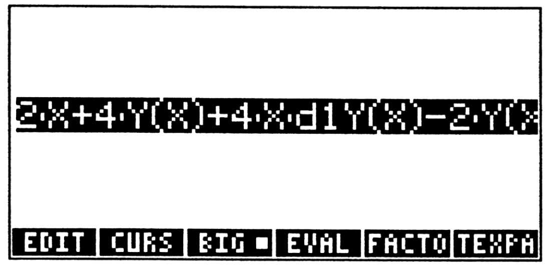


How do I do Implicit Differentiation?

The HP 49G is fully capable of performing implicit differentiation and, by using the SUBSTitute command, even isolating the derivative term. Here are two examples, one easy, one more involved.

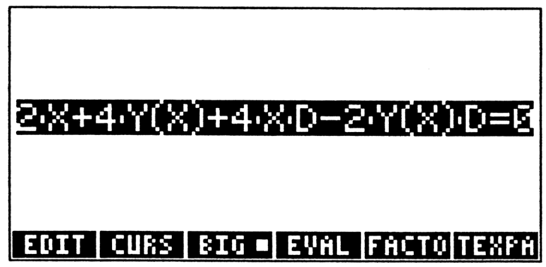
First, differentiate X^2+4•X•Y-Y^2=4, as follows: [EQW] [X] [y^x] [2] [▶] [+] [4] [X] [X] [ALPHA] [Y] [←] [()] [X] [→] [▲] [−] [ALPHA] [Y] [←] [()] [X] [▶] [y^x] [2] [→] [▲] [→] [=] [4] [→] [▲] Note that it is necessary to enter Y(X) rather than simply Y so that the calculator will know that Y is a function of X when you differentiate. You should see this:





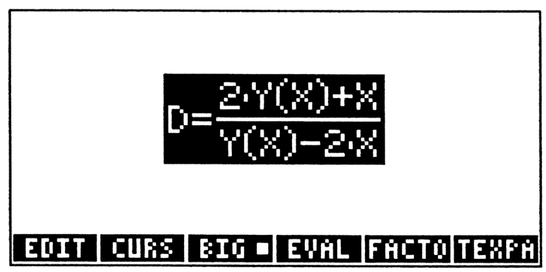
Now apply the derivative command to the equation: [→] [∂] [X] [→] [▲] [EVAL]

Note that the calculator names the derivative term d1Y(X). Replace that expression with the variable D, using the substitute command. (This is necessary because you need to isolate D in the result; the calculator can't isolate d1Y(X).) [→] [ALG] [6] [ENTER] [ALPHA] [←] [D] [1] [ALPHA] [Y] [←] [()] [X] [▶] [→] [=] [ALPHA] [D] [→] [▲] [EVAL].



To isolate D in this equation, first make a copy: [→] [COPY]. Then use [CANCEL] ([ON]) to return to the stack, and [←] [S.SLV] [2] [ENTER] [→] [PASTE] [→] ['] [ALPHA] [D] [ENTER]. Then [▼] will take the result back to the Equation Writer.

Here's what it looks like:

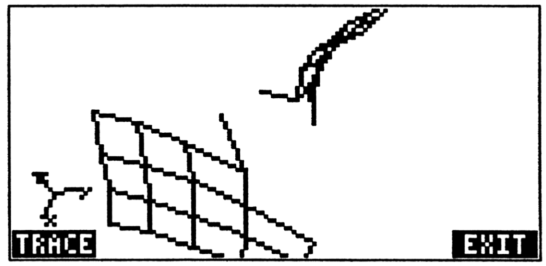


Now, you could leave this equation as it is, but you might want to change the Y(X) term to a usable variable so that you can use the derivative in other calculator environments. To do this, just use the substitute command to change Y(X) to Y: [→] [ALG] [6] [ENTER] [ALPHA] [Y] [←] [()] [X] [▶] [→] [=] [ALPHA] [Y] [→] [▲] [EVAL].

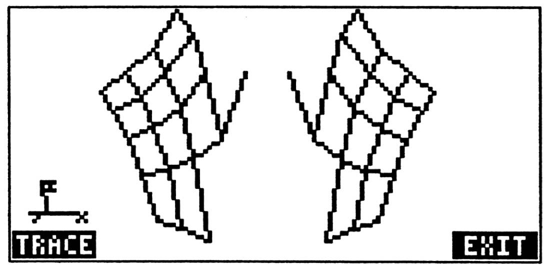
One common calculator environment you may want to use, of course, is graphing. Now that you've made the equation entirely usable, you can copy its right hand side and use the Fast-3D graphing utility to take a look at it: ▽ ▷ ↱COPY CANCEL ↰2D/3D CHOOS.

Use ▽ as necessary to scroll down and find the Fast3D selection. OK to select it for the plot Type, then ▽ to highlight the EQ field, and ↱PASTE ENTER.

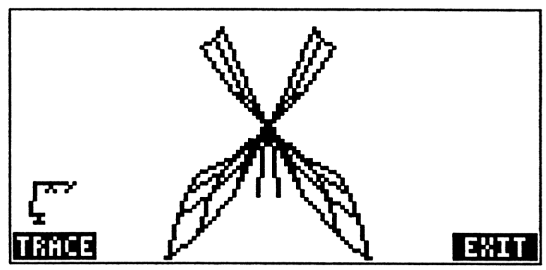
Make sure the independent variable is X and the dependent variable is Y. Then press ERASE DRAW.



In the Fast3D plot, the arrow keys can be used to move the eye point around the figure.

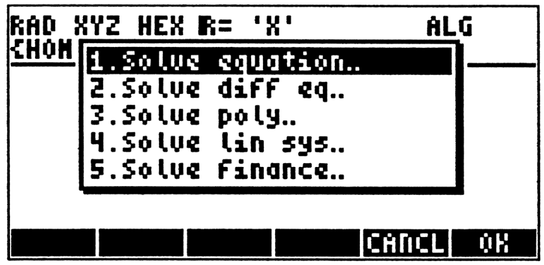


Notice how the axes in the lower left hand corner of the screen rotate with the image to give an idea of the orientation.



Numerical Solving

In either ALG or RPN mode, pressing [→][NUM.SLV] will bring up a menu of 5 separate numerical solving features:

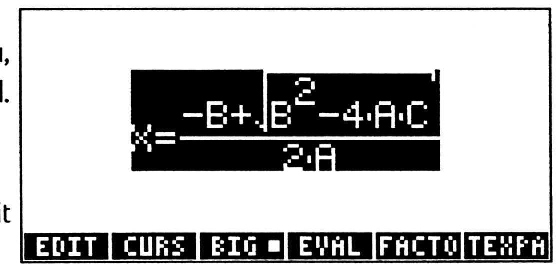


Any of these can be accessed by highlighting it and pressing [ENTER].

Solve Equation

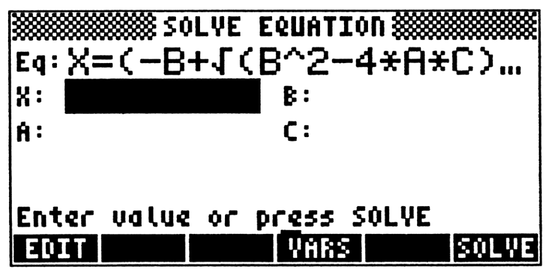
First, note that if you choose to type equations without using the Equation Writer, only ALG mode understands implied multiplication between numbers and variables (but not between two variables); RPN mode does not. Of course, a good way to enter any equation is the Equation Writer, which understands implied multiplication in either mode—and the Equation Writer is accessible from within the `Solve equation` tool.

First, select the `Solve equation` tool (via [→][NUM.SLV]'s menu, as shown above), and make sure the cursor is on the `Eq` field. Then press [EQW] and enter your equation.

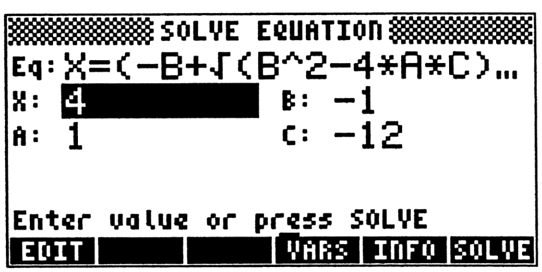


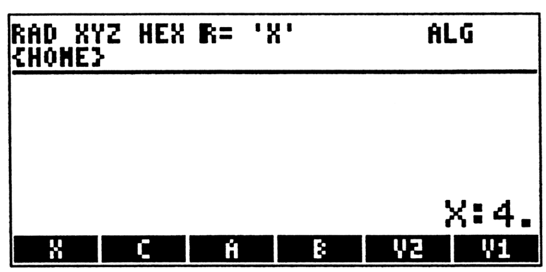
(When finished, highlight the entire equation and copy it (press [→][COPY]) for easier editing later.)

Now press [ENTER] and the equation will appear in the proper form in the `Eq` field. Notice how the solver creates fields for each of the variables in the equation. (If these don't yet appear and the `Eq` field is still highlighted, press [ENTER] again.)



Now, you simply move to each known variable and enter its value. For the variable you want to solve for when all the others have known values, highlight it and press [SOLVE]. The correct value will be returned into that variable slot—and will also be placed on the stack.





To get the other quadratic solution, highlight `Eq`, then go back to the Equation Writer ([EQW]), paste in your equation (press [→][PASTE]), change the sign in the formula, then [ENTER] and repeat the solving process.

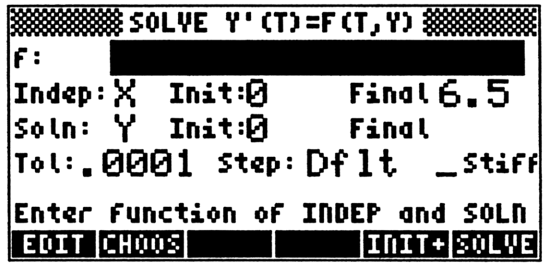
Solve Diff EQ:

The Solve diff eq tool will take you to the screen called SOLVE Y'(T)=F(T,Y), where you can calculate the solution to a differential equation between initial and final values of the independent variable.

Example: Find the solution to $\frac{\partial y}{\partial x} = x^2$ from $x = 1$ to $x = 3$

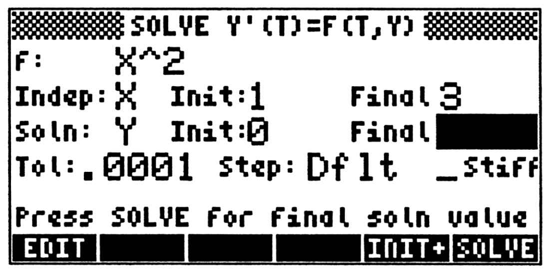
The fields on the screen are as follows:

F: The expression to be solved.
Indep: The name of the independent variable.
Init (indep): The initial value of the independent variable.
Final (indep): The final value of the independent variable.
Soln: The name of the variable to be solved for.
Init (soln): The initial value of the solution variable.
Final (soln): The final value of the solution variable.

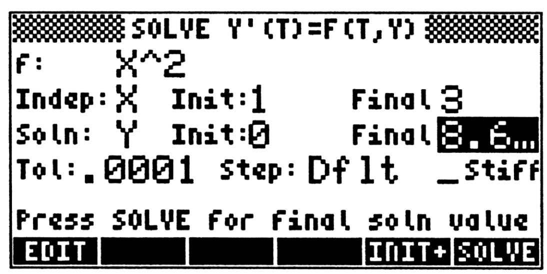


For the above problem, therefore, the screen looks like this:

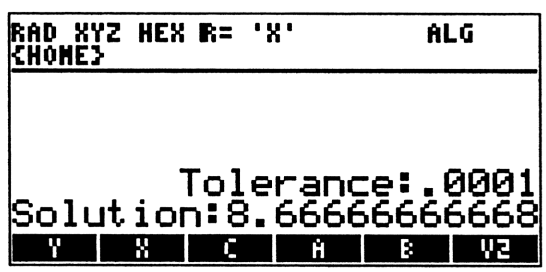
Note: You can't enter the expression if the variable(s) used in it contain values; purge all such variables beforehand. For example, you need to purge X in this case.



Now, with the highlight on the Final (soln) field, press SOLVE and you get this:



Pressing ENTER will put the solution back on the stack and give a full view of the number:

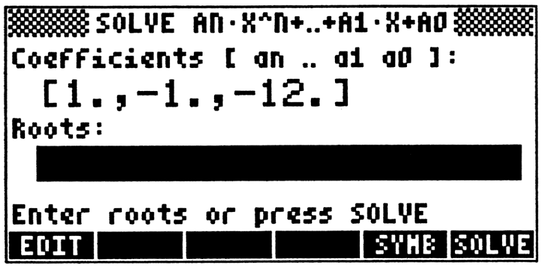


Solve Poly

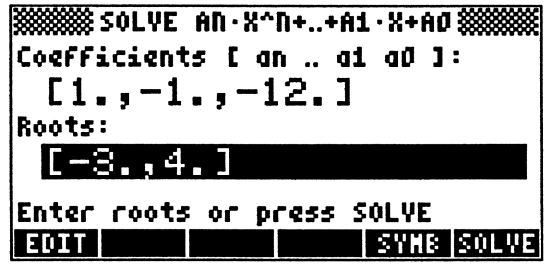
In the polynomial solver (i.e. at the screen called SOLVE An·X^n+..+A1·X+A0), you key in the polynomial in a quick fashion, via a simple vector containing the coefficients of the terms, in descending order of degree.

For example, to solve X^2-X-12=0, you would enter the polynomial in the Coefficients field as follows:
(⇦)([ ]) (1) (⇨)(,) (1)(+/-) (⇨)(,) (1)(2)(+/-) (ENTER)

The cursor will move to the Roots field.

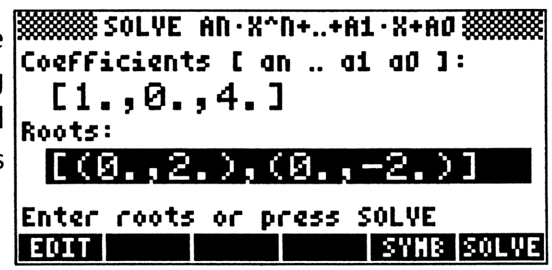


Press SOLVE and the roots will appear there.

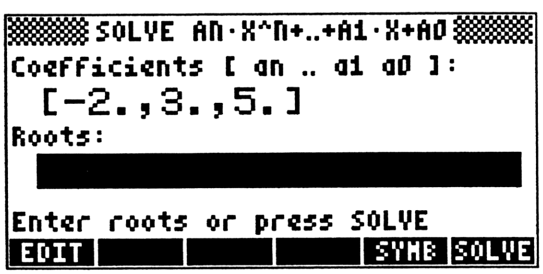


Note that SYMB will send the results to the stack, with the roots in factored form (or—if you've solved for a polynomial rather than roots—the solution polynomial in conventional decreasing-degree order).

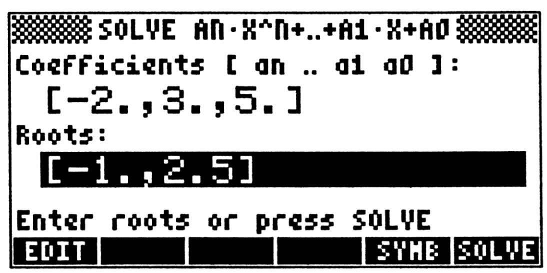
Try another. Find the roots of X^2+4=0, by filling in the Coefficients field as shown here. (Notice how the missing degree in the polynomial must nevertheless be represented with a zero coefficient.) With the Roots field highlighted, press SOLVE... voila. (Complex roots appear as ordered pairs.)



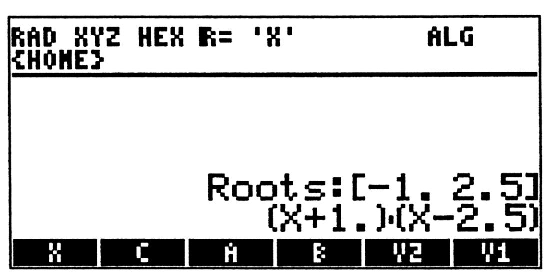
Try one more. Suppose that you know the roots, say -2, 3 and 5, and you want to find the corresponding polynomial. You just enter the roots...



... and SOLVE for the polynomial.



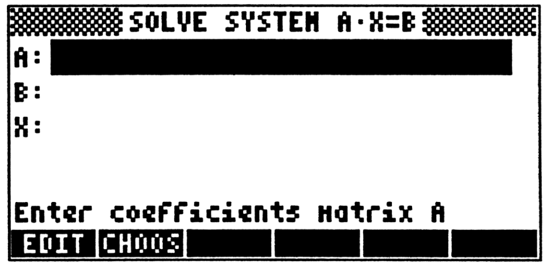
And the stack version looks pretty good when you send the results there via SYMB (then (ENTER)):



Solve lin sys

In the linear systems solver (i.e. at the screen called `SOLVE SYSTEM A·X=B`), you key in two matrices:

- `A:` A square matrix whose rows contain the coefficients of the respective equations in the system
- `B:` A column matrix containing the constants of respective equations in the system.

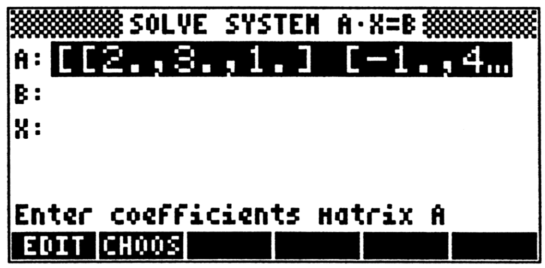


The solver will return the solution (column) matrix, `X`.

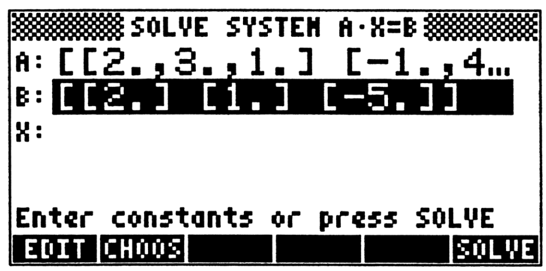
For example, solve this system:

$$2a + 3b + c = 2$$
$$-a + 4b + 2c = 1$$
$$3a - 2b + 2c = -5$$

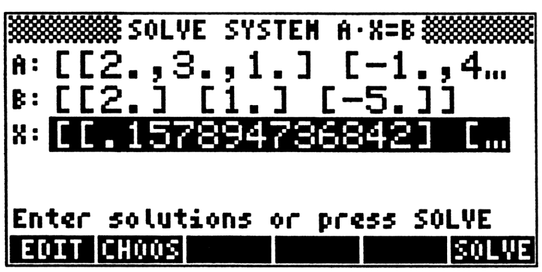
With the cursor on the `A` field, press **EDIT**. This will take you to the Matrix Writer tool for easy data entry. Make sure that **GO→** appears on the menu line. (If not, press **GO→** to change it.) Then enter the values: [2][ENTER] [3][ENTER] [1][ENTER] [▼][◀][◀][◀]. This establishes it as a 3-column matrix and take you back to the first column; from now on, you won't need to repeat those keystrokes at the end of each row: [1][+/−][ENTER] [4][ENTER] [2][ENTER] [3][ENTER] [2][+/−][ENTER] [2][ENTER] [ENTER]. The matrix will now appear in `A:`

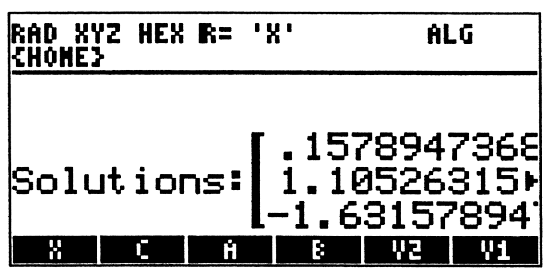


Use [▼] to move to the `B:` entry, then **EDIT**. This time you want **GO↓** to appear. (If necessary, press **GO↓**.) Then enter the matrix values: [2][ENTER] [1][ENTER] [5][+/−][ENTER] [ENTER] This matrix will now appear in `B:`



Press [▼] **SOLVE** and the solutions will appear in decimal form. To view the full values, press **EDIT** and move through the matrix. Pressing [ENTER] while the `X:` is highlighted will return the solutions to the stack, as well.



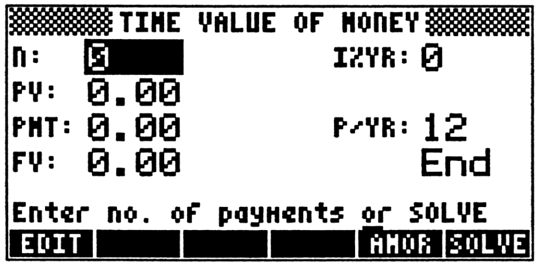


Solve Finance

(The `Solve finance` tool under [→][NUM.SLV] is exactly the same as pressing [←][FINANCE]. That section is found elsewhere in this Guide.)

Finance

The HP 49G allows you quickly to do calculations involving compound interest—also known as the Time Value of Money. Just press [⬅][FINANCE] to go to the TIME VALUE OF MONEY screen:

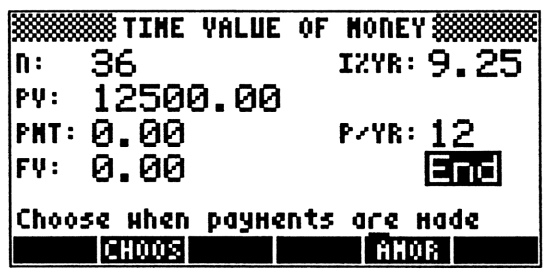


n:	The number of periods (and payments to be made) in the term of the loan.
I%YR:	The annualized interest rate, as a percent.
PV:	The Present Value (total amount to be financed).
PMT:	The periodic payment amount.
FV:	The Future Value (total amount still owing at the end of the loan).
P/YR:	The number of periods (also payments) in a year.
End/Begin	The point in each period when the payment is made—either at the beginning or end.

You enter all necessary data, then highlight the item you want to solve for and press SOLVE.

Try an example. How much per month would it cost to take out a 3 year loan of $12,500 at 9.25%? To find out, press [⬅][FINANCE] (if you're not already there), then move the highlight to the n field and press:

[3][6][ENTER],
[9][•][2][5][ENTER],
[1][2][5][0][0][ENTER].
[▶] past the PMT field for now (since that's your unknown),
[1][2][ENTER]
[0][ENTER].



The payment mode should be END. Adjust it if necessary (via CHOOS), then use the arrow keys to return to the PMT field. Press SOLVE and you should get -398.95. This will be the monthly payment amount.

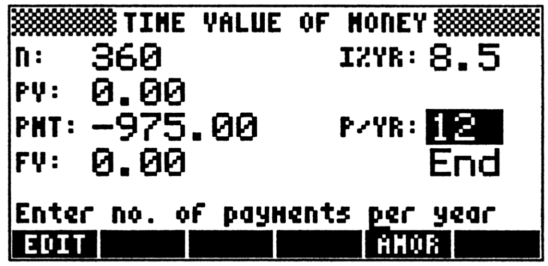
Note: If you press [CANCEL] ([ON]), you will find that this payment value was also returned to the first line of the stack. (If you exit the TVM screen to see the stack, just press [⬅][FINANCE] again to get back; the values you have entered will still be there.)

Of course, the beauty of the TVM screen—like the other solver screens—is that you can easily change one value and solve again. (And each time you solve for something, it will be left on the stack). Try another example....

Suppose you can afford to pay $975/month (principal and interest) for a mortgage payment. How much money can you borrow? It depends on the mortgage interest rate. Use the Finance solver to test scenarios.

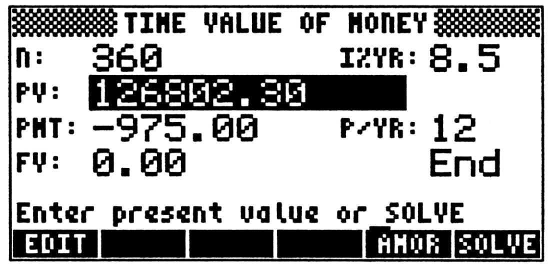
If you can get a 30 year (i.e. 360-month) mortgage at 8.5% APR, how large a mortgage can you afford?

At the TVM screen, key in the values as shown here. (The negative sign for the payment, PMT, indicates the direction cash is flowing from your point of view: You received the loan, PV, to buy a house, so the PV amount is positive; you pay the payment amount, so it's negative.)

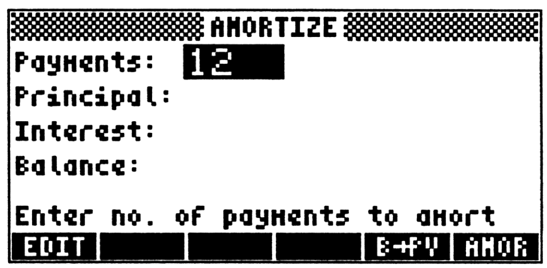


Now, highlight PV and press SOLVE

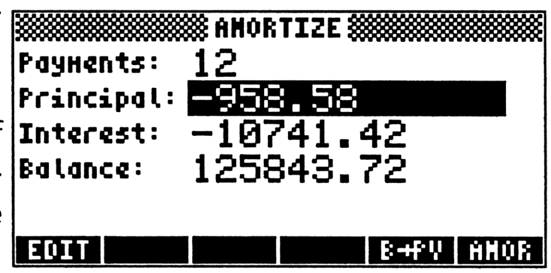
Under these loan terms, you can afford a mortgage in the range of $126,000 range.



Now that you've solved for the payment, you can also use another tool, AMOR, to itemize your payments into principal and interest. Press AMOR now, and it will bring you to this screen:

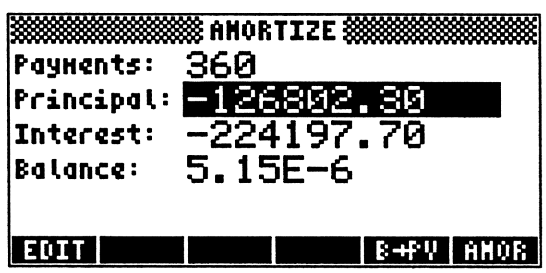


You can specify any number of payments made during the life of the loan. For the first year, for example, you can just leave the 12 in the Payments field. Now ▽ down to highlight the Principal field and AMOR....



In the first year of your mortgage, you'd be paying a total of 12 * $975 in payments, but only $958.58 of that would reduceyour balance (and so you'd still owe $125,843.72). The other $10,742.42 you paid would be interest.

So, how much would the house cost you out of pocket over the full 30 years (360 months) of the mortgage? Find out: Just enter 360 in the Payments field and AMOR again.... That $126,800 loan will cost about $351,000 in total payments.



(Note: the balance of 5.15E-6 or: .00000515, is the calculator's way of telling you that you owe nothing. The payments and amounts are, due to rounding, off by a few hundred thousandths from zero.)

Symbolic Solving

Pressing [←][S.SLV] in either ALG or RPN mode will bring up a symbolic solver menu with seven tools on it. (The seventh item, not shown here, is ZEROS.)

The mode you're using (ALG or RPN) affects the rules for use and entry, so what follows are examples of each.

Algebraic Mode

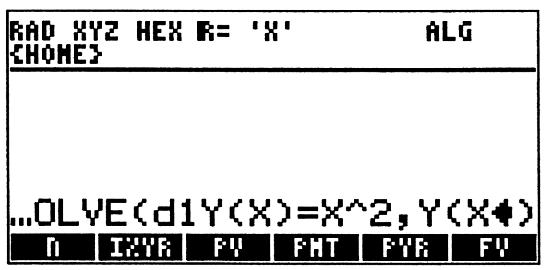
DESOLVE

The DESOLVE tool will solve certain first-order differential equations with respect to the current variable. In ALG mode, DESOLVE needs a list of two arguments: the differential equation and the variable to solve for. (Be sure to purge all variables used in the equation first. For example here you might want to press [TOOL] PURGE [←][{}] [→]['] [X] [→][,][SPC][→]['] [ALPHA][Y] [ENTER].)

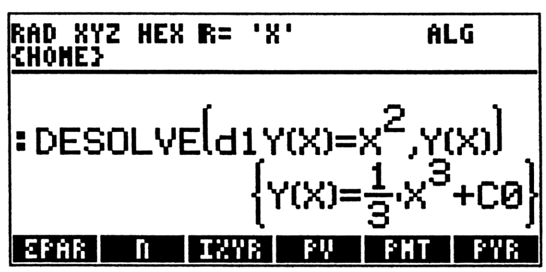
Example: Find $y(x)$ if $y'(x) = x^2$.

Press [←][S.SLV][ENTER] [ALPHA][←][D][1][ALPHA][Y][←][()][X] [▶] [→][=] [X][y^x][2] [→][,] [ALPHA] [Y][←][()][X].

This is what you should see:



Press [ENTER] and you should get this result, which is the correct symbolic solution (including the constant, denoted here as C0):



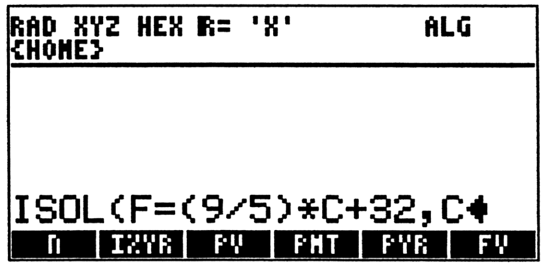
ISOL

The ISOL tool will symbolically isolate a variable in a given expression. In ALG mode, you supply a list with two arguments—the expression and the variable to be isolated.

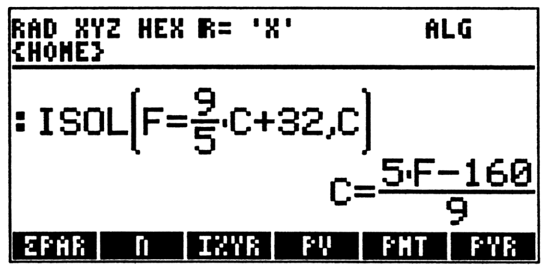
Example: Isolate the variable C in the temperature conversion formula $F = \frac{9}{5}\,C + 32.$

To get ISOL(F=(9/5)*C+32,C) on the stack, press:

[←][S.SLV] [2] [ENTER] [ALPHA][F] [→][=] [←][()][9][÷][5] [▶] [×] [ALPHA][C] [+] [3][2] [→][,] [ALPHA][C].



Your screen should look like this:

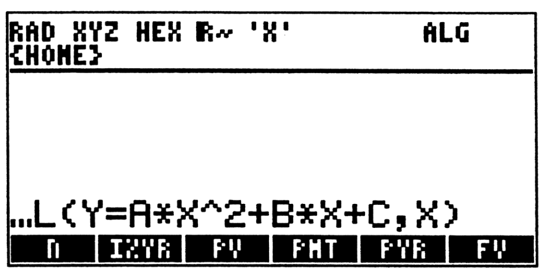


Press [ENTER] and you should get this result:

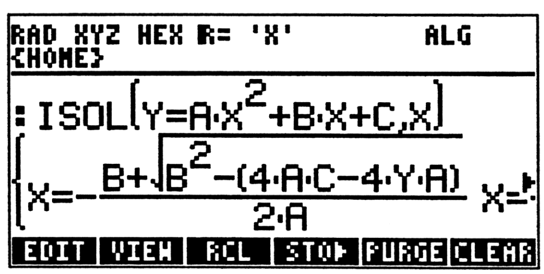
Try another example that yields a familiar result.:

Isolate X in the quadratic equation Y=A*X^2+B*X+C

To do so, press: [←][S.SLV] [2] [ENTER] [ALPHA][Y] [→][=] [ALPHA][A][×][X][y^x][2] [+] [ALPHA][B][×][X] [+] [ALPHA][C] [→][,][X].



Your screen should look like this:



Pressing [ENTER] gives you this:

LDEC

The LDEC tool will solve a linear differential equation with constant coefficients or a first order differential equation with variable coefficients. In ALG mode, you must supply it with a list of two arguments.

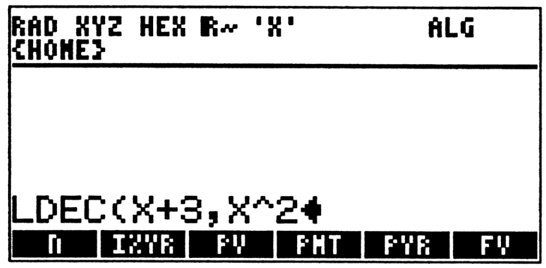
The first argument is the function forming the right hand side of the equation, if you're dealing with a single equation. (For a system of equations, this argument would be an array of the terms not containing the dependent variables.)

The second argument is the auxiliary polynomial for the single equation. (For a system of equations, it's the matrix of coefficients of the dependent variables.)

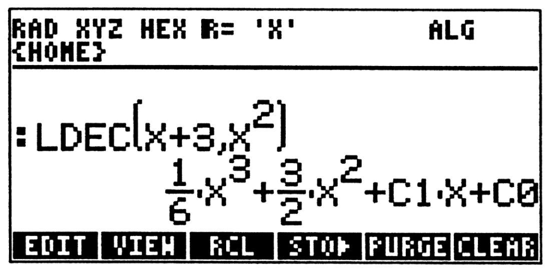
Example: Solve the differential equation $y''(x) = x + 3$

You need to put LDEC(X+3,X^2) onto the stack.

To do so, press [←][S.SLV] [3][ENTER] [X][+][3][→][,] [X][y^x][2]. The screen should now look like this:



Now press [ENTER] and your screen should display the solution, like this:



LINSOLVE

The LINSOLVE tool solves a system of linear equations. In ALG mode, you must supply it with a list containing two vectors—the equations to be solved and the variables being used.

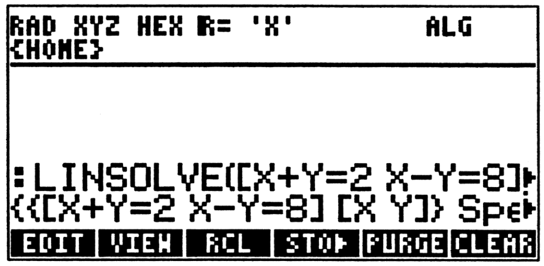
For example, suppose you want to solve this system of equations:

$$x + y = 2$$
$$x - y = 8$$

You need to put `LINSOLVE([X+Y=2,X-Y=8],[X,Y])` onto the stack.

To do so, press [←][S.SLV] [4] [ENTER] [←][[ ]] [X] [+] [ALPHA][Y] [→][=] [2] [→][,] [X] [−] [ALPHA][Y] [→][=] [8] [▶] [→][,] [←][[ ]] [X] [→][,] [ALPHA][Y] [ENTER].

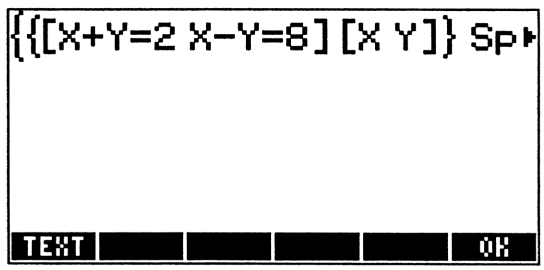
Your screen should look like this:



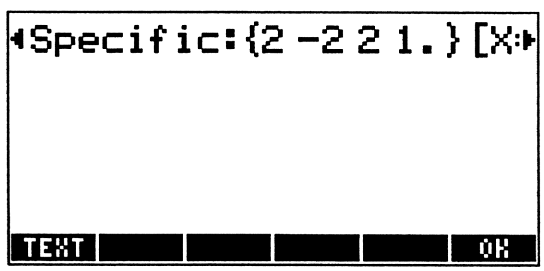
The result comes in three separate pieces—in a list that is usually too wide for the display. To view all of this list, use VIEW (and [◀] and [▶] to scroll your view as needed.)

.

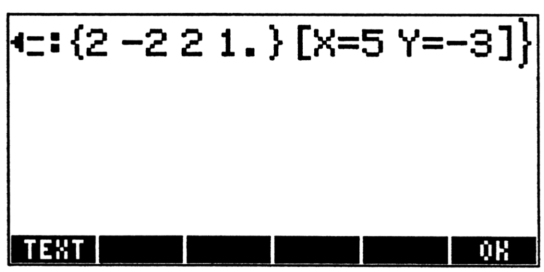
First you'll see the original system echoed back to you.



Then comes a list of the "specific" pivots.



Last comes the solution vector.

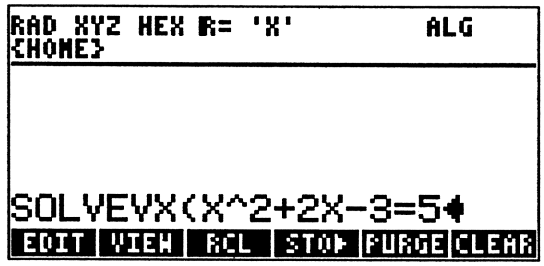


SOLVEX

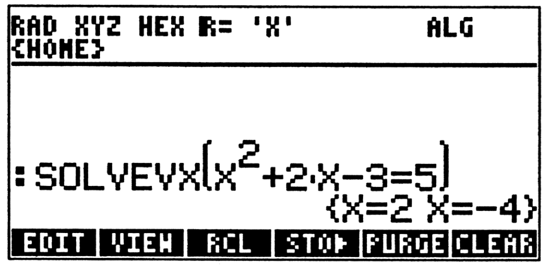
The SOLVEX tool solves a given equation specifically for the variable X. (If given an expression rather than an equation, it will equate the expression to zero and solve accordingly.) In ALG mode you simply enter the equation (or expression) and invoke this solver.

Example: Solve $x^2 + 2x - 3 = 5$ for x.

First, enter SOLVEX(X^2+2*X-3=5) onto the stack:
[⬅][S.SLV][5][ENTER] [X][y^x][2] [+] [2][X] [−] [3] [↱][=] [5]
The screen should look like this:

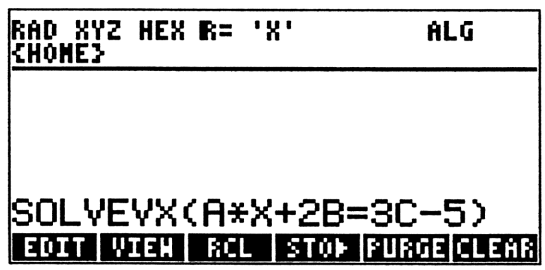


Now press [ENTER] and you'll see the solutions displayed as a list, like this:

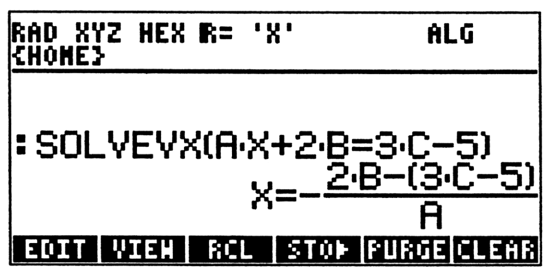


Example: Solve $Ax + 2B = 3C - 5$ for x.

Enter SOLVEX(A*X+2*B=3*C-5) onto the stack:
[⬅][S.SLV][5][ENTER] [ALPHA][A][X][X] [+] [2][ALPHA][B] [↱][=]
[3][ALPHA][C] [−] [5]. The screen should look like this:

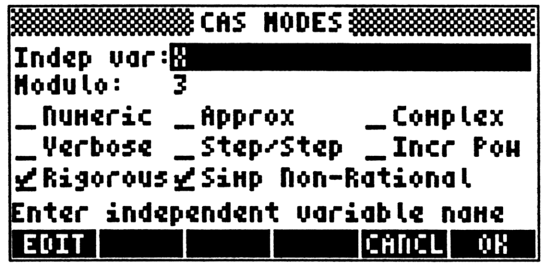


Now press [ENTER] and you'll see the solutions displayed as a list, like this, with the input on the left and the solution on the right:



Example: Solve $x^2 + 4 = 0$ for x.

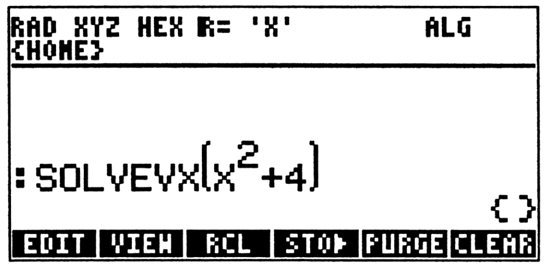
In this case, the solutions are complex numbers. The machine can produce these solutions correctly, *provided* that complex mode is active. If not, you will get null results.



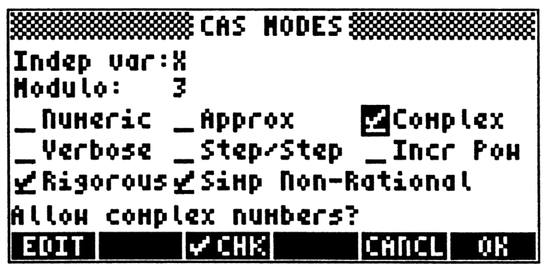
To check on the status of complex mode, press (MODE), then CAS, to see this screen:

Just for illustration, be sure that the _Complex field is inactive (unchecked) and continue with the problem that way....

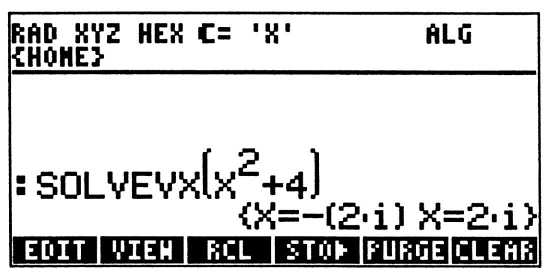
Press (ENTER) (ENTER) to return to the stack, then: (⬅)(S.SLV)(5)(ENTER)(X)(yˣ)(2)(+)(4). (No need to enter = 0 because the HP 49G will assume it if not told otherwise.)



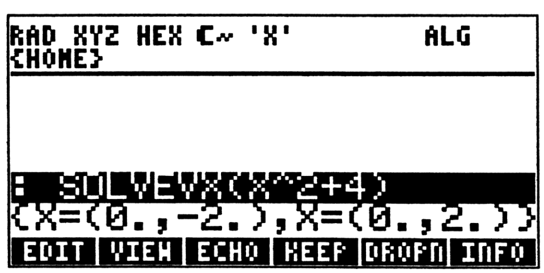
Now pressing (ENTER) should give this result—an empty list, indicating no solutions (i.e. no *real* solutions):



But now go back to the CAS MODES screen ((MODE), then CAS) and activate Complex mode (i.e. check the _Complex field). Also, un-check the _Approx field, if it's checked:



Now repeat the above solution keystrokes. Pressing (ENTER) should give you these results:



Note: If Approximate mode is on, a little tilde, ~, will have replaced the = in the Annunciator area, and the results will instead look like this:

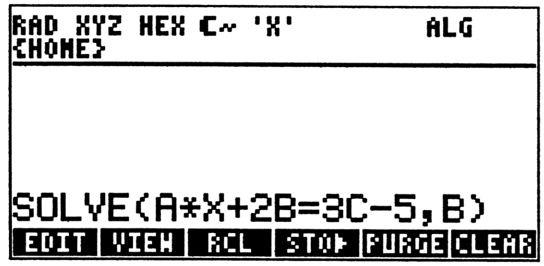
SOLVE

The SOLVE tool solves a given equation for the specified variable. (If given an expression rather than an equation, it will equate the expression to zero and solve accordingly.) In ALG mode you enter a list of two arguments—the equation or expression and the variable to be solved for.

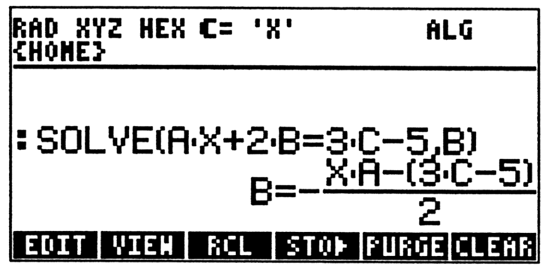
Try an example. Solve for B in this equation: $Ax + 2B = 3C - 5$

To do this, type [←][S.SLV][6][ENTER] [ALPHA][A][×][X] [+] [2][ALPHA][B] [→][=] [3][ALPHA][C] [−] [5] [→][,] [ALPHA][B].

Your screen should now look like this:



Pressing [ENTER] will yield the solution:

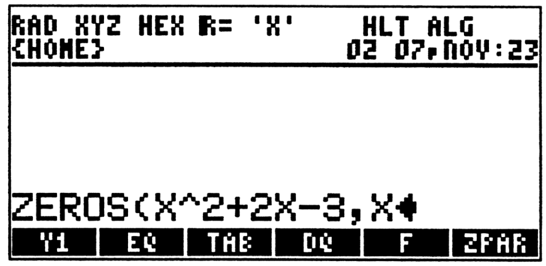


ZEROS

The ZEROS tool will solve for the zeros of a single-variable function. That is, it will set to zero the given expression and solve that equation for the variable specified. In ALG mode, you must supply a list with two arguments—the expression and the variable to be solved for.

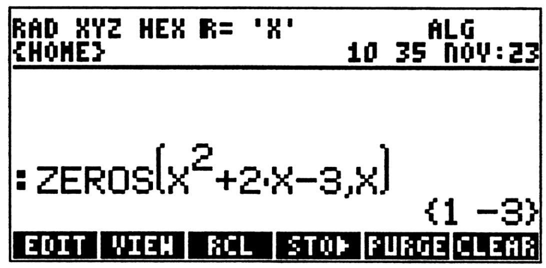
Example: Find the zeros of $x^2 + 2x - 3$.

Press [←][S.SLV][7] [ENTER] [X][y^x][2] [+] [2][X] [−] [3] [→][,] [X].

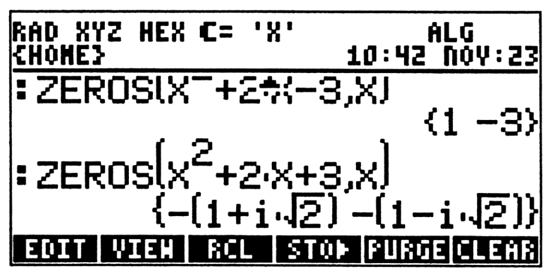


Your screen should now look like this:

Press [ENTER] to get this:

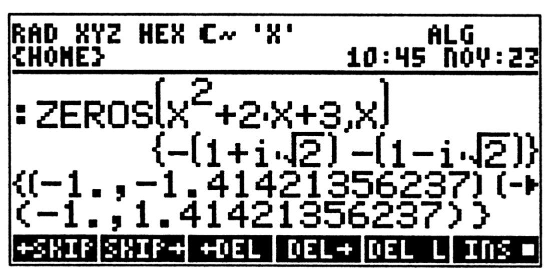


If Complex mode is active (check the _Complex field on the CAS MODES screen), ZEROS can return complex roots too. For example, find the zeros of $x^2 + 2x + 3$.



Press [←][S.SLV][7] [ENTER] [X][y^x][2] [+] [2][X] [+] [3] [→][,] [X] [ENTER]

Note: If Approximate mode is active (check the CAS MODES screen or look for a tilde, ~, rather than a =, in the status area), the results will instead look like this:



S.Slv in RPN Mode:

The main difference between ALG and RPN modes is in the formatting and "timing" of the arguments you provide: ALG mode looks for multiple arguments in a list that follows (and is a part of) the desired command; RPN mode expects to find its arguments already on the stack (one argument per level) when you enter the command. The *order* in which you enter the arguments is the same in either mode.

Other noticeable differences:

- In RPN, a command is not echoed on the stack. It is executed (assuming the stack is arranged correctly) as soon as it is pressed. The arguments and commands then disappear; only the output remains.
- RPN does not understand implied multiplication between numbers and variables. You must provide every operator explicitly.
- In RPN, you must enter variables and expressions between apostrophes, like this: `'X'`. (The ['] key is the [↱]-shifted version of [EQW].)

Here are examples of the use of each of the [↰][S.SLV] tools in RPN mode. For the sake of comparison these are the same examples as given for ALG mode.

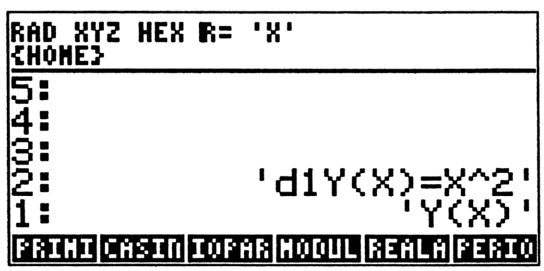
DESOLVE

Example: Find $y(x)$ if $y'(x) = x^2$.

Keystrokes: [↱]['][ALPHA][↰][D][1][ALPHA][Y][↰][()][X][▶][↱][=][X][y^x][2][ENTER].

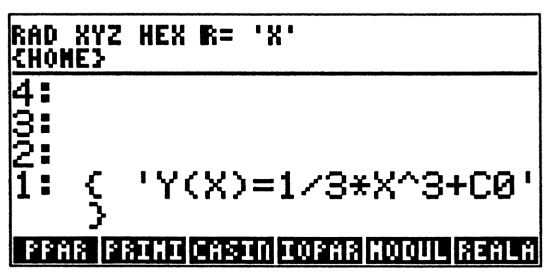
That's the first argument. Now enter the second one:
[↱]['][ALPHA][Y][↰][()][X][ENTER].

Your screen should look like this:



Now just execute the DESOLVE command:
[↰][S.SLV][1][ENTER]

(If you don't get the results shown, it's most likely a modes problem. Be sure that the machine is set to exact mode, not approximate mode.)

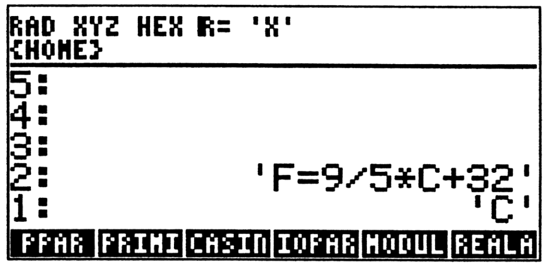


ISOL

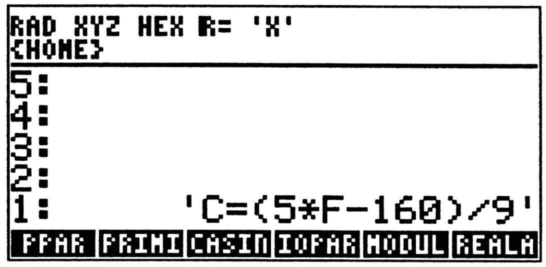
Example: Isolate the variable C in the temperature conversion formula $F = \frac{9}{5}C + 32$.

Keystrokes: [→] ['] [ALPHA] [F] [→] [=] [←] [()] [9] [÷] [5] [▶] [×] [ALPHA] [C] [+] [3] [2] [ENTER] [→] ['] [ALPHA] [C] [ENTER].

You should see this:



Now execute the ISOL command, [←] [S.SLV] [2] [ENTER], to get this:

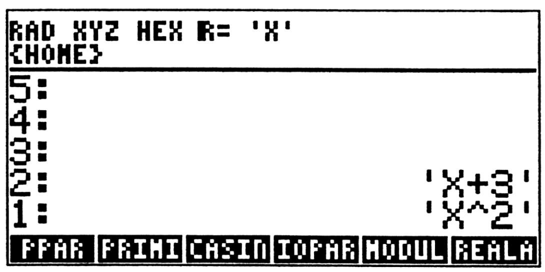


LDEC

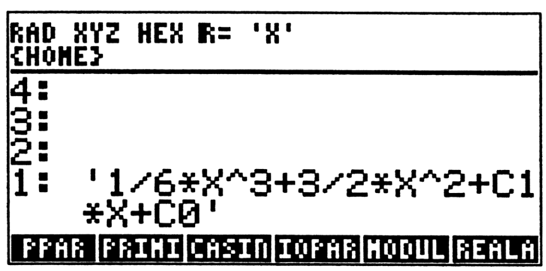
Example: Solve the differential equation $y''(x) = x + 3$

Keystrokes: [→] ['] [X] [+] [3] [ENTER]
[→] ['] [X] [y^x] [2] [ENTER]

Here's what you should see:



Now execute the LDEC command, [←] [S.SLV] [3] [ENTER], and see this:

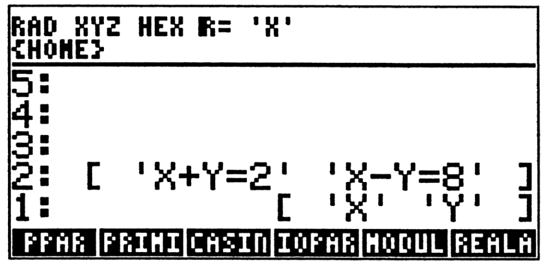


LINSOLVE:

Solve this system of equations: $x + y = 2$
$x - y = 8$

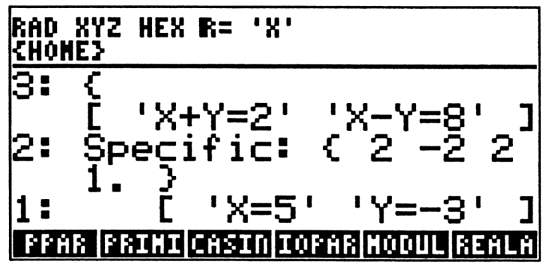
Keystrokes: [←][[ ]] [→]['] [X] [+] [ALPHA][Y] [→][=] [2] [▶] [→]['] [X] [−] [ALPHA][Y] [→][=] [8] [ENTER]
And: [←][[ ]] [→]['] [X] [▶] [→]['] [ALPHA][Y] [ENTER]

You should see this screen:



(Note: You may see different notation—i.e. without the "tick marks"—if the Stack display is set to Textbook notation in [MODE] DISP.)

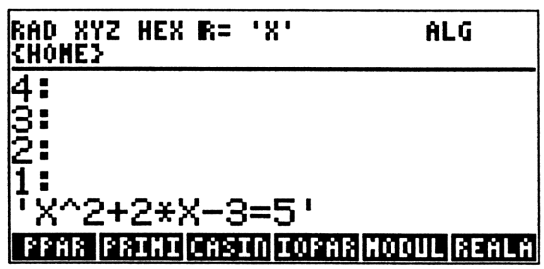
Now execute LINSOLVE, [←][S.SLV][4] [ENTER], to get this screen:



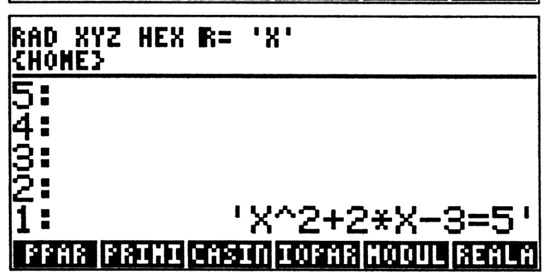
SOLVEX

Example: Solve $x^2 + 2x - 3 = 5$ for x.

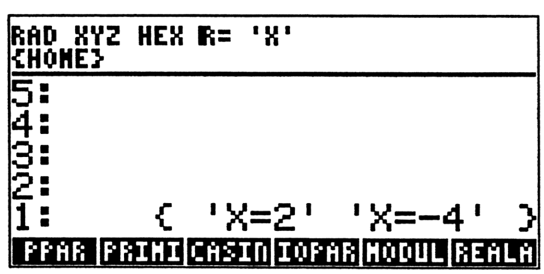
Keystrokes: [→]['] [X][y^x][2] [+] [2][X][X] [−] [3] [→][=] [5]



Now press [ENTER]....



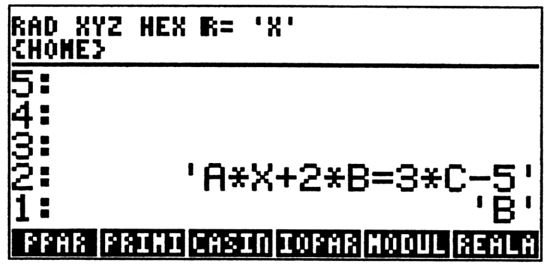
Now use SOLVEX, [←][S.SLV][5] [ENTER], to get this screen:



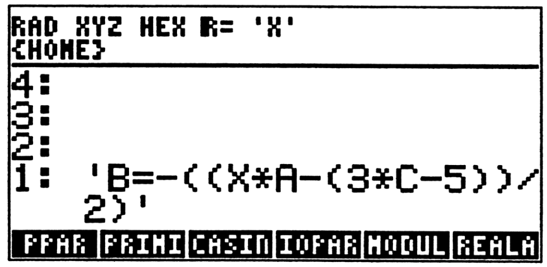
SOLVE

Solve for B in this equation: $Ax + 2B = 3C - 5$

Keystrokes: [↱] ['] [ALPHA] [A] [×] [X] [+] [2] [×] [ALPHA] [B] [↱] [=] [3] [×] [ALPHA] [C] [−] [5] [ENTER].
Then: [↱] ['] [ALPHA] [B] [ENTER].



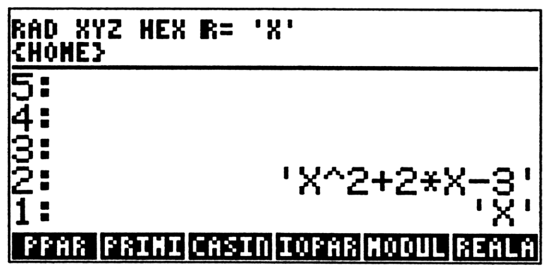
Now execute the SOLVE command: [↰] [S.SLV] [6] [ENTER].
You should see this screen:



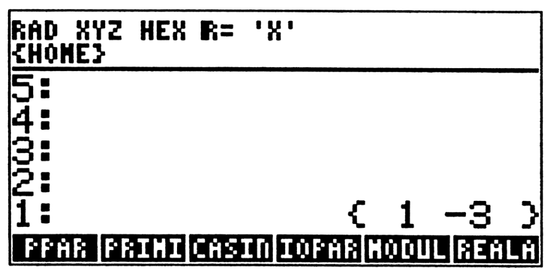
ZEROS

Example: Find the zeros of $x^2 + 2x - 3$.

Keystrokes: [↱] ['] [X] [y^x] [2] [+] [2] [×] [X] [−] [3] [ENTER]
And: [↱] ['] [X] [ENTER].



Now execute the ZEROS command, [↰] [S.SLV] [7] [ENTER], and you should see this screen:



The [←][EXP&LN] Key

Just as the name implies, most of the commands contained in the [←][EXP&LN] menu deal with logarithmic, exponential, or transcendental operations. Each of these commands takes a single expression as an argument and then returns the transformation of that expression.

1. EXPLN transforms an expression of trig functions to an equivalent expression containing exponential and logarithmic terms, using the Euler identities:

$$\sin x = \frac{e^{ix} - e^{-ix}}{2i} \qquad \cos x = \frac{e^{ix} + e^{-ix}}{2}$$

   EXPLN requres that Complex mode be active. (Use the CAS MODES screen to activate it.)

2. EXPM returns e^x - 1.

3. LIN linearizes expressions of exponential terms. For example, applying LIN to EXP(X)*EXP(Y) gives EXP(X+Y). LIN also linearizes trig functions, after converting them to complex exponentials.

4. LNCOLLECT simplifies an expression by collecting logarithmic terms, using properties of logarithm functions: $\log(a) + \log(b) = \log(ab)$ and $\log(a) - \log(b) = \log(a/b)$. For example, if you apply LNCOLLECT to LN(X)-LN(X^2)+LN(1/X^3), you'll get LN(X/X^2*1/X^3). If you then use [→][EVAL], the result is LN(1/X^4).

5. TEXPAND expands expressions involving transcendental functions. When applied to EXP(X+Y), TEXPAND returns EXP(X)*EXP(Y). Applied to SIN(X+Y), it returns COS(Y)SIN(X) +SIN(Y)COS(X).

6. TSIMP tries to reduce the set of variables and/or expressions in an expression to a set of rationally independent variables. (You'll seldom need to use this—try other commands first.)

Note that some of the above commands also appear on other menus. For example, TSIMP and TEXPAND appear on the [→][TRIG] menu.

Note, too, that other commands not found in the [←][EXP&LN] menu nevertheless perform transformations that are closely related. For example, TLIN will linearize expressions with trigonometric terms. Applying TLIN to SIN(X)*COS(Y)+COS(X)*SIN(Y) gives SIN(X+Y).

The ⮣ ALG Key

The commands contained in the ⮣ ALG menu offer various ways to evaluate, manipulate or recombine algebraic expression or equations.

1. EXPAND expands algebraic expressions. For example, EXPAND applied to (A+B)^2 will give A^2+2*B*A+B^2. And EXPAND applied to (X*Y*Z)^5 gives Z^5*Y^5*X^5.

2. FACTOR factors the argument. When FACTOR is applied to 24, it gives 2^3*3. When applied to 60X^2+71X-12, it gives (20X-3)*(3X+4). Applied to X*SIN(X)+A*B*SIN(X)^2, it gives SIN(X)*(X+B*A*SIN(X)).

   Note that FACTOR's behavior is dependent on whether Complex mode is active (adjusted via the CAS MODES screen). For example, in Real mode, FACTOR(X^2+4) does nothing; in Complex mode, it returns (X+2i)*(X-2i).

3. (LNCOLLECT is also on the ⮢ EXP&LN menu and is explained there.)

4. (LIN is also on the ⮢ EXP&LN menu and is explained there.)

5. SOLVE computes the value of a given argument that satisfies a given equation. If given two expressions, it creates an equation by setting the first expression to zero, then returns the value(s) of the second expression that satisfies that equation. For example, SOLVE(X-5,X) returns X=5. If the first argument is already an equation, SOLVE simply returns the value(s) of the second argument that satisfies that equation. For example, SOLVE(X^2-X=2,X) returns {X=2 X=-1}.

   Note that SOLVE's behavior is dependent on whether Complex mode is active (adjusted via the CAS MODES screen). For example, SOLVE(X^2+4,X) returns {} in Real mode; in Complex mode it gives {X=-(2i) X=2i}.

   Note also that SOLVE cannot be applied to an expression or equation in the Equation Writer, because it might return a list of solutions. (The Equation Writer cannot handle lists.)

6. SUBST replaces a variable with the specified expression. SUBST(X^2-5X-14=0,X=LN(X)) returns LN(X)^2-5LN(X)-14=0. You can also replace an *expression$_1$* with another *expression$_2$* if the equation *expression$_1$=expression$_2$* has a trivial solution that could be found via the ISOL (isolate) command. For example, SUBST(SIN(sqrt(X))+COS(sqrt(X)),sqrt(X)=A) will return SIN(A)+COS(A).

The ⬑CALC Key

The ⬑CALC menu is divided into three major groups: 1. Commands involving derivatives and integrals; 2. Commands involving limits and series; and 3. Commands involving differential equations. Note that, as usual, the correct syntax to enter the argument(s) for a command depends on whether you're working in ALG or RPN mode: In ALG mode, you invoke the command name and then list the arguments after it, separating multiple arguments with commas. In RPN mode, you enter the arguments onto the stack and then invoke the command name. In either mode, the order in which you type the arguments is the same.

Derivatives and Integrals

1.1 `CURL` computes the Curl of a 3-dimensional vector function, given two arguments: a 3-dimensional vector function; and a vector listing those three variables. For example,
`CURL([X^2*Y,X^2*Y,Y^2*Z],[X,Y,Z])` returns `[Z*(2*Y),0,Y*(2*X)-X^2]`.

1.2 `DERIV` computes the derivative of a specified function (the first argument) with respect to a specified variable (the second argument). Note that you can also use the keyboard's ⮣∂ for differentiation.

1.3 `DERVX` computes the derivative of a given function (the only argument) with respect to the variable currently indicated by `VX`. The content of `VX` (by default, `'X'`) can be changed at the `Indep var` field on the `CAS MODES` screen—or by storing the desired name into `VX`. (Notice that this status is indicated in the Annunciator area, too.) For example, with `VX` set to `'X'`, `DERVX(X*LN(X^2-1))` returns `LN(X^2-1)+X*(2*X)/(X^2-1)`.

1.4 `DIV` returns the divergence of a 3-dimensional vector function, given two arguments. a 3-dimensional vector function; and a vector listing those three variables. For example,
`DIV([X^2*Y,X^2*Y,Y^2*Z],[X,Y,Z])` returns `Y*(2*X)+(X^2+Y^2)`.

1.5 `FOURIER` evaluates the nth fourier coefficient of the specified function. It needs two arguments: an expression representing a function, $f(x)$; and n, a natural number.

The result: $\int_0^{2\pi} f(x)e^{inx}dx$

1.6 `HESS` finds the Hessian matrix and gradient of an expression (the first argument) with respect to the given variables (the second argument, a vector). The vector of variables is echoed as well. Example:
`HESS(X*Y+Y*Z+X*Z^2,[X,Y,Z])` produces

```
{[[0,1,2*Z]
  [1,0,1]
  [2*Z,1,2*X]],
[Y+Z^2,X+Z,Y+X*(2*Z)],
[X,Y,Z]}
```

1.7 IBP performs antidifferentiation by parts—but in RPN mode only. (Note that INTVX and INT will also antidifferentiate by parts.) IBP lets you choose u and dv.

In other words, to evaluate $\int udv$, you supply the following

stack arguments:	2:	$u(x)v'(x)$	and get these stack results:	2:	$u(x)v(x)$
	1:	$v(x)$		1:	$-u'(x)v(x)$

You then apply INTVX to the level-1 result, then ⊕ to get the final answer.

Example: Calculate $\int x \cos(x)dx$.

Arguments:	2:	'X*COS(X)'	Now apply IBP and get:	2:	'SIN(X)*X'
	1:	'SIN(X)'		1:	'-SIN(X)'

Apply INTVX :	2:	SIN(X)*X	Now apply ⊕ to get SIN(X)*X+COS(X).
	1:	COS(X)	

1.8 INTVX antidifferentiates the argument with respect to the current independent variable (which is indicated in the Annunicator area and specified on the CAS MODES screen). For example: INTVX(X*COS(X)) returns COS(X)+X*SIN(X).

Note that the INT command (which does not appear on a menu) allows you to specify the independent variable directly: INT(SIN(T),T,*expression*) gives -COS(*expression*).

1.9 LAPL returns the Laplacian of a function (the first argument) with respect to a list of variables (the second argument). Example: LAPL(X^2+SIN(Y)+Z,[X,Y,Z]) returns 2-SIN(Y).

1.10 PREVAL evaluates an antiderivative (which you first compute via INT or INTVX) between two limits of integration. It takes three arguments: the antiderivative expression, then the two limits of integration. Example: PREVAL(X^2,1,5) gives 24.

1.11 RISCH applies the Risch algorithm to evaluate the antiderivative of a given expression (the first argument) with respect to the specified variable (the second argument).
Example: RISCH(X/(1+X^2),X) returns 1/2*LN(X^2+1).

Limits and Series

2.1. DIVPC divides two polynomials. As arguments it requres (in this order): the dividend polynomial; the divisor polynomial; and the desired degree of the resulting polynomial. It then returns the quotient polynomial (in ascending powers), up to the degree specified.

Example: DIVPC(X^2-1,X+1,1) returns 1+X.

Example: DIVPC(1+X,1-X,4) returns 1+2*X+2*X^2+2*X^3+2*X^4.
(This is the Taylor Polynomial for (1+X)/(1-X) of order 4.)

2.2. LIMIT finds the limit of a given expression (the first argument) as the variable approaches a given value (the second argument, an equation—or just a value if the variable is the default). Some examples:

LIMIT(SIN(X)/X,X=0) gives 1. LIMIT(X^4/e^X,X=∞) gives ∞.

LIMIT(X^4/e^X,X=-∞) gives ∞. LIMIT((LN(X+H)-LN(X))/H,H=0) gives 1/X.

2.3. SERIES calculates a Taylor Series expansion for the given expression (the first argument) about a given point (the second argument, an equation—or just the variable if the point is 0). The expansion can be done at x = •. The third argument is the desired order of the expansion, a value between –2 and 20. If you use a positive real value here, the expansion is done from the right; if negative, from the left; if a binary integer (e.g. #5d), the expansion is bidirectional.

SERIES returns diagnostic information along with the expansion. First comes the bidirectional limit. Then comes a list with the series expansion and the order of the remainder. Then you get *h*, in terms of the original variable, so you can use SUBST to recover the expansion in terms of the original variable.

Example: The command SERIES(EXP(2X),X=1,5) returns
{{:Limit:e^2,Equiv:e^2,Expans:e^2+2*e^2*h+2*e^2*h^2
+4*e^2/3*h^3+2*e^2/3*h^4+4*e^2/15*h^5,Remain:^e2*h^6},h=X-1}.

You can now press [▲] [→][COPY] [CANCEL] [→][ALG] [6] [ENTER] [→][PASTE] [◄] [→][▲]. Then press [▶] seven times to move over to the right of the first curly brace, then [◄] to delete it. Now press [ENTER] to do the substitution, then [←][ANS] [←][[ ]] [3] [ENTER] to extract the series from the list.

2.4. TAYLOR0 returns the Taylor Polynomial about 0 for the specified expression (the only argument), expanded to the 4th degree term. (This can be applied in the Equation Writer, as well as from the stack.)

Example: TAYLOR0(SIN(X)) returns 1/120*X^5+-1/6*X^3+X.

2.5. TAYLR returns a Taylor Polynomial for the specified expression (the first argument) expanded in a specified variable (the second argument) about 0, to a given degree (the third argument). Example:

TAYLR(EXP(X),X,5) returns 1+X+1/2*X^2+1/6*X^3+1/24*X^4+1/120*X^5.

(Note: You will probably want to activate the _Incr Pow option on the CAS MODES screen, so that the polynomial is displayed with increasing powers.)

Differential Equations

3.1 DESOLVE can compute the general solution to a differential equation or find a specific solution, given initial conditions. It requires two arguments. The first argument is either: an equation of the form `d1F(X)=` *expression*, where *expression* is in terms of `X` and `F(X)` and specifies the slope; or a vector whose first element is the slope equation and whose second element is an initial condition, specified in the form `F(A)=B`. The second argument for `DESOLVE` is simply the name of the function to be solved for, such as `F(X)`.

Example: `DESOLVE(d1F(X)=COS(X),F(X))` returns `{F(X)=SIN(X)+C0}`.

Example: `DESOLVE([d1F(X)=(X+1)*F(X),F(0)=1],F(X))`
returns `{F(X)=1*(EXP(X)*EXP(X^2/2))}`.

3.2 `ILAP` takes an expression in the current independent variable and returns the inverse Laplace Transform of the expression. Example: `ILAP(1/(X-1)^3)` returns `1/2*X^2*EXP(X)`.

3.3 `LAP` takes an expression in the current independent variable and returns its Laplace Transform:

$$F(s) = \int_0^\infty f(x)e^{-sx}\,dx$$

Example: `LAP(SIN(X))` returns `1/(1+X^2)`.

3.4 `LDEC` can solve either a system of linear differential equation with constant coefficients, or a first order differential equation with variable coefficients.

`LDEC` takes two arguments. For a single equation, the first argument is the function on the right hand side of the equation; for a system of equations, the first argument is a vector of the terms not containing dependent variables. The second argument is the auxiliary polynomial, in the case of a single equation; for a system of equations, it's a matrix of the coefficients of the dependent variables.

Example: `LDEC(X^2,2X+1)` returns `8-4*X+X^2-(8-C0)*EXP(-1/2*X)`.

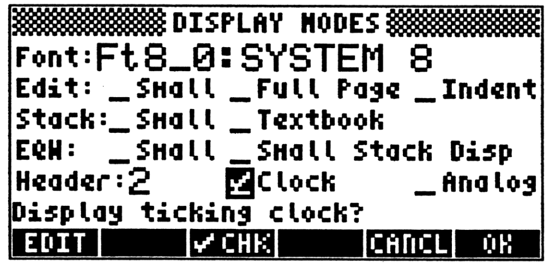
Example: `LDEC(g,X+k/m)` returns `m*g/k+-(m*g-k*C0)/k*EXP(-(k/m*X))`.
(This describes the velocity of a free falling body with air resistance taken into account.)

Time and Alarms

The HP 49G has an internal calendar and clock, which it can display if you wish. It also allows you to set alarms. These time features are independent of mode (RPN or ALG).

Time and Date

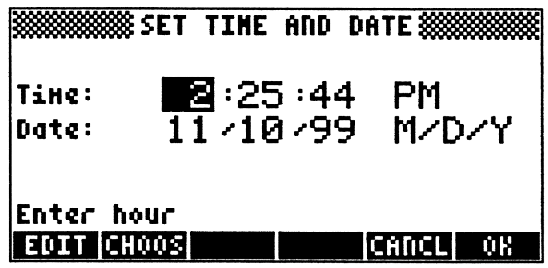
To display the time and date:



Press (MODE) DISP and ▽ down to the Header field and make sure it's set to 2. Then press ▷ to check (✓CHK) the _Clock field.

Press (ENTER)(ENTER) to return to the home screen.

To set the time and date:



Press (→)(TIME)(3)(ENTER).

This brings up the SET TIME AND DATE screen:

The cursor will start on the hour setting. Just type the correct hour of the day, then (ENTER). Next, type in the minute, then (ENTER), then the seconds and (ENTER), etc. Notice that for the AM/PM setting, you can CHOOS a 24-hour (or military) time format, as well as AM or PM.

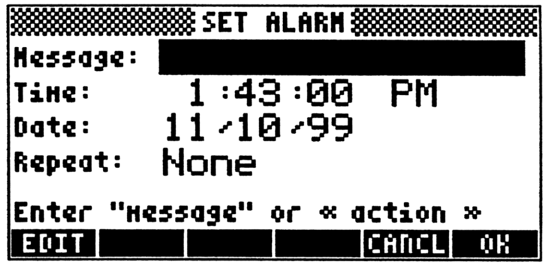
Do likewise for the date settings (pressing ▷ or ▽ to get to those fields): Enter the numbers of the month, day and year at the appropriate fields. (Just the last two digits of the year are sufficient—yes the HP 49G is Y2K compliant!)

The last field on the Date line lets you CHOOS how the date is formatted for display—either Month/Day/Year or Day,Month,Year.

Press (ENTER)(ENTER) to return to the home screen.

Alarms

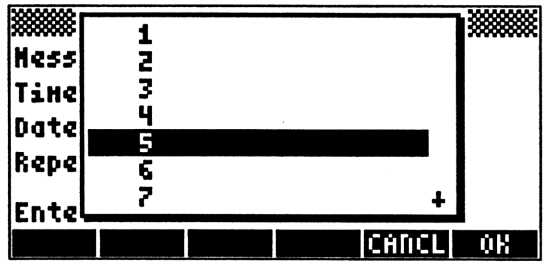
To set an alarm:



Press [→][TIME][2][ENTER] to get the `SET ALARM` screen:

This is where you enter all the various alarm parameters.

In the first field, you can enter a text message that will appear onscreen when the alarm is triggered. Then enter the exact time and date of the alarm.



Notice the final two fields (bottom line): You can opt to let the alarm `Repeat` (from 0 to 10 times) at a regular interval. You specify that interval (if the `Repeat` field is non-zero) in the `alarm repeat unit` field, to the right.

When you are done, hit [ENTER] to return to the stack.

To acknowledge an alarm:

While an alarm is sounding—it will beep for about 15 seconds—the message (if any) will display. If you acknowledge the alarm by pressing any key during this time, the beep will stop, the alarm annunciator, ((•)), will turn off, and the message will be deleted.

If you don't acknowledge the alarm during this time, the message will disappear but not be deleted. And if the alarm is non-repeating, the annunciator will stay on to indicate that you have an alarm that is now past due. To view past due alarms, press [→][TIME] and select `Browse alarms...` (You'll need to delete a past due alarm using **PURGE** before the ((•)) will turn off.)

Lists

Lists operate differently depending on the operating mode (RPN or Algebraic). This chapter is split into two sections, one for RPN mode, one for Algebraic mode, with identical examples in each, for comparison.
A quick reminder on modes (press (MODE)): The first field on the screen is the Operating Mode. For the next 3 pages, this mode must be RPN; for the section following that, it should be Algebraic. To adjust this mode, highlight that field with the cursor, press CHOOS, select the desired mode, and (ENTER) or OK. There's one other mode to check at this point, too (good for either section below). At the CALCULATOR MODES screen, press CAS. The _Numeric field on this CAS MODES screen should be checked. If it isn't, use the arrow keys to highlight the blank and press ✓CHK. Then (ENTER) and (ENTER) again, and you're ready.

Lists in RPN Mode

Entering and Storing Lists

In RPN, lists are enclosed by braces, { }, and the elements are separated by spaces or commas. For example, suppose you wanted to put the list { 1 2 3 4 5 } onto the stack. You would press (⬅)({}) to get a set of braces, then type the elements in order, separating them with spaces or commas—say, spaces here: (1)(SPC)(2)(SPC)(3)(SPC)(4)(SPC)(5). Then you'd just press (ENTER).

With the list now at level 1 of the stack, you can now store this list, if you wish. Suppose you want to store it in a variable named L1. Type: (ALPHA)(L)(1) (STO▶). Both list and name will disappear from the stack, but they're not lost: Press (VAR) to see a menu of all your stored variables. There, on the left side, you should now see a menu item, L1. If you "press" this L1 "key" (i.e. press the (F1) key directly beneath it), this invokes the name L1 and puts its value on the stack; you'll see the list { 1 2 3 4 5 } on level 1.

You can also use the interactive stack to enter a list. Try it: Press (2)(ENTER) (4)(ENTER) (6)(ENTER) (8)(ENTER) (9)(ENTER). Now press (▲)(▲)(▲)(▲)(▲) so that you're pointing to the line containing 2, the first element in your soon-to-be list. Now press (NXT), then →LIST and finally (ENTER). You'll now have a freshly-made five-element list on level 1. Now store this list in a variable named L2: (ALPHA)(L)(2) (STO▶).

Editing a List

You can also edit a list in the interactive stack. For example, to edit your L2 list so that the final element is 10 rather than 9: Press L2 to put a copy of the list back on the stack. Now use the (▲) key to start the interactive stack, then press EDIT. { 2 4 6 8 9 } will appear on the command line. Now you can use (◀) and (▶) to move around and the (⬅) key to delete. Change the 9 to a 10, then (ENTER) to end the edit. Don't forget to store this new version back into L2—at this point, it's only on the stack!

Computational Examples with Lists in RPN Mode

To perform an arithmetic operation on two lists, they must be of the same length, because the operation is performed between each pair of corresponding elements in the two lists, with a new list of the same length as a result. If you do an arithmetic operation on a list and a number, the result is a list obtained by distributing the operation of the number with each element of the list. These examples use the lists L1 and L2 ({ 1 2 3 4 5 } and { 2 4 6 8 10 }) from the previous page.

Subtraction

L2 – L1	[L2] [L1] [−]	{ 1 2 3 4 5 }
L2 – 1	[L2] [1] [−]	{ 1. 3. 5. 7. 9. }

Multiplication

(L1)(L2)	[L1] [L2] [×]	{ 2 8 18 32 50 }
(L2)(.5)	[L2] [.] [5] [×]	{ 1. 2. 3. 4. 5. }

Division

L2 ÷ L1	[L2] [L1] [÷]	{ 2. 2. 2. 2. 2. }
L2 ÷ 2	[L2] [2] [÷]	{ 1. 2. 3. 4. 5. }

Exponentiation

$(L1)^2$	[L1] [2] [y^x]	{ 1. 4. 9. 16. 25. }
$(3)^{L1}$	[3] [ENTER] [L1] [y^x]	{ 3. 9. 27. 81. 243. }
$(L1)^{L1}$	[L1] [L1] [y^x]	{ 1. 4. 27. 256. 3125. }

Addition

The [+] key works differently than you'd expect. It concatenates (joins) two lists into one longer list. To add the respective elements of two lists, use the ADD command (under LIST in the [↰][MTH] menu, or simply typed). Thus, either [L1] [L2] [↰][MTH] [3] [ENTER] [6] [ENTER] or [L1] [L2] [ALPHA] [ALPHA] [A] [D] [D] [ENTER] will result in { 3 6 9 12 15 }.

Commands Applied to Lists in RPN Mode

Lists can be used as inputs for single-argument commands. The output of such a command will be a list (with the same length as the input list) containing the outputs of the command as it is applied component-wise to the input list. For instance, pressing L1 then (SIN) will result in a list containing the sine of each of the elements of L1.

Lists can also be used as inputs for multiple-argument commands. For instance, the command ADD is a command requiring two arguments, and one or both of those arguments may be lists. For example, L1 (4)(ENTER) (ALPHA)(ALPHA)(A)(D)(D) (ENTER) will give you { 5 6 7 8 9 }.

Of course, you can also define your own functions and commands that use lists as arguments (and results)—they're very handy for many purposes. But be very careful with list arithmetic! Remember that such arithmetic demands lists of matching sizes. And if you forget and use a + rather than ADD, you will get concatenation (or an error) instead of the addition you intended.

Special List Operations in RPN Mode

Some built-in commands are specifically made to work on lists. You'll find these collected as the third sub-menu in the menu under the (⬅)(MTH) key. (In other words, press (⬅)(MTH)(3)(ENTER).) This sub-menu offers the following commands (and ADD appears here, too):

ΔLIST gives the list of first differences. That is, it subtracts the first element from the second, the second from the third, and so on—resulting in a list one element shorter than the original:

{ 4 16 36 64 100 } ΔLIST gives { 12 20 28 36 }.

ΣLIST sums all list elements: { 12 20 28 36 } ΣLIST gives 96.

ΠLIST multiplies all list elements: { 1 2 3 4 5 } ΠLIST gives 120.

SORT arranges list elements in increasing order: { 2 7 8 1 } SORT gives { 1 2 7 8 }.

REVLIST reverses list elements: {1 2 7 8} REVLI gives { 8 7 2 1 }.

Lists in Algebraic Mode

(A reminder here to revisit the CALCULATOR MODES screen, via [MODE], and make sure that the Operating Mode field is set to Algebraic for the next 3 pages.)

Storing Lists

In Algebraic mode, lists are enclosed by braces, { }, and elements are separated by commas. (You can't use spaces to separate list elements in Algebraic mode because this will be taken as implied multiplication instead.)

For example, to enter {1,2,3,4,5} at the stack, you would press [↰][{}] to get a set of braces, then type the elements, in order, separated by commas ([↱][,]), then press [ENTER].

To store this list in a variable named L1, press the [STO▶] key then [ALPHA][L][1]. The calculator will display: ANS(1)▶L1. Now press [ENTER].

If you look at your variable menu (press [VAR]), which shows you all the variables you have created, you should see a new item, L1, on the far left. Press this menu "key," L1 (i.e. press the [F2] key directly beneath it), then [ENTER]. Your L1 list will be put onto the stack.

Now use the above procedure again to store the list {2,4,6,8,9} into a variable named L2:
[↰][{}] [2][↱][,] [4][↱][,] [6][↱][,] [8][↱][,] [9] [ENTER] [STO▶][ALPHA][L][2] [ENTER].

Editing a List

To edit a list in Algebraic mode, use the [▲] key to point to a list on the stack, then press ECHO. The list will be copied to the command line. At this point, any keystrokes you make will be inserted on this line (except that you may use [◀] and [▶] to maneuver through the list, and [⬅] to delete characters).

Example: Change the final element in list L2 from 9 to 10. Press L2, [▲] and ECHO. Now [▶] over to the right of the 9 and [⬅] [1][0] [ENTER]. Now you have the corrected version on the stack, but it's not yet stored into the variable name, L2—don't forget this important final step! [STO▶][ALPHA][L][2] [ENTER].

Computational Examples with Lists in Algebraic Mode

When you perform an arithmetic operation on two lists, they must be of the same length. The result is a list of the component-wise results of the operation. An arithmetic operation on a list and a number results in a list obtained by distributing the operation of the number to each element of the given list. You cannot perform these operations using only names; at least one list must be given on the command line or by ANS. These examples use lists L1 and L2 ({1,2,3,4,5} and {2,4,6,8,10}), stored previously:

Subtraction

L2 – L1	L2 ENTER − L1 ENTER	{1,2,3,4,5}
L2 – 1	L2 ENTER − 1 ENTER	{1.,3.,5.,7.,9.}

Multiplication

(L1)(L2)	L1 ENTER × L2 ENTER	{2,8,18,32,50}
(L2)(.5)	L2 ENTER × · 5 ENTER	{1.,2.,3.,4.,5.}

Division

L2 ÷ L1	L2 ENTER ÷ L1 ENTER	{2.,2.,2.,2.,2.}
L2 ÷ 2	L2 ENTER ÷ 2 ENTER	{1.,2.,3.,4.,5.}

Exponentiation

$(L1)^2$	L1 ENTER y^x 2 ENTER	{1.,4.,9.,16.,25.}
$(3)^{L1}$	L1 ENTER 3 y^x ↰ ANS ENTER	{3.,9.,27.,81.,243.}
$(L1)^{L1}$	L1 ENTER y^x L1 ENTER	{1.,4.,27.,256.,3125.}

Addition

The + key works differently than you may expect. It concatenates (joins) two lists into one longer list. To add two lists together component-wise, use the ADD command (found under LIST via the ↰ MTH key, or simply typed). Thus L1 ENTER ALPHA ALPHA A D D ALPHA ↰ () ↰ ANS ↱ , L2 ENTER will result in {3.,6.,9.,12.,15.}. ADD will not work on two list variable names.

Commands Applied to Lists in Algebraic Mode

Explicitly stated lists (i.e. not just their names) can be used as inputs for single-argument commands in Algebraic mode. The output of such a command will be a list (with the same length as the input list) containing the outputs of the command applied component-wise to the input list.

For instance, pressing L1 ENTER SIN ← ANS ENTER will result in a list containing the sine of each of the elements of L1.

Lists can also serve as inputs for multiple-argument commands. For instance, the ADD command requires two arguments, one or both of which can be lists: L1 ENTER ALPHA ALPHA A D D ALPHA ← () ← ANS → , 4 ENTER gives {5.,6.,7.,8.,9.}.

Lists are handy, but be careful when building and applying your own user-defined functions to lists. For example, if the function contains a +, you may get concatenation (or an error) instead of addition.

Special List Operations in Algebraic Mode

Some built-in commands are specifically made to work on lists. These are found as the third sub-menu in the ← MTH menu. (Press ← MTH 3 ENTER.) This offers the following commands (and ADD also appears in this menu):

ΔLIST gives the list of first differences. That is, it subtracts the first element from the second, the second from the third, and so on—resulting in a list one element shorter than the original:

ΔLIST({4,16,36,64,100}) ENTER gives {12,20,28,36}.

ΣLIST sums all list elements: ΣLIST({12.,20.,28.,36.}) ENTER gives 96.

ΠLIST multiplies all list elements: ΠLIST({1,2,3,4,5}) ENTER gives 120.

SORT arranges list elements in increasing order: SORT({2,7,8,1}) ENTER gives {1,2,7,8}.

REVLIST reverses list elements: REVLIST({1,2,7,8}) ENTER gives {8,7,2,1}.

Vectors and Matrices

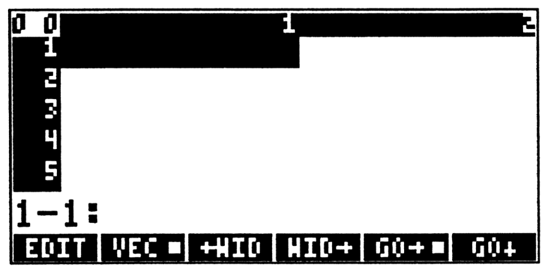
You can enter vectors and matrices right at the stack in either RPN and Algebraic mode, but there's also a special application called the Matrix Writer that simplifies your data entry.

Entering Matrices using the Matrix Writer

To begin using the Matrix Writer, press [←][MTRW]. You'll see a screen that looks something like a spreadsheet. Press **VEC**. Notice that this menu item is a toggle: one press will put you into vector mode (i.e. **VEC** becomes **VEC■**); another press will take you out of it—back to matrix mode (i.e. **VEC■** becomes **VEC**). For this example, you'll need to have the Matrix Writer in vector mode (so **VEC■** should show).

Next, you need to decide whether you want a row vector or a column vector. The two softkeys **GO→** and **GO↓** determine the direction the cursor will move after you enter each element. Press **GO→**, if necessary to activate it (i.e. to change it to **GO→■**).

Now you're ready to enter data. At this point, your screen should look like this:



Now press [1][ENTER] [3][ENTER] [3][ENTER].

Nothing to it, right? Notice that you can change the calculator display via **←WID** and **WID→**. To make each column wider (but see fewer of them), press **WID→**; to see more (narrower) columns, press **←WID**. The width of the columns has no effect on the stored accuracy of the elements; it just allows more comfortable viewing for you.

What if you want to edit an existing vector or matrix? In the Matrix Writer, you just select an element by moving the highlight (using the arrow keys). For example, highlight row 1, column 2 (which should have a 3) and press **EDIT**. The command line appears, with the current value that you can now edit. And your editing options aren't limited to just deleting and replacing individual values. Press [NXT] to see the rest of the editing menu, with items that allow you to add or cut a row or column, or place a single element onto the stack.

When you finish entering or editing with the Matrix Writer, just press [ENTER] to put the vector or matrix on the stack.

RPN and Algebraic Modes

Although they're entered similarly in either mode, vectors and matrices are manipulated quite differently in RPN mode than in Algebraic mode. From here on, therefore, this chapter is split into two corresponding sections, with identical examples in each section.

Vectors and Matrices in RPN Mode

First, you need to visit the modes screens to make sure that the machine's operating mode is RPN and the CAS mode is set to Numeric. Press (MODE). If necessary, CHOOS RPN for the Operating Mode field. OK that, then press CAS and be sure that the _Numeric field on this screen is checked. (If not, highlight that field and press ✓CHK.) Press OK OK and you're ready to go.

Entering and Storing Vectors and Matrices

A vector on the HP 49G is indicated by brackets (the left shifted version of the (×) key), with individual elements separated by commas or spaces.

For example, enter the vector `[ 1 2 3 ]`: (←)([]) (1)(SPC)(2)(SPC)(3)(ENTER). Now store this vector into a variable named `V1` by pressing (→)(')(ALPHA)(V)(1) (STO▶). Press (VAR) and you'll have a menu item called V1. If you press that menu key, your vector, `[ 1 2 3 ]`, will be put onto level 1 of the stack.

Try another. (You'll need these two vectors in later examples.) Use the same procedure to enter the vector `[ -1 2 ]` and store it into a variable named `V2`. (Reminder: In RPN, you type (1)(+/−) to get `-1`.)

`V1` and `V2` are examples of row vectors. A matrix on the HP 49G is a row vector made up of row vectors.

For example, the matrix $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ is denoted as `[[1 2] [3 4]]`.

Try entering this matrix by pressing (←)([]) (←)([]) (1)(SPC)(2) (▶) (←)([]) (3)(SPC)(4) (ENTER).
Now store this matrix into a variable named `M1` by pressing (→)(')(ALPHA)(M)(1) (STO▶).

Of course, you can also enter a matrix using the MatrixWriter. Press (←)(MTRW) and be sure that the vector toggle is unchecked (VEC). Then enter the matrix $\begin{bmatrix} 2 & -1 \\ 3 & 1 \end{bmatrix}$. Store this into a variable named `M2`. (You will use both `M1` and `M2` later.)

Editing a Vector or Matrix

Editing a vector or matrix on the interactive stack is easy. Simply press (▲) until you are pointing to the entry you wish to edit, press EDIT, use the arrow keys to navigate through the object. Any keystrokes will be inserted at the cursor, and you can use the (⇐) key to delete characters.

Use this procedure now to change the matrix `M2` to $\begin{bmatrix} 2 & -1 \\ -2 & 1 \end{bmatrix}$. (Don't forget to store it back into `M2`!)

Computational Examples with Vectors and Matrices in RPN Mode

These examples use the vectors `V1` and `V2` and matrices `M1` and `M2` that you just stored.

Multiplication of a vector by a scalar

3(V1)	3 V1 ×	`[ 3 6 9 ]`

Addition of two vectors or matrices (with same dimensions)

[3 6 9] + V1	V1 +	`[ 4 8 12 ]`
M1 + M2	M1 M2 +	`[[ 3 1 ]` `[ 1 5 ]]`

Matrix multiplication (with compatible dimensions)

(M1)(M2)	M1 M2 ×	`[[ -2 1 ]` `[ -2 1 ]]`
(M2)(M1)	M2 M1 ×	`[[ -1 0 ]` `[ 1 0 ]]`

Multiplication of a matrix and a vector (so long as the dimensions make it possible).

(M2)(V2)	M2 V2 ×	`[ -4 4 ]`

Matrix inversion

$(M1)^{-1}$	M1 1/x	`[[ -2 1 ]` `[ 1.5 -.5 ]]`

Special Vector and Matrix Commands in RPN Mode

The HP 49G offers a wide variety of commands for vectors and matrices—only a small sample are discussed here—which you can find by pressing ⇦ MTH, or by simply typing the command names from the keyboard. (In general, typing a command name on the command line followed by ENTER will result in that command being performed on object(s) on the stack.)

For example, to find the magnitude of V1 (using the ABS command) you could press V1 ⇦ MTH ENTER ENTER; or you could type V1 ALPHA ALPHA A B S ENTER.

Dot product of two vectors

[4 5] • V2	⇦ [ ] 4 SPC 5 ENTER V2 ⇦ MTH ENTER 2 ENTER	6.

Cross product of two vectors

[4 5] × V2	⇦ [ ] 4 SPC 5 ENTER V2 ⇦ MTH ENTER 3 ENTER	[0 0 13.]

The transpose of a matrix

$M1^t$	M1 ⇦ MTH 2 ENTER ENTER 3 ENTER	[[1. 3.] [2. 4.]]

The determinant of a matrix

|M2|	M2 ⇦ MTH 2 ENTER 2 ENTER 8 ENTER	0.

Vectors and Matrices in Algebraic Mode

For this section (the next 3 pages), re-visit the CALCULATOR MODES screen now (press (MODE)) and set the Operating Mode to Algebraic. Then visit the CAS MODES screen (press CAS) and ✓CHK the _Numeric field if it's not checked already. Then OK OK and you're ready to go.

Entering and Storing Vectors and Matrices

A vector on the HP 49G is indicated by brackets (⬅[ ]) with individual elements separated by commas. Although the finished result will appear with spaces, you can't type spaces to separate vector or matrix elements in Algebraic mode, because they will be taken to mean implied multiplication instead.

For example, to enter the vector [1 2 3], press ⬅[ ] (1) ➡(,) (2) ➡(,) (3) (ENTER). Now store this vector in a variable named V1 by pressing (STO▶) (ALPHA)(V)(1) (ENTER). You should now have a menu item labeled V1 (press (VAR), if necessary, to see your variables menu). If you press that menu key, then (ENTER), you'll see the vector [1. 2. 3.] appear on level 1 of the stack.

Repeat this procedure in order to store the vector [-1, 2] into a variable named V2. You will use both of these vectors later.

V1 and V2 are examples of row vectors. A matrix on the HP 49G is a row vector made up of row vectors.

For example, the matrix $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ is indicated on the HP 49G as [[1, 2] [3, 4]].

Try entering that. Press ⬅[ ] ⬅[ ] (1) ➡(,) (2) (▶) ⬅[ ] (3) ➡(,) (4) (ENTER). Now store it in a variable named M1: (STO▶) (ALPHA)(M)(1) (ENTER).

Of course, you can also enter a matrix using the MatrixWriter. To do so, press ⬅(MTRW) and first make sure that the VEC toggle is off (i.e. that it's not VEC▪).

Now enter the matrix $\begin{bmatrix} 2 & -1 \\ 3 & 1 \end{bmatrix}$. Store this into a variable named M2—you'll use it later.

Editing a Vector or Matrix

Editing a vector or matrix on the interactive stack is easy. Simply press (▲) until you're pointing to the entry you wish to edit, and press ECHO. Then use the arrow keys to position the cursor; any keystrokes will be inserted at the cursor (except (⬅), which deletes characters). Use this procedure now to change the matrix stored in M2 to $\begin{bmatrix} 2 & -1 \\ -2 & 1 \end{bmatrix}$. Then don't forget to store it back into M2!

Computational Examples with Vectors/Matrices in Algebraic Mode

These examples use the vectors V1 and V2 and the matrices M1 and M2 that you just stored. Note that you can't perform operations on two list names; at least one of the lists must be explicitly given on the command line—or implicitly stated by the ANS variable.

Multiplication of a vector by a scalar

3(V1)	V1 ENTER × 3 ENTER	[3.,6.,9.]

Addition of two vectors or matrices (with the same dimensions)

[3,6,9]+V1	[3,6,9] + V1 ENTER	[4.,8.,12.]
M1+M2	M1 ENTER + M2 ENTER	[[3.,1.] [1.,5.]]

Matrix multiplication (with compatible dimensions)

(M1)(M2)	M1 ENTER × M2 ENTER	[[-2.,1.] [-2.,1.]]
(M2)(M1)	M2 ENTER × M1 ENTER	[[-1.,0.] [1.,0.]]

Multiplication of a matrix and a vector (with compatible dimensions)

(M2)(V2)	M2 ENTER × V2 ENTER	[-4.,4.]

Matrix inversion

$(M1)^{-1}$	M1 ENTER 1/x ← ANS ENTER	[[-2.,1.] [1.5,-.5]]

Special Vector and Matrix Commands in Algebraic Mode

The HP 49G offers a wide variety of commands for vectors and matrices, only a small sample of which are discussed here. You'll find these commands via the ⇦ MTH key, or you can type them from the keyboard. In general, a command name on the command line, followed by an explicit reference—or a reference via the ANS variable—to a vector or matrix as the argument in parentheses, will produce the result of the command being performed on the given vector or matrix.)

For example, to find the magnitude of V1 (using the ABS command) you either
do this: V1 ENTER ⇦ MTH ENTER ENTER ⇦ ANS ENTER;
or this: V1 ENTER ALPHA ALPHA A B S ⇦ () ⇦ ANS ENTER.

Dot product of 2 vectors

`DOT([4 5],V2)`	V2 ENTER ⇦ MTH ENTER 2 ENTER ⇦ [] 4 ⇨ , 5 ▶ ⇨ , ⇦ ANS ENTER	`6.`

Cross product of 2 vectors

`CROSS([4 5],V2)`	V2 ENTER ⇦ MTH ENTER 3 ENTER ⇦ [] 4 ⇨ , 5 ▶ ⇨ , ⇦ ANS ENTER	`[0.,0.,13.]`

Transpose of a matrix

`TRN(M1)`	M1 ENTER ⇦ MTH 2 ENTER ENTER 3 ENTER ⇦ ANS ENTER	`[[1.,3.]` `[2.,4.]]`

Determinant of a matrix

`DET(M2)`	M2 ENTER ⇦ MTH 2 ENTER 2 ENTER 8 ENTER ⇦ ANS ENTER	`0.`

Statistics

The HP 49G offers you three different groups of powerful statistical features: single-variable, two-variable, and inferential.

Single-Variable Statistics

Press (→)(STAT) to bring up the statistics choose box. Select the Single-var.. option and press (ENTER) to go to the SINGLE-VARIABLE STATISTICS input screen. The first field on this screen, labeled ΣDAT, is where you enter the matrix of data to be analyzed. (All of the statistical routines work with the matrix named ΣDAT.) Highlight this field and press EDIT. This takes you to the Matrix Writer environment

As a first exercise, enter the planetary data from the table here. The first data column contains the period of revolution of each of the nine planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Neptune, Uranus, and Pluto), measured in Earth years. The second column contains the mean distance from each of the planets to the Sun, measured in astronomical units. (1 au = the Earth's mean distance from the Sun)

Period (yrs)	Mean solar distance (au)
.241	.381
.615	.723
1	1
1.881	1.574
11.862	5.203
29.458	9.539
84.013	19.183
164.794	30.058
248.430	39.519

For convenient entry, note that you can set either GO→ mode (to enter the data by row) or GO↓ mode (to enter by column).

After entering the last element, press (ENTER) once more to return to the SINGLE-VARIABLE STATISTICS input screen. Now set the Col field to 1, so that the statistics will be computed for the first column of your data—the periods of revolution. Next, set the Type field to Sample. (After all, your data are not complete; there are other objects, such as asteroids and comets, that also orbit the sun.)

Now check (✓CHK) all of the blanks for these statistics:

_Mean	the arithmetic average of the data
_Std Dev	the standard deviation of the sample or population
_Variance	the variance of the sample or population
_Total	the sum of the data
_Maximum	the largest data value
_Minimum	the smallest data value

Press OK to compute the statistics. On the stack, you'll find the values of all the statistics you requested. (You may have to use (▲) to see them.) Now go back to the SINGLE-VARIABLE STATISTICS input screen once more ((→)(STAT)(ENTER)), change the Col field to 2 and compute likewise all the same statistics for the second column, the planets' mean distances from the Sun.

About ΣDAT

Press (VAR) and notice the menu item ΣDAT. ΣDAT is now stored in the current directory. ΣDAT is a matrix that you can manipulate just like any other (or store a copy of it, by putting its contents onto the stack and storing them into another variable name). But the name ΣDAT is reserved—don't use it to store other types of objects—as the HP 49G's statistical features always use the contents of ΣDAT for statistical data.

One other note: You don't need the (↱)(STAT) environment to enter data into ΣDAT. You can also start the Matrix Writer right from the stack, enter data, then store it into ΣDAT yourself (i.e. (STO▶) ΣDAT (ENTER)).

Frequencies

Sorting data into bins is another single-variable procedure. Press (↱)(STAT), then select the Frequencies.. option (or press (2)), then (ENTER). This will take you to the FREQUENCIES input screen.

Notice that the ΣDAT field is again the first item, and it should still contain whatever data were there previously (in this case, the planet data)—no need to mess with it. Select the Col field to 2, if it's not already. Then set the X-Min field to 1, the Bin Count field to 3, and the Bin Width field to 10. These settings instruct the calculator to sort the data in column 2 of ΣDAT (the planets' mean solar distances) into 3 bins with a width of 10, starting with a value of 1. In other words, the bin intervals are [1,11), [11,21), and [21,31).

Now press OK to do the actual sorting. You'll find the results displayed on the stack in the form of a matrix (on level two) and a vector (on level one). In this case, the matrix is [[4.][1.][1.]], indicating the frequencies of data in each of the bin intervals: 4 entries are in the interval [1,11), 1 entry in the interval [11,21), and 1 entry in the interval [21,31). The vector [2., 1.] means that 2 of the entries are less than the X-Min (1); and 1 entry is greater than or equal to the upper bound of the last interval (31).

Histograms

A graphical way to display single-variable data is by a histogram. Press (↰)(2D/3D) to go to the PLOT SETUP screen. Use CHOOS to set the plot type to Histogram. Notice that the ΣDAT field still contains your now-familiar planet data. Set the Col field to 2, and you're finished with this screen. Press (ENTER), which will store these settings and send you back to the stack.

Now press (↰)(WIN). This brings up the PLOT WINDOW - HISTOGRAM screen, where you can now input the following horizontal and vertical view intervals and the bar width:

H-View:	0	40
V-View:	-1	7
Bar Width:	10	

Once you've done that, just press ERASE DRAW to generate the histogram. Notice that you can then press X,Y and move the cursor around with the arrow keys to investigate this plot.

Two-Variable Statistics

Statistics relating to one or both columns of data can be computed using summary statistics. Press (→)(STAT) and select the Summary stats.. option.

At the SUMMARY STATISTICS input screen, you'll see the ΣDAT field, as usual (still containing your planetary data). You'll also see fields for X-Col and Y-Col. Set these to 1 and 2, respectively.

You can select (by checking, ✓CHK) any combination of these six summary statistics:

_ΣX	The sum of the data in the x-column
_ΣY	The sum of the data in the y-column
_ΣX2	The sum of the squares of each of the values in the x-column
_ΣY2	The sum of the squares of each of the values in the y-column
_ΣXY	The sum of the products of each x-y data pair
_nΣ	The number of data pairs

After you select the statistics you want, you just press OK, and those statistics will be computed and displayed on the stack.

Fitting a Model to Data

Two-variable statistics allow for the investigation of relationships between variables. For example, with your planetary data, you might ask: Is there any relationship between the period of revolution of each of the planets, and its mean distance from the Sun?

Press (→)(STAT) and select the Fit data.. option. At the FIT DATA input screen, you'll find the usual fields: ΣDATA, X-Col and Y-Col. These latter two field values specify the column numbers of ΣDATA that will serve as the independent (X-Col) and dependent (Y-Col) variables. In this case, they should be set to 1 and 2, respectively.

The last field on this screen is Model, which selects the mathematical model, to use as a fit for the data:

Linear Fit	Returns the best-fitting expression of the form $b+mx$.
Logarithmic Fit	Returns the best-fitting expression of the form $b+a\ln(x)$.
Exponential Fit	Returns the best-fitting expression of the form $ce^{(b+ax)}$.
Power Fit	Returns the best-fitting expression of the form ax^b.
Best Fit	Chooses the above option that fits the data the best.

After you choose a model, there are two things you can do. If you press PRED, X and Y fields will appear. You can enter a value into one of these fields, highlight the other, then press PRED. The calculator will then compute the value of the highlighted field that is computed (by the selected model) using the value in the other field. If you press OK the HP 49G will display the best fitting expression of the model selected, along with the Correlation and the Covariance with respect to that model.

A word about the Correlation value. With the Linear Fit model selected, the Correlation value is the linear correlation coefficient, a measure of how linear the data is, which is a real number ranging from –1 to 1. A value of –1 indicates a perfect linear relationship with negative slope; 1 indicates a perfect linear relationship with positive slope; and 0 indicates a complete lack of any linear relationship. If the model selected is not linear, the calculator then computes a correlation on the linear transformation of the data, so that, again, the value of the Correlation reported by the calculator indicates how well the selected model type fits the data.

Try applying a Power Fit model to the planetary data.... Notice how close the correlation is to 1, and look at the power fit expression itself. (You may have to ▲ up to it and press VIEW to see the whole thing.) Notice that the exponent is very close to 2/3. This is an illustration of Kepler's third law, which states that the cube of the mean radius divided by the square of the period of revolution is a constant for all objects in the solar system. This law was discovered around 1600!

Scatterplots

A scatterplot is a useful graph for analyzing two-variable data. Press (↰)(2D/3D) to go to the PLOT SETUP screen, highlight the Type field, press CHOOS, and select Scatter. (The contents of the ΣDATA field should contain your planet data.)

You specify the independent and dependent variables in the Cols field. The first number identifies the column to plotted by the horizontal axis—the independent variable—set this to 1. Set the second number to 2, which will plot the second column of ΣDAT by the vertical axis—the dependent variable. Make sure that H-Tick and V-Tick are set to 10 pixels, then press (ENTER) to save all these settings.

Now press (↰)(WIN) and enter the following values to match the data:

H-View: 0 250
V-View: -5 40

Press ERASE DRAW to generate the scatterplot.... Notice that one of the menu items beneath the scatterplot is STATL. Pressing this will superimpose a "perfect-fit" curve for the current model. All of the options available in a function plot, such as tracing, root finding etc. can now be applied to this curve. (Bear in mind that if you use any of these options, the plot type is actually changed to Function, and the current model expression is placed in EQ.)

Press (CANCEL) to return to the PLOT WINDOW screen, then (CANCEL) again to get back to the stack.

Inferential Statistics

The HP 49G offers two types of inferential statistics: confidence intervals and hypothesis testing. In either case, you have the following six options:

Z-statistic, 1 μ	For inference about the mean of a population of known standard deviation (σ_{pop}).
Z-statistic, $\mu_1 - \mu_2$	For inference comparing the means of two populations with known σ_{pop}'s.
Z-statistic, 1 P	For inference about a single population proportion.
Z-statistic, 1 $P_1 - P_2$	For inference comparing two population proportions.
T-statistic, 1 μ	For inference about the mean of a population of unknown σ_{pop}.
T-statistic, $\mu_1 - \mu_2$	For inference comparing the means of two populations with unknown σ_{pop}'s.

Hypothesis Testing

Suppose that you toss a coin 10,000 times and it comes up heads 5072 times. You suspect that the coin may be biased toward landing on heads. Test this hypothesis at the $\alpha = 0.05$ level. Press ⮣STAT and choose the `Hypoth. tests..` option.

Then, since you're testing a single proportion, select `Z-test, 1 P`. Input these settings:

$H_0 = .5$
$x = 5072$
$n = 10000$
$\alpha = 0.05$

Press **OK**, this brings up the Alternative Hypothesis choose box. Select the $n > .5$ option and press **OK**. The calculator will display the results of this test: Accept H_0, along with some details such as the z-score associated with this proportion, the P-value of the test, the critical z-score, and the critical x-value that marks the boundary of the reject region.

Press **GRAPH** to see a graphical display of this test result with the reject region identified.

Press **HELP** for a general description of this hypothesis testing procedure.

Confidence Intervals

A manufacturer of laundry detergent packages the detergent in 5-pound boxes. To check the filling machine, they took a sample of 1219 boxes and weighed them. The average weight of this sample was 5.05 pounds, and the sample standard deviation was 0.02 pounds. What is the 99% confidence interval for the population mean weight of the boxes?

Press [→][STAT] and choose **Conf. Interval**. Then, since you want a confidence interval for a single population mean, and you have only a sample standard deviation to work with, select the **T-Int, 1 μ** option.

Now input these settings:

$\bar{x} = 5.02$
$s_x = .02$
$n = 1219$
$C = .99$

Press **OK**. The 99% confidence interval for the population mean will be displayed.

Press **GRAPH** to see a graphical display of this confidence intervaL

Press **HELP** for a general description of this confidence interval procedure.