HP 40gs graphing calculator

user's guide

Edition1
Part Number F2225AA-90001

Notice

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Preface

The HP 40gs is a feature-rich graphing calculator. It is also a powerful mathematics learning tool, with a built-in computer algebra system (CAS). The HP 40gs is designed so that you can use it to explore mathematical functions and their properties.

You can get more information on the HP 40gs from Hewlett-Packard’s Calculators web site. You can download customized aplets from the web site and load them onto your calculator. Customized aplets are special applications developed to perform certain functions, and to demonstrate mathematical concepts.

Hewlett Packard’s Calculators web site can be found at:

http://www.hp.com/calculators

Manual conventions

The following conventions are used in this manual to represent the keys that you press and the menu options that you choose to perform the described operations.

- Key presses are represented as follows:

  SIN, COS, HOME, etc.

- Shift keys, that is the key functions that you access by pressing the SHIFT key first, are represented as follows:

  SHIFT *CLEAR*, SHIFT *MODES*, SHIFT *ACOS*, etc.

- Numbers and letters are represented normally, as follows:

  5, 7, A, B, etc.

- Menu options, that is, the functions that you select using the menu keys at the top of the keypad are represented as follows:

  STO▶, CANCL, OK.

- Input form fields and choose list items are represented as follows:

  `Function`, `Polar`, `Parametric`

- Your entries as they appear on the command line or within input forms are represented as follows:

  $2*X^{2}-3X+5$

Notice

1

Getting started

On/off, cancel operations

To turn on

Press [ON] to turn on the calculator.

To cancel

When the calculator is on, the [ON] key cancels the current operation.

To turn off

Press [SHIFT] *OFF* to turn the calculator off.

To save power, the calculator turns itself off after several minutes of inactivity. All stored and displayed information is saved.

If you see the ((•)) annunciator or the `Low Bat` message, then the calculator needs fresh batteries.

HOME

HOME is the calculator’s home view and is common to all aplets. If you want to perform calculations, or you want to quit the current activity (such as an aplet, a program, or an editor), press [HOME] . All mathematical functions are available in the HOME. The name of the current aplet is displayed in the title of the home view.

Protective cover

The calculator is provided with a slide cover to protect the display and keyboard. Remove the cover by grasping both sides of it and pulling down.

You can reverse the slide cover and slide it onto the back of the calculator. this will help prevent you losing the cover while you are using the calculator.

To prolong the life of the calculator, always place the cover over the display and keyboard when you are not using the calculator.

The display

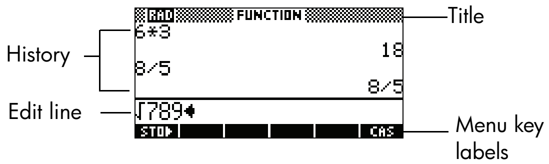
To adjust the contrast

Simultaneously press [ON] and [+] (or [-]) to increase (or decrease) the contrast.

To clear the display

- Press *CANCEL* to clear the edit line.
- Press [SHIFT] *CLEAR* to clear the edit line and the display history.

Parts of the display



Menu key or **soft key labels.** The labels for the menu keys' current meanings. STO▸ is the label for the first menu key in this picture. "Press STO▸ " means to press the first menu key, that is, the leftmost top-row key on the calculator keyboard.

Edit line. The line of current entry.

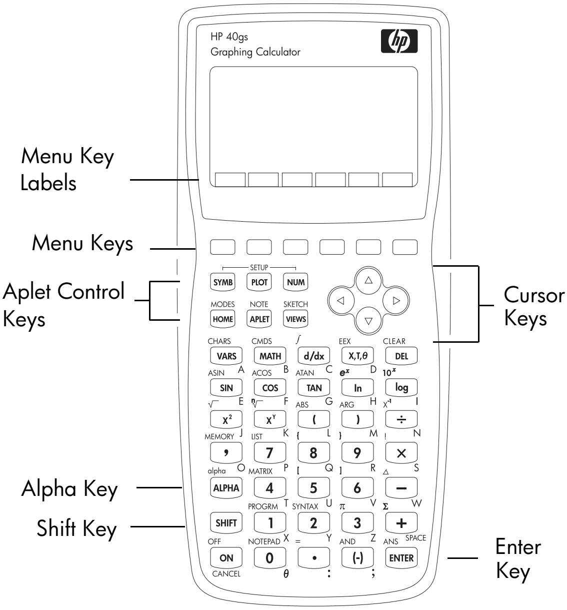
History. The HOME display ([HOME]) shows up to four lines of history: the most recent input and output. Older lines scroll off the top of the display but are retained in memory.

Title. The name of the current aplet is displayed at the top of the HOME view. RAD, GRD, DEG specify whether Radians, Grads or Degrees angle mode is set for HOME. The ▼ and ▲ symbols indicate whether there is more history in the HOME display. Press the [▼] and [▲] to scroll in the HOME display.

Annunciators. Annunciators are symbols that appear above the title bar and give you important status information.

Annunciator	Description
	Shift in effect for next keystroke. To cancel, press SHIFT again.
α	Alpha in effect for next keystroke. To cancel, press ALPHA again.
((•))	Low battery power.
	Busy.
	Data is being transferred.

The keyboard



Menu keys

- On the calculator keyboard, the top row of keys are called menu keys. Their meanings depend on the context—that's why they are blank. The menu keys are sometimes called "soft keys".
- The bottom line of the display shows the labels for the menu keys' current meanings.

Aplet control keys

The aplet control keys are:

Key	**Meaning**
SYMB	Displays the Symbolic view for the current aplet. See "Symbolic view" on page 1-16.
PLOT	Displays the Plot view for the current aplet. See "Plot view" on page 1-16.
NUM	Displays the Numeric view for the current aplet. See "Numeric view" on page 1-17.
HOME	Displays the HOME view. See "HOME" on page 1-1.
APLET	Displays the Aplet Library menu. See "Aplet library" on page 1-16.
VIEWS	Displays the VIEWS menu. See "Aplet views" on page 1-16.

Entry/Edit keys

The entry and edit keys are:

Key	Meaning
[ON] (*CANCEL*)	Cancels the current operation if the calculator is on by pressing [ON]. Pressing [SHIFT], then *OFF* turns the calculator off.
[SHIFT]	Accesses the function printed in blue above a key.
[HOME]	Returns to the HOME view, for performing calculations.
[ALPHA]	Accesses the alphabetical characters printed in orange below a key. Hold down to enter a string of characters.
[ENTER]	Enters an input or executes an operation. In calculations, [ENTER] acts like "=". When OK or START is present as a menu key, [ENTER] acts the same as pressing OK or START.
[(-)]	Enters a negative number. To enter –25, press [(-)] 25. *Note: this is not the same operation that the subtract button performs* ([-]).
[X,T,θ]	Enters the independent variable by inserting *X*, *T*, θ, or *N* into the edit line, depending on the current active aplet.
[DEL]	Deletes the character under the cursor. Acts as a backspace key if the cursor is at the end of the line.
[SHIFT] *CLEAR*	Clears all data on the screen. On a settings screen, for example Plot Setup, [SHIFT] *CLEAR* returns all settings to their default values.
[◄], [►], [▲], [▼]	Moves the cursor around the display. Press [SHIFT] first to move to the beginning, end, top or bottom.

Key	Meaning (Continued)
[SHIFT] *CHARS*	Displays a menu of all available characters. To type one, use the arrow keys to highlight it, and press OK . To select multiple characters, select each and press ECHO , then press OK .

Shifted keystrokes

There are two shift keys that you use to access the operations and characters printed above the keys: [SHIFT] and [ALPHA] .

Key	Description
[SHIFT]	Press the [SHIFT] key to access the operations printed in blue above the keys. For instance, to access the Modes screen, press [SHIFT], then press [HOME] . (*MODES* is labeled in blue above the [HOME] key). You do not need to hold down [SHIFT] when you press HOME. This action is depicted in this manual as "press [SHIFT] *MODES*." To cancel a shift, press [SHIFT] again.
[ALPHA]	The alphabetic keys are also shifted keystrokes. For instance, to type Z, press [ALPHA] Z. (The letters are printed in orange to the lower right of each key.) To cancel Alpha, press [ALPHA] again. For a lower case letter, press [SHIFT] [ALPHA] . For a string of letters, hold down [ALPHA] while typing.

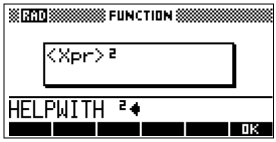
HELPWITH

The HP 40gs built-in help is available in HOME only. It provides syntax help for built-in math functions.

Access the HELPWITH command by pressing [SHIFT] *SYNTAX* and then the math key for which you require syntax help.

Example

Press [SHIFT] *SYNTAX* [X^2] [ENTER]



Note: Remove the left parenthesis from built-in functions such as sine, cosine, and tangent before invoking the HELPWITH command.

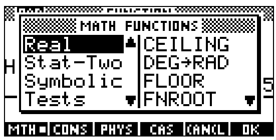
Note: In the CAS system, pressing the [SHIFT] SYNTAX will show the CAS help menu.

Math keys

HOME ([HOME]) is the place to do non-symbolic calculations. (For symbolic calculations, use the computer algebra system, referred throughout this manual as CAS).

Keyboard keys. The most common operations are available from the keyboard, such as the arithmetic (like [+]) and trigonometric (like [SIN]) functions. Press [ENTER] to complete the operation: [SHIFT] √‾ 256 [ENTER] displays 16.

MATH menu. Press [MATH] to open the MATH menu. The MATH menu is a comprehensive list of math functions that do not appear on the keyboard. It also includes categories for all other functions and constants. The functions are grouped by category, ranging in alphabetical order from Calculus to Trigonometry.



- The arrow keys scroll through the list ([▼], [▲]) and move from the category list in the left column to the item list in the right column ([◄], [►]).
- Press **OK** to insert the selected command onto the edit line.
- Press **CANCL** to dismiss the MATH menu without selecting a command.

- Pressing **CONS** displays the list of Program Constants. You can use these in programs that you develop.
- Pressing **PHYS** displays a menu of physical constants from the fields of chemistry, physics, and quantum mechanics. You can use these constants in calculations. (pSee “Physical constants” on page 13-25 for more information.)
- Pressing **MTH** takes you to the beginning of the MATH menu.

See “Math functions by category” on page 13-2 for details of the math functions.

HINT When using the MATH menu, or any menu on the HP 40gs, pressing an alpha key takes you straight to the first menu option beginning with that alpha character. With this method, you do not need to press [ALPHA] first. Just press the key that corresponds to the command’s beginning alpha character.

Note that when the MATH menu is open, you can also access CAS commands. You do this by pressing **CAS** . This enables you to use CAS commands on the HOME screen, without opening CAS. See Chapter 14 for details of CAS commands.

Program commands

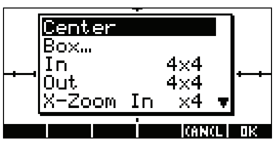
Pressing [SHIFT] *CMDS* displays the list of Program Commands. See “Programming commands” on page 21-13.

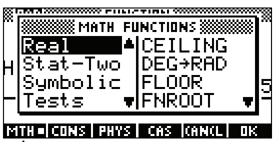
Inactive keys

If you press a key that does not operate in the current context, a warning symbol like this ⚠ appears. There is no beep.

Menus

A menu offers you a choice of items. Menus are displayed in one or two columns.





- The [▼] arrow in the display means more items below.
- The [▲] arrow in the display means more items above.

To search a menu

- Press [▼] or [▲] to scroll through the list. If you press [SHIFT] [▼] or [SHIFT] [▲], you'll go all the way to the end or the beginning of the list. Highlight the item you want to select, then press **OK** (or [ENTER]).
- If there are two columns, the left column shows general categories and the right column shows specific contents within a category. Highlight a general category in the left column, then highlight an item in the right column. The list in the right column changes when a different category is highlighted.

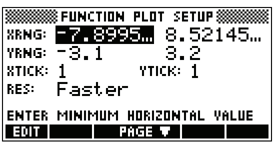
  Press **OK** or [ENTER] when you have highlighted your selection.
- To speed-search a list, type the first letter of the word. For example, to find the Matrix category in [MATH], press [)], the Alpha "M" key.
- To go up a page, you can press [SHIFT] [◄]. To go down a page, press [SHIFT] [►].

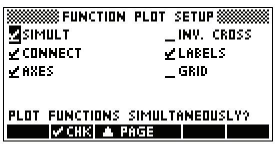
To cancel a menu

Press [ON] (for *CANCEL)* or **CANCL**. This cancels the current operation.

Input forms

An input form shows several fields of information for you to examine and specify. After highlighting the field to edit, you can enter or edit a number (or expression). You can also select options from a list (**CHOOS**). Some input forms include items to check (**✓CHK**). See below for examples input forms.





Reset input form values

To reset a field to its default values in an input form, move the cursor to that field and press [DEL]. To reset all default field values in the input form, press [SHIFT] *CLEAR*.

Mode settings

You use the Modes input form to set the modes for HOME.

HINT Although the numeric setting in Modes affects only HOME, the angle setting controls HOME and the current aplet. The angle setting selected in Modes is the angle setting used in both HOME and current aplet. To further configure an aplet, you use the *SETUP* keys ([SHIFT] [PLOT] and [SHIFT] [NUM]).

Press [SHIFT] *MODES* to access the HOME MODES input form.

Setting	Options
Angle Measure	Angle values are: **Degrees**. 360 degrees in a circle. **Radians**. 2π radians in a circle. **Grads**. 400 grads in a circle. The angle mode you set is the angle setting used in both HOME and the current aplet. This is done to ensure that trigonometric calculations done in the current aplet and HOME give the same result.
Number Format	The number format mode you set is the number format used in both HOME and the current aplet. **Standard**. Full-precision display. **Fixed**. Displays results rounded to a number of decimal places. Example: 123.456789 becomes 123.46 in Fixed 2 format. **Scientific**. Displays results with an exponent, one digit to the left of the decimal point, and the specified number of decimal places. Example: 123.456789 becomes 1.23E2 in Scientific 2 format.

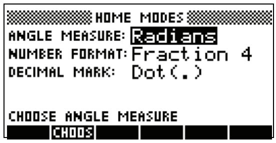
Setting	Options (Continued)
	Engineering. Displays result with an exponent that is a multiple of 3, and the specified number of significant digits beyond the first one. Example: 123.456E7 becomes 1.23E9 in Engineering 2 format.
	Fraction. Displays results as fractions based on the specified number of decimal places. Examples: 123.456789 becomes 123 in Fraction 2 format, and .333 becomes 1/3 and 0.142857 becomes 1/7. See "Using fractions" on page 1-25.
	Mixed Fraction. Displays results as mixed fractions based on the specified number of decimal places. A mixed fraction has an integer part and a fractional part. Examples: 123.456789 becomes 123+16/35 in Fraction 2 format, and 7÷ 3 returns 2+1/3. See "Using fractions" on page 1-25.
Decimal Mark	**Dot** or **Comma**. Displays a number as 12456.98 (Dot mode) or as 12456,98 (Comma mode). Dot mode uses commas to separate elements in lists and matrices, and to separate function arguments. Comma mode uses periods (dot) as separators in these contexts.

Setting a mode

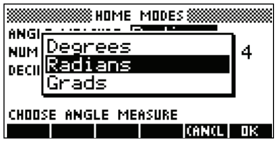
This example demonstrates how to change the angle measure from the default mode, radians, to degrees for the current aplet. The procedure is the same for changing number format and decimal mark modes.

1. Press [SHIFT] *MODES* to open the HOME MODES input form.

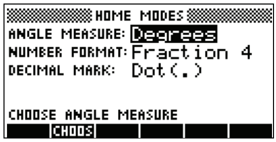
The cursor (highlight) is in the first field, Angle Measure.



2. Press CHOOS to display a list of choices.



3. Press ▲ to select `Degrees`, and press OK. The angle measure changes to degrees.



4. Press HOME to return to HOME.

HINT Whenever an input form has a list of choices for a field, you can press + to cycle through them instead of using CHOOS.

Aplets (E-lessons)

Aplets are the application environments where you explore different classes of mathematical operations. You select the aplet that you want to work with.

Aplets come from a variety of sources:

- Built-in the HP 40gs (initial purchase).
- Aplets created by saving existing aplets, which have been modified, with specific configurations. See "Creating new aplets based on existing aplets" on page 22-1.
- Downloaded from HP's Calculators web site.
- Copied from another calculator.

Aplets are stored in the Aplet library. See "Aplet library" on page 1-16 for further information.

You can modify configuration settings for the graphical, tabular, and symbolic views of the aplets in the following table. See "Aplet view configuration" on page 1-18 for further information.

Aplet name	**Use this aplet to explore:**
Function	Real-valued, rectangular functions *y* in terms of *x*. Example: $y = 2x^2 + 3x + 5$.
Inference	Confidence intervals and Hypothesis tests based on the Normal and Students-t distributions.
Parametric	Parametric relations *x* and *y* in terms of *t*. Example: *x* = cos(*t*) and *y* = sin(*t*).
Polar	Polar functions *r* in terms of an angle θ. Example: $r = 2\cos(4\theta)$.
Sequence	Sequence functions *U* in terms of *n*, or in terms of previous terms in the same or another sequence, such as U_{n-1} and U_{n-2}. Example: $U_1 = 0$, $U_2 = 1$ and $U_n = U_{n-2} + U_{n-1}$.
Solve	Equations in one or more real-valued variables. Example: $x + 1 = x^2 - x - 2$.
Finance	Time Value of Money (TVM) calculations.
Linear Solver	Solutions to sets of two or three linear equations.
Triangle Solver	Unknown values for the lengths and angles of triangles.
Statistics	One-variable (*x*) or two-variable (*x* and *y*) statistical data.

In addition to these aplets, which can be used in a variety of applications, the HP 40gs is supplied with two teaching aplets: Quad Explorer and Trig Explorer. You cannot modify configuration settings for these aplets.

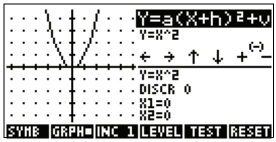
A great many more teaching aplets can be found at HP's web site and other web sites created by educators, together with accompanying documentation, often with student work sheets. These can be downloaded free of charge and transferred to the HP 40gs using the provided Connectivity Kit.

Quad Explorer aplet

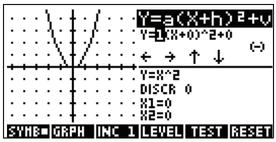
The **Quad Explorer** aplet is used to investigate the behaviour of $y = a(x+h)^2 + v$ as the values of *a*, *h* and *v* change, both by manipulating the equation and seeing the change in the graph, *and* by manipulating the graph and seeing the change in the equation.

HINT More detailed documentation, and an accompanying student work sheet can be found at HP's web site.

Press [APLET], select `Quad Explorer`, and then press **START**. The Quad Explorer aplet opens in **GRAPH■** mode, in which the arrow keys, the [+] and [-] keys, and the [(-)] key are used to change the shape of the graph. This changing shape is reflected in the equation displayed at the top right corner of the screen, while the original graph is retained for comparison. In this mode the graph controls the equation.



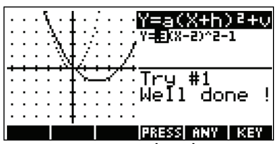
It is also possible to have the equation control the graph. Pressing **SYMB** displays a sub-expression of your equation.



Pressing the [▶] and [◀] key moves between sub-expressions, while pressing the [▲] and [▼] key changes their values.

Pressing **LEVEL** allows the user to select whether all three sub-expressions will be explored at once or only one at a time.

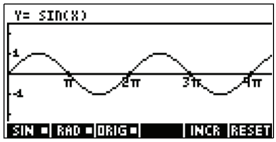
A **TEST** button is provided to evaluate the student's knowledge. Pressing **TEST** displays a target quadratic graph. The student must manipulate the equation's parameters to make the equation match the target graph. When a student feels that they have correctly chosen the parameters a **CHECK** button evaluates the answer and provide feedback. An **ANSW** button is provided for those who give up!



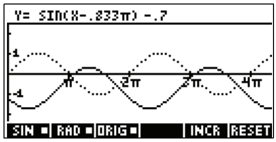
Trig Explorer aplet

The **Trig Explorer** aplet is used to investigate the behaviour of the graph of $y = a\sin(bx + c) + d$ as the values of *a*, *b*, *c* and *d* change, both by manipulating the equation and seeing the change in the graph, or by manipulating the graph and seeing the change in the equation.

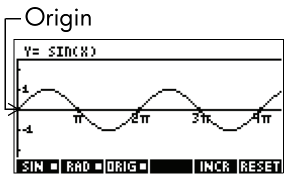
Press APLET , select `Trig Explorer`, and then press START to display the screen shown right.



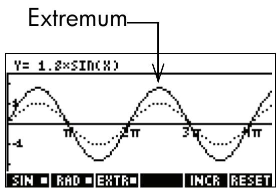
In this mode, the graph controls the equation. Pressing the ▲ ▼ and ◄ ► keys transforms the graph, with these transformations reflected in the equation.



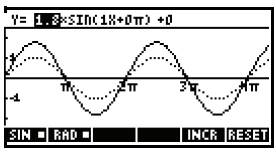
The button labelled ORIG is a toggle between ORIG and EXTR. When ORIG is chosen, the 'point of control' is at the origin (0,0) and the ▲ ▼ and ◄ ► keys control vertical and horizontal transformations. When EXTR is chosen the 'point of control' is on the first extremum of the graph (i.e. for the sine graph at $(\pi/2, 1)$.



The arrow keys change the amplitude and frequency of the graph. This is most easily seen by experimenting.



Pressing SYMB displays the equation at the top of the screen. The equation is controlled by the graph. Pressing the ► and ◄ keys moves from parameter to parameter. Pressing the ▲ or ▼ key changes the parameter's values.



The default angle setting for this aplet is radians. The angle setting can be changed to degrees by pressing RAD.

Aplet library

Aplets are stored in the Aplet library.

To open an aplet

Press APLET to display the Aplet library menu. Select the aplet and press START or ENTER.

From within an aplet, you can return to HOME any time by pressing HOME.

Aplet views

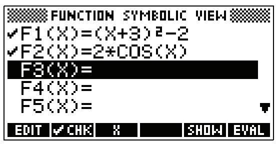
When you have configured an aplet to define the relation or data that you want to explore, you can display it in different views. Here are illustrations of the three major aplet views (Symbolic, Plot, and Numeric), the six supporting aplet views (from the VIEWS menu), and the two user-defined views (Note and Sketch).

Note: some aplets—such as the Linear Solver aplet and the Triangle Solver aplet—only have a single view, the Numeric view.

Symbolic view

Press SYMB to display the aplet's Symbolic view.

You use this view to define the function(s) or equation(s) that you want to explore.

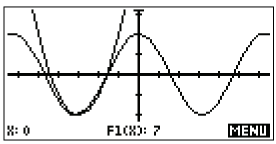


See "About the Symbolic view" on page 2-1 for further information.

Plot view

Press PLOT to display the aplet's Plot view.

In this view, the functions that you have defined are displayed graphically.

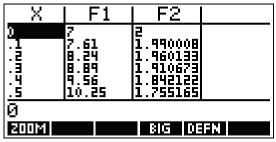


See "About the Plot view" on page 2-5 for further information.

Numeric view

Press [NUM] to display the aplet's Numeric view.

In this view, the functions that you have defined are displayed in tabular format.



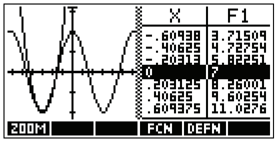
See "About the numeric view" on page 2-16 for further information.

Plot-Table view

The VIEWS menu contains the Plot-Table view.

[VIEWS]

Select `Plot-Table` OK



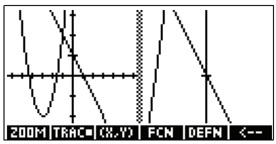
Splits the screen into the plot and the data table. See "Other views for scaling and splitting the graph" on page 2-13 for futher information.

Plot-Detail view

The VIEWS menu contains the Plot-Detail view.

[VIEWS]

Select `Plot-Detail` OK



Splits the screen into the plot and a close-up.

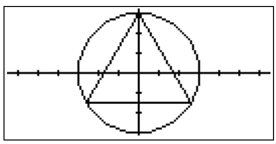
See "Other views for scaling and splitting the graph" on page 2-13 for further information.

Overlay Plot view

The VIEWS menu contains the Overlay Plot view.

[VIEWS]

Select `Overlay Plot` OK



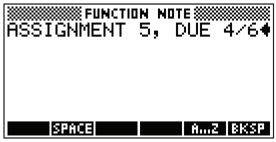
Plots the current expression(s) *without* erasing any pre-existing plot(s).

See "Other views for scaling and splitting the graph" on page 2-13 for further information.

Note view

Press [SHIFT] *NOTE* to display the aplet's note view.

This note is transferred with the aplet if it is sent to another calculator or to a PC. A note view contains text to supplement an aplet.



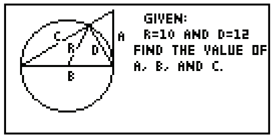
See "Notes and sketches" on page 20-1 for further information.

Sketch view

Press [SHIFT] *SKETCH* to display the aplet's sketch view.

Displays pictures to supplement an aplet.

See "Notes and sketches" on page 20-1 for further information.

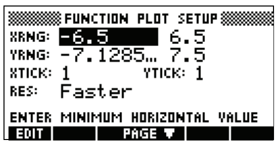


Aplet view configuration

You use the *SETUP* keys ([SHIFT] [PLOT], and [SHIFT] [NUM]) to configure the aplet. For example, press [SHIFT] *SETUP-PLOT* ([SHIFT] [PLOT]) to display the input form for setting the aplet's plot settings. Angle measure is controlled using the *MODES* view.

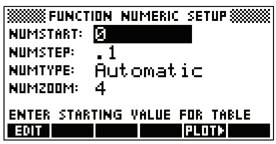
Plot Setup

Press [SHIFT] *SETUP-PLOT*. Sets parameters to plot a graph.



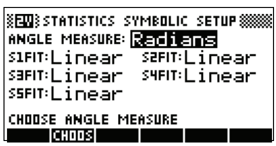
Numeric Setup

Press [SHIFT] *SETUP-NUM*. Sets parameters for building a table of numeric values.



Symbolic Setup

This view is only available in the Statistics aplet in 2VAR mode, where it plays an important role in choosing data models.
Press [SHIFT] *SETUP-SYMB*.



To change views

Each view is a separate environment. To change a view, select a different view by pressing SYMB , NUM , PLOT keys or select a view from the VIEWS menu. To change to HOME, press HOME . You do not explicitly close the current view, you just enter another one—like passing from one room into another in a house. Data that you enter is automatically saved as you enter it.

To save aplet configuration

You can save an aplet configuration that you have used, and transfer the aplet to other HP 40gs calculators. See "Creating new aplets based on existing aplets" on page 22-1.

Mathematical calculations

The most commonly used math operations are available from the keyboard. Access to other math functions is via the MATH menu (MATH). You can also CAS for symbolic calculations. See "Computer Algebra System (CAS)" on page 14-1 for further information.

To access programming commands, press SHIFT *CMDS*. See "Programming commands" on page 21-13 for further information.

Where to start

The home base for the calculator is the HOME view (HOME). You can do all non-symbolic calculations here, and you can access all MATH operations. (Symbolic calculations are done using CAS.)

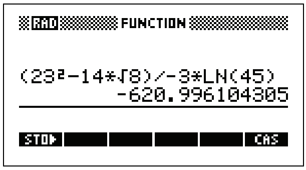
Entering expressions

- In the HOME view, you enter an expression in the same left-to-right order that you would write the expression. This is called *algebraic entry*. (In CAS you enter expressions using the Equation Writer, explained in detail in Chapter 15, "Equation Writer".)
- To enter functions, select the key or MATH menu item for that function. You can also enter a function by using the Alpha keys to spell out its name.
- Press ENTER to evaluate the expression you have in the edit line (where the blinking cursor is). An *expression* can contain numbers, functions, and variables.

Example

Calculate $\frac{23^2 - 14\sqrt{8}}{-3}\ln(45)$:

[(] 23 [X²]
[–] 14
[×] [SHIFT] √‾ 8 [)]
[÷] [(-)] 3 [×]
[ln] 45 [)]
[ENTER]



Long results

If the result is too long to fit on the display line, or if you want to see an expression in textbook format, press [▲] to highlight it and then press SHOW .

Negative numbers

Type [(-)] to start a negative number or to insert a negative sign.

To raise a negative number to a power, enclose it in parentheses. For example, $(–5)^2 = 25$, whereas $–5^2 = –25$.

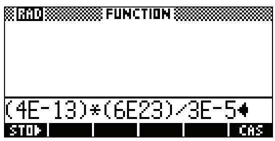
Scientific notation (powers of 10)

A number like 5×10^4 or 3.21×10^{-7} is written in *scientific notation*, that is, in terms of powers of ten. This is simpler to work with than 50000 or 0.000000321. To enter numbers like these, use *EEX*. (This is easier than using [×] 10 [X²] .)

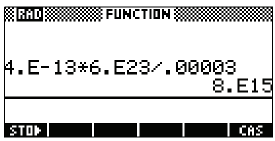
Example

Calculate $\frac{(4 \times 10^{-13})(6 \times 10^{23})}{3 \times 10^{-5}}$

[(] 4 [SHIFT] *EEX*
[(-)] 13 [)]
[×] [(] 6 [SHIFT] *EEX*
23 [)] [÷] 3 [SHIFT] *EEX*
[(-)] 5



[ENTER]



Explicit and implicit multiplication

Implied multiplication takes place when two operands appear with no operator in between. If you enter AB, for example, the result is A*B.

However, for clarity, it is better to include the multiplication sign where you expect multiplication in an expression. It is clearest to enter `AB` as `A*B`.

HINT Implied multiplication will not always work as expected. For example, entering `A(B+4)` will not give `A*(B+4)`. Instead an error message is displayed: "Invalid User Function". This is because the calculator interprets `A(B+4)` as meaning 'evaluate function `A` at the value `B+4`', and function `A` does not exist. When in doubt, insert the * sign manually.

Parentheses

You need to use parentheses to enclose arguments for functions, such as SIN(45). You can omit the final parenthesis at the end of an edit line. The calculator inserts it automatically.

Parentheses are also important in specifying the order of operation. *Without* parentheses, the HP 40gs calculates according to the order of *algebraic precedence* (the next topic). Following are some examples using parentheses.

Entering...	**Calculates...**
[SIN] 45 [+] [SHIFT] π	sin (45 + π)
[SIN] 45 [)] [+] [SHIFT] π	sin (45) + π
[SHIFT] √ 85 [×] 9	$\sqrt{85} \times 9$
[SHIFT] √ [(] 85 [×] 9 [)]	$\sqrt{85 \times 9}$

Algebraic precedence order of evaluation

Functions within an expression are evaluated in the following order of precedence. Functions with the same precedence are evaluated in order from left to right.

1. Expressions within parentheses. Nested parentheses are evaluated from inner to outer.
2. Prefix functions, such as SIN and LOG.
3. Postfix functions, such as !
4. Power function, ^, NTHROOT.
5. Negation, multiplication, and division.
6. Addition and subtraction.
7. AND and NOT.
8. OR and XOR.
9. Left argument of | (where).
10. Equals, =.

Largest and smallest numbers

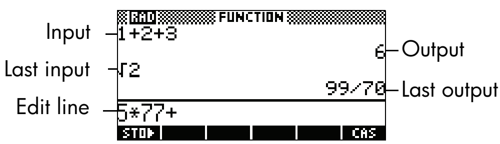
The smallest number the HP 40gs can represent is 1×10^{-499}(1E–499). A smaller result is displayed as zero. The largest number is $9.99999999999 \times 10^{499}$ (1E499). A greater result is displayed as this number.

Clearing numbers

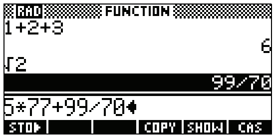
- DEL clears the character under the cursor. When the cursor is positioned after the last character, DEL deletes the character to the left of the cursor, that is, it performs the same as a backspace key.
- *CANCEL* (ON) clears the edit line.
- SHIFT *CLEAR* clears all input and output in the display, including the display history.

Using previous results

The HOME display (HOME) shows you four lines of input/output history. An unlimited (except by memory) number of previous lines can be displayed by scrolling. You can retrieve and reuse any of these values or expressions.



When you highlight a previous input or result (by pressing ▲), the COPY and SHOW menu labels appear.



To copy a previous line

Highlight the line (press ▲) and press COPY. The number (or expression) is copied into the edit line.

To reuse the last result

Press SHIFT *ANS* (last answer) to put the last result from the HOME display into an expression. *ANS* is a variable that is updated each time you press ENTER.

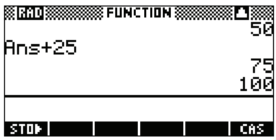
To repeat a previous line

To repeat the very last line, just press ENTER. Otherwise, highlight the line (press ▲) first, and then press ENTER. The highlighted expression or number is re-entered. If the previous line is an expression containing the *ANS*, the calculation is repeated iteratively.

Example

See how SHIFT *ANS* retrieves and reuses the last result (50), and ENTER updates *ANS* (from 50 to 75 to 100).

50 ENTER + 25
ENTER ENTER



You can use the last result as the first expression in the edit line without pressing SHIFT *ANS*. Pressing +, -, (-), or ÷, (or other operators that require a preceding argument) automatically enters *ANS* before the operator.

You can reuse any other expression or value in the HOME display by highlighting the expression (using the arrow keys), then pressing COPY. See "Using previous results" on page 1-22 for more details.

The variable *ANS* is different from the numbers in HOME's display history. A value in *ANS* is stored internally with the full precision of the calculated result, whereas the displayed numbers match the display mode.

HINT When you retrieve a number from *ANS*, you obtain the result to its full precision. When you retrieve a number from the HOME's display history, you obtain exactly what was displayed.

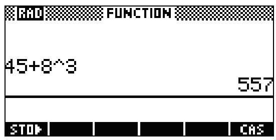
Pressing ENTER evaluates (or re-evaluates) the last input, whereas pressing SHIFT *ANS* copies the last result (as *ANS*) into the edit line.

Storing a value in a variable

You can save an answer in a variable and use the variable in later calculations. There are 27 variables available for storing real values. These are *A* to *Z* and θ. See Chapter 17, "Variables and memory management" for more information on variables. For example:

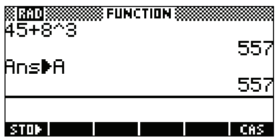
1. Perform a calculation.

   45 + 8 X^Y 3
   ENTER



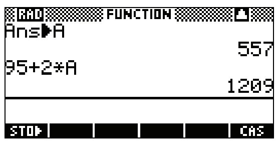
2. Store the result in the *A* variable.

   STO▶ ALPHA A
   ENTER



3. Perform another calculation using the *A* variable.

   95 + 2 × ALPHA A
   ENTER



Accessing the display history

Pressing ▲ enables the highlight bar in the display history. While the highlight bar is active, the following menu and keyboard keys are very useful:

Key	Function
▲, ▼	Scrolls through the display history.
COPY	Copies the highlighted expression to the position of the cursor in the edit line.
SHOW	Displays the current expression in standard mathematical form.
DEL	Deletes the highlighted expression from the display history, unless there is a cursor in the edit line.
SHIFT *CLEAR*	Clears all lines of display history and the edit line.

Clearing the display history

It's a good habit to clear the display history (SHIFT *CLEAR*) whenever you have finished working in HOME. It saves calculator memory to clear the display history. Remember that *all* your previous inputs and results are saved until you clear them.

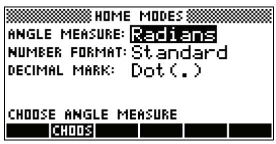
Using fractions

To work with fractions in HOME, you set the number format to `Fraction` or `Mixed Fraction`, as follows:

Setting Fraction mode

1. In HOME, open the HOME MODES input form.

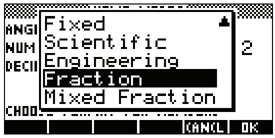
   SHIFT *MODES*



2. Select `Number Format`, press CHOOS to display the options, and highlight `Fraction` or `Mixed Fraction`.

   CHOOS

   ▼ ▼ ▼ ▼



3. Press OK to select the Number Format option, then move to the precision value field.

   OK ▶

4. Enter the precision value that you want to use, and press OK to set the precision. Press HOME to return to HOME.

   See “Setting fraction precision” below for more information.

Setting fraction precision

The fraction precision setting determines the precision in which the HP 40gs converts a decimal value to a fraction. The greater the precision value that is set, the closer the fraction is to the decimal value.

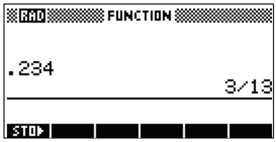
By choosing a precision of 1 you are saying that the fraction only has to match 0.234 to at least 1 decimal place (3/13 is 0.23076...).

The fractions used are found using the technique of continued fractions.

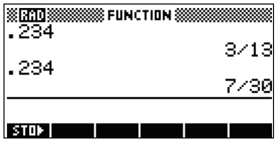
When converting recurring decimals this can be important. For example, at precision 6 the decimal 0.6666 becomes 3333/5000 (6666/10000) whereas at precision 3, 0.6666 becomes 2/3, which is probably what you would want.

For example, when converting .234 to a fraction, the precision value has the following effect:

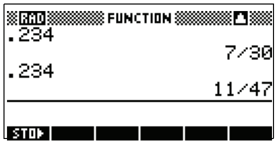
- Precision set to 1:



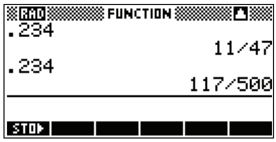
- Precision set to 2:



- Precision set to 3:



- Precision set to 4



Fraction calculations

When entering fractions:

- You use the [÷] key to separate the numerator part and the denominator part of the fraction.
- To enter a mixed fraction, for example, $1\,{}^1/_2$, you enter it in the format $(1+{}^1/_2)$.

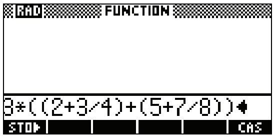
For example, to perform the following calculation:

$3(2\,{}^3/_4 + 5\,{}^7/_8)$

1. Set the Number format mode to `Fraction` or `Mixed Fraction` and specify a precision value of 4. In this example, we'll select `Fraction` as our format.)

   [SHIFT] *MODES* [▼]
   CHOOS *Select* `Fraction`
   [ENTER] [►] 4 OK

2. Enter the calculation.



3 [×] [(] [(] 2 [+] 3 [÷] 4 [)] [+] [(] 5 [+] 7 [÷] 8 [)] [)]

Note: Ensure you are in the HOME view.

3. Evaluate the calculation.

[ENTER]

Note that if you had selected `Mixed Fraction` instead of `Fraction` as the Number format, the answer would have been expressed as 25+7/8.

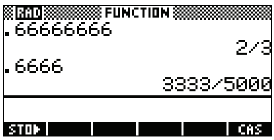
Converting decimals to fractions

To convert a decimal value to a fraction:

1. Set the number format mode to `Fraction` or `Mixed Fraction`.
2. Either retrieve the value from the History, or enter the value on the command line.
3. Press [ENTER] to convert the number to a fraction.

When converting a decimal to a fraction, keep the following points in mind:

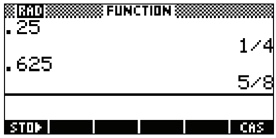
- When converting a recurring decimal to a fraction, set the fraction precision to about 6, and ensure that you include more than six decimal places in the recurring decimal that you enter.



In this example, the fraction precision is set to 6. The top calculation returns the correct result. The bottom one does not.

- To convert an exact decimal to a fraction, set the fraction precision to at least two more than the number of decimal places in the decimal.

In this example, the fraction precision is set to 6.



Complex numbers

Complex results

The HP 40gs can return a complex number as a result for some math functions. A complex number appears as an ordered pair (x, y), where x is the real part and y is the imaginary part. For example, entering $\sqrt{-1}$ returns (0,1).

To enter complex numbers

Enter the number in either of these forms, where x is the real part, y is the imaginary part, and i is the imaginary constant, $\sqrt{-1}$:

- (x, y) or
- $x + iy$.

To enter *i*:

- press [SHIFT] [ALPHA] [I]

  or

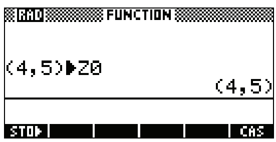
- press [MATH], [▲] or [▼] keys to select `Constant`, [▶] to move to the right column of the menu, [▼] to select `i`, and OK .

Storing complex numbers

There are 10 variables available for storing complex numbers: Z0 to Z9. To store a complex number in a variable:

- Enter the complex number, press STO▸ , enter the variable to store the number in, and press [ENTER] .

[(]4[,]5[)] STO▸
[ALPHA] Z 0 [ENTER]



Catalogs and editors

The HP 40gs has several catalogs and editors. You use them to create and manipulate objects. They access features and stored values (numbers or text or other items) that are independent of aplets.

- A *catalog* lists items, which you can delete or transmit, for example an aplet.
- An *editor* lets you create or modify items and numbers, for example a note or a matrix.

Catalog/Editor	**Contents**
Aplet library ([APLET])	Aplets.
Sketch editor ([SHIFT] *SKETCH*)	Sketches and diagrams, See Chapter 20, "Notes and sketches".
List ([SHIFT] *LIST*)	Lists. In HOME, lists are enclosed in {}. See Chapter 19, "Lists".
Matrix ([SHIFT] *MATRIX*)	One- and two-dimensional arrays. In HOME, arrays are enclosed in []. See Chapter 18, "Matrices".
Notepad ([SHIFT] *NOTEPAD*)	Notes (short text entries). See Chapter 20, "Notes and sketches".
Program ([SHIFT] *PROGRM*)	Programs that you create, or associated with user-defined aplets. See Chapter 21, "Programming".
Equation Writer ([CAS])	The editor used for creating expressions and equations in CAS. See Chapter 15, "Equation Writer".

2

Aplets and their views

Aplet views

This section examines the options and functionality of the three main views for the Function, Polar, Parametric, and Sequence aplets: Symbolic, Plot, and Numeric views.

About the Symbolic view

The Symbolic view is the *defining view* for the Function, Parametric, Polar, and Sequence aplets. The other views are derived from the symbolic expression.

You can create up to 10 different definitions for each Function, Parametric, Polar, and Sequence aplet. You can graph any of the relations (in the same aplet) simultaneously by selecting them.

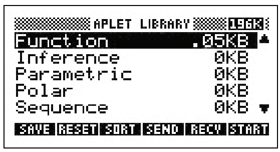
Defining an expression (Symbolic view)

Choose the aplet from the Aplet Library.

[APLET]

Press [▲] or [▼] to select an aplet.

START

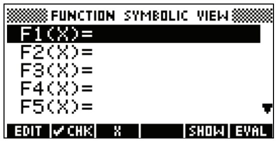


The Function, Parametric, Polar, and Sequence aplets start in the Symbolic view.

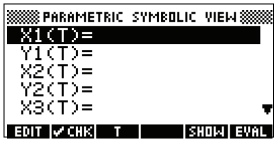
If the highlight is on an existing expression, scroll to an empty line—unless you don't mind writing over the expression—or, clear one line ([DEL]) or all lines ([SHIFT] *CLEAR*).

Expressions are selected (check marked) on entry. To deselect an expression, press ✔CHK. All selected expressions are plotted.

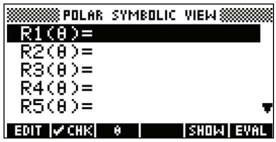
– **For a Function definition**, enter an expression to define *F(X)*. The only independent variable in the expression is *X*.



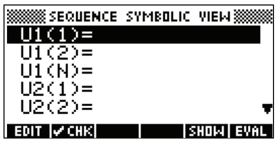
– **For a Parametric definition**, enter a pair of expressions to define *X(T)* and *Y(T)*. The only independent variable in the expressions is *T*.



– **For a Polar definition**, enter an expression to define *R*(θ). The only independent variable in the expression is θ.



– **For a Sequence definition**, either enter the first term, or the first and second terms, for *U* (*U1*, or...*U9, or U0*). Then define the *n*th term of the sequence in terms of *N* or of the prior terms, *U(N–1) and/or U(N–2)*. The expressions should produce real-valued sequences with integer domains. Or define the *n*th term as a non-recursive expression in terms of *n* only. In this case, the calculator inserts the first two terms based on the expression that you define.



– *Note*: You will have to enter the second term if the hp40gs is unable to calculate it automatically. Typically if Ux(N) depends on Ux(N–2) then you must enter Ux(2).

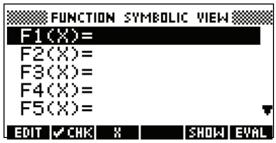
Evaluating expressions

In aplets

In the Symbolic view, a variable is a symbol only, and does not represent one specific value. To evaluate a function in Symbolic view, press EVAL . If a function calls another function, then EVAL resolves all references to other functions in terms of their independent variable.

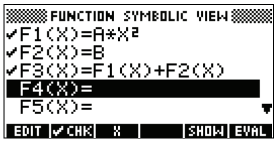
1. Choose the Function aplet.

   APLET
   Select `Function`
   START



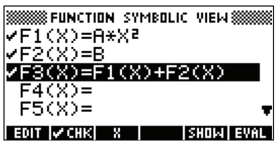
2. Enter the expressions in the Function aplet's Symbolic view.

   ALPHA A × X
   X^2 OK
   ALPHA B OK
   ALPHA F1 (X)
   +
   ALPHA F2 (X) OK



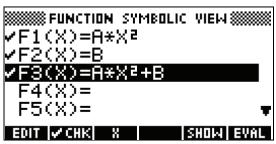
3. Highlight F3(X).

   ▲



4. Press EVAL

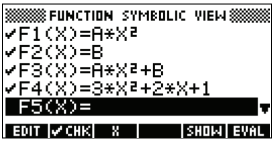
   Note how the values for F1(X) and F2(X) are substituted into F3(X).

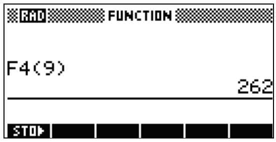


In HOME

You can also evaluate any expression in HOME by entering it into the edit line and pressing ENTER.

For example, define F4 as below. In HOME, type `F4(9)` and press ENTER. This evaluates the expression, substituting `9` in place of `X` into `F4`.





SYMB view keys

The following table details the menu keys that you use to work with the Symbolic view.

Key	Meaning
EDIT	Copies the highlighted expression to the edit line for editing. Press OK when done.
✓CHK	Checks/unchecks the current expression (or set of expressions). Only checked expression(s) are evaluated in the Plot and Numeric views.
X	Enters the independent variable in the Function aplet. Or, you can use the X,T,θ key on the keyboard.
T	Enters the independent variable in the Parametric aplet. Or, you can use the X,T,θ key on the keyboard.
θ	Enters the independent variable in the Polar aplet. Or, you can use the X,T,θ key on the keyboard.
N	Enters the independent variable in the Sequence aplet. Or, you can use the X,T,θ key on the keyboard.
SHOW	Displays the current expression in text book form.
EVAL	Resolves all references to other definitions in terms of variables and evaluates all arithmetic expressions.
VARS	Displays a menu for entering variable names or contents of variables.

Key	Meaning (Continued)
MATH	Displays the menu for entering math operations.
SHIFT *CHARS*	Displays special characters. To enter one, place the cursor on it and press OK. To remain in the CHARS menu and enter another special character, press ECHO.
DEL	Deletes the highlighted expression or the current character in the edit line.
SHIFT *CLEAR*	Deletes all expressions in the list or clears the edit line.

About the Plot view

After entering and selecting (check marking) the expression in the Symbolic view, press PLOT. To adjust the appearance of the graph or the interval that is displayed, you can change the Plot view settings.

You can plot up to ten expressions at the same time. Select the expressions you want to be plotted together.

Setting up the plot (Plot view setup)

Press SHIFT *SETUP-PLOT* to define any of the settings shown in the next two tables.

1. Highlight the field to edit.
   - If there is a number to enter, type it in and press ENTER or OK.
   - If there is an option to choose, press CHOOS, highlight your choice, and press ENTER or OK. As a shortcut to CHOOS, just highlight the field to change and press + to cycle through the options.
   - If there is an option to select or deselect, press ✓CHK to check or uncheck it.
2. Press PAGE▼ to view more settings.
3. When done, press PLOT to view the new plot.

Plot view settings

The plot view settings are:

Field	Meaning
XRNG, YRNG	Specifies the minimum and maximum horizontal (*X*) and vertical (*Y*) values for the plotting window.
RES	For function plots: Resolution; “Faster” plots in alternate pixel columns; “Detail” plots in every pixel column.
TRNG	Parametric aplet: Specifies the t-values (*T*) for the graph.
θRNG	Polar aplet: Specifies the angle (θ) value range for the graph.
NRNG	Sequence aplet: Specifies the index (*N*) values for the graph.
TSTEP	For Parametric plots: the increment for the independent variable.
θSTEP	For Polar plots: the increment value for the independent variable.
SEQPLOT	For Sequence aplet: Stairstep or Cobweb types.
XTICK	Horizontal spacing for tickmarks.
YTICK	Vertical spacing for tickmarks.

Those items with space for a checkmark are settings you can turn on or off. Press PAGE▼ to display the second page.

Field	Meaning
SIMULT	If more than one relation is being plotted, plots them simultaneously (otherwise sequentially).
INV. CROSS	Cursor crosshairs invert the status of the pixels they cover.

Field	Meaning (Continued)
CONNECT	Connect the plotted points. (The Sequence aplet always connects them.)
LABELS	Label the axes with XRNG and YRNG values.
AXES	Draw the axes.
GRID	Draw grid points using XTICK and YTICK spacing.

Reset plot settings

To reset the default values for all plot settings, press [SHIFT] *CLEAR* in the Plot Setup view. To reset the default value for a field, highlight the field, and press [DEL].

Exploring the graph

Plot view gives you a selection of keys and menu keys to explore a graph further. The options vary from aplet to aplet.

PLOT view keys

The following table details the keys that you use to work with the graph.

Key	Meaning
[SHIFT] *CLEAR*	Erases the plot and axes.
[VIEWS]	Offers additional pre-defined views for splitting the screen and for scaling ("zooming") the axes.
[SHIFT] [◄] [SHIFT] [►]	Moves cursor to far left or far right.
[▲] [▼]	Moves cursor between relations.
PAUSE or [ON]	Interrupts plotting.
CONT	Continues plotting if interrupted.

Key	Meaning (Continued)
MENU	Turns menu-key labels on and off. When the labels are off, pressing MENU turns them back on. • Pressing MENU once displays the full row of labels. • Pressing MENU a second time removes the row of labels to display only the graph. • Pressing MENU a third time displays the coordinate mode.
ZOOM	Displays the ZOOM menu list.
TRACE	Turns trace mode on/off. A white box appears over the E on TRACE.
GOTO	Opens an input form for you to enter an *X* (or *T* or *N* or θ) value. Enter the value and press OK . The cursor jumps to the point on the graph that you entered.
FCN	Function aplet only: turns on menu list for root-finding functions (see "Analyse graph with FCN functions" on page 3-4).
DEFN	Displays the current, *defining* expression. Press MENU to restore the menu.

Trace a graph

You can trace along a function using the ◄ or ► key which moves the cursor along the graph. The display also shows the current coordinate position (*x, y*) of the cursor. Trace mode and the coordinate display are automatically set when a plot is drawn.

Note: Tracing might not appear to exactly follow your plot if the resolution (in Plot Setup view) is set to Faster. This is because RES: FASTER plots in only every other column, whereas tracing always uses every column.

In Function and Sequence Aplets: You can also scroll (move the cursor) left or right beyond the edge of the display window in trace mode, giving you a view of more of the plot.

To move between relations

If there is more than one relation displayed, press ▲ or ▼ to move between relations.

To jump directly to a value

To jump straight to a value rather than using the Trace function, use the **GOTO** menu key. Press **GOTO**, then enter a value. Press **OK** to jump to the value.

To turn trace on/off

If the menu labels are not displayed, press **MENU** first.

- Turn off trace mode by pressing **TRAC■**.
- Turn on trace mode by pressing **TRACE**.
- To turn the coordinate display off, press **MENU**.

Zoom within a graph

One of the menu key options is **ZOOM** . Zooming redraws the plot on a larger or smaller scale. It is a shortcut for changing the Plot Setup.

The `Set Factors...` option enables you to set the factors by which you zoom in or zoom out, and whether the zoom is centered about the cursor.

ZOOM options

Press **ZOOM** , select an option, and press **OK** . (If **ZOOM** is not displayed, press **MENU**.) Not all **ZOOM** options are available in all aplets.

Option	Meaning
`Center`	Re-centers the plot around the current position of the cursor *without* changing the scale.
`Box...`	Lets you draw a box to zoom in on. See "Other views for scaling and splitting the graph" on page 2-13.
`In`	Divides horizontal and vertical scales by the X-factor and Y-factor. For instance, if zoom factors are 4, then zooming in results in 1/4 as many units depicted per pixel. (see `Set Factors...`)
`Out`	Multiplies horizontal and vertical scales by the X-factor and Y-factor (see `Set Factors...`).
`X-Zoom In`	Divides horizontal scale only, using X-factor.
`X-Zoom Out`	Multiplies horizontal scale, using X-factor.

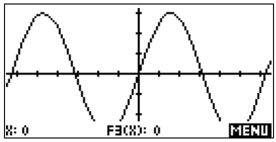
Option	Meaning (Continued)
`Y-Zoom In`	Divides vertical scale only, using Y-factor.
`Y-Zoom Out`	Multiplies vertical scale only, using Y-factor.
`Square`	Changes the vertical scale to match the horizontal scale. (Use this after doing a Box Zoom, X-Zoom, or Y-Zoom.)
`Set Factors...`	Sets the X-Zoom and Y-Zoom factors for zooming in or zooming out. Includes option to recenter the plot before zooming.
`Auto Scale`	Rescales the vertical axis so that the display shows a representative piece of the plot, for the supplied *x* axis settings. (For Sequence and Statistics aplets, autoscaling rescales both axes.) The autoscale process uses the first selected function only to determine the best scale to use.
`Decimal`	Rescales both axes so each pixel = 0.1 units. Resets default values for XRNG (–6.5 to 6.5) and YRNG (–3.1 to 3.2). (Not in Sequence or Statistics aplets.)
`Integer`	Rescales horizontal axis only, making each pixel =1 unit. (Not available in Sequence or Statistics aplets.)
`Trig`	Rescales horizontal axis so 1 pixel = $\pi/24$ radians, 7.58, or $8^{1}/_{3}$ grads; rescales vertical axis so 1 pixel = 0.1 unit. (Not in Sequence or Statistics aplets.)

Option	Meaning (Continued)
`Un-zoom`	Returns the display to the previous zoom, or if there has been only one zoom, un-zoom displays the graph with the original plot settings.

ZOOM examples

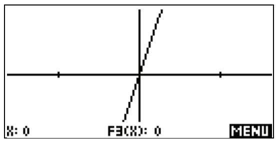
The following screens show the effects of zooming options on a plot of $3\sin x$.

Plot of $3\sin x$



Zoom In:

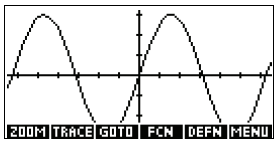
MENU **ZOOM** `In` **OK**



Un-zoom:

ZOOM `Un-zoom` **OK**

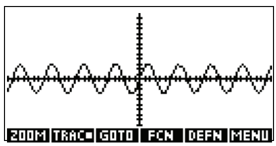
Note: Press ▲ *to move to the bottom of the Zoom list.*



Zoom Out:

ZOOM `Out` **OK**

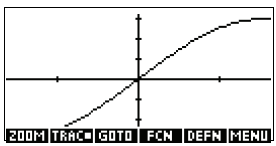
Now un-zoom.



X-Zoom In:

ZOOM `X-Zoom In` **OK**

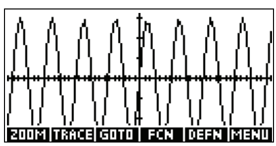
Now un-zoom.



X-Zoom Out:

ZOOM `X-Zoom Out` **OK**

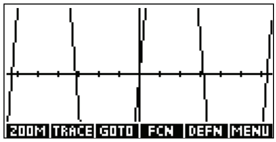
Now un-zoom.



Y-Zoom In:

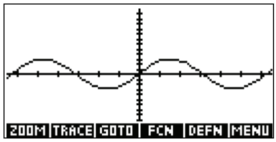
ZOOM `Y-Zoom In` OK

Now un-zoom.



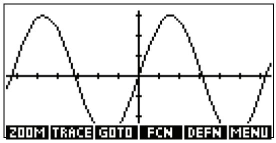
Y-Zoom Out:

ZOOM `Y-Zoom Out` OK



Zoom Square:

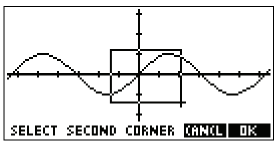
ZOOM `Square` OK



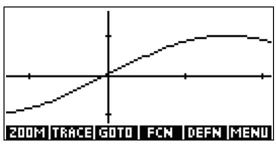
To box zoom

The Box Zoom option lets you draw a box around the area you want to zoom in on by selecting the endpoints of one diagonal of the zoom rectangle.

1. If necessary, press MENU to turn on the menu-key labels.
2. Press ZOOM and select `Box...`
3. Position the cursor on one corner of the rectangle. Press OK .
4. Use the cursor keys (▼, etc.) to drag to the opposite corner.



5. Press OK to zoom in on the boxed area.



To set zoom factors

1. In the Plot view, press MENU.
2. Press ZOOM .
3. Select `Set Factors...` and press OK .
4. Enter the zoom factors. There is one zoom factor for the horizontal scale (`XZOOM`) and one for the vertical scale (`YZOOM`).

   Zooming out *multiplies* the scale by the factor, so that a greater scale distance appears on the screen. Zooming in *divides* the scale by the factor, so that a shorter scale distance appears on the screen.

Other views for scaling and splitting the graph

The preset viewing options menu (VIEWS) contains options for drawing the plot using certain pre-defined configurations. This is a shortcut for changing Plot view settings. For instance, if you have defined a trigonometric function, then you could select `Trig` to plot your function on a trigonometric scale. It also contains split-screen options.

In certain aplets, for example those that you download from the world wide web, the preset viewing options menu can also contain options that relate to the aplet.

VIEWS menu options

Press VIEWS, select an option, and press OK .

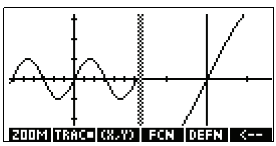
Option	Meaning
`Plot-Detail`	Splits the screen into the plot and a close-up.
`Plot-Table`	Splits the screen into the plot and the data table.
`Overlay Plot`	Plots the current expression(s) *without* erasing any pre-existing plot(s).

Option	Meaning (Continued)
`Auto Scale`	Rescales the vertical axis so that the display shows a representative piece of the plot, for the supplied *x* axis settings. (For Sequence and Statistics aplets, autoscaling rescales both axes.) The autoscale process uses the first selected function only to determine the best scale to use.
`Decimal`	Rescales both axes so each pixel = 0.1 unit. Resets default values for XRNG (–6.5 to 6.5) and YRNG (–3.1 to 3.2). (Not in Sequence or Statistics aplets.)
`Integer`	Rescales horizontal axis only, making each pixel=1 unit. (Not available in Sequence or Statistics aplets.)
`Trig`	Rescales horizontal axis so 1 pixel=$\pi/24$ radian, 7.58, or $8^1/_3$ grads; rescales vertical axis so 1 pixel =0.1 unit. (Not in Sequence or Statistics aplets.)

Split the screen

The Plot-Detail view can give you two simultaneous views of the plot.

1. Press VIEWS. Select `Plot-Detail` and press **OK**. The graph is plotted twice. You can now zoom in on the right side.
2. Press **MENU** **ZOOM** , select the zoom method and press **OK** or ENTER. This zooms the right side. Here is an example of split screen with `Zoom In`.



   – The Plot menu keys are available as for the full plot (for tracing, coordinate display, equation display, and so on).

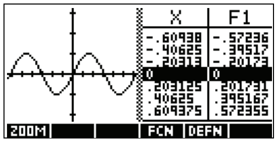
   – SHIFT ◄ moves the leftmost cursor to the screen’s left edge and SHIFT ► moves the rightmost cursor to the screen’s right edge.

   – The <-- menu key copies the right plot to the left plot.

3. To un-split the screen, press PLOT. The left side takes over the whole screen.

The Plot-Table view gives you two simultaneous views of the plot.

1. Press VIEWS. Select `Plot-Table` and press OK. The screen displays the plot on the left side and a table of numbers on the right side.



2. To move up and down the table, use the ◄ and ► cursor keys. These keys move the tra.ce point left or right along the plot, and in the table, the corresponding values are highlighted.

3. To move between functions, use the PLOT and ▼ cursor keys to move the cursor from one graph to another.

4. To return to a full Numeric (or Plot) view, press NUM (or PLOT).

Overlay plots

If you want to plot over an existing plot *without erasing* that plot, then use VIEWS `Overlay Plot` instead of PLOT. Note that tracing follows only the current functions from the current aplet.

Decimal scaling

Decimal scaling is the default scaling. If you have changed the scaling to Trig or Integer, you can change it back with Decimal.

Integer scaling

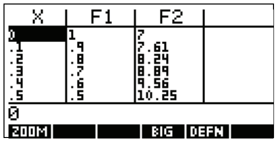
Integer scaling compresses the axes so that each pixel is 1×1 and the origin is near the screen center.

Trigonometric scaling

Use trigonometric scaling whenever you are plotting an expression that includes trigonometric functions. Trigonometric plots are more likely to intersect the axis at points factored by π.

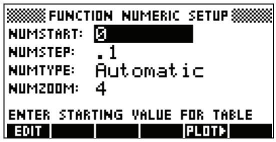
About the numeric view

After entering and selecting (check marking) the expression or expressions that you want to explore in the Symbolic view, press [NUM] to view a table of data values for the independent variable (*X*, T, θ, or *N*) and dependent variables.



Setting up the table (Numeric view setup)

Press [SHIFT] *NUM* to define any of the table settings. Use the Numeric Setup input form to configure the table.



1. Highlight the field to edit. Use the arrow keys to move from field to field.
   - If there is a number to enter, type it in and press [ENTER] or OK. To modify an existing number, press EDIT.
   - If there is an option to choose, press CHOOS, highlight your choice, and press [ENTER] or OK.
   - **Shortcut:** Press the PLOT▸ key to copy values from the Plot Setup into `NUMSTART` and `NUMSTEP`. Effectively, the PLOT▸ menu key allows you to make the table match the pixel columns in the graph view.
2. When done, press [NUM] to view the table of numbers.

Numeric view settings

The following table details the fields on the Numeric Setup input form.

Field	Meaning
`NUMSTART`	The independent variable's starting value.
`NUMSTEP`	The size of the increment from one independent variable value to the next.

Field	Meaning (Continued)
`NUMTYPE`	Type of numeric table: Automatic or Build Your Own. To build your own table, you must type each independent value into the table yourself.
`NUMZOOM`	Allows you to zoom in or out on a selected value of the independent variable.

Reset numeric settings

To reset the default values for all table settings, press SHIFT *CLEAR*.

Exploring the table of numbers

NUM view menu keys

The following table details the menu keys that you use to work with the table of numbers.

Key	Meaning
ZOOM	Displays ZOOM menu list.
BIG	Toggles between two character sizes.
DEFN	Displays the *defining* function expression for the highlighted column. To cancel this display, press DEF■.

Zoom within a table

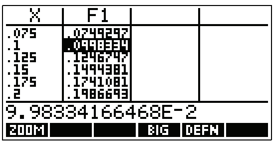
Zooming redraws the table of numbers in greater or lesser detail.

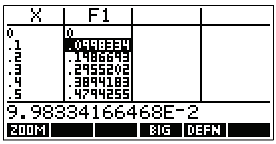
ZOOM options

The following table lists the zoom options:

Option	Meaning
`In`	Decreases the intervals for the independent variable so a narrower range is shown. Uses the `NUMZOOM` factor in Numeric Setup.
`Out`	Increases the intervals for the independent variable so that a wider range is shown. Uses the `NUMZOOM` factor in Numeric Setup.
`Decimal`	Changes intervals for the independent variable to 0.1 units. Starts at zero. (Shortcut to changing `NUMSTART` and `NUMSTEP`.)
`Integer`	Changes intervals for the independent variable to 1 unit. Starts at zero. (Shortcut to changing `NUMSTEP`.)
`Trig`	Changes intervals for independent variable to $\pi/24$ radian or 7.5 degrees or $8^{1}/_{3}$ grads. Starts at zero.
`Un-zoom`	Returns the display to the previous zoom.

The display on the right is a Zoom In of the display on the left. The `ZOOM` factor is 4.





HINT To jump to an independent variable value in the table, use the arrow keys to place the cursor in the independent variable column, then enter the value to jump to.

Automatic recalculation

You can enter any new value in the *X* column. When you press ENTER, the values for the dependent variables are recalculated, and the entire table is regenerated with the same interval between *X* values.

Building your own table of numbers

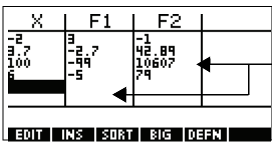
The default `NUMTYPE` is "Automatic", which fills the table with data for regular intervals of the independent (*X*, *T*, θ, or *N*) variable. With the `NUMTYPE` option set to "Build Your Own", you fill the table yourself by typing in the independent-variable values you want. The dependent values are then calculated and displayed.

Build a table

1. Start with an expression defined (in Symbolic view) in the aplet of your choice. *Note: Function, Polar, Parametric, and Sequence aplets only.*
2. In the Numeric Setup (SHIFT *NUM*), choose `NUMTYPE: Build Your Own`.
3. Open the Numeric view (NUM).
4. Clear existing data in the table (SHIFT *CLEAR*).
5. Enter the independent values in the left-hand column.

   Type in a number and press ENTER. You do not have to enter them in order, because the SORT function can rearrange them. To insert a number between two others, use INS.

You enter numbers into the X column



F1 and F2 entries are generated automatically

Clear data

Press SHIFT *CLEAR*, YES to erase the data from a table.

"Build Your Own" menu keys

Key	Meaning
EDIT	Puts the highlighted independent value (*X*, *T*, θ, or *N*) into the edit line. Pressing ENTER replaces this variable with its current value.
INS	Inserts a zero value at the position of the highlight. Replace a zero by typing the number you want and pressing ENTER .
SORT	Sorts the independent variable values into ascending or descending order. Press SORT and select the ascending or descending option from the menu, and press OK .
BIG	Toggles between two character sizes.
DEFN	Displays the defining function expression for the highlighted column.
DEL	Deletes the highlighted row.
SHIFT *CLEAR*	Clears *all* data from the table.

Example: plotting a circle

Plot the circle, $x^2 + y^2 = 9$. First rearrange it to read $y = \pm\sqrt{9 - x^2}$.

To plot both the positive and negative *y* values, you need to define two equations as follows:

$y = \sqrt{9 - x^2}$ and $y = -\sqrt{9 - x^2}$

1. In the Function aplet, specify the functions.

APLET *Select* Function START

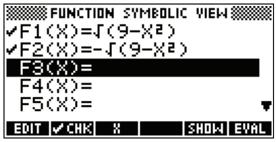
SHIFT √‾ (9

− X,T,θ X²)

ENTER

(−) SHIFT √‾ (9

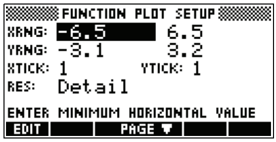
− X,T,θ X²) ENTER



2. Reset the graph setup to the default settings.

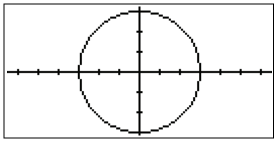
SHIFT *SETUP-PLOT*

SHIFT *CLEAR*



3. Plot the two functions and hide the menu so that you can see all the circle.

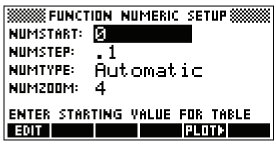
PLOT MENU MENU



4. Reset the numeric setup to the default settings.

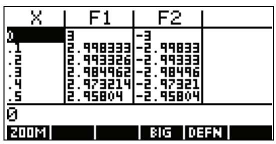
SHIFT *SETUP-NUM*

SHIFT *CLEAR*



5. Display the functions in numeric form.

NUM



3

Function aplet

About the Function aplet

The Function aplet enables you to explore up to 10 real-valued, rectangular functions *y* in terms of *x*. For example $y = 2x + 3$.

Once you have defined a function you can:

- create graphs to find roots, intercepts, slope, signed area, and extrema
- create tables to evaluate functions at particular values.

This chapter demonstrates the basic tools of the Function aplet by stepping you through an example. See “Aplet views” on page 2-1 for further information about the functionality of the Symbolic, Numeric, and Plot views.

Getting started with the Function aplet

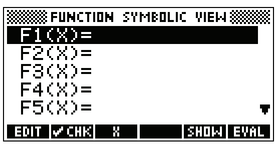
The following example involves two functions: a linear function $y = 1 - x$ and a quadratic equation $y = (x + 3)^2 - 2$.

Open the Function aplet

1. Open the Function aplet.

   APLET *Select* `Function`

   START

   The Function aplet starts in the Symbolic view.

   The Symbolic view is the *defining view* for Function, Parametric, Polar, and Sequence aplets. The other views are derived from the symbolic expression.

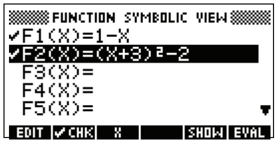
Define the expressions

2. There are 10 function definition fields on the Function aplet's Symbolic view screen. They are labeled F1(X) to F0(X). Highlight the function definition field you want to use, and enter an expression. (You can press DEL to delete an existing line, or SHIFT *CLEAR* to clear all lines.)

   1 - X,T,θ ENTER

   (X,T,θ + 3) X^2

   - 2 ENTER

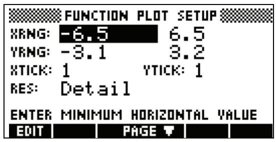


Set up the plot

You can change the scales of the *x* and *y* axes, graph resolution, and the spacing of the axis ticks.

3. Display plot settings.

   SHIFT *SETUP-PLOT*

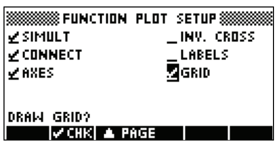


Note: For our example, you can leave the plot settings at their default values since we will be using the Auto Scale feature to choose an appropriate y axis for our x axis settings. If your settings do not match this example, press SHIFT *CLEAR to restore the default values.*

4. Specify a grid for the graph.

   PAGE▼

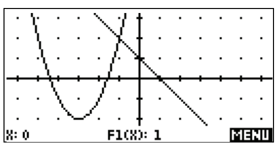
   ▶ ▼ ▼ ✓CHK



Plot the functions

5. Plot the functions.

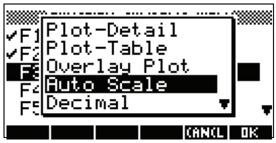
   PLOT

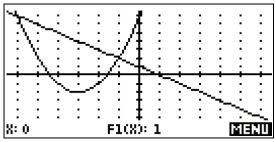


Change the scale

6. You can change the scale to see more or less of your graphs. In this example, choose `Auto Scale`. (See “VIEWS menu options” on page 2-13 for a description of Auto Scale).

   [VIEWS] *Select* `Auto Scale` [OK]

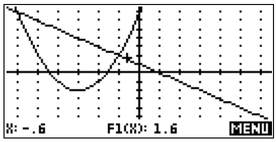




Trace a graph

7. Trace the linear function.

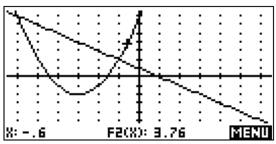
   [◄] *6 times*



   Note: By default, the tracer is active.

8. Jump from the linear function to the quadratic function.

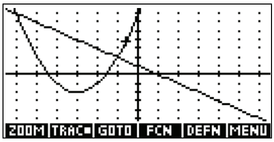
   [▲]



Analyse graph with FCN functions

9. Display the Plot view menu.

MENU



From the Plot view menu, you can use the functions on the FCN menu to find roots, intersections, slopes, and areas for a function defined in the Function aplet (and any Function-based aplets). The FCN functions act on the currently selected graph. See “FCN functions” on page 3-10 for further information.

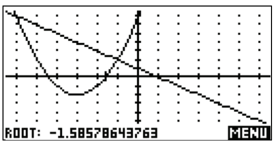
To find a root of the quadratic function

10. Move the cursor to the graph of the quadratic equation by pressing the ▲ or ▼ key. Then move the cursor so that it is near $x = -1$ by pressing the ▶ or ◀ key.

FCN *Select* `Root`

OK

The root value is displayed at the bottom of the screen.

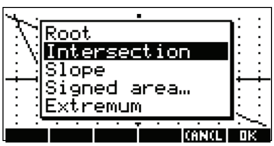


Note: If there is more than one root (as in our example), the coordinates of the root closest to the current cursor position are displayed.

To find the intersection of the two functions

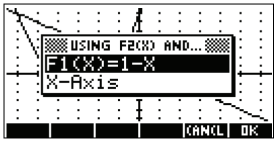
11. Find the intersection of the two functions.

MENU FCN ▼ OK

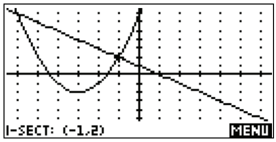


12. Choose the linear function whose intersection with the quadratic function you wish to find.

OK



The coordinates of the intersection point are displayed at the bottom of the screen.



Note: If there is more than one intersection (as in our example), the coordinates of the intersection point closest to the current cursor position are displayed.

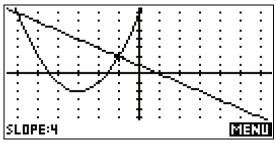
To find the slope of the quadratic function

13. Find the slope of the quadratic function at the intersection point.

MENU FCN

Select `Slope`

OK



The slope value is displayed at the bottom of the screen.

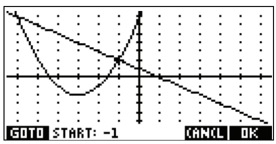
To find the signed area of the two functions

14. To find the area between the two functions in the range $-2 \le x \le -1$, first move the cursor to $F1(x) = 1 - x$ and select the signed area option.

MENU FCN

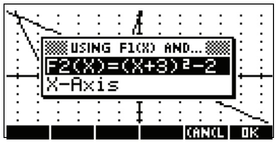
Select `Signed area`

OK



15. Move the cursor to $x = -2$ by pressing the ▶ or ◀ key.

OK



16. Press OK to accept using $F2(x) = (x + 3)^2 – 2$ as the other boundary for the integral.

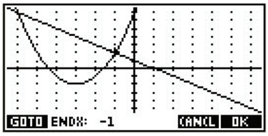
17. Choose the end value for *x*.

GOTO

(-) 1

OK

The cursor jumps to $x = –1$ on the linear function.



18. Display the numerical value of the integral.

OK

Note: See "Shading area" on page 3-11 for another method of calculating area.

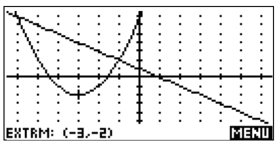
To find the extremum of the quadratic

19. Move the cursor to the quadratic equation and find the extremum of the quadratic.

▲ MENU FCN

Select `Extremum` OK

The coordinates of the extremum are displayed at the bottom of the screen.

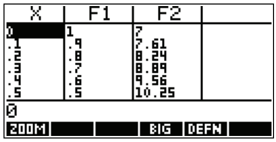


HINT The Root and Extremum functions return one value only even if the function has more than one root or extremum. The function finds the value closest to the position of the cursor. You need to re-locate the cursor to find other roots or extrema that may exist.

Display the numeric view

20. Display the numeric view.

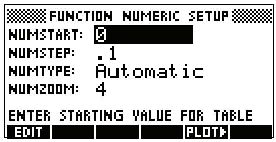
NUM



Set up the table

21. Display the numeric setup.

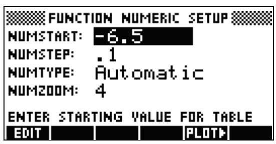
SHIFT *SETUP-NUM*



See "Setting up the table (Numeric view setup)" on page 2-16 for more information.

22. Match the table settings to the pixel columns in the graph view.

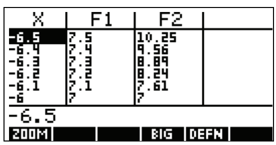
PLOT OK



Explore the table

23. Display the table of values.

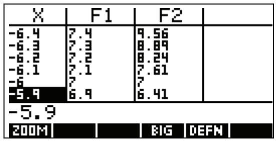
NUM



To navigate around a table

24. Move to X = –5.9.

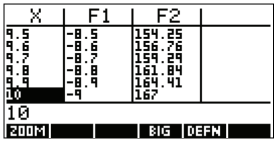
▼ *6 times*



To go directly to a value

25. Move directly to X = 10.

1 0 OK

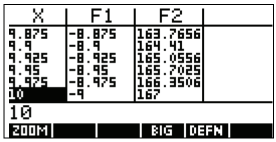


To access the zoom options

26. Zoom in on X = 10 by a factor of 4. *Note:* `NUMZOOM` *has a setting of 4.*

ZOOM `In`

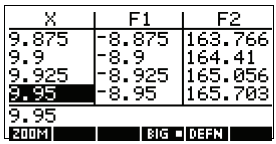
OK



To change font size

27. Display table numbers in large font.

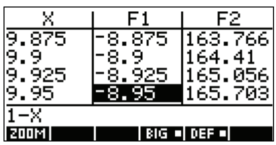
BIG



To display the symbolic definition of a column

28. Display the symbolic definition for the F1 column.

▶ DEFN



The symbolic definition of F1 is displayed at the bottom of the screen.

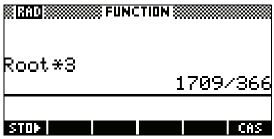
Function aplet interactive analysis

From the Plot view ([PLOT]), you can use the functions on the FCN menu to find roots, intersections, slopes, and areas for a function defined in the Function aplet (and any Function-based aplets). See “FCN functions” on page 3-10. The FCN operations act on the currently selected graph.

The results of the FCN functions are saved in the following variables:

- Area
- Extremum
- Isect
- Root
- Slope

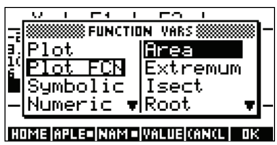
For example, if you use the Root function to find the root of a plot, you can use the result in calculations in HOME.



Access FCN variables

The FCN variables are contained on the VARS menu.

To access FCN variables in HOME:



[VARS] APLET
Select `Plot FCN`
[▶]
[▲] or [▼] to choose a variable OK

To access FCN variable in the Function aplet’s Symbolic view:

[VARS]
Select `Plot FCN`
[▶]
[▲] or [▼] to choose a variable
OK

FCN functions

The FCN functions are:

Function	Description
`Root`	Select `Root` to find the root of the current function nearest the cursor. If no root is found, but only an extremum, then the result is labeled `EXTR:` instead of `ROOT:`. (The root-finder is also used in the Solve aplet. See also "Interpreting results" on page 7-6.) The cursor is moved to the root value on the x-axis and the resulting *x*-value is saved in a variable named ROOT.
`Extremum`	Select `Extremum` to find the maximum or minimum of the current function nearest the cursor. This displays the coordinate values and moves the cursor to the extremum. The resulting value is saved in a variable named EXTREMUM.
`Slope`	Select `Slope` to find the numeric derivative at the current position of the cursor. The result is saved in a variable named SLOPE.
`Signed area`	Select `Signed area` to find the numeric integral. (If there are two or more expressions checkmarked, then you will be asked to choose the second expression from a list that includes the *x*-axis.) Select a starting point, then move the cursor to selection ending point. The result is saved in a variable named AREA.

Function	Description (Continued)
`Intersection`	Select `Intersection` to find the intersection of two graphs nearest the cursor. *(You need to have at least two selected expressions in Symbolic view.)* Displays the coordinate values and moves the cursor to the intersection. (Uses Solve function.) The resulting *x*-value is saved in a variable named ISECT.

Shading area

You can shade a selected area between functions. This process also gives you an approximate measurement of the area shaded.

1. Open the Function aplet. The Function aplet opens in the Symbolic view.
2. Select the expressions whose curves you want to study.
3. Press PLOT to plot the functions.
4. Press ◄ or ► to position the cursor at the starting point of the area you want to shade.
5. Press MENU .
6. Press FCN , then select `Signed area` and press OK .
7. Press OK , choose the function that will act as the boundary of the shaded area, and press OK .
8. Press the ◄ or ► key to shade in the area.
9. Press OK to calculate the area. The area measurement is displayed near the bottom of the screen.

To remove the shading, press PLOT to re-draw the plot.

Plotting a piecewise-defined function

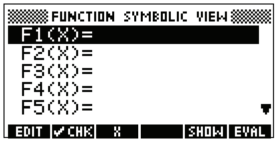
Suppose you wanted to plot the following piecewise-defined function.

$$f(x) = \begin{cases} x + 2 & ; x \le -1 \\ x^2 & ; -1 < x \le 1 \\ 4 - x & ; x \ge 1 \end{cases}$$

1. Open the Function aplet.

   APLET *Select* `Function`

   START



2. Highlight the line you want to use, and enter the expression. (You can press DEL to delete an existing line, or SHIFT *CLEAR* to clear all lines.)

   (X + 2) ÷

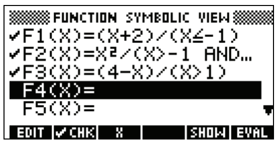
   (X SHIFT *CHARS* ≤

   OK (-) 1) ENTER

   X X^2 ÷ (X

   SHIFT *CHARS* > (-) 1

   SHIFT *AND* X SHIFT *CHARS* ≤ 1) ENTER

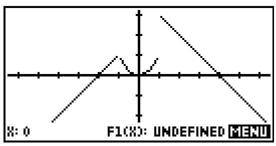


   (4 − X) ÷ (

   X

   SHIFT *CHARS* > 1)

   ENTER



Note: You can use the X *menu key to assist in the entry of equations. It has the same effect as pressing* X,T,θ.

4

Parametric aplet

About the Parametric aplet

The Parametric aplet allows you to explore parametric equations. These are equations in which both *x* and *y* are defined as functions of *t*. They take the forms $x = f(t)$ and $y = g(t)$.

Getting started with the Parametric aplet

The following example uses the parametric equations

$$x(t) = 3\sin t$$
$$y(t) = 3\cos t$$

Note: This example will produce a circle. For this example to work, the angle measure must be set to degrees.

Open the Parametric aplet

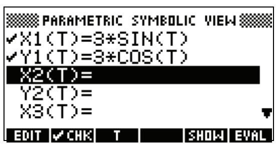
1. Open the Parametric aplet.

APLET *Select*
`Parametric`
START

Define the expressions

2. Define the expressions.

3 × SIN X,T,θ)
ENTER
3 × COS X,T,θ)
ENTER



Set angle measure

3. Set the angle measure to degrees.

   SHIFT *MODES*

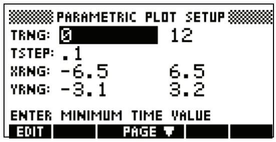
   CHOOS

   Select `Degrees` OK

Set up the plot

4. Display the graphing options.

   SHIFT *PLOT*

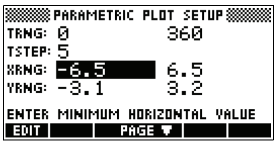


   The Plot Setup input form has two fields not included in the Function aplet, `TRNG` and `TSTEP`. `TRNG` specifies the range of *t* values. `TSTEP` specifies the step value between *t* values.

5. Set the `TRNG` and `TSTEP` so that *t* steps from 0° to 360° in 5° steps.

   ▶ 360 OK

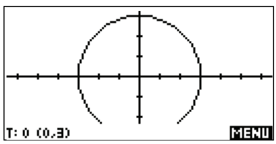
   5 OK



Plot the expression

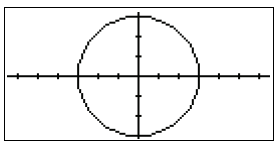
6. Plot the expression.

   PLOT



7. To see all the circle, press MENU twice.

   MENU MENU



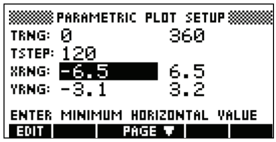
Overlay plot

8. Plot a triangle graph over the existing circle graph.

   SHIFT *PLOT*

   ▼

   120 OK

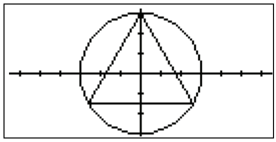
   

   VIEWS

   Select `Overlay Plot`

   OK

   MENU MENU

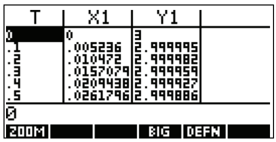
   A triangle is displayed rather than a circle (without changing the equation) because the changed value of `TSTEP` ensures that points being plotted are 120° apart instead of nearly continuous.

   You are able to explore the graph using trace, zoom, split screen, and scaling functionality available in the Function aplet. See “Exploring the graph” on page 2-7 for further information.

Display the numbers

9. Display the table of values.

   NUM

   You can highlight a *t*-value, type in a replacement value, and see the table jump to that value. You can also zoom in or zoom out on any *t*-value in the table.

   You are able to explore the table using ZOOM, GOTO, build your own table, and split screen functionality available in the Function aplet. See “Exploring the table of numbers” on page 2-17 for further information.

5

Polar aplet

Getting started with the Polar aplet

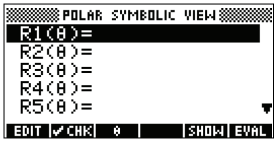
Open the Polar aplet

1. Open the Polar aplet.

   [APLET] *Select* `Polar`

   RESET YES START

   Like the Function aplet, the Polar aplet opens in the Symbolic view.



Define the expression

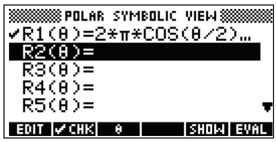
2. Define the polar equation $r = 2\pi\cos(\theta/2)\cos(\theta)^2$.

   2 [SHIFT] π [COS]

   [X,T,θ] [÷] 2 [)]

   [COS] [X,T,θ] [)]

   [X^2] [ENTER]



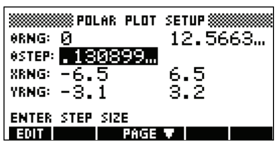
Specify plot settings

3. Specify the plot settings. In this example, we will use the default settings, except for the θRNG fields.

   [SHIFT] *SETUP-PLOT*

   [SHIFT] *CLEAR*

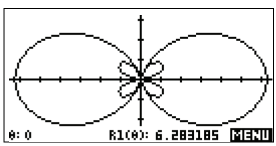
   [▶] 4 [SHIFT] π OK



Plot the expression

4. Plot the expression.

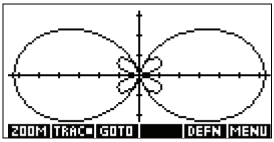
   [PLOT]



Explore the graph

5. Display the Plot view menu key labels.

   MENU

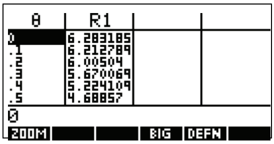
   

   The Plot view options available are the same as those found in the Function aplet. See “Exploring the graph” on page 2-7 for further information.

Display the numbers

6. Display the table of values for θ and R1.

   NUM

   The Numeric view options available are the same as those found in the Function aplet. See “Exploring the table of numbers” on page 2-17 for further information.

6

Sequence aplet

About the Sequence aplet

The Sequence aplet allows you to explore sequences.

You can define a sequence named, for example, U1:

- in terms of n
- in terms of U1$(n-1)$
- in terms of U1$(n-2)$
- in terms of another sequence, for example, U2(n)
- in any combination of the above.

The Sequence aplet allows you to create two types of graphs:

– A **Stairsteps** graph plots *n* on the horizontal axis and U_n on the vertical axis.

– A **Cobweb** graph plots U_{n-1} on the horizontal axis and U_n on the vertical axis.

Getting started with the Sequence aplet

The following example defines and then plots an expression in the Sequence aplet. The sequence illustrated is the well-known Fibonacci sequence where each term, from the third term on, is the sum of the preceding two terms. In this example, we specify three sequence fields: the first term, the second term and a rule for generating all subsequent terms.

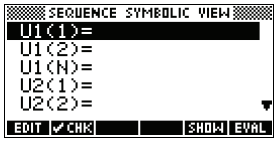
However, you can also define a sequence by specifying just the first term and the rule for generating all subsequent terms. You will, though,have to enter the second term if the hp40gs is unable to calculate it automatically. Typically if the *n*th term in the sequence depends on *n*−2, then you must enter the second term.

Open the Sequence aplet

1. Open the Sequence aplet.

   APLET *Select* `Sequence`

   START

   The Sequence aplet starts in the Symbolic view.

Define the expression

2. Define the Fibonacci sequence, in which each term (after the first two) is the sum of the preceding two terms:

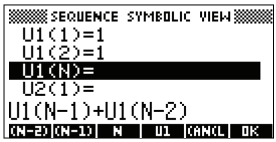
   $U_1 = 1$, $U_2 = 1$, $U_n = U_{n-1} + U_{n-2}$ for $n > 3$.

   In the Symbolic view of the Sequence aplet, highlight the U1(1) field and begin defining your sequence.

   1 ENTER 1 ENTER

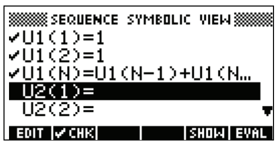
   U1 (N-1) + U1

   (N-2)

   Note: You can use the N, (N-2), (N-1), U1, *and* U2 *menu keys to assist in the entry of equations.*

   ENTER

Specify plot settings

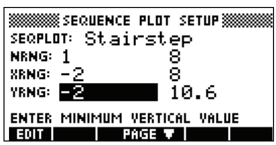
3. In Plot Setup, first set the `SEQPLOT` option to `Stairstep`. Reset the default plot settings by clearing the Plot Setup view.

   SHIFT *SETUP-PLOT*

   SHIFT *CLEAR*

   ▼ ▶ 8 ENTER

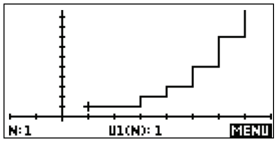
   ▶ 8 ENTER

Plot the sequence

4. Plot the Fibonacci sequence.

   [PLOT]



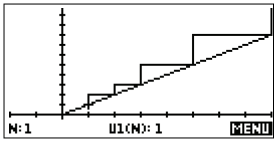
5. In Plot Setup, set the `SEQPLOT` option to `Cobweb`.

   [SHIFT] *SETUP-PLOT*

   CHOOS *Select* `Cobweb`

   OK

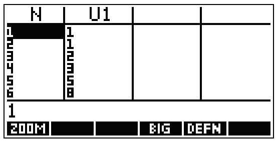
   [PLOT]



Display the table

6. Display the table of values for this example.

   [NUM]



7

Solve aplet

About the Solve aplet

The Solve aplet solves an equation or an expression for its *unknown variable*. You define an equation or expression in the symbolic view, then supply values for all the variables *except one* in the numeric view. Solve works only with real numbers.

Note the differences between an equation and an expression:

- An *equation* contains an equals sign. Its solution is a value for the unknown variable that makes both sides have the same value.
- An *expression* does not contain an equals sign. Its solution is a *root*, a value for the unknown variable that makes the expression have a value of zero.

You can use the Solve aplet to solve an equation for any one of its variables.

When the Solve aplet is started, it opens in the Solve Symbolic view.

- In Symbolic view, you specify the expression or equation to solve. You can define up to ten equations (or expressions), named E0 to E9. Each equation can contain up to 27 real variables, named A to Z and θ.
- In Numeric view, you specify the values of the known variables, highlight the variable that you want to solve for, and press SOLVE.

You can solve the equation as many times as you want, using new values for the knowns and highlighting a different unknown.

Note: It is not possible to solve for more than one variable at once. Simultaneous linear equations, for example, should be solved using the Linear Solver aplet,matrices or graphs in the Function aplet.

Getting started with the Solve aplet

Suppose you want to find the acceleration needed to increase the speed of a car from 16.67 m/sec (60 kph) to 27.78 m/sec (100 kph) in a distance of 100 m.

The equation to solve is:

$$V^2 = U^2 + 2AD$$

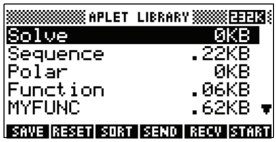
Open the Solve aplet

1. Open the Solve aplet.

   [APLET] *Select* `Solve`

   START

   The Solve aplet starts in the symbolic view.



Define the equation

2. Define the equation.

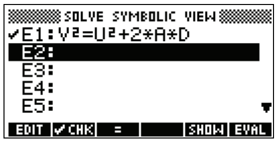
   [ALPHA] V [X²]

   = [ALPHA] U [X²]

   [+] 2 [×]

   [ALPHA] A [×]

   [ALPHA] D [ENTER]

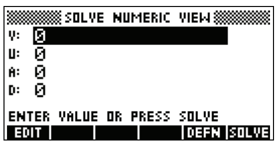


   Note: You can use the = menu key to assist in the entry of equations.

Enter known variables

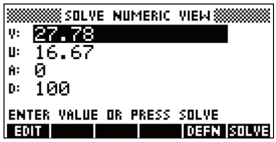
3. Display the Solve numeric view screen.

   [NUM]



4. Enter the values for the known variables.

2 7 [.] 7 8 [ENTER]
1 6 [.] 6 7 [ENTER]
[▼]
1 0 0 [ENTER]

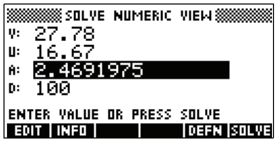


HINT If the Decimal Mark setting in the Modes input form ([SHIFT] *MODES*) is set to Comma, use [,] instead of [.].

Solve the unknown variable

5. Solve for the unknown variable (A).

[▼] [▼] SOLVE



Therefore, the acceleration needed to increase the speed of a car from 16.67 m/sec (60 kph) to 27.78 m/sec
(100 kph) in a distance of 100 m is approximately 2.47 m/s^2.

Because the variable *A* in the equation is linear we know that we need not look for any other solutions.

Plot the equation

The Plot view shows one graph for each side of the selected equation. You can choose any of the variables to be the independent variable.

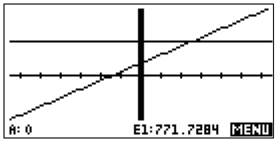
The current equation is $V^2 = U^2 + 2AD$.

One of these is $Y = V^2$, with $V = 27.78$, that is, $Y = 771.7284$. This graph will be a horizontal line. The other graph will be $Y = U^2 + 2AD$, with $U = 16.67$ and $D = 100$, that is, $Y = 200A + 277.8889$. This graph is also a line. The desired solution is the value of *A* where these two lines intersect.

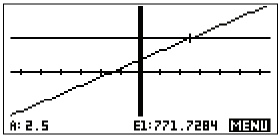
6. Plot the equation for variable A.

   [VIEWS] *Select* `Auto Scale`

   OK



7. Trace along the graph representing the left side of the equation until the cursor nears the intersection.



   [▶] ≈ *20 times*

   Note the value of *A* displayed near the bottom left corner of the screen.

   The Plot view provides a convenient way to find an approximation to a solution instead of using the Numeric view Solve option. See "Plotting to find guesses" on page 7-7 for more information.

Solve aplet's NUM view keys

The Solve aplet's NUM view keys are:

Key	Meaning
EDIT	Copies the highlighted value to the edit line for editing. Press OK when done.
INFO	Displays a message about the solution (see "Interpreting results" on page 7-6).
PAGE	Displays other pages of variables, if any.
DEFN	Displays the symbolic definition of the current expression. Press OK when done.
SOLVE	Finds a solution for the highlighted variable, based on the values of the other variables.

Key	Meaning (Continued)
DEL	Clears highlighted variable to zero *or* deletes current character in edit line, if edit line is active.
SHIFT *CLEAR*	Resets all variable values to zero *or* clears the edit line, if cursor is in edit line.

Use an initial guess

You can usually obtain a faster and more accurate solution if you supply an estimated value for the unknown variable *before* pressing SOLVE . Solve starts looking for a solution at the initial guess.

Before plotting, make sure the unknown variable is highlighted in the numeric view. Plot the equation to help you select an initial guess when you don't know the range in which to look for the solution. See "Plotting to find guesses" on page 7-7 for further information.

HINT An initial guess is especially important in the case of a curve that could have more than one solution. In this case, only the solution closest to the initial guess is returned.

Number format

You can change the number format for the Solve aplet in the Numeric Setup view. The options are the same as in HOME MODES: Standard, Fixed, Scientific, Engineering, Fraction and Mixed Fraction. For all except Standard, you also specify how many digits of accuracy you want. See "Mode settings" on page 1-10 for more information.

You might find it handy to set a different number format for the Solve aplet if, for example, you define equations to solve for the value of money. A number format of `Fixed 2` would be appropriate in this case.

Interpreting results

After Solve has returned a solution, press INFO in the Numeric view for more information. You will see one of the following three messages. Press OK to clear the message.

Message	Condition
Zero	The Solve aplet found a point where both sides of the equation were equal, or where the expression was zero (a root), within the calculator's 12-digit accuracy.
Sign Reversal	Solve found two points where the difference between the two sides of the equation has opposite signs, but it cannot find a point in between where the value is zero. Similarly, for an expression, where the value of the expression has different signs but is not precisely zero. This might be because either the two points are neighbours (they differ by one in the twelfth digit), or the equation is not real-valued between the two points. Solve returns the point where the value or difference is closer to zero. If the equation or expression is continuously real, this point is Solve's best approximation of an actual solution.
Extremum	Solve found a point where the value of the expression approximates a local minimum (for positive values) or maximum (for negative values). This point may or may not be a solution. Or: Solve stopped searching at 9.99999999999E499, the largest number the calculator can represent. Note that the value returned is probably not valid.

If Solve could not find a solution, you will see one of the following two messages.

Message	Condition
Bad Guess(es)	The initial guess lies outside the domain of the equation. Therefore, the solution was not a real number or it caused an error.
Constant?	The value of the equation is the same at every point sampled.

HINT It is important to check the information relating to the solve process. For example, the solution that the Solve aplet finds is not a solution, but the closest that the function gets to zero. Only by checking the information will you know that this is the case.

The Root-Finder at work

You can watch the process of the root-finder calculating and searching for a root. Immediately after pressing SOLVE to start the root-finder, press any key except ON. You will see two intermediate guesses and, to the left, the sign of the expression evaluated at each guess. For example:

+ 2 2.219330555745
– 1 21.31111111149

You can watch as the root-finder either finds a sign reversal or converges on a local extrema or does not converge at all. If there is no convergence in process, you might want to cancel the operation (press ON) and start over with a different initial guess.

Plotting to find guesses

The main reason for plotting in the Solve aplet is to help you find initial guesses and solutions for those equations that have difficult-to-find or multiple solutions.

Consider the equation of motion for an accelerating body:

$$X = V_0T + \frac{AT^2}{2}$$

where *X* is distance, V_0 is initial velocity, *T* is time, and *A* is acceleration. This is actually *two* equations, *Y* = *X* and $Y = V_0 T + (AT^2) / 2$.

Since this equation is quadratic for *T*, there can be both a positive and a negative solution. However, we are concerned only with positive solutions, since only positive distance makes sense.

1. Select the Solve aplet and enter the equation.

   [APLET] *Select* `Solve` START

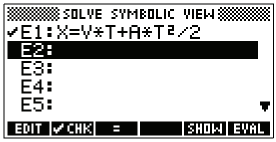
   [ALPHA] X =

   [ALPHA] V [×]

   [ALPHA] T [+]

   [ALPHA] A

   [×] [ALPHA] T [X^2] [÷] 2 OK



2. Find the solution for *T* (time) when *X*=30, *V*=2, and *A*=4. Enter the values for *X*, *V*, and *A*; then highlight the independent variable, *T*.

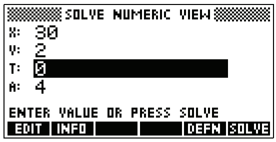
   [NUM]

   30 [ENTER]

   2 [ENTER]

   [▼] 4 [ENTER]

   [▼] [▼] *to highlight T*

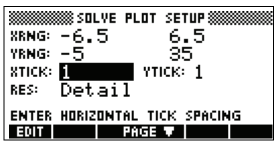


3. Use the Plot view to find an initial guess for *T*. First set appropriate *X* and *Y* ranges in the Plot Setup. With equation $X = V \text{ x } T + A \text{ x } T^2 /2$, the plot will produce two graphs: one for $Y = X$ and one for $X = V \text{ x } T + A \text{ x } T^2 /2$. Since we have set $X = 30$ in this example, one of the graphs will be $Y = 30$. Therefore, make the `YRNG` –5 to 35. Keep the `XRNG` default of –6.5 to 6.5.

   [SHIFT] *SETUP-PLOT*

   [▼] [(-)] *5* [ENTER] *35*

   [ENTER]

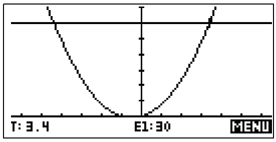


4. Plot the graph.

   [PLOT]

5. Move the cursor near the positive (right-side) intersection. This cursor value will be an initial guess for T.

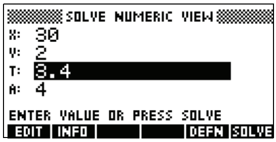
   Press ▶ *until the cursor is at the intersection.*

   The two points of intersection show that there are two solutions for this equation. However, only positive values for *X* make sense, so we want to find the solution for the intersection on the right side of the *y*-axis.

6. Return to the Numeric view.

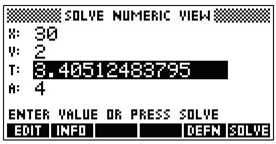
   NUM

   Note: the T-value is filled in with the position of the cursor from the Plot view.

7. Ensure that the T value is highlighted, and solve the equation.

   SOLVE

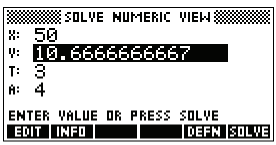
   

Use this equation to solve for another variable, such as velocity. How fast must a body's initial velocity be in order for it to travel 50 m within 3 seconds? Assume the same acceleration, 4 m/s^2. *Leave the last value of V as the initial guess.*

3 ENTER ▲ ▲ ▲

50 ENTER

SOLVE



Using variables in equations

You can use any of the real variable names, *A* to *Z* and θ. Do not use variable names defined for other types, such as *M*1 (a matrix variable).

Home variables

All home variables (other than those for aplet settings, like `Xmin` and `Ytick`) are *global*, which means they are *shared* throughout the different aplets of the calculator. A value that is assigned to a home variable anywhere remains with that variable wherever its name is used.

Therefore, if you have defined a value for *T* (as in the above example) in another aplet or even another Solve equation, that value shows up in the Numeric view for this Solve equation. When you then redefine the value for *T* in this Solve equation, that value is applied to *T* in all other contexts (until it is changed again).

This sharing allows you to work on the same problem in different places (such as HOME and the Solve aplet) without having to update the value whenever it is recalculated.

HINT As the Solve aplet uses existing variable values, be sure to check for existing variable values that may affect the solve process. (You can use SHIFT *CLEAR* to reset all values to zero in the Solve aplet's Numeric view if you wish.)

Aplet variables

Functions defined in other aplets can also be referenced in the Solve aplet. For example, if, in the Function aplet, you define $F1(X)=X^2+10$, you can enter `F1(X)=50` in the Solve aplet to solve the equation $X^2+10=50$.

8

Linear Solver aplet

About the Linear Solver aplet

The Linear Solver aplet allows you to solve a set of linear equations. The set can contain two or three linear equations.

In a two-equation set, each equation must be in the form $ax + by = k$. In a three-equation set, each equation must be in the form $ax + by + cz = k$.

You provide values for *a*, *b*, and *k* (and *c* in three-equation sets) for each equation, and the Linear Solver aplet will attempt to solve for *x* and *y* (and *z* in three-equation sets).

The hp40gs will alert you if no solution can be found, or if there is an infinite number of solutions.

Note that the Linear Solver aplet only has a numeric view.

Getting started with the Linear Solver aplet

The following example defines a set of three equations and then solves for the unknown variables.

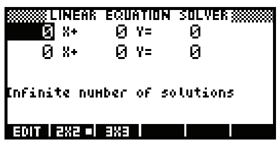
Open the Linear Solver aplet

1. Open the Linear Sequence aplet.

   APLET *Select* `Linear Solver`

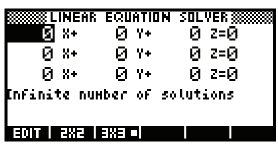
   START

   The Linear Equation Solver opens.



Choose the equation set

2. If the last time you used the Linear Solver aplet you solved for two equations, the two-equation input form is displayed (as in the



example in the previous step). To solve a three-equation set, press **3X3**. Now the input form displays three equations.

If the three-equation input form is displayed and you want to solve a two-equation set, press **2X2**.

In this example, we are going to solve the following equation set:

$$6x + 9y + 6z = 5$$

$$7x + 10y + 8z = 10$$

$$6x + 4y = 6$$

Hence we need the three-equation input form.

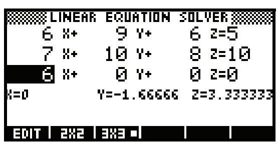
Define and solve the equations

3. You define the equations you want to solve by entering the co-efficients of each variable in each equation and the constant term. Notice that the cursor is immediately positioned at the co-efficient of *x* in the first equation. Enter that co-efficient and press **OK** or ENTER.

4. The cursor moves to the next co-efficient. Enter that co-efficient, press **OK** or ENTER, and continue doing likewise until you have defined all the equations.

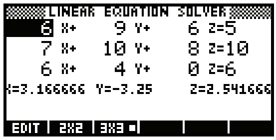
   Note: you can enter the name of a variable for any co-efficient or constant. Press ALPHA and begin entering the name. The **A...Z** menu key appears. Press that key to lock alphabetic entry mode. Press it again to cancel the lock.

   Once you have entered enough values for the solver to be able to generate solutions, those solutions appear on the display. In the example at the right,

   the solver was able to find solutions for *x*, *y*, and *z* as soon as the first co-efficient of the last equation was entered.

As you enter each of the remaining known values, the solution changes. The example at the right shows the final solution once all the co-efficients and constants are entered for the set of equations we set out to solve.



9

Triangle Solve aplet

About the Triangle Solver aplet

The Triangle Solver aplet allows you to determine the length of a side of a triangle, or the angle at the vertex of a triangle, from information you supply about the other lengths and/or other angles.

You need to specify at least three of the six possible values—the lengths of the three sides and the size of the three angles—before the solver can calculate the other values. Moreover, at least one value you specify must be a length. For example, you could specify the lengths of two sides and one of the angles; or you could specify two angles and one length; or all three lengths. In each case, the solver will calculate the remaining lengths or angles.

The HP 40gs will alert you if no solution can be found, or if you have provided insufficient data.

If you are determining the properties of a right-angled triangle, a simpler input form is available by pressing the RECT menu key.

Note that the Triangle Solver aplet only has a numeric view.

Getting started with the Triangle Solver aplet

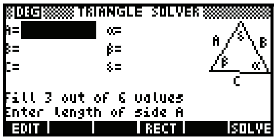
The following example solves for the unknown length of the side of a triangle whose two known sides—of lengths 4 and 6—meet at an angle of 30 degrees.

Before you begin: You should make sure that your angle measure mode is appropriate. If the angle information you have is in degrees (as in this example) and your current angle measure mode is radians or grads, change the mode to degrees before running the solver. (See "Mode settings" on page 1-10 for instructions.) Because the angle measure mode is associated with the aplet, you should start the aplet first and then change the setting.

Open the Triangle Solver aplet

1. Open the Triangle Solver aplet.

   [APLET] *Select*
   `Triangle Solver`
   START

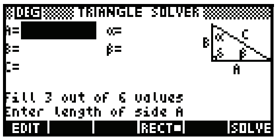
   

   The Triangle Solver aplet opens.

   Note: if you have already used the Triangle Solver, the entries and results from the previous use will still be displayed. To start the Triangle Solver afresh, clear the previous entries and results by pressing [SHIFT] *CLEAR*.

Choose the triangle type

2. If the last time you used the Triangle Solver aplet you used the right-angled triangle input form, that input form is displayed again (as in the example at the right).

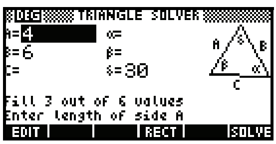
   

   If the triangle you are investigating is not a right-angled triangle, or you are not sure what type it is, you should use the general input form (illustrated in the previous step). To switch to the general input form, press **RECT■**.

   If the general input form is displayed and you are investigating a right-angled triangle, press **RECT** to display the simpler input form.

Specify the known values

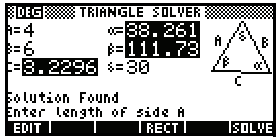
3. Using the arrow keys, move to a field whose value you know, enter the value and press **OK** or [ENTER]. Repeat for each known value.

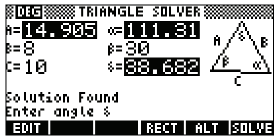
   Note that the lengths of the sides are labeled *A*, *B*, and *C*, and the angles are labeled α, β, and δ. It is important that you enter the known values in the appropriate fields. In our example, we know the length of two sides and the angle at which those sides meet. Hence if we specify the lengths of sides A and B, we must enter the angle as δ (since δ is the angle where A and B meet). If instead we entered the lengths as B and C, we would need to specify the angle as α. The illustration on the display will help you determine where to enter the known values.

Note: if you need to change the angle neasure mode, press [SHIFT] *MODES*, change the mode, and then press [NUM] to return to the aplet.

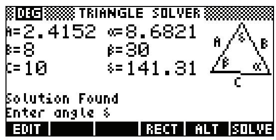
4. Press SOLVE. The solver calculates the values of the unknown variables and displays. As the illustration at the right shows, the length of the unknown side in our example is 3.2296. (The other two angles have also been calculated.)



Note: if two sides and an adjacent acute angle are entered and there are two solutions, only one will be displayed initially.



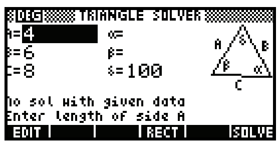
In this case, an ALT menu key is displayed (as in this example). You press ALT to display the second solution, and ALT again to return to the first solution.



Errors

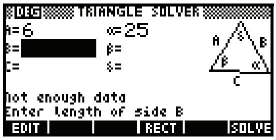
No solution with given data

If you are using the general input form and you enter more than 3 values, the values might not be consistent, that is, no triangle could possibly have all the values you specified. In these cases, `No sol with given data` appears on the screen.



The situation is similar if you are using the simpler input form (for a right-angled triangle) and you enter more than two values.

Not enough data



If you are using the general input form, you need to specify at least three values for the Triangle Solver to be able to calculate the remaining attributes of the triangle. If you specify less than three, `Not enough data` appears on the screen.

If you are using the simplified input form (for a right-angled triangle), you must specify at least two values.

In addition, you cannot specify only angles and no lengths.

10

Statistics aplet

About the Statistics aplet

The Statistics aplet can store up to ten data sets at one time. It can perform one-variable or two-variable statistical analysis of one or more sets of data.

The Statistics aplet starts with the Numeric view which is used to enter data. The Symbolic view is used to specify which columns contain data and which column contains frequencies.

You can also compute statistics values in HOME and recall the values of specific statistics variables.

The values computed in the Statistics aplet are saved in variables, and many of these variables are listed by the STATS function accessible from the Statistics aplet's Numeric view screen.

Getting started with the Statistics aplet

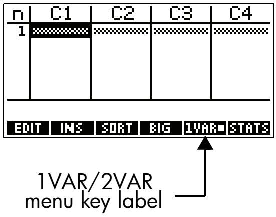
The following example asks you to enter and analyze the advertising and sales data (in the table below), compute statistics, fit a curve to the data, and predict the effect of more advertising on sales.

Advertising minutes (independent, x)	Resulting Sales ($) (dependent, y)
2	1400
1	920
3	1100
5	2265
5	2890
4	2200

Open the Statistics aplet

1. Open the Statistics aplet and clear existing data by pressing RESET.

   APLET
   Select `Statistics`
   RESET YES
   START



   The Statistics aplet starts in the Numerical view.

   At any time the Statistics aplet is configured for only one of two types of statistical explorations: one-variable (1VAR) or two-variable (2VAR). The 5th menu key label in the Numeric view toggles between these two options and shows the current option.

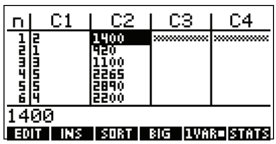
2. Select 2VAR.

   You need to select 2VAR because in this example we are analyzing a dataset comprising two variables: advertising minutes and resulting sales.

Enter data

3. Enter the data into the columns.

   2 ENTER 1 ENTER
   3 ENTER 5 ENTER
   5 ENTER 4 ENTER



   ▶ *to move to the next column*

   1400 ENTER 920 ENTER
   1100 ENTER 2265 ENTER
   2890 ENTER 2200 ENTER

Choose fit and data columns

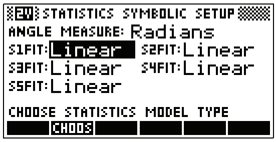
4. Select a fit in the Symbolic setup view.

   SHIFT *SETUP-SYMB*

   ▼ CHOOS

   Select `Linear`

   OK

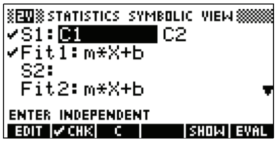


   You can create up to five explorations of two-variable data, named `S1` to `S5`. In this example, we will create just one: `S1`.

5. Specify the columns that hold the data you want to analyze.

   SYMB

   You could have entered your data into columns other than `C1` and `C2`.

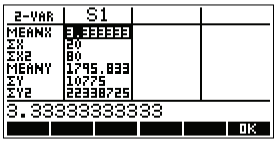


Explore statistics

6. Find the mean advertising time (`MEANX`) and the mean sales (`MEANY`).

   NUM STATS

   `MEANX` is 3.3 minutes and `MEANY` is about $1796.

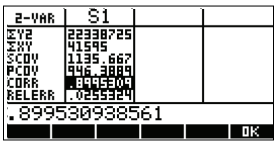


7. Scroll down to display the value for the correlation coefficient (`CORR`). The `CORR` value indicates how well the linear model fits the data.

   ▼ *9 times*

   The value is .8995.

   OK



Setup plot

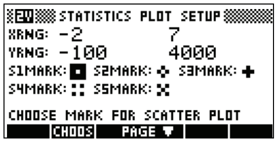
8. Change the plotting range to ensure all the data points are plotted (and select a different point mark, if you wish).

   SHIFT *SETUP-PLOT*

   ▶ 7 ENTER

   (-) 100 ENTER

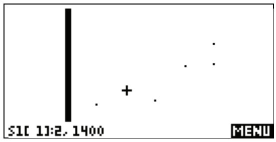
   4000 ENTER



Plot the graph

9. Plot the graph.

   PLOT

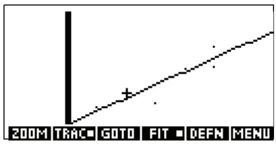


Draw the regression curve

10. Draw the regression curve (a curve to fit the data points).

    MENU FIT

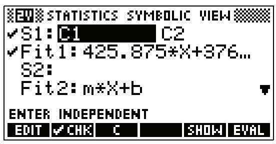
    This draws the regression line for the best linear fit.



Display the equation for best linear fit

11. Return to the Symbolic view.

    SYMB

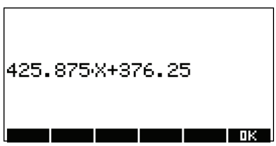


12. Display the equation for the best linear fit.

    ▼ *to move to the* `FIT1` *field*

    SHOW

    The full `FIT1` expression is shown.
    The slope (*m*) is 425.875. The *y*-intercept (*b*) is 376.25.



Predict values

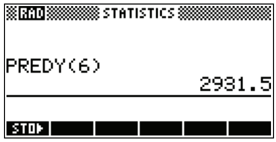
13. To find the predicted sales figure if advertising were to go up to 6 minutes:

    OK HOME

    MATH S (*to highlight* `Stat-Two`)

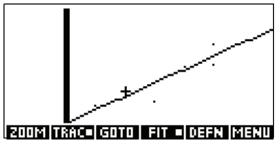
    ▶ ▲ (*to highlight* `PREDY`)

    OK 6 ENTER



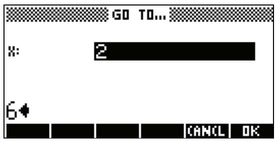
14. Return to the Plot view.

    PLOT



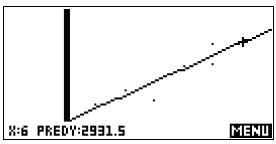
15. Jump to the indicated point on the regression line.

    ▼ GOTO
    6



OK

Observe the predicted *y*-value in the left bottom corner of the screen.



Entering and editing statistical data

The Numeric view (NUM) is used to enter data into the Statistics aplet. Each column represents a variable named `C0` to `C9`. After entering the data, you must define the data set in the Symbolic view (SYMB).

HINT A data column must have at least four data points to provide valid two-variable statistics, or two data points for one-variable statistics.

You can also store statistical data values by copying lists from HOME into Statistics data columns. For example, in HOME, `L1` STO▶ `C1` stores a copy of the list `L1` into the data-column variable `C1`.

Statistics aplet's NUM view keys

The Statistics aplet's Numeric view keys are:

Key	**Meaning**
EDIT	Copies the highlighted item into the edit line.
INS	Inserts a zero value above the highlighted cell.
SORT	Sorts the specified *independent* data column in ascending or descending order, and rearranges a specified dependent (or frequency) data column accordingly.
BIG	Switches between larger and smaller font sizes.
1VAR■ 2VAR■	A toggle switch to select one-variable or two-variable statistics. This setting affects the statistical calculations and plots. The label indicates which setting is current.
STATS	Computes descriptive statistics for each data set specified in Symbolic view.

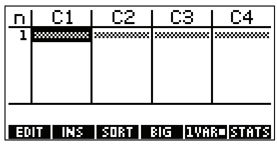
Key	Meaning (Continued)
DEL	Deletes the currently highlighted value.
SHIFT *CLEAR*	Clears the current column or all columns of data. Pregss SHIFT *CLEAR* to display a menu list, then select the current column or all columns option, and press OK .
SHIFT `cursor key`	Moves to the first or last row, or first or last column.

Example

You are measuring the height of students in a classroom to find the mean height. The first five students have the following measurements 160cm, 165cm, 170cm, 175cm, 180cm.

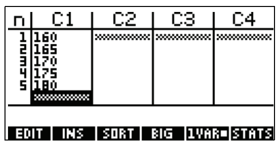
1. Open the Statistics aplet.

   APLET *Select*
   `Statistics`
   RESET YES
   START

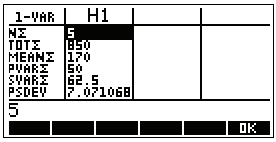


2. Enter the measurement data.

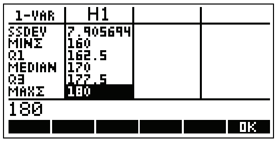
   160 ENTER
   165 ENTER
   170 ENTER
   175 ENTER
   180 ENTER



3. Find the mean of the sample.

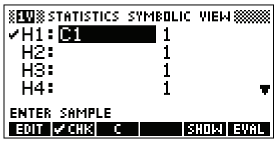
   

   Ensure the 1VAR / 2VAR menu key label reads 1VAR■. Press STATS to see the statistics calculated from the sample data in `C1`.

   Note that the title of the column of statistics is `H1`. There are 5 data set definitions available for one-variable statistics: `H1–H5`. If data is entered in `C1`, `H1` is automatically set to use `C1` for data, and the frequency of each data point is set to 1. You can select other columns of data from the Statistics Symbolic setup view.

4. Press OK to close the statistics window and press SYMB key to see the data set definitions.

   The first column indicates the associated column of data for each data set definition, and the second column indicates the constant frequency, or the column that holds the frequencies.

   The keys you can use from this window are:

Key	**Meaning**
EDIT	Copies the column variable (or variable expression) to the edit line for editing. Press OK when done.
✓CHK	Checks/unchecks the current data set. Only the checkmarked data set(s) are computed and plotted.
C or F	Typing aid for the column variables (C) or for the Fit expressions (F).

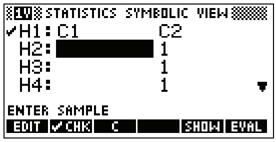
Key	Meaning (Continued)
SHOW	Displays the current variable expression in standard mathematical form. Press OK when done.
EVAL	Evaluates the variables in the highlighted column (C1, etc.) expression.
VARS	Displays the menu for entering variable names or contents of variables.
MATH	Displays the menu for entering math operations.
DEL	Deletes the highlighted variable *or* the current character in the edit line.
SHIFT *CLEAR*	Resets default specifications for the data sets *or* clears the edit line (if it was active). *Note: If* SHIFT *CLEAR is used the data sets will need to be selected again before re-use.*

To continue our example, suppose that the heights of the rest of the students in the class are measured, but each one is rounded to the nearest of the five values first recorded. Instead of entering all the new data in `C1`, we shall simply add another column, `C2`, that holds the frequencies of our five data points in `C1`.

Height (cm)	Frequency
160	5
165	3
170	8
175	2
180	1

5. Move the highlight bar into the right column of the `H1` definition and replace the frequency value of 1 with the name `C2`.

   C 2



6. Return to the numeric view.

   [NUM]

7. Enter the frequency data shown in the above table.

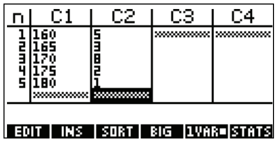
   [▶] 5 [ENTER]

   3 [ENTER]

   8 [ENTER]

   2 [ENTER]

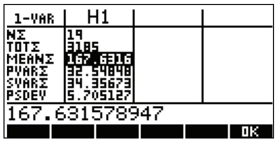
   1 [ENTER]



8. Display the computed statistics.

   STATS

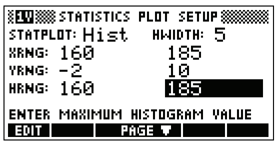
   The mean height is approximately 167.63cm.



9. Setup a histogram plot for the data.

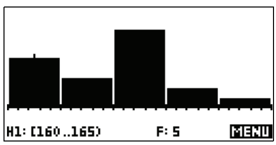
   OK [SHIFT] *SETUP-PLOT*

   Enter set up information appropriate to your data.



10. Plot a histogram of the data.

    [PLOT]



Save data

The data that you enter is automatically saved. When you are finished entering data values, you can press a key for another Statistics view (like [SYMB]), or you can switch to another aplet or HOME.

Edit a data set

In the Numeric view of the Statistics aplet, highlight the data value to change. Type a new value and press ENTER, or press EDIT to copy the value to the edit line for modification. Press ENTER after modifying the value on the edit line.

Delete data

- To delete a single data item, highlight it and press DEL. The values below the deleted cell will scroll up one row.
- To delete a column of data, highlight an entry in that column and press SHIFT *CLEAR*. Select the column name.
- To delete all columns of data, press SHIFT *CLEAR*. Select `All columns`.

Insert data

Highlight the entry *following* the point of insertion. Press INS, then enter a number. It will write over the zero that was inserted.

Sort data values

1. In Numeric view, highlight the column you want to sort, and press SORT.
2. Specify the Sort Order. You can choose either `Ascending` or `Descending`.
3. Specify the `INDEPENDENT` and `DEPENDENT` data columns. Sorting is by the *independent* column. For instance, if Age is `C1` and Income is `C2` and you want to sort by Income, then you make `C2` the independent column for the sorting and `C1` the dependent column.
   – To sort just one column, choose None for the dependent column.
   – For one-variable statistics with two data columns, specify the frequency column as the dependent column.
4. Press OK.

Defining a regression model

The Symbolic view includes an expression (Fit1 through Fit5) that defines the regression model, or "fit", to use for the regression analysis of each two-variable data set.

There are three ways to select a regression model:

- Accept the default option to fit the data to a straight line.
- Select one of the available fit options in Symbolic Setup view.
- Enter your own mathematical expression in Symbolic view. This expression will be plotted, *but it will not be fitted to the data points*.

Angle Setting

You can ignore the angle measurement mode *unless* your Fit definition (in Symbolic view) involves a trigonometric function. In this case, you should specify in the mode screen whether the trigonometric units are to be interpreted in degrees, radians, or grads.

To choose the fit

1. In Numeric view, make sure 2VAR■ is set.
2. Press SHIFT *SETUP-SYMB* to display the Symbolic Setup view. Highlight the Fit number (`S1FIT` to `S5FIT`) you want to define.
3. Press CHOOS and select from the list. Press OK when done. The regression formula for the fit is displayed in Symbolic view.

Fit models

Ten fit models are available:

Fit model	Meaning
`Linear`	(Default.) Fits the data to a straight line, $y = mx+b$. Uses a least-squares fit.
`Logarithmic`	Fits to a logarithmic curve, $y = m \ln x + b$.
`Exponential`	Fits to an exponential curve, $y = be^{mx}$.
`Power`	Fits to a power curve, $y = bx^m$.

Fit model	Meaning (Continued)
`Quadratic`	Fits to a quadratic curve, $y = ax^2 + bx + c$. Needs at least three points.
`Cubic`	Fits to a cubic curve, $y = ax^3 + bx^2 + cx + d$. Needs at least four points.
`Logistic`	Fits to a logistic curve, $y = \frac{L}{1 + ae^{(-bx)}}$, where *L* is the saturation value for growth. You can store a positive real value in *L*, or—if *L*=0—let *L* be computed automatically.
`Exponent`	Fits to an exponent curve, $y = ab^x$.
`Trigonometric`	Fits to a trigonometric curve, $y = a \cdot \sin(bx + c) + d$. Needs at least three points.
`User Defined`	Define your own expression (in Symbolic view.)

To define your own fit

1. In Numeric view, make sure 2VAR is set.
2. Display the Symbolic view.
3. Highlight the Fit expression (`Fit1`, etc.) for the desired data set.
4. Type in an expression and press ENTER.

   The independent variable must be *X*, and the expression must not contain any unknown variables. Example: $1.5 \times \cos x + 0.3 \times \sin x$.

This automatically changes the Fit type (`S1FIT`, etc.) in the Symbolic Setup view to User Defined.

Computed statistics

One-variable

Statistic	Definition
NΣ	Number of data points.
TOTΣ	Sum of data values (with their frequencies).
MEANΣ	Mean value of data set.
PVARΣ	Population variance of data set.
SVARΣ	Sample variance of data set.
PSDEV	Population standard deviation of data set.
SSDEV	Sample standard deviation of data set.
MINΣ	Minimum data value in data set.
Q1	First quartile: median of values to left of median.
MEDIAN	Median value of data set.
Q3	Third quartile: median of values to right of median.
MAXΣ	Maximum data value in data set.

When the data set contains an odd number of values, the data set's median value is not used when calculating Q1 and Q3 in the table above. For example, for the following data set:

`{3,5,7,8,15,16,17}`

only the first three items, 3, 5, and 7 are used to calculate Q1, and only the last three terms, 15, 16, and 17 are used to calculate Q3.

Two-variable

Statistic	Definition
MEANX	Mean of x- (independent) values.
ΣX	Sum of x-values.
ΣX2	Sum of x^2-values.
MEANY	Mean of y- (dependent) values.
ΣY	Sum of y-values.
ΣY2	Sum of y^2-values.
ΣXY	Sum of each xy.
SCOV	Sample covariance of independent and dependent data columns.
PCOV	Population covariance of independent and dependent data columns
CORR	Correlation coefficient of the independent and dependent data columns *for a linear fit only* (regardless of the Fit chosen). Returns a value from 0 to 1, where 1 is the best fit.
RELERR	The relative error for the selected fit. Provides a measure of accuracy for the fit.

Plotting

You can plot:

- histograms (1VAR)
- box-and-whisker plots (1VAR)
- scatter plots (2VAR).

Once you have entered your data (NUM), defined your data set (SYMB), and defined your Fit model for two-variable statistics (SHIFT *SETUP-SYMB*), you can plot your data. You can plot up to five scatter or box-and-whisker plots at a time. You can plot only one histogram at a time.

To plot statistical data

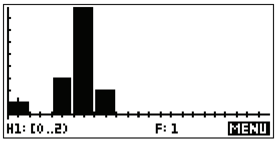
1. In Symbolic view (SYMB), select (✔CHK) the data sets you want to plot.
2. For one-variable data (1VAR), select the plot type in Plot Setup (SHIFT *SETUP-PLOT*). Highlight STATPLOT, press CHOOS , select either `Histogram` or `BoxWhisker`, and press OK .
3. For any plot, but especially for a histogram, adjust the plotting scale and range in the Plot Setup view. If you find histogram bars too fat or too thin, you can adjust them by adjusting the `HWIDTH` setting.
4. Press PLOT . If you have not adjusted the Plot Setup yourself, you can try VIEWS *select* `Auto Scale` OK .

Auto Scale can be relied upon to give a good starting scale which can then be adjusted in the Plot Setup view.

Plot types

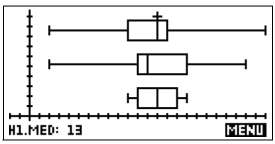
Histogram

One-variable statistics. The numbers below the plot mean that the current bar (where the cursor is) starts at 0 and ends at 2 (not including 2), and the frequency for this column, (that is, the number of data elements that fall between 0 and 2) is 1. You can see information about the next bar by pressing the ▶ key.



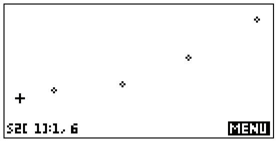
Box and Whisker Plot

One-variable statistics. The left whisker marks the minimum data value. The box marks the first quartile, the median (where the cursor is), and the third quartile. The right whisker marks the maximum data value. The numbers below the plot mean that this column has a median of 13.

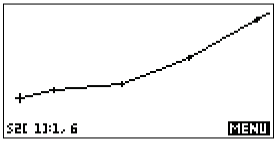


Scatter Plot

Two-variable statistics. The numbers below the plot indicate that the cursor is at the first data point for S2, at (1, 6). Press ▶ to move to the next data point and display information about it.



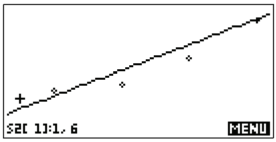
To connect the data points as they are plotted, checkmark CONNECT in the second page of the Plot Setup. *This is not a regression curve.*



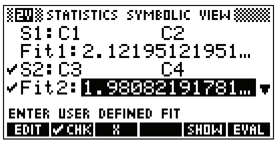
Fitting a curve to 2VAR data

In the Plot view, press FIT. This draws a curve to fit the checked two-variable data set(s). See "To choose the fit" on page 10-12.

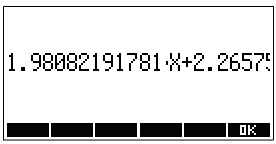
PLOT
MENU
FIT



SYMB



SHOW
The expression in Fit2 shows that the slope=1.98082191781 and the *y*-intercept=2.2657.



Correlation coefficient

The correlation coefficient is stored in the CORR variable. It is a measure of fit to a *linear* curve only. Regardless of the Fit model you have chosen, CORR relates to the linear model.

Relative Error

The relative error is a measure of the error between predicted values and actual values based on the specified Fit. A smaller number means a better fit.

The *relative error* is stored in a variable named RELERR. The relative error provides a measure of fit accuracy for all fits, and it *does* depend on the Fit model you have chosen.

HINT

In order to access the CORR and RELERR variables after you plot a set of statistics, you must press NUM to access the numeric view and then STATS to display the correlation values. The values are stored in the variables when you access the Symbolic view.

Setting up the plot (Plot setup view)

The Plot Setup view (SHIFT *SETUP-PLOT*) sets most of the same plotting parameters as it does for the other built-in aplets.
See "Setting up the plot (Plot view setup)" on page 2-5.
Settings unique to the Statistics aplet are as follows:

Plot type (1VAR)

STATPLOT enables you to specify either a histogram or a box-and-whisker plot for one-variable statistics (when 1VAR is set). Press CHOOS to change the highlighted setting

Histogram width

HWIDTH enables you to specify the width of a histogram bar. This determines how many bars will fit in the display, as well as how the data is distributed (how many values each bar represents).

Histogram range

HRNG enables you to specify the range of values for a set of histogram bars. The range runs from the left edge of the leftmost bar to the right edge of the rightmost bar. You can limit the range to exclude any values you suspect are outliers.

Plotting mark (2VAR)

S1MARK through S5MARK enables you to specify one of five symbols to use to plot each data set. Press CHOOS to change the highlighted setting.

Connected points (2VAR)

CONNECT (on the second page), when checkmarked, connects the data points as they are plotted. *The resulting line is not the regression curve.* The order of plotting is according to the ascending order of independent values.

For instance, the data set (1,1), (3,9), (4,16), (2,4) would be plotted and traced in the order (1,1), (2,4), (3,9), (4,16).

Trouble-shooting a plot

If you have problems plotting, check that you have the following:

- The correct 1VAR or 2VAR menu label on (Numeric view).
- The correct fit (regression model), if the data set is two-variable.
- Only the data sets to compute or plot are checkmarked (Symbolic view).
- The correct plotting range. Try using VIEWS Auto Scale (instead of PLOT), *or* adjust the plotting parameters (in Plot Setup) for the ranges of the axes and the width of histogram bars (`HWIDTH`).

In 2VAR mode, ensure that both paired columns contain data, and that they are the same length.

In 1VAR mode, ensure that a paired column of frequency values is the same length as the data column that it refers to.

Exploring the graph

The Plot view has menu keys for zooming, tracing, and coordinate display. There are also scaling options under VIEWS. These options are described in "Exploring the graph" on page 2-7.

Statistics aplet's PLOT view keys

Key	Meaning
SHIFT *CLEAR*	Erases the plot.
VIEWS	Offers additional pre-defined views for splitting the screen, overlaying plots, and autoscaling the axes.
SHIFT ◄ SHIFT ►	Moves cursor to far left or far right.

Key	Meaning (Continued)
ZOOM	Displays ZOOM menu.
TRACE	Turns trace mode on/off. The white box appears next to the option when Trace mode is active.
FIT	Turns fit mode on or off. Turning FIT on draws a curve to fit the data points according to the current regression model.
GOTO (2var statistics only)	Enables you to specify a value on the line of best fit to jump to or a data point number to jump to.
DEFN	Displays the equation of the regression curve.
MENU	Hides and displays the menu key labels. When the labels are hidden, any menu key displays the (x,y) coordinates. Pressing MENU redisplays the menu labels.

Calculating predicted values

The functions `PREDX` and `PREDY` estimate (predict) values for *X* or *Y* given a hypothetical value for the other. The estimation is made based on the curve that has been calculated to fit the data according to the specified fit.

Find predicted values

1. In Plot view, draw the regression curve for the data set.
2. Press ▼ to move to the regression curve.
3. Press GOTO and enter the value of *X*. The cursor jumps to the specified point on the curve and the coordinate display shows *X* and the predicted value of *Y*.

In HOME:

- Enter `PREDX`(*y-value*) ENTER to find the predicted value for the independent variable given a hypothetical dependent value.

- Enter PREDY(*x-value*) to find the predicted value of the dependent variable given a hypothetical independent variable.

You can type `PREDX` and `PREDY` into the edit line, or you can copy these function names from the MATH menu under the Stat-Two category.

HINT In cases where more than one fit curve is displayed, the PREDY function uses the most recently calculated curve. In order to avoid errors with this function, uncheck all fits except the one that you want to work with, or use the Plot View method.

11

Inference aplet

About the Inference aplet

The Inference capabilities include calculation of confidence intervals and hypothesis tests based on the Normal Z-distribution or Student's t-distribution.

Based on the statistics from one or two samples, you can test hypotheses and find confidence intervals for the following quantities:

- mean
- proportion
- difference between two means
- difference between two proportions

Example data

When you first access an input form for an Inference test, by default, the input form contains example data. This example data is designed to return meaningful results that relate to the test. It is useful for gaining an understanding of what the test does, and for demonstrating the test. The calculator's on-line help provides a description of what the example data represents.

Getting started with the Inference aplet

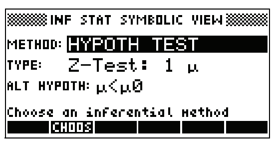
This example describes the Inference aplet's options and functionality by stepping you through an example using the example data for the Z-Test on 1 mean.

Open the Inference aplet

1. Open the Inference aplet.

   APLET
   Select `Inference`
   RESET YES START.

   The Inference aplet opens in the Symbolic view.



Inference aplet's SYMB view keys

The table below summarizes the options available in Symbolic view.

Hypothesis Tests	**Confidence Intervals**
Z: 1 μ, the Z-Test on 1 mean	Z-Int: 1 μ, the confidence interval for 1 mean, based on the Normal distribution
Z: $\mu_1 - \mu_2$, the Z-Test on the difference of two means	Z-Int: $\mu_1 - \mu_2$, the confidence interval for the difference of two means, based on the Normal distribution
Z: 1 π, the Z-Test on 1 proportion	Z-Int: 1 π, the confidence interval for 1 proportion, based on the Normal distribution
Z: $\pi 1 - \pi 2$, the Z-Test on the difference in two proportions	Z-Int: $\pi 1 - \pi 2$, the confidence interval for the difference of two proportions, based on the Normal distribution
T: 1 μ, the T-Test on 1 mean	T-Int: 1 μ, the confidence interval for 1 mean, based on the Student's t-distribution
T: $\mu_1 - \mu_2$, the T-Test on the difference of two means	T-Int: $\mu_1 - \mu_2$, the confidence interval for the difference of two means, based on the Student's t-distribution

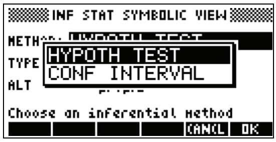
If you choose one of the hypothesis tests, you can choose the alternative hypothesis to test against the null hypothesis. For each test, there are three possible choices for an alternative hypothesis based on a quantitative comparison of two quantities. The null hypothesis is always that the two quantities are equal.Thus, the alternative hypotheses cover the various cases for the two quantities being unequal: $<$, $>$, and $\neq$.

In this section, we will use the example data for the Z-Test on 1 mean to illustrate how the aplet works and what features the various views present.

Select the inferential method

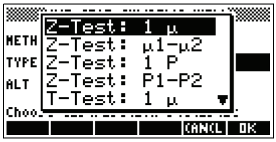
2. Select the `Hypothesis` Test inferential method.

   CHOOS
   Select `HYPOTH TEST`



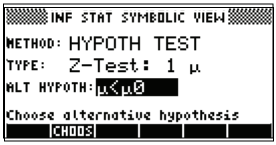
3. Define the type of test.

   OK ▼
   CHOOS
   `Z-Test:` 1 μ



4. Select an alternative hypothesis.

   OK ▼
   CHOOS
   μ< μ0
   OK



Enter data

5. Enter the sample statistics and population parameters.

   SHIFT `setup-NUM`

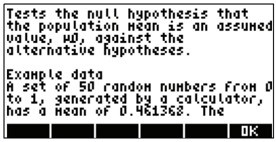
The table below lists the fields in this view for our current `Z-Test:` 1 μ example.

Field name	**Definition**
μ0	Assumed population mean
σ	Population standard deviation
x̄	Sample mean
n	Sample size
α	Alpha level for the test

By default, each field already contains a value. These values constitute the example database and are explained in the HELP feature of this aplet.

Display on-line help

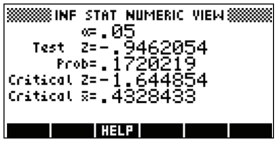
6. To display the on-line help, press HELP
7. To close the on-line help, press OK .



Display test results in numeric format

8. Display the test results in numeric format.

NUM



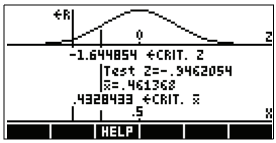
The test distribution value and its associated probability are displayed, along with the critical value(s) of the test and the associated critical value(s) of the statistic.

Note: You can access the on-line help in Numeric view.

Plot test results

9. Display a graphic view of the test results.

PLOT



Horizontal axes are presented for both the distribution variable and the test statistic. A generic bell curve represents the probability distribution function. Vertical lines mark the critical value(s) of the test, as well as the value of the test statistic. The rejection region is marked ←R and the test numeric results are displayed between the horizontal axes.

Importing sample statistics from the Statistics aplet

The Inference aplet supports the calculation of confidence intervals and the testing of hypotheses based on data in the Statistics aplet. Computed statistics for a sample of data in a column in any Statistics-based aplet can be imported for use in the Inference aplet. The following example illustrates the process.

A calculator produces the following 6 random numbers:

0.529, 0.295, 0.952, 0.259, 0.925, and 0.592

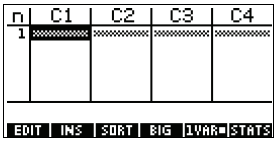
Open the Statistics aplet

1. Open the Statistics aplet and reset the current settings.

   [APLET] *Select* `Statistics`

   RESET **YES**

   START



   The Statistics aplet opens in the Numeric view.

Enter data

2. In the C1 column, enter the random numbers produced by the calculator.

   [.]529 [ENTER]

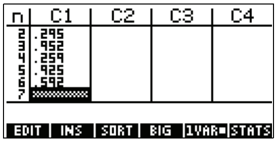
   [.]295 [ENTER]

   [.]952 [ENTER]

   [.]259 [ENTER]

   [.]925 [ENTER]

   [.]592 [ENTER]



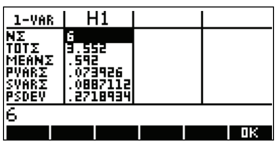
HINT If the Decimal Mark setting in the Modes input form ([SHIFT] `modes`) is set to Comma, use [,] instead of [.].

3. If necessary, select 1-variable statistics. Do this by pressing the fifth menu key until **1VAR■** is displayed as its menu label.

Calculate statistics

4. Calculate statistics.

   STATS



   The mean of 0.592 seems a little large compared to the expected value of 0.5. To see if the difference is statistically significant, we will use the statistics computed here to construct a confidence interval for the true mean of the population of random numbers and see whether or not this interval contains 0.5.

5. Press **OK** to close the computed statistics window.

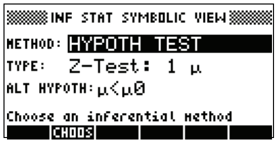
Open Inference aplet

6. Open the Inference aplet and clear current settings.

   APLET *Select* `Inference`

   RESET YES

   START



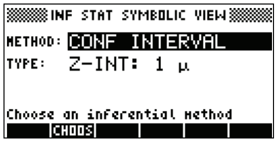
Select inference method and type

7. Select an inference method.

   CHOOS

   Select `CONF INTERVAL`

   OK

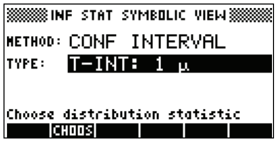


8. Select a distribution statistic type.

   ▼ CHOOS

   Select `T-Int: 1 μ`

   OK



Set up the interval calculation

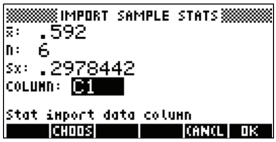
9. Set up the interval calculation. Note: The default values are derived from sample data from the on-line help example.

   SHIFT `Setup-NUM`

Import the data

10. Import the data from the Statistics aplet. *Note: The data from C1 is displayed by default.*

IMPRT



Note: Press OK *to see the statistics before importing them into the Numeric Setup view.*
Also, if there is more than one aplet based on the Statistics aplet, you are prompted to choose one.

OK

11. Specify a 90% confidence interval in the C: field.

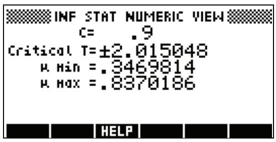
▼ ▼ ▼ *to move to the C: field*

0.9 ENTER

Display Numeric view

12. Display the confidence interval in the Numeric view. *Note: The interval setting is 0.5.*

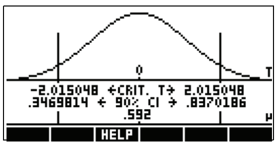
NUM



Display Plot view

13. Display the confidence interval in the Plot view.

PLOT



You can see, from the second text row, that the mean is contained within the 90% confidence interval (CI) of 0.3469814 to 0.8370186.

Note: The graph is a simple, generic bell-curve. It is not meant to accurately represent the t-distribution with 5 degrees of freedom.

Hypothesis tests

You use hypothesis tests to test the validity of hypotheses that relate to the statistical parameters of one or two populations. The tests are based on statistics of samples of the populations.

The HP 40gs hypothesis tests use the Normal Z-distribution or Student's t-distribution to calculate probabilities.

One-Sample Z-Test

Menu name

Z-Test: 1 μ

On the basis of statistics from a single sample, the One-Sample Z-Test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the population mean equals a specified value H_0: $\mu = \mu_0$.

You select one of the following alternative hypotheses against which to test the null hypothesis:

$$H_1 : \mu_1 < \mu_2$$

$$H_1 : \mu_1 > \mu_2$$

$$H_1 : \mu_1 \neq \mu_2$$

Inputs

The inputs are:

Field name	Definition
$\bar{x}$	Sample mean.
n	Sample size.
μ_0	Hypothetical population mean.
σ	Population standard deviation.
α	Significance level.

Results

The results are:

Result	**Description**
Test Z	Z-test statistic.
Prob	Probability associated with the Z-Test statistic.
Critical Z	Boundary values of Z associated with the α level that you supplied.
Critical $\bar{x}$	Boundary values of $\bar{\mathbf{x}}$ required by the α value that you supplied.

Two-Sample Z-Test

Menu name

Z-Test: $\mu 1 - \mu 2$

On the basis of two samples, each from a separate population, this test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the mean of the two populations are equal (H_0: $\mu 1 = \mu 2$).

You select one of the following alternative hypotheses against which to test the null hypothesis:

$$H_1 : \mu_1 < \mu_2$$

$$H_1 : \mu_1 > \mu_2$$

$$H_1 : \mu_1 \neq \mu_2$$

Inputs

The inputs are:

Field name	**Definition**
$\bar{x}1$	Sample 1 mean.
$\bar{x}2$	Sample 2 mean.
n1	Sample 1 size.
n2	Sample 2 size.
$\sigma 1$	Population 1 standard deviation.

Field name	Definition
$\sigma 2$	Population 2 standard deviation.
α	Significance level.

Results

The results are:

Result	Description
Test Z	Z-Test statistic.
Prob	Probability associated with the Z-Test statistic.
Critical Z	Boundary value of Z associated with the α level that you supplied.

One-Proportion Z-Test

Menu name

Z-Test: 1π

On the basis of statistics from a single sample, this test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the proportion of successes in the two populations is equal: $H_0 : \pi = \pi_0$

You select one of the following alternative hypotheses against which to test the null hypothesis:

$$H_1 : \pi < \pi_0$$

$$H_1 : \pi > \pi_0$$

$$H_1 : \pi \neq \pi_0$$

Inputs

The inputs are:

Field name	Definition
x	Number of successes in the sample.
n	Sample size.
π_0	Population proportion of successes.
α	Significance level.

Results

The results are:

Result	Description
Test P	Proportion of successes in the sample.
Test Z	Z-Test statistic.
Prob	Probability associated with the Z-Test statistic.
Critical Z	Boundary value of Z associated with the level you supplied.

Two-Proportion Z-Test

Menu name

Z-Test: $\pi 1 - \pi 2$

On the basis of statistics from two samples, each from a different population, the Two-Proportion Z-Test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the proportion of successes in the two populations is equal H0: $\pi_1 = \pi_2$.

You select one of the following alternative hypotheses against which to test the null hypothesis:

$$H_1 : \pi_1 < \pi_2$$

$$H_1 : \pi_1 > \pi_2$$

$$H_1 : \pi_1 \neq \pi_2$$

Inputs

The inputs are:

Field name	Definition
X1	Sample 1 mean.
X2	Sample 2 mean.
n1	Sample 1 size.
n2	Sample 2 size.
α	Significance level.

Results

The results are:

Result	Description
Test $\pi 1 - \pi 2$	Difference between the proportions of successes in the two samples.
Test Z	Z-Test statistic.
Prob	Probability associated with the Z-Test statistic.
Critical Z	Boundary values of Z associated with the α level that you supplied.

One-Sample T-Test

Menu name

T-Test: 1 μ

The One-sample T-Test is used when the population standard deviation is not known. On the basis of statistics from a single sample, this test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the sample mean has some assumed value,

$H_0 : \mu = \mu_0$

You select one of the following alternative hypotheses against which to test the null hypothesis:

$$H_1 : \mu < \mu_0$$

$$H_1 : \mu > \mu_0$$

$$H_1 : \mu \neq \mu_0$$

Inputs

The inputs are:

Field name	Definition
$\bar{x}$	Sample mean.
Sx	Sample standard deviation.
n	Sample size.
μ0	Hypothetical population mean.
α	Significance level.

Results

The results are:

Result	Description
Test T	T-Test statistic.
Prob	Probability associated with the T-Test statistic.
Critical T	Boundary value of T associated with the α level that you supplied.
Critical $\bar{x}$	Boundary value of $\bar{x}$ required by the α value that you supplied.

Two-Sample T-Test

Menu name

T-Test: μ1 – μ2

The Two-sample T-Test is used when the population standard deviation is not known. On the basis of statistics from two samples, each sample from a different population, this test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the two populations means are equal H_0: $\mu_1 = \mu_2$.

You select one of the following alternative hypotheses against which to test the null hypothesis

$$H_1 : \mu_1 < \mu_2$$

$$H_1 : \mu_1 > \mu_2$$

$$H_1 : \mu_1 \neq \mu_2$$

Inputs

The inputs are:

Field name	**Definition**
$\bar{x}$1	Sample 1 mean.
$\bar{x}$2	Sample 2 mean.
S1	Sample 1 standard deviation.
S2	Sample 2 standard deviation.
n1	Sample 1 size.
n2	Sample 2 size.
α	Significance level.
_Pooled?	Check this option to pool samples based on their standard deviations.

Results

The results are:

Result	Description
Test T	T-Test statistic.
Prob	Probability associated with the T-Test statistic.
Critical T	Boundary values of T associated with the α level that you supplied.

Confidence intervals

The confidence interval calculations that the HP 40gs can perform are based on the Normal Z-distribution or Student's t-distribution.

One-Sample Z-Interval

Menu name

Z-INT: μ 1

This option uses the Normal Z-distribution to calculate a confidence interval for m, the true mean of a population, when the true population standard deviation, s, is known.

Inputs

The inputs are:

Field name	Definition
$\bar{x}$	Sample mean.
σ	Population standard deviation.
n	Sample size.
C	Confidence level.

Results

The results are:

Result	Description
Critical Z	Critical value for Z.
μ min	Lower bound for μ.
μ max	Upper bound for μ.

Two-Sample Z-Interval

Menu name

Z-INT: $\mu 1 - \mu 2$

This option uses the Normal Z-distribution to calculate a confidence interval for the difference between the means of two populations, $\mu_1 - \mu_2$, when the population standard deviations, σ_1 and σ_2, are known.

Inputs

The inputs are:

Field name	Definition
$\bar{x}$1	Sample 1 mean.
$\bar{x}$2	Sample 2 mean.
n1	Sample 1 size.
n2	Sample 2 size.
σ1	Population 1 standard deviation.
σ2	Population 2 standard deviation.
C	Confidence level.

Results

The results are:

Result	Description
Critical Z	Critical value for Z.
$\Delta\ \mu$ Min	Lower bound for $\mu_1 - \mu_2$.
$\Delta\ \mu$ Max	Upper bound for $\mu_1 - \mu_2$.

One-Proportion Z-Interval

Menu name Z-INT: 1 π

This option uses the Normal Z-distribution to calculate a confidence interval for the proportion of successes in a population for the case in which a sample of size, *n*, has a number of successes, *x*.

Inputs The inputs are:

Field name	Definition
`x`	Sample success count.
`n`	Sample size.
`C`	Confidence level.

Results The results are:

Result	Description
Critical Z	Critical value for Z.
π Min	Lower bound for π.
π Max	Upper bound for π.

Two-Proportion Z-Interval

Menu name Z-INT: π1 – π2

This option uses the Normal Z-distribution to calculate a confidence interval for the difference between the proportions of successes in two populations.

Inputs The inputs are:

Field name	Definition
$\bar{x}1$	Sample 1 success count.
$\bar{x}2$	Sample 2 success count.

Field name	Definition (Continued)
`n1`	Sample 1 size.
`n2`	Sample 2 size.
`C`	Confidence level.

Results

The results are:

Result	Description
Critical Z	Critical value for Z.
$\Delta\pi$ Min	Lower bound for the difference between the proportions of successes.
$\Delta\pi$ Max	Upper bound for the difference between the proportions of successes.

One-Sample T-Interval

Menu name

T-INT: 1 μ

This option uses the Student's t-distribution to calculate a confidence interval for m, the true mean of a population, for the case in which the true population standard deviation, s, is unknown.

Inputs

The inputs are:

Field name	Definition
$\bar{x}$`1`	Sample mean.
`Sx`	Sample standard deviation.
`n`	Sample size.
`C`	Confidence level.

Results

The results are:

Result	Description
Critical T	Critical value for T.
μ Min	Lower bound for μ.
μ Max	Upper bound for μ.

Two-Sample T-Interval

Menu name

T-INT: μ1 – μ2

This option uses the Student's t-distribution to calculate a confidence interval for the difference between the means of two populations, μ1 – μ2, when the population standard deviations, s1and s2, are unknown.

Inputs

The inputs are:

Field name	Definition
$\bar{x}$1	Sample 1 mean.
$\bar{x}$2	Sample 2 mean.
s1	Sample 1 standard deviation.
s2	Sample 2 standard deviation.
n1	Sample 1 size.
n2	Sample 2 size.
C	Confidence level.
_Pooled	Whether or not to pool the samples based on their standard deviations.

Results

The results are:

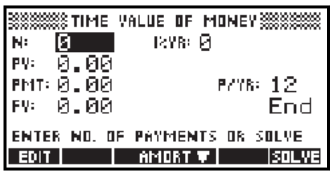
Result	Description
Critical T	Critical value for T.
$\Delta\ \mu$ Min	Lower bound for $\mu_1 - \mu_2$.
$\Delta\ \mu$ Max	Upper bound for $\mu_1 - \mu_2$.

12

Using the Finance Solver

The Finance Solver, or *Finance aplet*, is available by using the APLET key in your calculator. Use the up and down arrow keys to select the *Finance* aplet. Your screen should look as follows:

Press the ENTER key or the START soft menu key to activate the aplet. The resulting screen shows the different elements involved in the solution of financial problems with your HP 40gs calculator.



Background information on and applications of financial calculations are provided next.

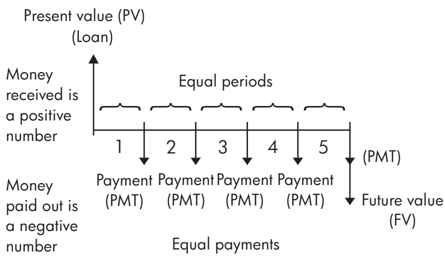
Background

The Finance Solver application provides you with the ability of solving time-value-of-money (TVM) and amortization problems. These problems can be used for calculations involving compound interest applications as well as amortization tables.

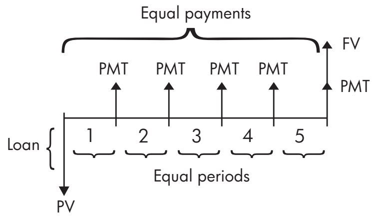
Compound interest is the process by which earned interest on a given principal amount is added to the principal at specified compounding periods, and then the combined amount earns interest at a certain rate. Financial calculations involving compound interest include savings accounts, mortgages, pension funds, leases, and annuities.

Time Value of Money (TVM) calculations, as the name implies, make use of the notion that a dollar today will be worth more than a dollar sometime in the future. A dollar today can be invested at a certain interest rate and generate a return that the same dollar in the future cannot. This TVM principle underlies the notion of interest rates, compound interest and rates of return.

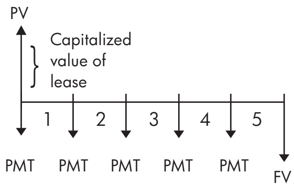
TVM transactions can be represented by using *cash flow diagrams*. A cash flow diagram is a time line divided into equal segments representing the compounding periods. Arrows represent the cash flows, which could be positive (upward arrows) or negative (downward arrows), depending on the point of view of the lender or borrower. The following cash flow diagram shows a loan from a *borrower's* point of view:



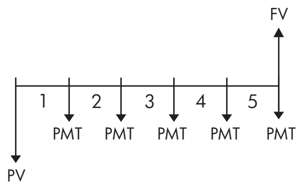
On the other hand, the following cash flow diagram shows a load from the *lender's* point of view:



In addition, cash flow diagrams specify *when* payments occur relative to the compounding periods: at the *beginning* of each period or at the *end*. The Finance Solver application provides both of these payment modes: Begin mode and End mode. The following cash flow diagram shows lease payments at the *beginning* of each period.



The following cash flow diagram shows deposits into an account at the *end* of each period.



As these cash-flow diagrams imply, there are five TVM variables:

N	The total number of compounding periods or payments.
I%YR	The nominal annual interest rate (or investment rate). This rate is divided by the number of payments per year (P/YR) to compute the nominal interest rate *per compounding period* -- which is the interest rate actually used in TVM calculations.
PV	The present value of the initial cash flow. To a lender or borrower, PV is the amount of the loan; to an investor, PV is the initial investment. PV always occurs at the beginning of the first period.

PMT	The periodic payment amount. The payments are the same amount each period and the TVM calculation assumes that no payments are skipped. Payments can occur at the beginning or the end of each compounding period -- an option you control by setting the Payment mode to Beg or End.
FV	The future value of the transaction: the amount of the final cash flow or the compounded value of the series of previous cash flows. For a loan, this is the size of the final balloon payment (beyond any regular payment due). For an investment this is the cash value of an investment at the end of the investment period.

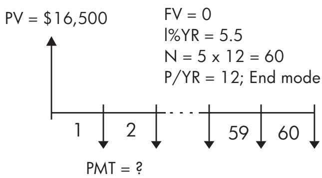
Performing TVM calculations

1. Launch the Financial Solver as indicated at the beginning of this section.
2. Use the arrow keys to highlight the different fields and enter the known variables in the TVM calculations, pressing the OK soft-menu key after entering each known value. Be sure that values are entered for at least four of the five TVM variables (namely, N, I%YR, PV, PMT, and FV).
3. If necessary, enter a different value for P/YR (default value is 12, i.e., monthly payments).
4. Press the key [+] to change the Payment mode (Beg or End) as required.
5. Use the arrow keys to highlight the TVM variable you wish to solve for and press the SOLVE soft-menu key.

Example 1 - Loan calculations

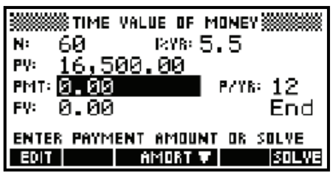
Suppose you finance the purchase of a car with a 5-year loan at 5.5% annual interest, compounded monthly. The purchase price of the car is $19,500, and the down payment is $3,000. What are the required monthly payments? What is the largest loan you can afford if your maximum monthly payment is $300? Assume that the payments start at the end of the first period.

Solution. The following cash flow diagram illustrates the loan calculations:



Start the Finance Solver, selecting P/YR = 12 and End payment option.

- Enter the known TVM variables as shown in the diagram above. Your input form should look as follows:

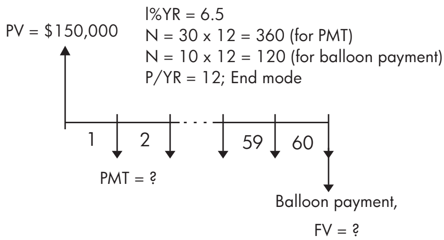


- Highlighting the PMT field, press the SOLVE soft menu key to obtain a payment of -315.17 (i.e., PMT = -$315.17).
- To determine the maximum loan possible if the monthly payments are only $300, type the value –300 in the PMT field, highlight the PV field, and press the SOLVE soft menu key. The resulting value is PV = $15,705.85.

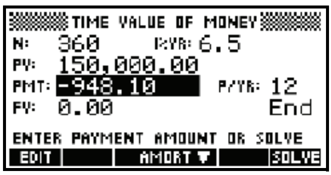
Example 2 - Mortgage with balloon payment

Suppose you have taken out a 30-year, $150,000 house mortgage at 6.5% annual interest. You expect to sell the house in 10 years, repaying the loan in a balloon payment. Find the size of the balloon payment, the value of the mortgage after 10 years of payment.

Solution. The following cash flow diagram illustrates the case of the mortgage with balloon payment:



- Start the Finance Solver, selecting P/YR = 12 and End payment option.
- Enter the known TVM variables as shown in the diagram above. Your input form, for calculating monthly payments for the 30-yr mortgage, should look as follows:



- Highlighting the PMT field, press the SOLVE soft menu key to obtain a payment of -948.10 (i.e., PMT = -$948.10)
- To determine the balloon payment or future value (FV) for the mortgage after 10 years, use N = 120, highlight the FV field, and press the SOLVE soft menu key. The resulting value is FV = -$127,164.19. The negative value indicates a payment from the homeowner. Check that the required balloon payments at the end of 20 years (N=240) and 25 years (N = 300) are -$83,497.92 and -$48,456.24, respectively.

Calculating Amortizations

Amortization calculations, which also use the TVM variables, determine the amounts applied towards principal and interest in a payment or series of payments.

To calculate amortizations:

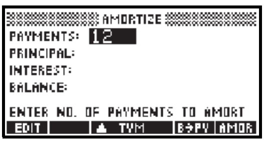
1. Start the Finance Solver as indicated at the beginning of this section.
2. Set the following TVM variables:

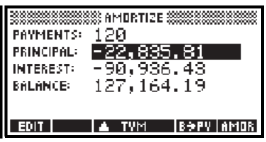
   a Number of payments per year (P/YR)

   b Payment at beginning or end of periods
3. Store values for the TVM variables I%YR, PV, PMT, and FV, which define the payment schedule.
4. Press the AMORT ▼ soft menu key and enter the number of payments to amortize in this batch.
5. Press the AMOR soft menu key to amortize a batch of payments. The calculator will provide for you the amount applied to interest, to principal, and the remaining balance after this set of payments have been amortized.

Example 3 - Amortization for home mortgage

For the data of Example 2 above, find the amortization of the loan after the first 10 years (12x10 = 120 payments). Pressing the AMORT ▼ soft menu key produces the screen to the left. Enter 120 in the PAYMENTS field, and press the AMOR soft menu key to produce the results shown to the right.





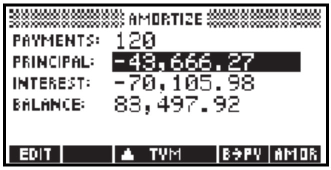
To continue amortizing the loan:

1. Press the B→PV soft menu key to store the new balance after the previous amortization as PV.
2. Enter the number of payments to amortize in the new batch.

3. Press the AMOR soft menu key to amortize the new batch of payments. Repeat steps 1 through 3 as often as needed.

Example 4 - Amortization for home mortgage

For the results of Example 3, show the amortization of the next 10 years of the mortgage loan. First, press the B→PV soft menu key. Then, keeping 120 in the PAYMENTS field, press the AMOR soft menu key to produce the results shown below.



To amortize a series of future payments starting at payment *p:*

1. Calculate the balance of the loan at payment *p-1*.
2. Store the new balance in PV using the B→PV soft menu key.
3. Amortize the series of payments starting at the new PV.

The amortization operation reads the values from the TVM variables, rounds the numbers it gets from PV and PMT to the current display mode, then calculates the amortization rounded to the same setting. The original variables are not changed, except for PV, which is updated after each amortization.

13

Using mathematical functions

Math functions

The HP 40gs contains many math functions. The functions are grouped in categories. For example, the Matrix category contains functions for manipulating matrices. The Probability category (shown as `Prob.` on the MATH menu) contains functions for working with probability.

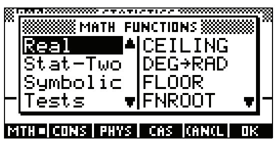
To use a math function in HOME view, you enter the function onto the command line, and include the arguments in parentheses after the function. You can also select a math function from the MATH menu.

Note that this chapter covers only the use of mathematical functions in HOME view. The use of mathematical functions in CAS is described in Chapter14, “Computer Algebra System (CAS)”.

The MATH menu

The MATH menu provides access to math functions, physical constants, and programming constants. You can also access CAS commands.

The MATH menu is organized by *category*. For each category of functions on the left, there is a list of function names on the right. The highlighted category is the current category.



- When you press MATH, you see the menu list of Math categories in the left column and the corresponding functions of the highlighted category in the right column. The menu key **MTH** indicates that the MATH FUNCTIONS menu list is active.

To select a function

1. Press MATH to display the MATH menu. The categories appear in alphabetical order.
2. Press ▼ or ▲ to scroll through the categories. To jump directly to a category, press the first letter of the category's name. *Note: You do not need to press* ALPHA *first.*
3. The list of functions (on the right) applies to the currently highlighted category (on the left). Use ► and ◄ to switch between the category list and the function list.
4. Highlight the name of the function you want and press OK. This copies the function name (and an initial parenthesis, if appropriate) to the edit line.

NOTE If you press CAS while the MATH menu is open, CAS functions and commands are displayed. You can select a CAS function or command in the same way that you select a function from the MATH menu (by pressing the arrow keys and then OK). The function or command selected appears on the edit line in HOME (and with an initial parenthesis, if appropriate).

Function categories (MATH menu)

- Calculus
- Complex numbers
- Constant
- Convert
- Hyperbolic trigonometry (Hyperb.)
- Lists
- Loop
- Matrix
- Polynomial
- Probability
- Real numbers (Real)
- Two-variable statistics (Stat-Two)
- Symbolic
- Tests
- Trigonometry (Trig)

Math functions by category

Syntax

Each function's definition includes its syntax, that is, the exact order and spelling of a function's name, its delimiters (punctuation), and its arguments. Note that the syntax for a function does not require spaces.

Functions common to keyboard and menus

These functions are common to the keyboard and MATH menu.

SHIFT π	For a description, see "p" on page 13-8.
SHIFT *ARG*	For a description, see "ARG" on page 13-7.
d/dx	For a description, see " ∂ " on page 11-7.
SHIFT *AND*	For a description, see "AND" on page 13-19.
SHIFT !	For a description, see "COMB(5,2) returns 10. That is, there are ten different ways that five things can be combined two at a time.!" on page 13-12.
SHIFT Σ	For a description, see "S" on page 13-11.
SHIFT *EEX*	For a description, see "Scientific notation (powers of 10)" on page 1-20.
SHIFT $\int$	For a description, see " $\int$ " on page 11-7.
SHIFT x^{-1}	The multiplicative inverse function finds the inverse of a square matrix, and the multiplicative inverse of a real or complex number. Also works on a list containing only these object types.

Keyboard functions

The most frequently used functions are available directly from the keyboard. Many of the keyboard functions also accept complex numbers as arguments.

[+], [-], [×], [÷]

Add, Subtract, Multiply, Divide. Also accepts complex numbers, lists and matrices.

value1+ value2, etc.

[SHIFT] e^x

Natural exponential. Also accepts complex numbers.

`e^`*value*

Example

`e^5` returns `148.413159103`

[ln]

Natural logarithm. Also accepts complex numbers.

`LN`(*value*)

Example

`LN(1)` returns `0`

[SHIFT] 10^x

Exponential (antilogarithm). Also accepts complex numbers.

`10^`*value*

Example

`10^3` returns `1000`

[log]

Common logarithm. Also accepts complex numbers.

`LOG`(*value*)

Example

`LOG(100)` returns `2`

[SIN], [COS], [TAN]

Sine, cosine, tangent. Inputs and outputs depend on the current angle format (Degrees, Radians, or Grads).

`SIN`(*value*)
`COS`(*value*)
`TAN`(*value*)

Example

`TAN(45)` returns `1` (Degrees mode).

[SHIFT] *ASIN*

Arc sine: $\sin^{-1} x$. Output range is from –90° to 90°, $-\pi/2$ to $\pi/2$, or –100 to 100 grads. Inputs and outputs depend on the current angle format. Also accepts complex numbers.

`ASIN`(*value*)

Example

`ASIN(1)` returns `90` (Degrees mode).

SHIFT *ACOS*

Arc cosine: $\cos^{-1}x$. Output range is from 0° to 180°, 0 to π, or 0 to 200 grads. Inputs and outputs depend on the current angle format. Also accepts complex numbers. Output will be complex for values outside the normal COS domain of $-1 \le x \le 1$.

`ACOS`(*value*)

Example

`ACOS(1)` returns `0` (Degrees mode).

SHIFT *ATAN*

Arc tangent: $\tan^{-1}x$. Output range is from –90° to 90°, 2π/2 to π/2, or –100 to 100 grads. Inputs and outputs depend on the current angle format. Also accepts complex numbers.

`ATAN`(*value*)

Example

`ATAN(1)` returns `45` (Degrees mode).

X^2

Square. Also accepts complex numbers.

$value^2$

Example

`18`^{2} returns `324`

SHIFT $\sqrt{\ }$

Square root. Also accepts complex numbers.

$\sqrt{\ }$ *value*

Example

$\sqrt{324}$ returns `18`

(–)

Negation. Also accepts complex numbers.

–*value*

Example

`-(1,2)` returns `(-1,-2)`

X^Y

Power (*x* raised to *y*). Also accepts complex numbers.

value^*power*

Example

`2^8` returns `256`

SHIFT *ABS* Absolute value. For a complex number, this is $\sqrt{x^2+y^2}$.

`ABS`(*value*)
`ABS`((*x*, *y*))

Example

`ABS(-1)` returns `1`
`ABS((1,2))` returns `2.2360679775`

SHIFT $\sqrt[x]{\ }$ Takes the *n*th root of *x*.

root `NTHROOT` *value*

Example

`3 NTHROOT 8` returns `2`

Calculus functions

The symbols for differentiation and integration are available directly form the keyboard— d/dx and S respectively—as well as from the MATH menu.

∂ Differentiates *expression* with respect to the *variable* of differentiation. From the command line, use a formal name (S1, etc.) for a non-numeric result. See “Finding derivatives” on page 13-21.

∂ *variable*(*expression*)

Example

∂ `s1(s1`^{2}`+3*s1)` returns `2*s1+3`

∫ Integrates *expression* from *lower* to *upper* limits with respect to the *variable* of integration. To find the definite integral, both limits must have numeric values (that is, be numbers or real variables). To find the indefinite integral, one of the limits must be a formal variable (s1, etc).

∫ (*lower, upper, expression, variable*)

See “Using formal variables” on page 13-20 for further details.

Example

∫ (0,s1,2*X+3,X) [ENTER] [▲] COPY [ENTER]
finds the indefinite result 3*s1+2*(s1^2/2)

See "To find the indefinite integral using formal variables" on page 13-23 for more information on finding indefinite integrals.

TAYLOR

Calculates the *n*th order Taylor polynomial of *expression* at the point where the given *variable* = 0.

TAYLOR (*expression, variable, n*)

Example

TAYLOR(1 + sin(s1)^2,s1,5) with Radians angle measure and Fraction number format (set in MODES) returns 1+s1^2+-(1/3)*s1^4.

Complex number functions

These functions are for complex numbers only. You can also use complex numbers with all trigonometric and hyperbolic functions, and with some real-number and keyboard functions. Enter complex numbers in the form (x,y), where x is the real part and y is the imaginary part.

ARG

Argument. Finds the angle defined by a complex number. Inputs and outputs use the current angle format set in Modes.

ARG((x, y))

Example

ARG((3,3)) returns 45 (Degrees mode)

CONJ

Complex conjugate. Conjugation is the negation (sign reversal) of the imaginary part of a complex number.

CONJ((x, y))

Example

CONJ((3,4)) returns (3,-4)

IM

Imaginary part, *y*, of a complex number, (x, y).

IM ((x, y))

Example

`IM((3,4))` returns `4`

RE

Real part x, of a complex number, (x, y).

`RE`$((x, y))$

Example

`RE((3,4))` returns `3`

Constants

The constants available from the MATH FUNCTIONS menu are mathematical constants. These are described in this section. The HP 40gs has two other menus of constants: program constants and physical constants. These are described in “Program constants and physical constants” on page 13-24.

e

Natural logarithm base. Internally represented as 2.71828182846.

e

i

Imaginary value for $\sqrt{-1}$, the complex number (0,1).

i

MAXREAL

Maximum real number. Internally represented as $9.99999999999 \times 10^{499}$.

MAXREAL

MINREAL

Minimum real number. Internally represented as 1×10^{-499}.

MINREAL

π

Internally represented as 3.14159265359.

π

Conversions

The conversion functions are found on the **Convert** menu. They enable you to make the following conversions.

→C Convert from Fahrenheit to Celcius.

Example

`→C(212)` returns `100`

→F Convert from Celcius to Fahrenheit.

Example

`→F(0)` returns `32`

→CM Convert from inches to centimeters.

→IN Convert from centimeters to inches.

→L Convert from US gallons to liters.

→LGAL Convert from liters to US gallons.

→KG Convert from pounds to kilograms.

→LBS Convert from kilograms to pounds.

→KM Convert from miles to kilometers.

→MILE Convert from kilometers to miles.

→DEG Convert from radians to degrees.

→RAD Convert from degrees to radians.

Hyperbolic trigonometry

The hyperbolic trigonometry functions can also take complex numbers as arguments.

ACOSH Inverse hyperbolic cosine : $\cosh^{-1} x$.

`ACOSH`(*value*)

ASINH Inverse hyperbolic sine : $\sinh^{-1} x$.

`ASINH`(*value*)

ATANH Inverse hyperbolic tangent : $\tanh^{-1} x$.

`ATANH`(*value*)

COSH

Hyperbolic cosine

`COSH`(*value*)

SINH

Hyperbolic sine.

`SINH`(*value*)

TANH

Hyperbolic tangent.

`TANH`(*value*)

ALOG

Antilogarithm (exponential). This is more accurate than `10^x` due to limitations of the power function.

`ALOG`(*value*)

EXP

Natural exponential. This is more accurate than e^x due to limitations of the power function.

`EXP`(*value*)

EXPM1

Exponent minus 1 : $e^x - 1$. This is more accurate than EXP when *x* is close to zero.

`EXPM1`(*value*)

LNP1

Natural log plus 1 : $\ln(x+1)$. This is more accurate than the natural logarithm function when x is close to zero.

`LNP1`(*value*)

List functions

These functions work on list data. See “List functions” on page 19-6.

Loop functions

The loop functions display a result after evaluating an expression a given number of times.

ITERATE

Repeatedly for *#times* evaluates an *expression* in terms of *variable*. The value for *variable* is updated each time, starting with *initialvalue*.

`ITERATE(`*expression, variable, initialvalue, #times*`)`

Example

`ITERATE(X`^{2}`,X,2,3)` returns `256`

RECURSE Provides a method of defining a sequence without using the Symbolic view of the Sequence aplet. If used with | ("where"), RECURSE will step through the evaluation.

`RECURSE(`*sequencename*, *term*$_n$, *term*$_1$, *term*$_2$`)`

Example

`RECURSE(U,U(N-1)*N,1,2)` STO▶ `U1(N)`
Stores a factorial-calculating function named U1.

When you enter `U1(5)`, for example, the function calculates `5!` (`120`).

Σ Summation. Finds the sum of *expression* with respect to *variable* from *initialvalue* to *finalvalue.*

`Σ(`*variable*=*initialvalue*, *finalvalue*, *expression*`)`

Example

`Σ(C=1,5,C`^{2}`)` returns 55.

Matrix functions

These functions are for matrix data stored in matrix variables. See "Matrix functions and commands" on page 18-10.

Polynomial functions

Polynomials are products of constants (*coefficients*) and variables raised to powers (*terms*).

POLYCOEF Polynomial coefficients. Returns the coefficients of the polynomial with the specified *roots*.

`POLYCOEF` ([*roots*])

Example

To find the polynomial with roots 2, –3, 4, –5:
`POLYCOEF([2,-3,4,-5])` returns `[1,2,-25,-26,120]`, representing $x^4+2x^3-25x^2-26x+120$.

POLYEVAL Polynomial evaluation. Evaluates a polynomial with the specified *coefficients* for the *value* of `x`.

`POLYEVAL([`*coefficients*`],` *value*`)`

Example

For $x^4+2x^3-25x^2-26x+120$:
`POLYEVAL([1,2,-25,-26,120],8)` returns `3432`.

POLYFORM

Polynomial form. Creates a polynomial in *variable1* from *expression*.

`POLYFORM(`*expression, variable1*`)`

Example

`POLYFORM((X+1)^2+1,X)` returns *X^2+2*X+2*.

POLYROOT

Polynomial roots. Returns the roots for the *n*th-order polynomial with the specified *n*+1 *coefficients*.

`POLYROOT([`*coefficients*`])`

Example

For $x^4+2x^3-25x^2-26x+120$:
`POLYROOT([1,2,-25,-26,120])` returns `[2,-3,4,-5]`.

HINT The results of POLYROOT will often not be easily seen in HOME due to the number of decimal places, especially if they are complex numbers. It is better to store the results of POLYROOT to a matrix.

For example, `POLYROOT([1,0,0,-8]` STO▶ `M1` will store the three complex cube roots of 8 to matrix M1 as a complex vector. Then you can see them easily by going to the Matrix Catalog. and access them individually in calculations by referring to M1(1), M1(2) etc.

Probability functions

COMB

Number of combinations (without regard to order) of *n* things taken *r* at a time: $n!/(r!(n-r))$.

`COMB`(n, r)

Example

`COMB(5,2)` returns `10`. That is, there are ten different ways that five things can be combined two at a time.!

Factorial of a positive integer. For non-integers, $! = \Gamma(x + 1)$. This calculates the gamma function.

value!

PERM

Number of permutations (with regard to order) of *n* things taken *r* at a time: $n!/(r!(n-r)!$

`PERM` (*n, r*)

Example

`PERM(5,2)` returns `20`. That is, there are 20 different permutations of five things taken two at a time.

RANDOM

Random number (between zero and 1). Produced by a pseudo-random number sequence. The algorithm used in the RANDOM function uses a seed number to begin its sequence. To ensure that two calculators must produce different results for the RANDOM function, use the RANDSEED function to seed different starting values before using RANDOM to produce the numbers.

`RANDOM`

HINT The setting of Time will be different for each calculator, so using RANDSEED(Time) is guaranteed to produce a set of numbers which are as close to random as possible. You can set the seed using the command RANDSEED.

UTPC

Upper-Tail Chi-Squared Probability given *degrees* of freedom, evaluated at *value*. Returns the probability that a χ^2 random variable is greater than *value.*

`UTPC`(*degrees, value*)

UTPF

Upper-Tail Snedecor's F Probability given *numerator* degrees of freedom and *denominator* degrees of freedom (of the F distribution), evaluated at *value*. Returns the probability that a Snedecor's F random variable is greater than *value.*

`UTPF`(*numerator, denominator, value*)

UTPN

Upper-Tail Normal Probability given *mean* and *variance*, evaluated at *value*. Returns the probability that a normal random variable is greater than *value* for a normal distribution. *Note: The variance is the square of the standard deviation.*

`UTPN`(*mean, variance, value*)

UTPT

Upper-Tail Student's t-Probability given *degrees* of freedom, evaluated at *value*. Returns the probability that the Student's t- random variable is greater than *value*.

`UTPT`(*degrees*, *value*)

Real-number functions

Some real-number functions can also take complex arguments.

CEILING

Smallest integer greater than or equal to *value*.

`CEILING`(*value*)

Examples

`CEILING(3.2)` returns `4`
`CEILING(-3.2)` returns `-3`

DEG→RAD

Degrees to radians. Converts *value* from Degrees angle format to Radians angle format.

`DEG→RAD`(*value*)

Example

`DEG→RAD(180)` returns `3.14159265359`, the value of π.

FLOOR

Greatest integer less than or equal to *value*.

`FLOOR`(*value*)

Example

`FLOOR(-3.2)` returns `-4`

FNROOT

Function root-finder (like the Solve aplet). Finds the value for the given *variable* at which *expression* most nearly evaluates to zero. Uses *guess* as initial estimate.

`FNROOT`(*expression, variable, guess*)

Example

`FNROOT(M*9.8/600-1,M,1)` returns `61.2244897959`.

FRAC

Fractional part.

`FRAC`(*value*)

Example

`FRAC (23.2)` returns `.2`

HMS→

Hours-minutes-seconds to decimal. Converts a number or expression in *H.MMSSs* format (time or angle that can include fractions of a second) to *x.x* format (number of hours or degrees with a decimal fraction).

`HMS→(`*H.MMSSs*`)`

Example

`HMS→(8.30)` returns `8.5`

→HMS

Decimal to hours-minutes-seconds. Converts a number or expression in *x.x* format (number of hours or degrees with a decimal fraction) to *H.MMSSs* format (time or angle up to fractions of a second).

`→HMS(`*x.x*`)`

Example

`→HMS(8.5)` returns `8.3`

INT

Integer part.

`INT(`*value*`)`

Example

`INT(23.2)` returns `23`

MANT

Mantissa (significant digits) of *value*.

`MANT(`*value*`)`

Example

`MANT(21.2E34)` returns `2.12`

MAX

Maximum. The greater of two values.

`MAX(`*value1*, *value2*`)`

Example

`MAX(210,25)` returns `210`

MIN

Minimum. The lesser of two values.

`MIN(`*value1*, *value2*`)`

Example

`MIN(210,25)` returns `25`

MOD

Modulo. The remainder of *value1*/*value2*.

value1 `MOD` *value2*

Example

9 MOD 4 returns 1

%

x percent of *y*; that is, $x/100*y$.

%(*x*, *y*)

Example

%(20,50) returns 10

%CHANGE

Percent change from *x* to *y*, that is, $100(y-x)/x$.

%CHANGE(*x*, *y*)

Example

%CHANGE(20,50) returns 150

%TOTAL

Percent total : (100)*y/x*. What percentage of *x*, is *y*.

%TOTAL(*x*, *y*)

Example

%TOTAL(20,50) returns 250

RAD→DEG

Radians to degrees. Converts *value* from radians to degrees.

RAD→DEG (*value*)

Example

RAD→DEG(π) returns 180

ROUND

Rounds *value* to decimal *places*. Accepts complex numbers.

ROUND(*value*, *places*)

Round can also round to a number of significant digits as showed in example 2.

Examples

ROUND(7.8676,2) returns 7.87

ROUND (0.0036757,-3) returns 0.00368

SIGN

Sign of *value*. If positive, the result is 1. If negative, –1. If zero, result is zero. For a complex number, this is the unit vector in the direction of the number.

SIGN(*value*)
SIGN((*x*, *y*))

Examples

`SIGN (–2)` returns `–1`

`SIGN((3,4))` returns `(.6,.8)`

TRUNCATE Truncates *value* to decimal *places*. Accepts complex numbers.

`TRUNCATE`(*value*, *places*)

Example

`TRUNCATE(2.3678,2)` returns `2.36`

XPON Exponent of *value*.

`XPON`(*value*)

Example

`XPON(123.4)` returns `2`

Two-variable statistics

These are functions for use with two-variable statistics. See "Two-variable" on page 10-15.

Symbolic functions

The symbolic functions are used for symbolic manipulations of expressions. The variables can be formal or numeric, but the result is usually in symbolic form (not a number). You will find the symbols for the symbolic functions = and | (*where*) in the CHARS menu (SHIFT *CHARS*) as well as the MATH menu.

= (*equals*) Sets an equality for an equation. This is *not* a logical operator and does *not* store values. (See "Test functions" on page 13-19.)

expression1=*expression2*

ISOLATE Isolates the first occurrence of *variable* in *expression*=0 and returns a new expression, where *variable*=*newexpression*. The result is a general solution that represents multiple solutions by including the (formal) variables *S1* to represent any sign and *n1* to represent any integer.

`ISOLATE(`*expression*, *variable*`)`

Examples

`ISOLATE(2*X+8,X)` returns `-4`
`ISOLATE(A+B*X/C,X)` returns `-(A*C/B)`

LINEAR?

Tests whether *expression* is linear for the specified *variable*. Returns `0` (false) or `1` (true).

`LINEAR?(`*expression*, *variable*`)`

Example

`LINEAR?((X^2-1)/(X+1),X)` returns `0`

QUAD

Solves quadratic *expression*=`0` for *variable* and returns a new expression, where *variable*=*newexpression*. The result is a general solution that represents both positive and negative solutions by including the formal variable *S1* to represent any sign: + or – .

`QUAD(`*expression*, *variable*`)`

Example

`QUAD((X-1)`^{2}`-7,X)` returns `(2+s1*(2*√7))/2`

QUOTE

Encloses an expression that should not be evaluated numerically.

`QUOTE(`*expression*)

Examples

`QUOTE(SIN(45))` **STO▶** `F1(X)` stores the expression SIN(45) rather than the value of SIN(45).

Another method is to enclose the expression in single quotes.

For example, `X^3+2*X` **STO▶** `F1(X)` puts the expression `X^3+2*X` into `F1(X)` in the Function aplet.

| (*where*)

Evaluates *expression* where each given variable is set to the given *value*. Defines numeric evaluation of a symbolic expression.

expression | (*variable1=value1, variable2=value2,...*)

Example

`3*(X+1)|(X=3)` returns `12`.

Test functions

The test functions are *logical* operators that always return either a 1 (*true*) or a 0 (*false*).

<

Less than. Returns 1 if true, 0 if false.

value1<*value2*

≤

Less than or equal to. Returns 1 if true, 0 if false.

value1≤*value2*

==

Equals (logical test). Returns 1 if true, 0 if false.

value1==*value2*

≠

Not equal to. Returns 1 if true, 0 if false.

value1≠*value2*

>

Greater than. Returns 1 if true, 0 if false.

value1>*value2*

≥

Greater than or equal to. Returns 1 if true, 0 if false.

value1≥*value2*

AND

Compares *value1* and *value2*. Returns 1 if they are both non-zero, otherwise returns 0.

value1 `AND` *value2*

IFTE

If *expression* is true, do the *trueclause*; if not, do the *falseclause*.

`IFTE(`*expression*, *trueclause*, *falseclause*`)`

Example

IFTE(X>0,X^2,X^3)

NOT

Returns 1 if *value* is zero, otherwise returns 0.

`NOT` *value*

OR

Returns 1 if either *value1* or *value2* is non-zero, otherwise returns 0.

value1 `OR` *value2*

XOR

Exclusive OR. Returns 1 if either *value1* or *value2*—but not both of them—is non-zero, otherwise returns 0.

value1 `XOR` *value2*

Trigonometry functions

The trigonometry functions can also take complex numbers as arguments. For SIN, COS, TAN, ASIN, ACOS, and ATAN, see the Keyboard category.

ACOT

Arc cotangent.

`ACOT`(*value*)

ACSC

Arc cosecant.

`ACSC`(*value*)

ASEC

Arc secant.

`ASEC`(*value*)

COT

Cotangent: cos*x*/sin*x*.

`COT`(*value*)

CSC

Cosecant: 1/sin*x*

`CSC`(*value*)

SEC

Secant: 1/cos*x*.

`SEC`(*value*)

Symbolic calculations

Although CAS provides the richest environment for performing symbolic calculations, you can perform some symbolic calculations in HOME and with the Function aplet. CAS functions that you can perform in HOME (such as DERVX and INTVX) are discussed in “Using CAS functions in HOME” on page 14-7.

In HOME

When you perform calculations that contain normal variables, the calculator substitutes values for any variables. For example, if you enter A+B on the command line and press [ENTER], the calculator retrieves the values for A and B from memory and substitutes them in the calculation.

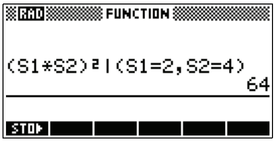
Using formal variables

To perform symbolic calculations, for example symbolic differentiations and integrations, you need to use formal names. The HP 40gs has six formal names available for use in symbolic calculations. These are S1 to S5. When you perform a calculation that contains a formal name, the HP 40gs does not carry out any substitutions.

You can mix formal names and real variables. Evaluating $(A+B+S1)^2$ will evaluate `A+B`, but not `S1`.

If you need to evaluate an expression that contains formal names numerically, you use the | (*where*) command, listed in the Math menu under the Symbolic category.

For example to evaluate `(S1*S2)`^{2} when $S1=2$ and $S2=4$, you would enter the calculation as follows:



(The | symbol is in the CHARS menu: press SHIFT *CHARS*. The = sign is listed in the MATH menu under Symbolic functions.)

Symbolic calculations in the Function aplet

You can perform symbolic operations in the Function aplet's Symbolic view. For example, to find the derivative of a function in the Function aplet's Symbolic view, you define two functions and define the second function as a derivative of the first function. You then evaluate the second function. See "To find derivatives in the Function aplet's Symbolic view" on page 13-22 for an example.

Finding derivatives

The HP 40gs can perform symbolic differentiation on some functions. There are two ways of using the HP 40gs to find derivatives.

- You can perform differentiations in HOME by using the formal variables, S1 to S5.
- You can perform differentiations of functions of X in the Function aplet.

To find derivatives in HOME

To find the derivative of the function in HOME, use a formal variable in place of X. If you use X, the differentiation function substitutes the value that X holds, and returns a numeric result.

For example, consider the function:

$$dx(\sin(x^2) + 2\cos(x))$$

1. Enter the differentiation function onto the command line, substituting S1 in place of X.

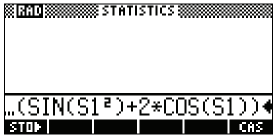
[d/dx] [ALPHA] S1

[(] [SIN] [ALPHA] S1

[X^2] [)] [+] 2 [×]

[COS] [ALPHA] S1

[)] [)]

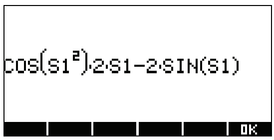


2. Evaluate the function.

[ENTER]

3. Show the result.

[▲] SHOW



To find derivatives in the Function aplet's Symbolic view

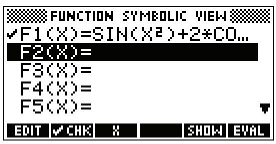
To find the derivative of the function in the Function aplet's Symbolic view, you define two functions and define the second function as a derivative of the first function. For example, to differentiate $\sin(x^2) + 2\cos x$:

1. Access the Function aplet's Symbolic view and define F1.

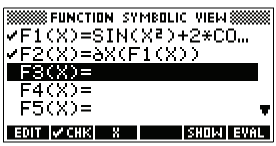
[SYMB] [SIN] X^2 [X^2]

[)] [+] 2 [×] [COS]

X^2 [)] OK



2. Define F2(X) as the derivative of F(1).

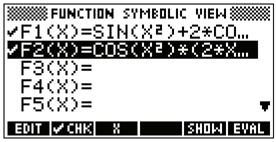


[d/dx] [X²] [(] [ALPHA]

F1 [(] [X²] [)] [)]

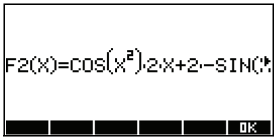
OK

3. Select F2(X) and evaluate it.



[▲] EVAL

4. Press SHOW to display the result. *Note: Use the arrow keys to view the entire function.*



SHOW |

You could also just define

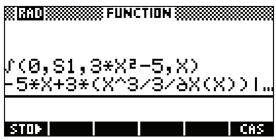
$$F1(x)= \ dx(\sin(x^2)+2\cos(x))\ .$$

To find the indefinite integral using formal variables

For example, to find the indefinite integral of $\int 3x^2 - 5dx$ use:

$$\int(0, S1, 3X^2 - 5, X)$$

1. Enter the function.



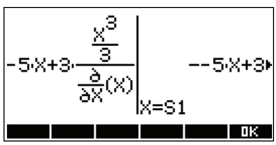
[SHIFT] [d/dx] 0 [,]

[ALPHA] S1 [,] 3 [×]

[ALPHA] X [X²] [-] 5 [,]

[ALPHA] X [)] [ENTER]

2. Show the result format.



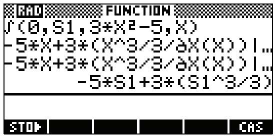
[▲]

SHOW

3. Press OK to close the show window.

4. Copy the result and evaluate.

   COPY ENTER



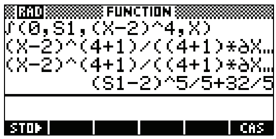
   Thus, substituting X for S1, it can be seen that:

$$\int 3x^2 - 5dx = -5x + 3\left(\frac{\frac{x^3}{3}}{\frac{\partial}{\partial X}(X)}\right)$$

This result is derived from substituting X=S1 and $X=0$ into the original expression found in step 1. However, substituting $X=0$ will not always evaluate to zero and may result in an unwanted constant.

To see this, consider: $\int (x-2)^4 dx = \frac{(x-2)^5}{5}$

The 'extra' constant of 32/5 results from the substitution of $x = 0$ into $(x-2)^5/5$, and should be disregarded if an *indefinite* integral is required.



Program constants and physical constants

When you press MATH, three menus of functions and constants become available:

- the math functions menu (which appears by default)
- the program constants menu, and
- the physical constants menu.

The math functions menu is described extensively earlier in this chapter.

Program constants

The program constants are numbers that have been assigned to various calculator settings to enable you to test for or specify such a setting in a program. For example, the various display formats are assigned the following numbers:

1 Standard

2 Fixed

3 Scientific

4 Engineering

5 Fraction

6 Mixed fraction

In a program, you could store the constant number of a particular format into a variable and then subsequently test for that particular format.

To access the menu of program constants:

1. Press MATH.
2. Press CONS.
3. Use the arrow keys to navigate through the options.
4. Click OK and then ENTER to display the number assigned to the option you selected in the previous step.

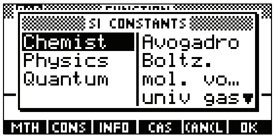
The use of program constants is illustrated in more detail in "Programming" on page 21-1

Physical constants

There are 29 physical constants—from the fields of chemistry, physics and quantum mechanics—that you can use in calculations. A list of all these constants can be found in "Physical Constants" on page R-16.

To access the menu of physical constants:

1. Press MATH.
2. Press PHYS.



3. Use the arrow keys to navigate through the options.
4. To see the symbol and value of a selected constant, press INFO. (Click OK to close the information window that appears.)

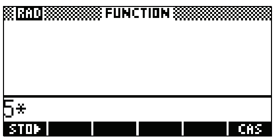
   The following example shows the information available about the speed of light (one of the physics constants).

5. To use the selected constant in a calculation, press OK. The constant appears at the position of the cursor on the edit line.

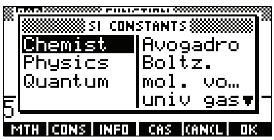
Example

Suppose you want to know the potential energy of a mass of 5 units according to the equation $E = mc^2$.

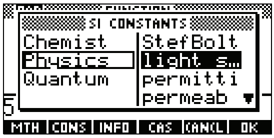
1. Enter 5 [×]



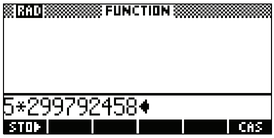
2. Press [MATH] and then press PHYS.



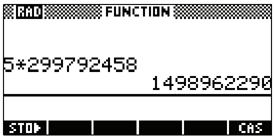
3. Select `light s...` from the Physics menu.



4. Press OK . The menu closes and the value of the selected constant is copied to the edit line.



5. Complete the equation as you would normally and press ENTER to get the result.



14

Computer Algebra System (CAS)

What is a CAS?

A computer algebra system (hereafter CAS) enables you to perform symbolic calculations. With a CAS you manipulate mathematical equations and expressions in symbolic form, rather than manipulating approximations of the numerical quantities represented by those symbols. In other words, a CAS works in *exact mode*, giving you infinite precision. On the other hand, non-CAS calculations, such as those performed in HOME view or by an aplet, are numerical calculations and are limited by the precision of the calculator (to 10^{-12} in the case of the HP 40gs).

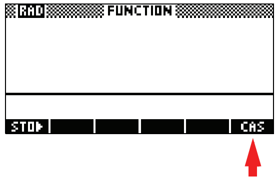
For example, with Standard as your numerical format, 1/2 + 1/6 returns 0.6666666666667 if you are working in the HOME screen; however, 1/2 + 1/6 returns 2/3 if you are working with CAS. HOME calculations are restricted to *approximate* (or *numeric*) mode, while CAS calculations always work in exact mode (unless you specifically change the default CAS modes).

Each mode has advantages and disadvantages. For example, in exact mode there is no rounding error, but some calculations will take much longer to complete and require more memory than equivalent calculations in numeric mode.

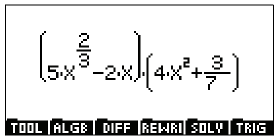
Performing symbolic calculations

You perform CAS calculations with a special tool known as the *Equation Writer*. Some computer algebra operations can also be done in the HOME screen, as long as you take certain precautions (see “Using CAS functions in HOME” on page 14-7). Moreover, some computer algebra operations can only be done in the HOME screen; for example, symbolic linear algebra using vectors and matrices. (Vectors and matrices cannot be entered using the Equation Writer).

To open the Equation Writer, press the CAS soft-key on the menu bar of the HOME screen.



The illustration at the right shows an expression being written in the Equation Writer. The soft keys on the menu bar provide access to CAS functions and commands.



To leave the Equation Writer, press HOME to return to the HOME screen. Note that expressions written in the Equation Writer (and the results of evaluating an expression) are not automatically copied to the HOME history when you leave the Equation Writer. (You can, however, manually copy them to HOME: see page 14-8).

CAS functions are described in detail in “CAS functions in the Equation Writer” on page 14-9. Chapter 15, “Equation Writer”, explains in detail how to enter an expression in the Equation Writer and contains numerous worked examples of CAS in operation.

An example

To give you an idea of how CAS works, let’s consider a simple example. Suppose you want to convert *C* to the form $d \cdot \sqrt{5}$ where *C* is $2\sqrt{45} - \sqrt{20}$ and *d* is a whole number.

1. Open the Equation Writer by pressing the CAS soft-key on the HOME screen.
2. Enter the expression for *C*.

   [**Hint:** use the keys on the keyboard as you would if entering the expression in HOME. Press the ▶ key twice to select the entire first term before entering the second term.]

3. Press ▶ and ▼ to select just the 20 in the $\sqrt{20}$ term.

4. Press the ALGB menu key and choose `FACTOR`. Then press OK .

Note that the `FACTOR` function is added to the selected term.

5. Press ENTER to factor the selected term.

6. Press ▲ to select the entire second term, and then press ENTER to simplify it.

7. Press ▶ ▶ ▼ ▼ ▶ ▼ to select the 45 in the first term.

8. As you did earlier, press the ALGB menu key and choose `FACTOR`. Then press OK and ENTER to factor the selected term.

9. Press ▲ to select the entire second term, and then press ENTER to simplify it.

10. Press [▶] three times to select the entire expression and then press [ENTER] to simplify it to the form required.

CAS variables

When you use the symbolic calculation functions, you are working with symbolic variables (variables that do not contain a permanent value). In the HOME screen, a variable of this kind must have a name like S1…S5, s1…s5, n1…n5, but not X, which is assigned to a real value. (By default, X is assigned to 0). To store symbolic expressions, you must use the variables E0, E1…E9.

In the Equation Writer, all the variables may, or may not be, assigned. For example, X is not assigned to a real value by default, so computing X + X will return 2X.

Moreover, Equation Writer variables can have long names, like XY or ABC, unlike in HOME where implied multiplication is assumed. (For example ABC is interpreted as A × B × C in HOME.) For these reasons, variables used in the Equation Writer cannot be used in HOME, and vice versa.

Using the `PUSH` command, you can transfer expressions from the HOME screen history to CAS history (see page 14-8). Likewise, you can use the `POP` command to transfer expressions from CAS history to the HOME screen history (see page 14-8).

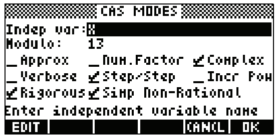
The current variable

In the Equation Writer, the current variable is the name of the symbolic variable contained in VX. It is almost always X. (The current variable is always S1 in HOME.)

Some CAS functions depend on a current variable; for example, the function DERVX calculates the derivative with respect to the current variable. Hence in the Equation Writer, DERVX(2*X+Y) returns 2 if VX = X, but 1 if VX = Y. However, in the HOME screen, DERVX(2*S1+S2) returns 2, but DERIV(2*S1+S2,S2) returns 1.

CAS modes

The modes that determine how CAS operates can be set on CAS MODES screen. To display CAS MODES screen, press:



SHIFT CAS

·To navigate through the options in CAS MODES screen, press the arrow keys.

To select or deselect a mode, navigate to the appropriate field and press ✓CHK until the correct setting is displayed (indicated by a check mark in the field). For some settings (such as INDEP VAR and MODULO), you will need to press EDIT to be able to change the setting.

Press OK to close CAS MODES screen.

NOTE You can also set CAS modes from within the Equation Writer. See “Configuration menus” on page 15-3 for information.

Selecting the independent variable

Many of the functions provided by CAS use a pre-determined independent variable. By default, that variable is the letter X (upper case) as shown in CAS MODES screen above. However, you can change this variable to any other letter, or combination of letters and numbers, by editing the INDEP VAR field in CAS MODES screen. To change the setting, press EDIT, enter a new value and then press OK .

The variable VX in the calculator's {HOME CASDIR} directory takes, by default, the value of 'X'. This is the name of the preferred independent variable for algebraic and calculus applications. If you use another independent variable name, some functions (for example, HORNER) will not work properly.

Selecting the modulus

The MODULO option on CAS MODES screen lets you specify the modulo you want to use in modular arithmetic. The default value is 13.

Approximate vs. Exact mode

When the APPROX mode is selected, symbolic operations (for example, definite integrals, square roots, etc.), will be calculated numerically. When this mode is unselected, *exact mode* is active, hence symbolic operations will be calculated as closed-form algebraic expressions, whenever possible. [Default: unselected.]

Num. Factor mode

When the NUM FACTOR setting is selected, approximate roots are used when factoring. For example, $x^5 + 5x + 1$ is irreducible over the integers but has approximate roots over the reals. With NUM FACTOR set, the approximate roots are returned. [Default: unselected.]

Complex vs. Real mode

When COMPLEX is selected and an operation results in a complex number, the result will be shown in the form *a* + *bi* or in the form of an ordered pair (*a*,*b*). If COMPLEX mode is not selected and an operation results in a complex number, you will be asked to switch to COMPLEX mode. If you decline, the calculator will report an error. [Default: unselected.]

When in COMPLEX mode, CAS is able to perform a wider range of operations than in non-complex (or real) mode, but it will also be considerably slower. Thus, it is recommended that you don't select COMPLEX mode unless requested by the calculator in the performance of a particular operation.

Verbose vs. non-verbose mode

When VERBOSE is selected, certain calculus applications are provided with comment lines in the main display. The comment lines will appear in the top lines of the display, but only while the operation is being calculated. [Default: unselected.]

Step-by-step mode

When STEP/STEP is selected, certain operations will be shown one step at a time in the display. You press ENTER to show each step in turn. [Default: selected.]

Increasing-powers mode

When INCR POW is selected, polynomials will be listed so that the terms will have increasing powers of the independent variable (which is the opposite to how polynomials are normally written). [Default: unselected.]

Rigorous setting

When RIGOROUS is selected, any algebraic expression of the form |X|, i.e., the absolute value of X, is not simplified to X. [Default: selected.]

Simplify non-rational setting

When SIMP NON-RATIONAL is selected, non-rational expressions will be automatically simplified. [Default: selected.]

Using CAS functions in HOME

You can use many computer algebra functions directly in the HOME screen, as long as you take certain precautions. CAS functions that take matrices as an argument work only from HOME.

CAS functions can be accessed by pressing CAS when MATH menu is displayed. You can also directly type a function name when you are in alpha mode.

Note that certain calculations will be performed in approximate mode because numbers are interpreted as reals instead of integers in HOME. To do exact calculations, you should use the XQ command. This command converts an approximate argument into an exact argument.

For example, if Radians is your angle setting, then:

ARG(XQ(1 + i)) = $\pi/4$ but

ARG(1 + i) = 0.7853...

Similarly:

FACTOR(XQ(45)) = $3^2 \times 5$ but

FACTOR(45) = 45

Note too that the symbolic HOME variable S1 serves as the current variable for CAS functions in HOME. For example:

DERVX($S1^2 + 2 \times S1$) = $2 \times S1 + 2$

The result $2 \times S1 + 2$ does not depend on the Equation Writer variable, `VX`.

Some CAS functions cannot work in HOME because they require a change to the current variable.

Remember that you must use S1,S2,…S5, s1,s2,…s5, and n1,n2,…n5 for symbolic variables and E0, E1,…E9 to store symbolic expressions. For example, if you type:

$S1^2 - 4 \times S2$ STO▶ E1

then you get:

DERVX(E1) = $S1 \times 2$

DERIV(E1, S2) = –4

INTVX(E1) = $1/3\ S1^3 - 4 \times (S2 \times S1)$

Symbolic matrices are stored as a list of lists and therefore must be stored in L0, L1…L9 (whereas numeric matrices are stored in M0, M1,…M9). CAS linear algebra instructions accept lists of lists as input.

For example, if you type in HOME:

XQ({{S2 + 1, 1}, { $\sqrt{2}$, 1}}) STO▶ L1

then you have:

TRAN(L1) = {{S2 + 1, $\sqrt{2}$ }, {1, 1}}

Some numeric linear algebra commands do not directly work on a list of lists, but will do so after a conversion by AXL. For example, if you enter:

DET(AXL(L1)) STO▶ E1

you get:

S2–(–1 + $\sqrt{2}$)

Send expressions from HOME to CAS history

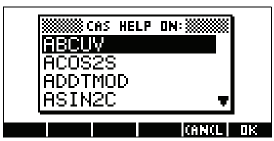
In the HOME screen, you can use the `PUSH` command to send expressions to CAS history. For example, if you enter PUSH(S1+1), S1+1 is written to CAS history.

Send expressions from CAS to HOME history

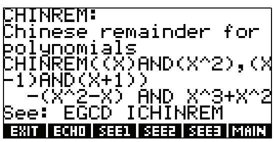
In the HOME screen, you can use the `POP` command to retrieve the last expression written to CAS history. For example, if S1+1 is the last expression written to CAS history and you enter POP in the HOME screen, S1+1 is written to the HOME screen history (and S1+1 is removed from CAS history).

Online Help

When you are working with the Equation Writer, you can display online help about any CAS command. To display the contents of the online help, press SHIFT 2.



Press ▼ to navigate to the command you want help with and then press OK.



You can also get CAS help from the HOME screen. Type

HELP and press [ENTER]. The menu of help topics appears.

Each help topic includes the required syntax, along with real sample values. You can copy the syntax, with the sample values, to the HOME screen or to the Equation Writer, by pressing ECHO.

TIP If you highlight a CAS command and then press [SHIFT] 2, help about the highlighted command is displayed.

You can display the online help in French rather than English. For instructions, see "Online Help language" on page 15-4.

CAS functions in the Equation Writer

You can display a menu of CAS functions in four ways:

- by displaying the MATH menu from HOME and then pressing CAS, or
- opening the Equation Writer and pressing [MATH],
- opening the Equation Writer and selecting a function from a soft-key menu, or
- opening the Equation Writer and pressing [SHIFT] [MATH].

You can also directly type the name of a CAS function when you are in ALPHA mode.

Note that in this section, CAS functions available from the sot-key menus in the Equation Writer are described. CAS functions available from the MATH menu are described in "CAS Functions on the MATH menu" on page 14-45.

NOTE When using CAS, you should be aware that the required syntax will vary depending on whether you are applying the command to an expression or a function. All CAS commands are designed to work with expressions; that is, they take expressions as arguments. If you are going to use a function—for example, F—you need to specify an expression made from this function, such as F(*x*), where *x* is the independent variable.

For example, suppose you have stored the *expression* x^2 in G, and have defined the *function* F(x) as x^2. Suppose now you want to calculate INTVX(X^2). You could:

- enter `INTVX(X²)` directly, or
- enter `INTVX(G)`, or
- enter `INTVX(F(X))`.

Note that you can apply the command directly to an expression or to a variable that holds an expression (the first two cases above). But where you want to apply it to a defined function, you need to specify the full function name, F(X), as in the third case above.

ALGB menu

COLLECT

Factors over the integers

COLLECT combines like terms and factors the expression over the integers.

Example

To factor $x^2 - 4$ over the integers you would type:

`COLLECT(X²-4)`

which gives in real mode:

$$(x+2)\cdot(x-2)$$

Example

To factor $x^2 - 2$ over the integers you would type:

`COLLECT(X²-2)`

which gives:

$$x^2 - 2$$

DEF

Define a function

For its argument, DEF takes an equality between:

1. the name of a function (with parentheses containing the variable), and
2. an expression defining the function.

DEF defines this function and returns the equality.

Typing:

```
DEF(U(N) = 2N+1)
```

produces the result:

```
U(N) = 2N+1
```

Typing:

```
U(3)
```

then returns:

```
7
```

Example

Calculate the first six Fermat numbers F1…F6 and determine whether they are prime.

So, you want to calculate:

$$F(k) = 2^{2^k} + 1 \text{ for } k = 1\ldots6$$

Typing the formula:

$$2^{2^2} + 1$$

gives a result of 17. You can then invoke the `ISPRIME?()` command, which is found in the `MATH` key's `Integer` menu. The response is 1, which means TRUE. Using the history (which you access by pressing the `SYMB` key), you put the expression $2^{2^2} + 1$ into the Equation Writer with `ECHO`, and change it to:

$$2^{2^3} + 1$$

Or better, define a function F(K) by selecting `DEF` from the `ALGB` menu on the menu bar and type:

$$DEF(F(K) = 2^{2^k} + 1)$$

The response is $2^{2^k} + 1$ and *F* is now listed amongst the variables (which you can verify using the `VARS` key).

For *K=5*, you then type:

```
F(5)
```

which gives

```
4294967297
```

You can factor *F(5)* with `FACTOR`, which you'll find in the `ALGB` menu on the menu bar.

Typing:

```
FACTOR(F(5))
```

gives:

```
641·6700417
```

Typing:

```
F(6)
```

gives:

```
18446744073709551617
```

Using `FACTOR` to factor it, then yields:

```
274177·67280421310721
```

EXPAND

Distributivity

EXPAND expands and simplifies an expression.

Example

Typing:

$$\mathrm{XPAND}((X^2 + \sqrt{2} \cdot X + 1) \cdot (X^2 - \sqrt{2} \cdot X + 1)$$

gives:

$$x^4 + 1$$

FACTOR

Factorization

FACTOR factors an expression.

Example

To factor:

$$x^4 + 1$$

type:

```
FACTOR(X^4+1)
```

`FACTOR` is located in the `ALGB` menu.

In real mode, the result is:

$$(x^2+\sqrt{2}\cdot x+1)\cdot(x^2-\sqrt{2}\cdot x+1)$$

In complex mode (using `CFG`), the result is:

$$\frac{1}{16}\cdot(2x+(1+i)\cdot\sqrt{2})\cdot(2x-(1+i)\cdot\sqrt{2})\cdot(2x+(1-i)\cdot\sqrt{2})$$
$$\cdot(2x-(1-i)\cdot\sqrt{2})$$

PARTFRAC

Partial fraction expansion

PARTFRAC has a rational fraction as an argument.

PARTFRAC returns the partial fraction decomposition of this rational fraction.

Example

To perform a partial fraction decomposition of a rational function, such as:

$$\frac{x^5-2\cdot x^3+1}{x^4-2\cdot x^3+2\cdot x^2-(2\cdot x+1)}$$

you use the `PARTFRAC` command.

In real and direct mode, this produces:

$$x+2+\frac{x-3}{2\cdot x^2+2}+\frac{-1}{2\cdot x-2}$$

In complex mode, this produces:

$$x+2+\frac{\frac{1-3i}{4}}{x+i}+\frac{\frac{-1}{2}}{x-1}+\frac{\frac{1+3i}{4}}{x-i}$$

QUOTE

Quoted expression

QUOTE(`expression`) is used to prevent an expression from being evaluated or simplified.

Example 1

Typing:

$$\mathrm{im}\left(QUOTE((2X-1)\cdot EXP(\frac{1}{X}-1), X=+\infty\right)$$

gives:

$$+\infty$$

Example 2

Typing:

```
SUBST(QUOTE(CONJ(Z)),Z=1+i)
```

gives:

```
CONJ(1+i)
```

STORE

Store an object in a variable

STORE stores an object in a variable.

`STORE` is found in the `ALGB` menu or the Equation Writer menu bar.

Example

Type:

`STORE(X`^{2}`-4,ABC)`

or type:

`X`^{2}`-4`

then select it and call `STORE`, then type `ABC`, then press ENTER to confirm the definition of the variable *ABC*.

To clear the variable, press `VARS` in the Equation Writer (then choose `PURGE` on the menu bar), or select `UNASSIGN` on the `ALGB` menu by typing, for example,

```
UNASSIGN(ABC)
```

|

Substitute a value for a variable

| is an infix operator used to substitute a value for a variable in an expression (similar to the function `SUBST`).

| has two parameters: an expression dependent on a parameter, and an equality (parameter=substitute value).

| substitutes the specified value for the variable in the expression.

Typing:

$$X^2-1|_{X=2}$$

gives:

$$2^2-1$$

SUBST

Substitute a value for a variable

SUBST has two parameters: an expression dependent on a parameter, and an equality (parameter=substitute value).

SUBST substitutes the specified value for the variable in the expression.

Typing:

`SUBST(A^2+1,A=2)`

gives:

$$2^2 + 1$$

TEXPAND

Develop in terms of sine and cosine

TEXPAND has a trigonometric expression or transcendental function as an argument.

TEXPAND develops this expression in terms of sin(x) and cos(x).

Example

Typing:

`TEXPAND(COS(X+Y))`

gives:

$$\cos(y) \cdot \cos(x) - \sin(y) \cdot \sin(x)$$

Example

Typing:

`TEXPAND(COS(3·X))`

gives:

$$4 \cdot \cos(x)^3 - 3 \cdot \cos(x)$$

UNASSIGN

Clear a variable

UNASSIGN is used to clear a variable, for example:

`UNASSIGN(`*`ABC`*`)`

DIFF menu

DERIV

Derivative and partial derivative

DERIV has two arguments: an expression (or a function) and a variable.

DERIV returns the derivative of the expression (or the function) with respect to the variable given as the second parameter (used for calculating partial derivatives).

Example

Calculate:

$$\frac{\partial(x \cdot y^2 \cdot z^3 + x \cdot y)}{\partial z}$$

Typing:

```
DERIV(X•Y²•Z³ + X•Y,Z)
```

gives:

$$3 \cdot x \cdot y^2 \cdot z^2$$

DERVX

Derivative

DERVX has one argument: an expression. DERVX calculates the derivative of the expression with respect to the variable stored in VX.

For example, given:

$$f(x) = \frac{x}{x^2 - 1} + \ln\left(\frac{x+1}{x-1}\right)$$

calculate the derivative of *f*.

Type:

$$\text{ERVX}\left(\frac{X}{X^2 - 1} + \text{LN}\left(\frac{X+1}{X-1}\right)\right.$$

Or, if you have stored the definition of *f(x)* in F, that is, if you have typed:

$$\text{TORE}\left(\frac{X}{X^2 - 1} + \text{LN}\left(\frac{X+1}{X-1}\right), \text{F}\right.$$

then type:

```
DERVX(F)
```

Or, if you have defined *F(X)* using `DEF`, that is, if you have typed:

$$\text{DEF}(\text{F}(\text{X}) = \frac{X}{X^2-1} + \text{LN}\left(\frac{X+1}{X-1}\right))$$

then type:

```
DERVX(F(X))
```

Simplify the result to get:

$$-\frac{3 \cdot x^2 - 1}{x^4 - 2 \cdot x^2 + 1}$$

DIVPC

Division in increasing order by exponent

DIVPC has three arguments: two polynomials A(X) and B(X) (where B(0) ≠0), and a whole number n.

DIVPC returns the quotient Q(X) of the division of A(X) by B(X), in increasing order by exponent, and with deg(Q) <= n or Q = 0.

Q[X] is then the limited nth-order expansion of:

$$\frac{A[X]}{B[X]}$$

in the vicinity of X= 0.

Typing:

DIVPC(1+X^2+X^3,1+X^2,5)

gives:

$$1 + x^3 - x^5$$

NOTE: When the calculator displays a request to change to increasing powers mode, respond yes.

FOURIER

Fourier coefficients

FOURIER has two parameters: an expression *f(x)* and a whole number *N*.

FOURIER returns the Fourier coefficient c_N of *f(x)*, considered to be a function defined over interval [0, *T*] and with period *T* (*T* being equal to the contents of the variable *PERIOD*).

If *f(x)* is a discrete series, then:

$$f(x) = \sum_{N=-\infty}^{+\infty} c_N e^{\frac{2iNx\pi}{T}}$$

Example

Determine the Fourier coefficients of a periodic function *f* with period 2π and defined over interval $[0, 2\pi]$ by $f(x)=x^2$.

Typing:

```
STORE(2π,PERIOD)
```

```
FOURIER(X²,N)
```

The calculator does not know that N is a whole number, so you have to replace EXP(2∗ i∗N∗π) with 1 and then simplify the expression. We get

$$\frac{2 \cdot i \cdot N \cdot \pi + 2}{N^2}$$

So if $N \neq 0$, then:

$$c_N = \frac{2 \cdot i \cdot N \cdot \pi + 2}{N^2}$$

Typing:

```
FOURIER(X²,0)
```

gives:

$$\frac{4 \cdot \pi^2}{3}$$

so if $N = 0$, then:

$$c_0 = \frac{4 \cdot \pi^2}{3}$$

IBP

Partial integration

IBP has two parameters: an expression of the form $u(x) \cdot v'(x)$ and $v(x)$.

IBP returns the AND of $u(x) \cdot v(x)$ and of $-v(x) \cdot u'(x)$

that is, the terms that are calculated when performing a partial integration.

It remains then to calculate the integral of the second term of the AND, then add it to the first term of the AND to obtain a primitive of $u(x) \cdot v'(x)$.

Typing:

```
IBP(LN(X),X)
```

gives:

```
X·LN(X) AND - 1
```

The integration is completed by calling `INTVX`:

```
INTVX(X·LN(X)AND - 1)
```

which produces the result:

```
X·LN(X) - X
```

NOTE: If the first IBP (or INTVX) parameter is an AND of two elements, IBP concerns itself only with the second element of the AND, adding the integrated term to the first element of the AND (so that you can perform multiple IBP in succession).

INTVX

Primitive and defined integral

INTVX has one argument: an expression.

INTVX calculates a primitive of its argument with respect to the variable stored in VX.

Example

Calculate a primitive of *sin(x)* × *cos(x)*.

Typing:

```
INTVX(SIN(X)·COS(X))
```

gives in step-by-step mode:

```
COS(X)·SIN(X)

Int[u'*F(u)] with u=SIN(X)
```

Pressing OK then sends the result to the Equation Writer:

$$\frac{\sin(x)^2}{2}$$

Example

Given:

$$f(x) = \frac{x}{x^2 - 1} + \mathrm{LN}\left(\frac{x+1}{x-1}\right)$$

calculate a primitive of *f*.

Type:

$$\mathrm{NTVX}\left(\frac{X}{X^2+1} + \mathrm{LN}\left(\frac{X+1}{X-1}\right)\right.$$

Or, if you have stored *f(x)* in F, that is, if you have already typed:

$$\mathrm{TORE}\left(\frac{X}{X^2-1} + \mathrm{LN}\left(\frac{X+1}{X-1}\right),\mathrm{F}\right.$$

then type:

```
INTVX(F)
```

Or, if you have used `DEF` to define f(*x*), that is, if you have already typed:

$$\mathrm{EF(F(X)} = \frac{X}{X^2-1} + \mathrm{LN}\left(\frac{X+1}{X-1}\right))$$

then type:

```
INTVX(F(X))
```

The result in all cases is equivalent to:

$$\cdot\ \mathrm{LN}\left(\frac{X+1}{X-1}\right) + \frac{3}{2} \cdot \mathrm{LN}(|X-1|) + \frac{3}{2} \cdot \mathrm{LN}(|X+1|$$

You will obtain absolute values only in *Rigorous* mode. (See “CAS modes” on page 14-5 for instructions on setting and changing modes.)

Example

Calculate:

$$\int \frac{2}{x^6 + 2 \cdot x^4 + x^2}\ dx$$

Typing:

$$\mathrm{NTVX}\left(\frac{2}{X^6 + 2 \cdot X^4 + X^2}\right)$$

gives a primitive:

$$-3 \cdot \mathrm{atan}(x) - \frac{2}{x} - \frac{x}{x^2 + 1}$$

Note You can also type $\int_1^X \frac{2}{X^6 + 2 \cdot X^4 + X^2} dX$ which gives the primitive which is zero for $x = 1$

$$-3 \cdot \mathrm{atan}(x) - \frac{2}{x} - \left(\frac{x}{x^2 + 1} + \frac{3 \cdot \pi + 10}{4}\right)$$

Example

Calculate:

$$\int \frac{1}{\sin(x) + \sin(2 \cdot x)} dx$$

Typing:

$$\mathrm{NTVX}\left(\frac{1}{\mathrm{SIN}(X) + \mathrm{SIN}(2 \cdot X)}\right)$$

gives the result:

$$\frac{1}{6} \cdot LN(|\cos(X) - 1|) + \frac{1}{2} \cdot LN(|\cos(X) + 1|) + \frac{-2}{3} \cdot LN(|2\cos(X) + 1|)$$

NOTE: If the argument to INTVX is the AND of two elements, INTVX concerns itself only with the second element of the AND, and adds the result to the first argument.

lim

Calculate limits

LIMIT or lim has two arguments: an expression dependent on a variable, and an equality (a variable = the value to which you want to calculate the limit).

You can omit the name of the variable and the sign =, when this name is in VX).

It is often preferable to use a quoted expression:

QUOTE(expression), to avoid rewriting the expression in normal form (i.e., not to have a rational simplification of the arguments) during the execution of the LIMIT command.

Example

Typing:

$$\lim\left(\mathrm{QUOTE}\left((2X-1)\cdot \mathrm{EXP}\left(\frac{1}{X-1}\right)\right), X = +\infty\right)$$

gives:

$+\infty$

To find a right limit, for example, type:

$$\lim\left(\frac{1}{X-1}, \mathrm{QUOTE}(1+0)\right)$$

gives (if *X* is the current variable):

$+\infty$

To find a left limit, for example, type:

$$\lim\left(\frac{1}{X-1}, \mathrm{QUOTE}(1-0)\right)$$

gives (if *X* is the current variable):

$-\infty$

It is not necessary to quote the second argument when it is written with =, for example:

$$\lim\left(\frac{1}{X-1}, (X = 1+0)\right)$$

gives:

$+\infty$

Example

For n > 2 in the following expression, find the limit as x approaches 0:

$$\frac{n\cdot\tan(x)-\tan(n\cdot x)}{\sin(n\cdot x)-n\cdot\sin(x)}$$

You can use the `LIMIT` command to do this.

Typing:

$$\lim\left(\frac{N \cdot TAN(X) - TAN(N \cdot X)}{SIN(N \cdot X) - N \cdot SIN(X)}, 0\right)$$

gives:

2

NOTE: To find the limit as x approaches a^{+}(resp a^{-}), the second argument is written:

`X=A+0(resp X=A-0)`

For the following expression, find the limit as x approaches +∞:

$$\sqrt{x + \sqrt{x + \sqrt{x}}} - \sqrt{x}$$

Typing:

$$\lim\left(\sqrt{X + \sqrt{X + \sqrt{X}}} - \sqrt{X},\ +\infty\right)$$

produces (after a short wait):

$$\frac{1}{2}$$

NOTE: the symbol ∞ is obtained by typing SHIFT 0.

To obtain –∞:

(–)∞

To obtain +∞:

(–)(–)∞

You can also find the symbol ∞ in the `MATH` key's `Constant` menu.

PREVAL

Evaluate a primitive

PREVAL has three parameters: an expression *F(VX)* dependent on the variable contained in *VX*, and two expressions A and B.

For example, if *VX* contains *X*, and if *F* is a function, `PREVAL (F(X),A,B)` returns `F(B)-F(A)`.

PREVAL is used for calculating an integral defined from a primitive: it evaluates this primitive between the two limits of the integral.

Typing:

```
PREVAL(X²+X,2,3)
```

gives:

```
6
```

RISCH

Primitive and defined integral

RISCH has two parameters: an expression and the name of a variable.

RISCH returns a primitive of the first parameter with respect to the variable specified in the second parameter.

Typing:

```
RISCH((2·X²+1)·EXP(X²+1),X)
```

gives:

```
X·EXP(X²+1)
```

NOTE: If the RISCH parameter is the AND of two elements, RISCH concerns itself only with the second element of the AND, and adds the result to the first argument.

SERIES

Limited *n*th-order expansion

SERIES has three arguments: an expression dependent on a variable, an equality (the variable x = the value a to which you want to calculate the expansion) and a whole number (the order n of the limited expansion).

You can omit the name of the variable and the = sign when this name is in `VX`).

SERIES returns the limited nth-order expansion of the expression in the vicinity of $x = a$.

- **Example — Expansion in the vicinity of x=a**

Give a limited 4th-order expansion of $\cos(2 \cdot x)^2$ in the vicinity of $x = \frac{\pi}{6}$.

For this you use the `SERIES` command.

Typing:

$$\text{SERIES}\left(COS(2 \cdot X)^2, X = \frac{\pi}{6}, 4\right)$$

gives:

$$\langle \frac{1}{4} - \sqrt{3}h + 2h^2 + \frac{8\sqrt{3}}{3}h^3 - \frac{8}{3}h^4 + 0\left(\frac{h^5}{4}\right) | h = X - \frac{\pi}{6} \rangle$$

- **Example — Expansion in the vicinity of *x*=+∞ or *x*=–∞**

Example 1

Give a 5th-order expansion of arctan(x) in the vicinity of x=+∞, taking as infinitely small $h = \frac{1}{x}$.

Typing:

```
SERIES(ATAN(X),X =+∞,5)
```

gives:

$$\left(\frac{\pi}{2} - h + \frac{h^3}{3} - \frac{h^5}{5} + 0\left(\frac{\pi \cdot h^6}{2}\right)\right) \Bigg| h = \frac{1}{x}$$

Example 2

Give a 2nd-order expansion of $(2x-1)e^{\frac{1}{x-1}}$ in the vicinity of x=+∞, taking as infinitely small $h = \frac{1}{x}$.

$$\text{SERIES}((2X-1) \cdot EXP\left(\frac{1}{X-1}\right), X = +\infty, 3)$$

gives:

$$\frac{12 + 6h + 12h^2 + 17h^3}{6 \cdot h} + 0(2 \cdot h^3) \Bigg| h = \frac{1}{x}$$

- **Unidirectional expansion**

To perform an expansion in the vicinity of x = a where x > a, use a positive real (such as 4.0) for the order.

To perform an expansion in the vicinity of x = a where x < a, use a negative real (such as –4.0) for the order.

You must be in Rigorous (not Sloppy) mode to apply SERIES with unidirectional expansion. (See "CAS modes" on page 14-5 for instructions on setting and changing modes.

Example 1

Give a 3rd-order expansion of $\sqrt{x^2+x^3}$ in the vicinity of $x = 0^+$.

Typing:

$$\texttt{SERIES}(\sqrt{X^2+X^3}, X = 0, 3.0)$$

gives:

$$\frac{1}{16} \cdot h^4 + \frac{-1}{8} \cdot h^3 + \frac{1}{2} \cdot h^2 + h + 0(h^5) \Big| (h = x)$$

Example 2

Give a 3rd-order expansion of $\sqrt{x^2+x^3}$ in the vicinity of $x = 0^-$.

Typing:

$$\texttt{SERIES}(\sqrt{X^2+X^3}, X = 0, -3.0)$$

gives:

$$\frac{-1}{16} \cdot h^4 + \frac{-1}{8} \cdot h^3 + \frac{-1}{2} \cdot h^2 + h + 0(h^5) \Big| (h = -x)$$

Note that $h = -x$ is positive as $x \to 0^-$.

Example 3

If you enter the order as an integer rather than a real, as in:

$$\texttt{SERIES}(\sqrt{X^2+X^3}, X = 0, 3)$$

you will get the following error:

```
SERIES Error: Unable to find sign.
```

Note that if you had been in Sloppy rather than Rigorous mode, all three examples above would have returned the same answer as you got when exploring in the vicinity of $x = 0^+$:

$$\frac{1}{16} \cdot h^4 + \frac{-1}{8} \cdot h^3 + \frac{1}{2} \cdot h^2 + h + 0(h^5)\Big|(h = x)$$

TABVAR

Variation table

TABVAR has as a parameter an expression with a rational derivative.

TABVAR returns the variation table for the expression in terms of the current variable.

Typing:

$\texttt{TABVAR(3X}^2\texttt{-8X-11)}$

gives, in step-by-step mode:

$$F = (3 \cdot x^2 - 8 \cdot x - 11)$$

$$F' = (3 \cdot 2 \cdot x - 8)$$

$$\to (2 \cdot (3 \cdot x - 4))$$

```
Variation table:
```

$$\left|\begin{array}{cccccc} -\infty & - & \frac{4}{3} & + & +\infty & \mathrm{X} \\ +\infty & \downarrow & \frac{-49}{3} & \uparrow & +\infty & \mathrm{F} \end{array}\right|$$

The arrows indicate whether the function is increasing or decreasing during the specified interval. This particular variation table indicates that the function F(x) decreases for x in the interval $[-\infty, \frac{4}{3}]$, reaching a minimum of $\frac{-49}{3}$ at $x = \frac{4}{3}$. It then increases in the interval $[\frac{4}{3}, +\infty]$, reaching a maximum of $+\infty$.

Note that "?" appearing in the variation table indicates that the function is not defined in the corresponding interval.

TAYLOR0

Limited expansion in the vicinity of 0

TAYLOR0 has a single argument: the function of x to expand. It returns the function's limited 4th-relative-order expansion in the vicinity of x=0 (if x is the current variable).

Typing:

$$\texttt{TAYLOR0}\left(\frac{\texttt{TAN(P·X) – SIN(P·X)}}{\texttt{TAN(Q·X) – SIN(Q·X)}}\right)$$

gives:

$$\frac{P^3}{Q^3} + \frac{P^5 - Q^2 \cdot P^3}{4 \cdot Q^3} \cdot x^2$$

Note 'th-order' means that the numerator and the denominator are expanded to the 4th relative order (here, the 5th absolute order for the numerator, and for the denominator, which is given in the end, the 2nd order (5–3), seeing that the exponent of the denominator is 3).

TRUNC

Truncate at order n - 1

TRUNC enables you to truncate a polynomial at a given order (used to perform limited expansions).

TRUNC has two arguments: a polynomial and X^n.

TRUNC returns the polynomial truncated at order n–1; that is, the returned polynomial has no terms with exponents ≥n.

Typing:

$$\texttt{TRUNC}\left(\left(1 + X + \frac{1}{2} \cdot X^2\right)^3, X^4\right)$$

gives:

$$4x^3 + \frac{9}{2}x^2 + 3x + 1$$

REWRI menu

The REWRI menu contains functions that enable you to rewrite an expression in another form.

DISTRIB

Distributivity of multiplication

DISTRIB enables you to apply the distributivity of multiplication in respect to addition in a single instance.

DISTRIB enables you, when you apply it several times, to carry out the distributivity step by step.

Typing:

```
DISTRIB((X+1)·(X+2)·(X+3))
```

gives:

$$x \cdot (x+2) \cdot (x+3) + 1 \cdot (x+2) \cdot (x+3)$$

EPSX0

Disregard small values

EPSX0 has as a parameter an expression in X, and returns the same expression with the values less than EPS replaced by zeroes.

Typing:

```
EPSX0(0.001 + X)
```

gives, if EPS=0.01:

0 + x

or, if EPS=0.0001:

.001 + x

EXPLN

Transform a trigonometric expression into complex exponentials

EXPLN takes as an argument a trigonometric expression. It transforms the trigonometric function into exponentials and logarithms without linearizing it.

EXPLN puts the calculator into complex mode.

Typing:

```
EXPLN(SIN(X))
```

gives:

$$\frac{\exp(i \cdot x) - \frac{1}{\exp(i \cdot x)}}{2 \cdot i}$$

EXP2POW

Transform exp(n∗ln(x)) as a power of x

EXP2POW transforms an expression of the form exp(n × ln(x)), rewriting it as a power of x.

Typing:

```
EXP2POW(EXP(N · LN(X)))
```

gives:

x^n

FDISTRIB

Distributivity

FDISTRIB has an expression as argument.

FDISTRIB enables you to apply the distributivity of multiplication with respect to addition all at once.

Typing:

```
FDISTRIB((X+1)·(X+2)·(X+3))
```

gives:

$x \cdot x \cdot x + 3 \cdot x \cdot x + x \cdot 2 \cdot x + 3 \cdot 2 \cdot x + x \cdot x \cdot 1 + 3 \cdot x \cdot 1 + x \cdot 2 \cdot 1 + 3 \cdot 2 \cdot 1$

After simplification (by pressing ENTER):

$x^3 + 6 \cdot x^2 + 11 \cdot x + 6$

LIN

Linearize the exponentials

LIN has as an argument an expression containing exponentials and trigonometric functions. LIN does not linearize trigonometric expressions (as does TLIN) but converts a trigonometric expression to exponentials and then linearizes the complex exponentials.

LIN puts the calculator into complex mode when dealing with trigonometric functions.

Example 1

Typing:

LIN((EXP(X)+1)^3)

gives:

$3 \cdot \exp(x) + 1 + 3 \cdot \exp(2 \cdot x) + \exp(3 \cdot x)$

Example 2

Typing:

LIN(COS(X)^2)

gives:

$$\frac{1}{4} \cdot \exp(-(2 \cdot i \cdot x)) + \frac{1}{2} + \frac{1}{4} \cdot \exp(2 \cdot i \cdot x)$$

Example 3

Typing:

```
LIN(SIN(X))
```

gives:

$$-\frac{i}{2} \cdot \exp i \cdot x + \frac{i}{2} \cdot \exp(-(i \cdot x))$$

LNCOLLECT

Regroup the logarithms

LNCOLLECT has as an argument an expression containing logarithms.

LNCOLLECT regroups the terms in the logarithms. It is therefore preferable to use an expression that has already been factored (using `FACTOR`).

Typing:

```
LNCOLLECT(LN(X+1)+LN(X-1))
```

gives:

ln((x+1)(x–1))

POWEXPAND

Transform a power

POWEXPAND writes a power in the form of a product.

Typing:

$\texttt{POWEXPAND((X+1)}^{3}\texttt{)}$

gives:

(x+1) · (x+1) · (x+1)

This allows you to do the development of $(x + 1)^3$ in step by step, using `DISTRIB` several times on the preceding result.

SINCOS

Transform the complex exponentials into sin and cos

SINCOS takes as an argument an expression containing complex exponentials.

SINCOS then rewrites this expression in terms of sin(x) and cos(x).

Typing:

`SINCOS(EXP(i·X))`

gives after turning on complex mode, if necessary:

$\cos(x) + i \cdot \sin(x)$

SIMPLIFY

Simplify

SIMPLIFY simplifies an expression automatically.

Typing:

$$\mathtt{SIMPLIFY}\left(\frac{\mathtt{SIN}(3\cdot \mathtt{X})+\mathtt{SIN}(7\cdot \mathtt{X})}{\mathtt{SIN}(5\cdot \mathtt{X})}\right)$$

gives, after simplification:

$4 \cdot \cos(x)^2 - 2$

XNUM

Evaluation of reals

XNUM has an expression as a parameter.

XNUM puts the calculator into approximate mode and returns the numeric value of the expression.

Typing:

`XNUM(√2)`

gives:

1.41421356237

XQ

Rational approximation

XQ has a real numeric expression as a parameter.

XQ puts the calculator into exact mode and gives a rational or real approximation of the expression.

Typing:

`XQ(1.41421)`

gives:

$$\frac{66441}{46981}$$

Typing:

```
XQ(1.414213562)
```

gives:

√2

SOLV menu

The SOLV menu contains functions that enable you to solve equations, linear systems, and differential equations.

DESOLVE

Solve differential equations

DESOLVE enables you to solve differential equations. (For linear differential equations having constant coefficients, it is better to use LDEC.)

DESOLVE has two arguments:

1. the differential equation where y' is written as d1Y(X) (or the differential equation and the initial conditions separated by AND),
2. the unknown Y(X).

The mode must be set to real.

Example 1

Solve:

$y'' + y = \cos(x)$

$y(0)=c_0$ $y'(0) = c_1$

Typing:

```
DESOLVE(d1d1Y(X)+Y(X) = COS(X),Y(X))
```

gives:

$$Y(X) = cC0 \cdot \cos(x) + \frac{x + 2 \cdot cC1}{2} \cdot \sin(x)$$

cC0 and cC1 are integration constants (y(0) = cC0 y′(0) = cC1).

You can then assign values to the constants using the `SUBST` command.

To produce the solutions for y(0) = 1, type:

$$\text{SUBST(Y(X) =}$$
$$\text{cC0}\cdot\text{COS(X)}+\frac{\text{X}+2\cdot\text{cC1}}{2}\cdot\text{SIN(X), cC0 = 1)}$$

which gives:

$$y(x) = \frac{2\cdot\cos(x)+(x+2\cdot cC1)\cdot\sin(x)}{2}$$

Example 2

Solve:

y″ + y = cos(x)

y(0) = 1 y′(0) = 1

It is possible to solve for the constants from the outset.

Typing:

```
DESOLVE((d1d1Y(X)+Y(X)=COS(X))
AND (Y(0)=1) AND (d1Y(0)=1),Y(X))
```

gives:

$$Y(x) = \cos x+\frac{2+x}{2}\cdot\sin(x)$$

ISOLATE

The zeros of an expression

ISOLATE returns the values that are the zeros of an expression or an equation.

ISOLATE has two parameters: an expression or equation, and the name of the variable to isolate (ignoring REALASSUME).

Typing:

ISOLATE(X^4-1=3,X)

gives in real mode:

(x = √2) OR (x = –√2)

and in complex mode:

(x = √2 · i) OR (x = –√2) OR
(x = –(√2 · i)) OR (x = √2)

LDEC

Linear differential equations having constant coefficients

LDEC enables you to directly solve linear differential equations having constant coefficients.

The parameters are the second member and the characteristic equation.

Solve:

$$y'' - 6 \cdot y' + 9 \cdot y = x \cdot e^{3 \cdot x}$$

Typing:

```
LDEC(X·EXP(3·X),X²–6·X+9)
```

gives:

$$-\left(\frac{(18 \cdot x - 6) \cdot cC0 - (6 \cdot x \cdot cC1 + x^3)}{6} \cdot \exp(3 \cdot x)\right)$$

cC0 and cC1 are integration constants (y(0) = cC0 and y′(0) = cC1).

LINSOLVE

Solve linear system

LINSOLVE enables you to solve a system of linear equations.

It is assumed that the various equations are of the form expression = 0.

LINSOLVE has two arguments: the first members of the various equations separated by AND, and the names of the various variables separated by AND.

Example 1

Typing:

```
LINSOLVE(X+Y+3 AND X-Y+1, X AND Y)
```

gives:

(x = –2) AND (y = –1)

or, in Step-by-step mode (CFG, etc.):

L2=L2–L1

$$\begin{bmatrix} 1 & 1 & 3 \\ 1 & -1 & 1 \end{bmatrix}$$

ENTER

L1=2L1+L2

$$\begin{bmatrix} 1 & 1 & 3 \\ 0 & -2 & -2 \end{bmatrix}$$

ENTER

`Reduction Result`

$$\begin{bmatrix} 2 & 0 & 4 \\ 0 & -2 & -2 \end{bmatrix}$$

then press ENTER. The following is then written to the Equation Writer:

(x = –2) AND (y = –1)

Example 2

Type:

`(2·X+Y+Z=1)AND(X+Y+2·Z=1)AND(X+2·Y+Z=4)`

Then, invoke `LINSOLVE` and type the unknowns:

`X AND Y AND Z`

and press the ENTER key.

The following result is produced if you are in Step-by-step mode (CFG, etc.):

L2=2L2–L1

$$\begin{bmatrix} 2 & 1 & 1 & -1 \\ 1 & 1 & 2 & -1 \\ 1 & 2 & 1 & -4 \end{bmatrix}$$

ENTER

L3=2L3–L1

$$\begin{bmatrix} 2 & 1 & 1 & -1 \\ 0 & 1 & 3 & -1 \\ 1 & 2 & 1 & -4 \end{bmatrix}$$

and so on until, finally:

`Reduction Result`

$$\begin{bmatrix} 8 & 0 & 0 & 4 \\ 0 & 8 & 0 & -20 \\ 0 & 0 & -8 & -4 \end{bmatrix}$$

then press ENTER. The following is then written to the Equation Writer:

$$\left(x = -\frac{1}{2}\right) \text{ AND } \left(y = \frac{5}{2}\right) \text{ AND } \left(z = -\frac{1}{2}\right)$$

SOLVE

Solve equations

SOLVE has as two parameters:

(1) either an equality between two expressions, or a single expression (in which case = 0 is implied), and

(2) the name of a variable.

SOLVE solves the equation in R in real mode and in C in complex mode (ignoring REALASSUME).

Typing:

```
SOLVE(X^4-1=3,X)
```

gives, in real mode:

$(x = -\sqrt{2})$ OR $(x = \sqrt{2})$

or, in complex mode:

$(x = -\sqrt{2})$ OR $(x = \sqrt{2})$ OR $(x = -i \cdot \sqrt{2})$ OR $(x = i\sqrt{2})$

Solve systems

SOLVE also enables you to solve a system of non-linear equations, if they are polynomials. (If they are not polynomials, use MSOLV in the HOME screen to get a numerical solution.)

It is assumed that the various equations are of the form expression = 0.

SOLVE has as arguments, the first members of the various equations separated by AND, and the names of the various variables separated by AND.

Typing:

```
SOLVE(X^2+Y^2-3 AND X-Y^2+1,X AND Y)
```

gives:

$(x = 1)$ AND $(y = -\sqrt{2})$ OR $(x = 1)$ AND $(y = \sqrt{2})$

SOLVEVX

Solve equations

SOLVEVX has as a parameter either:

(1) an equality between two expressions in the variable contained in VX, or

(2) a single such expression (in which case = 0 is implied).

SOLVEVX solves the equation.

Example 1

Typing:

$\texttt{SOLVEVX(X}^4\texttt{-1=3)}$

gives, in real mode:

$(x = -\sqrt{2})$ OR $(x = \sqrt{2})$

or, in complex mode, even if you have chosen X as real:

$(x = -\sqrt{2})$ OR $(x = \sqrt{2})$ OR $(x = -i \cdot \sqrt{2})$ OR $(x = i\sqrt{2})$

Example 2

Typing:

$\texttt{SOLVEVX(2X}^2\texttt{+X)}$

gives, in real mode:

$(x = -1/2)$ OR $(x = 0)$

TRIG menu

The TRIG menu contains functions that enable you to transform trigonometric expressions.

ACOS2S

Transform the arccos into arcsin

ACOS2S has as a trigonometric expression as an argument.

ACOS2S transforms the expression by replacing arccos(x) with $\frac{\pi}{2} - \arcsin(x)$.

Typing:

```
ACOS2S(ACOS(X) + ASIN(X))
```

gives, when simplified:

$$\frac{\pi}{2}$$

ASIN2C

Transform the arcsin into arccos

ASIN2C has as a trigonometric expression as an argument.

ASIN2C transforms the expression by replacing arcsin(x) with $\frac{\pi}{2}$ – arccos(x).

Typing:

```
ASIN2C(ACOS(X) + ASIN(X))
```

gives, when simplified:

$$\frac{\pi}{2}$$

ASIN2T

Transform the arccos into arctan

ASIN2T has a trigonometric expression as an argument.

ASIN2T transforms the expression by replacing arcsin(x) with $arc\tan\left(\frac{x}{\sqrt{1-x^2}}\right)$

Typing:

```
ASIN2T(ASIN(X))
```

gives:

$$\operatorname{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

ATAN2S

Transform the arctan into arcsin

ATAN2S has a trigonometric expression as an argument.

ATAN2S transforms the expression by replacing arctan(x) with $arc\sin\left(\frac{x}{\sqrt{1+x^2}}\right)$.

Typing:

```
ATAN2S(ATAN(X))
```

gives:

$$\operatorname{asin}\left(\frac{x}{\sqrt{x^2+1}}\right)$$

HALFTAN

Transform in terms of tan(x/2)

HALFTAN has a trigonometric expression as an argument.

HALFTAN transforms sin(x), cos(x) and tan(x) in the expression, rewriting them in terms of tan(x/2).

Typing:

HALFTAN(SIN(X)^2 + COS(X)^2)

gives (SQ(X) = X^2):

$$\left(\frac{2\cdot\tan\left(\frac{x}{2}\right)}{SQ\left(\tan\left(\frac{x}{2}\right)\right)+1}\right)^2+\left(\frac{1-SQ\left(\tan\left(\frac{x}{2}\right)\right)}{SQ\left(\tan\left(\frac{x}{2}\right)\right)+1}\right)^2$$

or, after simplification:

1

SINCOS

Transform the complex exponentials into sin and cos

SINCOS takes an expression containing complex exponentials as an argument.

SINCOS then rewrites this expression in terms of sin(x) and cos(x).

Typing:

```
SINCOS(EXP(i · X))
```

gives after turning on complex mode, if necessary:

cos(x) + i · sin(x)

TAN2CS2

Transform tan(x) with sin(2x) and cos(2x)

TAN2CS2 has a trigonometric expression as an argument.

TAN2CS2 transforms this expression by replacing tan(x) with $\frac{1-\cos(2\cdot x)}{\sin(2\cdot x)}$.

Typing:

```
TAN2CS2(TAN(X))
```

gives:

$$\frac{1-\cos(2\cdot x)}{\sin(2\cdot x)}$$

TAN2SC

Replace tan(x) with sin(x)/cos(x)

TAN2SC has a trigonometric expression as an argument.

TAN2SC transforms this expression by replacing tan(x) with $\frac{\sin(x)}{\cos(x)}$.

Typing:

```
TAN2SC(TAN(X))
```

gives:

$$\frac{\sin(x)}{\cos(x)}$$

TAN2SC2

Transform tan(x) with sin(2x) and cos(2x)

TAN2SC2 has a trigonometric expression as an argument.

TAN2SC2 transforms this expression by replacing tan(x) with $\frac{\sin(2\cdot x)}{1+\cos(2\cdot x)}$

Typing:

```
TAN2SC2(TAN(X))
```

gives:

$$\frac{\sin(2\cdot x)}{1+\cos(2\cdot x)}$$

TCOLLECT

Reconstruct the sine and the cosine of the same angle

TCOLLECT has a trigonometric expression as an argument.

TCOLLECT linearizes this expression in terms of sin(*n x*) and cos(*n x*), then (in Real mode) reconstructs the sine and cosine of the same angle.

Typing:

```
TCOLLECT(SIN(X) + COS(X))
```

gives:

$$\sqrt{2}\cdot\cos\left(x-\frac{\pi}{4}\right)$$

TEXPAND

Develop transcendental expressions

TEXPAND has as an argument a transcendental expression (that is, an expression with trigonometric, exponential or logarithmic functions). TEXPAND develops this expression in terms of sin(x), cos(x), exp(x) or ln(x).

Example 1

Typing:

```
TEXPAND(EXP(X+Y))
```

gives:

exp(x)·exp(y)

Example 2

Typing:

```
TEXPAND(LN(X•Y))
```

gives:

ln(y) + ln(x)

Example 3

Typing:

```
TEXPAND(COS(X+Y))
```

gives:

cos(y)·cos(x)–sin(y)·sin(x)

Example 4

Typing:

```
TEXPAND(COS(3•X))
```

gives:

$4 \cdot \cos(x)^3 - 3 \cdot \cos(x)$

TLIN

Linearize a trigonometric expression

TLIN has as an argument a trigonometric expression.

TLIN linearizes this expression in terms of sin(*n x*) and cos(*n x*).

Example 1

Typing:

```
TLIN(COS(X) · COS(Y))
```

gives:

$$\frac{1}{2} \cdot \cos(x-y) + \frac{1}{2} \cdot \cos(x+y)$$

Example 2

Typing:

`TLIN(COS(X)`^{3}`)`

gives:

$$\frac{1}{4} \cdot \cos(3 \cdot x) + \frac{3}{4} \cdot \cos(x)$$

Example 3

Typing:

`TLIN(4·COS(X)`^{2}`-2)`

gives:

$$2 \cdot \cos(2 \cdot x)$$

TRIG

Simplify using $\sin(x)^2 + \cos(x)^2 = 1$

TRIG has as an argument a trigonometric expression.

TRIG simplifies this expression using the identity $\sin(x)^2 + \cos(x)^2 = 1$.

Typing:

```
TRIG(SIN(X)^2 + COS(X)^2 + 1)
```

gives:

2

TRIGCOS

Simplify using the cosines

TRIGCOS has as an argument a trigonometric expression.

TRIGCOS simplifies this expression, using the identity $\sin(x)^2+\cos(x)^2 = 1$ to rewrite it in terms of cosines.

Typing:

```
TRIGCOS(SIN(X)^4 + COS(X)^2 + 1)
```

gives:

$$\cos(x)^4 - \cos(x)^2 + 2$$

TRIGSIN

Simplify using the sines

TRIGSIN has as an argument a trigonometric expression.

TRIGSIN simplifies this expression, using the identity $\sin(x)^2 + \cos(x)^2 = 1$ to rewrite it in terms of sines.

Typing:

```
TRIGSIN(SIN(X)^4 + COS(X)^2 + 1)
```

gives:

$$\sin(x)^4 - \sin(x)^2 + 2$$

TRIGTAN

Simplify using the tangents

TRIGTAN has as an argument a trigonometric expression.

TRIGTAN simplifies this expression, using the identity $\sin(x)^2 + \cos(x)^2 = 1$ to rewrite it in terms of tangents.

Typing:

```
TRIGTAN(SIN(X)^4 + COS(X)^2 + 1)
```

gives:

$$\frac{2 \cdot \tan(x)^4 + 3 \cdot \tan(x)^2 + 2}{\tan(x)^4 + 2 \cdot \tan(x)^2 + 1}$$

CAS Functions on the MATH menu

When you are in the Equation Writer and press MATH, a menu of additional CAS functions available to you is displayed. Many of the functions in this menu match the functions available from the soft-key menus in the Equation Writer; but there are other functions that are only available from this menu. This section describes CAS functions that are available when you press MATH in the Equation Writer (grouped by main menu name).

Algebra menu

All the functions on this menu are also available on the ALGB menu in the Equation Writer. See “ALGB menu” on page 14-10 for a description of these functions.

Complex menu

i

Inserts i (= $\sqrt{-1}$).

ABS

Determines the absolute value of the argument.

Example

Typing ABS(7 + 4i) yields $\sqrt{65}$, as does ABS(7 – 4i).

ARG

See “ARG” on page 13-7.

CONJ

See “CONJ” on page 13-7.

DROITE

DROITE returns the equation of the line through the Cartesian points, z_1, z_2. It takes two complex numbers, z_1 and z_2, as arguments.

Example

Typing:

DROITE((1, 2), (0, 1))

or:

DROITE(1 + 2·i, i)

returns:

Y = X −1 + 2

Pressing ENTER simplifies this to:

Y = X + 1

IM See “IM” on page 13-7.

– Specifies the negation of the argument.

RE See “RE” on page 13-8.

SIGN Determines the quotient of the argument divided by its modulus.

Example

Typing SIGN(7 + 4i) or SIGN(7,4) yields $\frac{7+4i}{\sqrt{65}}$.

Constant menu

e, i, π See “Constants” on page 13-8.

∞ Enters the sign for infinity.

Diff & Int menu

All the functions on this menu are also available on the DIFF menu in the Equation Writer. See “DIFF menu” on page 14-16 for a description of these functions.

Hyperb menu

All the functions on this menu are described in “Hyperbolic trigonometry” on page 13-9.

Integer menu

Note that many integer functions also work with Gaussian integers (*a* + *b*i where *a* and *b* are integers).

DIVIS

Gives the divisors of an integer.

Example

Typing:

DIVIS(12)

gives:

12 OR 6 OR 3 OR 4 OR 2 OR 1

Note: DIVIS(0) returns 0 OR 1.

EULER

Returns the Euler index of a whole number. The Euler index of *n* is the number of whole numbers less than *n* that are prime with *n*.

Example

Typing:

EULER(21)

gives:

12

Explanation: {2,4,5,7,8,10,11,13,15,16,17,19} is the set of whole numbers less than 21 and prime with 21. There are 12 members of the set, so the Euler index is12.

FACTOR

Decomposes an integer into its prime factors.

Example

Typing:

FACTOR(90)

gives:

$2 \cdot 3^2 \cdot 5$

GCD

Returns the *greatest common divisor* of two integers.

Example

Typing:

GCD(18, 15)

gives:

3

In step-by-step mode, there are a number of intermediate results:

18 mod 15 = 3

15 mod 3 = 0

Result: 3

Pressing [ENTER] or OK then causes 3 to be written to the Equation Writer.

Note that the last non-zero remainder in the sequence of remainders shown in the intermediate steps is the GCD.

IDIV2

Returns the quotient and the remainder of the Euclidean division between two integers.

Example

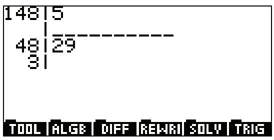
Typing:

IDIV2(148, 5)

gives:

29 AND 3

In step-by-step mode, the calculator shows the division process in longhand.



IEGCD

Returns the value of Bézout's Identity for two integers. For example, IEGCD(A,B) returns U AND V = D, with U, V, D such that AU+BV=D and D=GCD(A,B).

Example

Typing:

IEGCD(48, 30)

gives

2 AND –3 = 6

In other words: 2·48 + (–3)·30 = 6 and GCD(48,30) = 6.

In step-by-step mode, we get:

[z,u,v]:z=u*48+v*30

[48,1,0]

[30,0,1]*–1

[18,1,–1]*–1

[12,–1,2]*–1

[6,2,–3]*–2

Result: [6,2,–3]

Pressing ENTER or OK then causes 2 AND –3 = 6 to be written to the Equation Writer.

The intermediate steps shown are the combination of lines. For example, to get line L(n + 2), take L(n) – q*L(n + 1) where q is the Euclidean quotient of the integers at the beginning of the vector, these integers being the sequence of remainders).

IQUOT Returns the integer quotient of the Euclidean division of two integers.

Example

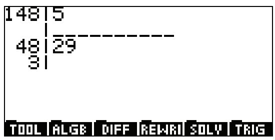
Typing:

IQUOT(148, 5)

gives:

29

In step-by-step mode, the division is carried out as if in longhand



Pressing ENTER or OK then causes 29 to be written to the Equation Writer.

IREMAINDER Returns the integer remainder from the Euclidean division of two integers.

Example 1

Typing:

IREMAINDER(148, 5)

gives:

3

IREMAINDER works with integers and with Gaussian integers. This is what distinguishes it from MOD.

Example 2

Typing:

IREMAINDER(2 + 3·i, 1 + i)

gives:

i

ISPRIME?

Returns a value indicating whether an integer is a prime number. ISPRIME?(*n*) returns 1 (TRUE) if *n* is a prime or pseudo-prime, and 0 (FALSE) if *n* is not prime.

Definition: For numbers less than 10^{14}, *pseudo-prime* and *prime* mean the same thing. For numbers greater than 10^{14}, a pseudo-prime is a number with a large probability of being prime.

Example 1

Typing:

ISPRIME?(13)

gives:

1.

Example 2

Typing:

ISPRIME?(14)

gives:

0.

LCM

Returns the *least common multiple* of two integers.

Example

Typing:

LCM(18, 15)

gives:

90

MOD

See “MOD” on page 13-15.

NEXTPRIME

NEXTPRIME(*n*) returns the smallest prime or pseudo-prime greater than *n*.

Example

Typing:

NEXTPRIME(75)

gives:

79

PREVPRIME

PREVPRIME(*n*) returns the greatest prime or pseudo-prime less than *n*.

Example

Typing:

PREVPRIME(75)

gives:

73

Modular menu

All the examples of this section assume that *p* =13; that is, you have entered MODSTO(13) or STORE(13,MODULO), or have specified 13 for `Modulo` in CAS `MODES` screen (as explained on page 15-16).

ADDTMOD

Performs an addition in Z/pZ.

Example 1

Typing:

ADDTMOD(2, 18)

gives:

–6

ADDTMOD can also perform addition in Z/pZ[X].

Example 2

Typing:

ADDTMOD(11X + 5, 8X + 6)

gives:

$$6x - 2$$

DIVMOD Division in Z/pZ or Z/pZ[X].

Example 1

In Z/pZ, the arguments are two integers: A and B. When B has an inverse in Z/pZ, the result is A/B simplified as Z/pZ.

Typing:

DIVMOD(5, 3)

gives:

6

Example 2

In Z/pZ[X], the arguments are two polynomials: A[X] and B[X]. The result is a rational fraction A[X]/B[X] simplified as Z/pZ[X].

Typing:

DIVMOD($2X^2$ + 5, $5X^2$ + 2X –3)

gives:

$$-\frac{4x+5}{3x+3}$$

EXPANDMOD Expand and simplify expressions in Z/pZ or Z/pZ[X].

Example 1

In Z/pZ, the argument is an integer expression.

Typing:

EXPANDMOD(2 · 3 + 5 · 4)

gives:

0

Example 2

In Z/pZ[X], the argument is a polynomial.

Typing:

EXPANDMOD(($2X^2$ + 12)·(5X – 4))

gives:

$$-(3 \cdot x^3 - 5 \cdot x^2 + 5 \cdot x - 4)$$

FACTORMOD

Factors a polynomial in Z/pZ[X], providing that p ≤ 97, p is prime and the order of the multiple factors is less than the modulo.

Example

Typing:

FACTORMOD(–(3X^3 – 5X^2 + 5X – 4))

gives:

$$-((3x-5)\cdot(x^2+6))$$

GCDMOD

Calculates the GCD of the two polynomials in Z/pZ[X].

Example

Typing:

GCDMOD(2X^2 + 5, 5X^2 + 2X – 3)

gives:

$$-(6x-1)$$

INVMOD

Calculates the inverse of an integer in Z/pZ.

Example

Typing:

INVMOD(5)

gives:

–5

since 5 · –5 = –25 = 1 (mod 13).

MODSTO

Sets the value of the MODULO variable *p*.

Example

Typing:

MODSTO(11)

sets the value of *p* to 11.

MULTMOD

Performs a multiplication in Z/pZ or in Z/pZ[X].

Example 1

Typing:

MULTMOD(11, 8)

gives:

–3

Example 2

Typing:

MULTMOD(11X + 5, 8X + 6)

gives:

$$-(3x^2 - 2x - 4)$$

POWMOD

Calculates A to the power of N in Z/pZ[X], and A(X) to the power of N in Z/pZ[X].

Example 1

If p = 13, typing:

POWMOD(11, 195)

gives:

5

In effect: 11^{12} = 1 mod 13, so $11^{195} = 11^{16\times12+3}$ = 5 mod 13.

Example 2

Typing:

POWMOD(2X + 1, 5)

gives:

$$6x^5 + 2x^4 + 2x^3 + x^2 - 3x + 1$$

since 32 = 6 (mod 13), 80 = 2 (mod 13), 40 = 1 (mod 13), 10 = –3 (mod 13).

SUBTMOD

Performs a subtraction in Z/pZ or Z/pZ[X].

Example 1

Typing:

SUBTMOD(29, 8)

gives:

–5

Example 2

Typing:

SUBTMOD(11X + 5, 8X + 6)

gives:

$3x - 1$

Polynomial menu

EGCD

Returns Bézout's Identity, the Extended Greatest Common Divisor (EGCD).

EGCD(A(X), B(X)) returns U(X) AND V(X) = D(X), with D, U, V such that D(X) = U(X)·A(X) + V(X)·B(X).

Example 1

Typing:

EGCD(X^2 + 2 · X + 1, X^2 – 1)

gives:

-1 AND $-1 = 2x + 2$

Example 2

Typing:

EGCD(X^2 + 2 · X + 1, X^3 + 1)

gives:

$-(x-2)$ AND $1 = 3x + 3$

FACTOR

Factors a polynomial.

Example 1

Typing:

FACTOR(X^2 – 2)

gives:

$$(x + \sqrt{2}) \cdot (x - \sqrt{2})$$

Example 2

Typing:

FACTOR(X^2 + 2·X + 1)

gives:

$$(x + 1)^2$$

GCD

Returns the GCD (Greatest Common Divisor) of two polynomials.

Example

Typing:

GCD(X^2 + 2·X + 1, X^2 – 1)

gives:

$$x + 1$$

HERMITE

Returns the Hermite polynomial of degree *n* (where *n* is a whole number). This is a polynomial of the following type:

$$H_n(x) = (-1)^n \cdot e^{\frac{x^2}{2}} \frac{d^n}{dx^n} e^{-\frac{x^2}{2}}$$

Example

Typing:

HERMITE(6)

gives:

$$64x^6 - 480x^4 + 720x^2 - 120$$

LCM

Returns the LCM (Least Common Multiple) of two polynomials.

Example

Typing:

LCM(X^2 + 2·X + 1, X^2 – 1)

gives:

$$(x^2+2x+1)\cdot(x-1)$$

LEGENDRE

Returns the polynomial L_n, a non-null solution of the differential equation:

$$(x^2-1)\cdot y''-2\cdot x\cdot y'-n(n+1)\cdot y\ =\ 0$$

where *n* is a whole number.

Example

Typing:

LEGENDRE(4)

gives:

$$\frac{35\cdot x^4-30\cdot x^2+3}{8}$$

PARTFRAC

Returns the partial fraction decomposition of a rational fraction.

Example

Typing:

$$\text{ARTFRAC}\left(\frac{X^5-2X^3+1}{X^4-2X^3+2X^2-2X+1}\right.$$

gives, in real and direct mode:

$$x+2+\frac{x-3}{2x^2+2}+\frac{-1}{2x-2}$$

and gives, in complex mode:

$$x+2+\frac{\frac{1-3\cdot i}{4}}{x+i}+\frac{\frac{-1}{2}}{x-1}+\frac{\frac{1+3\cdot i}{4}}{x-i}$$

PROPFRAC

PROPFRAC rewrites a rational fraction so as to bring out its whole number part.

PROPFRAC(A(X)/ B(X)) writes the rational fraction A(X)/ B(X) in the form:

$$Q(X) + \frac{R(X)}{B(X)}$$

where R''(X) = 0, or 0 ≤ *deg* (R(X) < *deg* (B(X).

Example

Typing:

$$\mathrm{ROPFRAC}\left(\frac{(5X+3)\cdot(X-1)}{X+2}\right.$$

gives:

$$5x - 12 + \frac{21}{x+2}$$

PTAYL

PTAYL rewrites a polynomial P(X) in order of its powers of X – a.

Example

Typing:

PTAYL(X^2 + 2·X + 1, 2)

produces the polynomial Q(X), namely:

$$x^2 + 6x + 9$$

Note that P(X) = Q(X–2).

QUOT

QUOT returns the quotient of two polynomials, A(X) and B(X), divided in decreasing order by exponent.

Example

Typing:

QUOT(X^2 + 2·X + 1, X)

gives:

$$x + 2$$

Note that in step-by-step mode, synthetic division is shown, with each polynomial represented as the list of its coefficients in descending order of power.

REMAINDER

Returns the remainder from the division of the two polynomials, A(X) and B(X), divided in decreasing order by exponent.

Example

Typing:

REMAINDER($X^3 - 1$, $X^2 - 1$)

gives:

$$x - 1$$

Note that in step-by-step mode, synthetic division is shown, with each polynomial represented as the list of its coefficients in descending order of power.

TCHEBYCHEFF

For $n > 0$, TCHEBYCHEFF returns the polynomial T_n such that:

$Tn(x) = \cos(n \cdot \arccos(x))$

For $n \geq 0$, we have:

$$T_n(x) = \sum_{k=0}^{[\frac{n}{2}]} C_n^{2k} (x^2 - 1)^k x^{n-2k}$$

For $n \geq 0$ we also have:

$$(1 - x^2) T_n''(x) - x T_n'(x) + n^2 T_n(x) = 0$$

For $n \geq 1$, we have:

$$T_{n+1}(x) = 2x T_n(x) - T_{n-1}(x)$$

If $n < 0$, TCHEBYCHEFF returns the 2nd-species Tchebycheff polynomial:

$$T_n(x) = \frac{\sin(n \cdot \arccos(x))}{\sin(\arccos(x))}$$

Example 1

Typing:

TCHEBYCHEFF(4)

gives:

$$8x^4 - 8x^2 + 1$$

Example 2

Typing:

TCHEBYCHEFF(–4)

gives:

$$8x^3 - 4x$$

Real menu

CEILING See “CEILING” on page 13-14.

FLOOR See “FLOOR” on page 13-14.

FRAC See “FRAC” on page 13-14.

INT See “INT” on page 13-15.

MAX See “MAX” on page 13-15.

MIN See “MIN” on page 13-15.

Rewrite menu

All the functions on this menu are also available on the **REWRI** menu in the Equation Writer. See “REWRI menu” on page 14-28 for a description of these functions.

Solve menu

All the functions on this menu are also available on the **SOLV** menu in the Equation Writer. See “SOLV menu” on page 14-33 for a description of these functions.

Tests menu

ASSUME

Use this function to make a hypothesis about a specified argument or variable.

Example

Typing:

ASSUME(X>Y)

sets an assumption that X is greater than Y. In fact, the calculator works only with *large* not *strict* relations, and thus ASSUME(X>Y) will actually set the assumption that X ≥ Y. (A message will indicate this when you enter an ASSUME function.) Note that X ≥ Y will be stored in the REALASSUME variable. To see the variable, press [VARS], select REALASSUME and press VIEW.

UNASSUME

Use this function to cancel all previously specified assumptions about a particular argument or variable.

Example

Typing:

UNASSUME(X)

cancels any assumptions made about X. It returns X in the Equation Writer. To see the assumptions, press [VARS], select REALASSUME and press VIEW.

>, ≥, <, ≤, ==, ≠ — See "Test functions" on page 13-19.

AND — See "AND" on page 13-19.

OR — See "OR" on page 13-19.

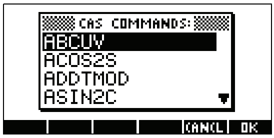
NOT — See "NOT" on page 13-19.

IFTE — See "IFTE" on page 13-19.

Trig menu

All the functions on this menu are also available on the TRIG menu in the Equation Writer. See "TRIG menu" on page 14-38 for a description of these functions.

CAS Functions on the CMDS menu



When you are in the Equation Writer and press SHIFT MATH, a menu of the full set of CAS functions available to you is displayed. Many of the functions in this menu match the functions available from the soft-key menus in the Equation Writer; but there are other functions that are only available from this menu. This section describes the additional CAS functions that are available when you press SHIFT MATH in the Equation Writer. (See the previous section for other CAS commands.)

ABCUV

This command applies the Bézout identity like EGCD, but the arguments are three polynomials A, B and C. (C must be a multiple of GCD(A,B).)

ABCUV(A[X], B[X], C[X]) returns U[X] AND V[X], where U and V satisfy:

$$C[X] = U[X] \cdot A[X] + V[X] \cdot B[X]$$

Example 1

Typing:

$$\text{ABCUV}(X^2 + 2 \cdot X + 1, X^2 - 1, X + 1)$$

gives:

$$\frac{1}{2} \text{ AND } -\frac{1}{2}$$

CHINREM

Chinese Remainders: CHINREM has two sets of two polynomials as arguments, each separated by AND.

CHINREM((A(X) AND R(X), B(X) AND Q(X)) returns an AND with two polynomials as components: P(X) and S(X). The polynomials P(X) and S(X) satisfy the following relations when GCD(R(X),Q(X)) = 1:

$$S(X) = R(X) \cdot Q(X),$$

$$P(X) = A(X) \text{ (mod}R(X)) \text{ and } P(X) = B(X) \text{ (mod}Q(X)).$$

There is always a solution, P(X), if R(X) and Q(X) are mutually primes and all solutions are congruent modulo S(X) = R(X) · Q(X).

Example

Find the solutions P(X) of:

$P(X) = X \pmod{X^2 + 1}$

$P(X) = X - 1 \pmod{X^2 - 1}$

Typing:

CHINREM((X) AND (X^2 + 1), (X – 1) AND (X^2 – 1))

gives:

$$-\frac{x^2 - 2x + 1}{2} \text{AND} \frac{x^4 - 1}{2}$$

That is:

$$P[X] = -\frac{x^2 - 2x + 1}{2} \quad \left(\text{mod}-\frac{x^4 - 1}{2}\right)$$

CYCLOTOMIC

Returns the cyclotomic polynomial of order *n*. This is a polynomial having the *n*th primitive roots of unity as zeros.

CYCLOTOMIC has an integer *n* as its argument.

Example 1

When *n* = 4 the fourth roots of unity are {1, i, –1, –i}. Among them, the primitive roots are: {i, –i}. Therefore, the cyclotomic polynomial of order 4 is (X – i).(X + i) = X^2 + 1.

Example 2

Typing:

CYCLOTOMIC(20)

gives:

$$x^8 - x^6 + x^4 - x^2 + 1$$

EXP2HYP

EXP2HYP has an expression enclosing exponentials as an argument. It transforms that expression with the relation:

exp(a) = sinh(a) + cosh(a).

Example 1

Typing:

EXP2HYP(EXP(A))

gives:

sinh(a) + cosh(a)

Example 2

Typing:

EXP2HYP(EXP(–A) + EXP(A))

gives:

$2 \cdot \cosh(a)$

GAMMA

Returns the values of the Γ function at a given point.

The Γ function is defined as:

$$\Gamma(x) = \int_0^{+\infty} e^{-t} t^{x-1} dt$$

We have:

$\Gamma(1) = 1$

$\Gamma(x + 1) = x \cdot \Gamma(x)$

Example 1

Typing:

GAMMA(5)

gives:

24

Example 2

Typing:

GAMMA(1/2)

gives:

$\sqrt{\pi}$

IABCUV

IABCUV(A,B,C) returns U AND V such that AU + BV = C where A, B and C are whole numbers.

C must be a multiple of GCD(A,B) to obtain a solution.

Example

Typing:

IABCUV(48, 30, 18)

gives:

6 AND –9

IBERNOULLI

Returns the *n*th Bernoulli's number B(*n*) where:

$$\frac{t}{e^t - 1} = \sum_{n=0}^{+\infty} \frac{B(n)}{n!} t^n$$

Example

Typing:

IBERNOULLI(6)

gives:

$$\frac{1}{42}$$

ICHINREM

Chinese Remainders: ICHINREM(A AND P,B AND Q) returns C AND R, where A, B, P and Q are whole numbers.

The numbers $X = C + k \cdot R$ where k is an integer are such that $X = A$ mod P and $X = B$ mod Q.

A solution X always exists when P and Q are mutually prime, (GCD(P,Q) = 1) and in this case, all the solutions are congruent modulo $R = P \cdot Q$.

Example

Typing:

ICHINREM(7 AND 10, 12 AND 15)

gives:

–3 AND 30

ILAP

LAP is the Laplace transform of a given expression. The expression is the value of a function of the variable stored in VX.

ILAP is the inverse Laplace transform of a given expression. Again, the expression is the value of a function of the variable stored in VX.

Laplace transform (LAP) and inverse Laplace transform (ILAP) are useful in solving linear differential equations with constant coefficients, for example:

$$y'' + p \cdot y' + q \cdot y = f(x)$$

$$y(0) = a \quad y'(0) = b$$

The following relations hold:

$$\mathrm{LAP(y)(x)} = \int_0^{+\infty} e^{-x \cdot t} y(t)dt$$

$$\mathrm{ILAP(f)(x)} = \frac{1}{2i\pi} \cdot \int_c e^{zx} f(z)dz$$

where *c* is a closed contour enclosing the poles of *f*.

The following property is used:

$$\mathrm{LAP}(y')(x) = -y(0) + x \cdot \mathrm{LAP}(y)(x)$$

The solution, *y*, of:

$$y'' + p \cdot y' + q \cdot y = f(x),\ y(0) = a,\ y'(0) = b$$

is then:

$$\mathrm{ILAP}\left(\frac{\mathrm{LAP}(f(x)) + (x+p) \cdot a + b}{x^2 + px + q}\right)$$

Example

To solve:

$$y''-6 \cdot y' + 9 \cdot y = x \cdot e^{3x},\ y(0) = a,\ y'(0) = b$$

c

type:

LAP(X · EXP(3 · X))

The result is:

$$\frac{1}{x^2 - 6x + 9}$$

Typing:

$$\mathrm{ILAP}\left(\frac{\frac{1}{X^2-6X+9}+(X-6)\cdot a+b}{X^2-6X+9}\right)$$

gives:

$$\left(\frac{x^3}{6}-(3a-b)\cdot x+a\right)\cdot e^{3x}$$

LAP See ILAP above.

PA2B2 Decomposes a prime integer *p* congruent to 1 modulo 4, as follows:

$p = a^2 + b^2$.

The calculator gives the result as $a + b \cdot$ i.

Example 1

Typing:

PA2B2(17)

gives:

4 + i

that is, $17 = 4^2 + 1^2$

Example 2

Typing:

PA2B2(29)

gives:

5 + 2 · i

that is, $29 = 5^2 + 2^2$

PSI Returns the value of the *n*th derivative of the Digamma function at *a*.

The Digamma function is the derivative of $\ln(\Gamma(x))$.

Example

Typing:

PSI(3, 1)

gives:

$$-\frac{5}{4}+\frac{1}{6}\cdot\pi^2$$

Psi

Returns the value of the Digamma function at *a*.

The Digamma function is defined as the derivative of $\ln(\Gamma(x))$, so we have PSI(*a*,0) = Psi(*a*).

Example

Typing:

Psi(3)

and pressing [NUM]

gives:

.922784335098

REORDER

Reorders the input expression following the order of variables given in the second argument.

Example

Typing:

REORDER($X^2 + 2 \cdot X \cdot A + A^2 + Z^2 - X \cdot Z$, A AND X AND Z)

gives:

$$A^2+2\cdot X\cdot A+X^2-Z\cdot X+Z^2$$

SEVAL

SEVAL simplifies the given expression, operating on all but the top-level operator of the expression.

Example

Typing:

SEVAL(SIN(3 · X – X) + SIN(X + X))

gives:

$$\sin(2\cdot x)+\sin(2\cdot x)$$

SIGMA

Returns the discrete antiderivative of the input function, that is, the function G, that satisfies the relation G(*x* + 1) – G(*x*) = f(*x*). It has two arguments: the first is a function f(*x*) of a variable *x* given as the second argument.

Example

Typing:

SIGMA(X · X!, X)

gives:

X!

because (X + 1)! – X! = X · X!.

SIGMAVX

Returns the discrete antiderivative of the input function, that is a function, G, that satisfies the relation: G(x + 1) – G(x) = f(x). SIGMAVX has as its argument a function f of the current variable VX.

Example

Typing:

SIGMAVX(X^2)

gives:

$$\frac{2x^3 - 3x^2 + x}{6}$$

because:

$$2(x+1)^3 - 3(x+1)^2 + x + 1 - 2x^3 + 3x^2 - x = 6x^2$$

STURMAB

Returns the number of zeros of P in [a, b[where P is a polynomial and a and b are numbers.

Example 1

Typing:

STURMAB(X^2 · (X^3 + 2), –2, 0)

gives:

1

Example 2

Typing:

STURMAB(X^2 · (X^3 + 2), –2, 1)

gives:

3

TSIMP

Simplifies a given expression by rewriting it as a function of complex exponentials, and then reducing the number of variables (enabling complex mode in the process).

Example

Typing:

$$\mathrm{TSIMP}\left(\frac{\mathrm{SIN}(3X)+\mathrm{SIN}(7X)}{\mathrm{SIN}(5X)}\right)$$

gives:

$$\frac{\mathrm{EXP}(i\cdot x)^4+1}{\mathrm{EXP}(i\cdot x)^2}$$

VER

Returns the version number of your CAS.

Example

Typing:

VER

might give:

4.20050219

This particular result means that you have a version 4 CAS, dated 19 February 2005. Note that this is not the same as VERSION (which returns the version of the calculator's ROM).

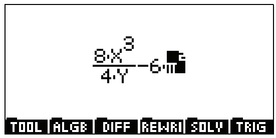
15

Equation Writer

Using CAS in the Equation Writer

The Equation Writer enables you to type expressions that you want to simplify, factor, differentiate, integrate, and so on, and then work them through as if on paper.

The CAS key on the HOME screen menu bar opens the Equation Writer, and the HOME key closes it.



This chapter explains how to write an expression in the Equation Writer using the menus and the keyboard, how to select a subexpression, how to apply CAS functions to an expression or subexpression and how to store values in the Equation Writer variables.

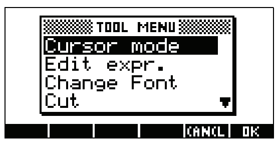
Chapter 14 explains all the symbolic calculation functions contained in the various menus, and chapter 16 provides numerous examples showing the use of the Equation Writer.

The Equation Writer menu bar

The Equation Writer has a number of soft menu keys.

TOOL menu

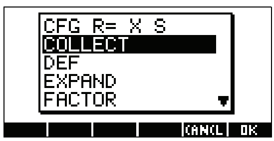
Unlike the other soft menu keys, the TOOL menu does not give access to CAS commands. Instead, it provides access to a number of utilities to help you work with the Equation Writer. The following table explains each of the utilities on the TOOL menu.



`Cursor mode`	Enables you to go into cursor mode, for quicker selection of expressions and subexpressions (see page 15-10).
`Edit expr.`	Enables you to edit the highlighted expression on the edit line, just as you do in the HOME screen (see page 15-11).
`Change font`	Enables you to choose to type using large or small characters (see page 15-10).
`Cut`	Copies the selection to the clipboard and erases the selection from Equation Writer.
`Copy`	Copies the selection to the clipboard.
`Paste`	Copies the contents of the clipboard to the location of the cursor. The clipboard contents will be either whatever `Copy` or `Cut` selected the last time you used these commands, or the highlighted level when you selected `COPY` in CAS history.

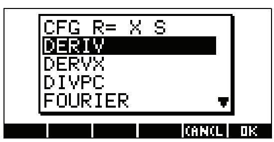
ALGB menu

The **ALGB** menu contains functions that enable you to perform algebra, such as factoring, expansion, simplification, substitution, and so on.



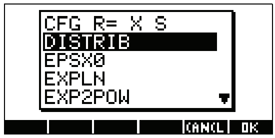
DIFF menu

The **DIFF** menu contains functions that enable you to perform differential calculus, such as differentiation, integration, series expansion, limits, and so on.



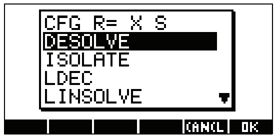
REWRI menu

The REWRI menu contains functions that enable you to rewrite an expression in another form.



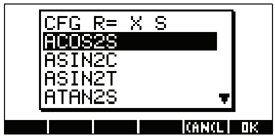
SOLV menu

The SOLV menu contains functions that enable you to solve equations, linear systems, and differential equations.



TRIG menu

The TRIG menu contains functions that enable you to transform trigonometric expressions.



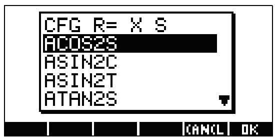
NOTE You can get online help about any CAS function by pressing SHIFT 2 and selecting that function (as explained in "Online Help" on page 14-8).

Configuration menus

You can directly see, and change, CAS modes while working with the Equation Writer. The first line in each of the Equation Writer menus (except TOOL) indicates the current CAS mode settings.

In the example at the right, the first line of the TRIG menu reads:

```
CFG R= X S
```



CFG stands for "configuration", and the symbols to the right of it indicate various mode settings.

- The first symbol, `R`, indicates that you are in real mode. If you were in complex mode, this symbol would be `C`.
- The second symbol, `=`, indicates that you are in exact mode. If you were in approximate mode, this symbol would be `~`.
- The third symbol, `X` in the above example, indicates the current independent variable.

- The fourth symbol, S, in the above example, indicates that you are in step-by-step mode. If you were not in step-by-step mode, this symbol would be D (which stands for Direct).

The first line of an Equation Writer menu only indicates some of the mode settings. To see more settings, highlight the first line and press OK. The configuration menu appears. The header of the configuration menu has additional symbols. In the example above, the upward-pointing arrow indicates that polynomials are displayed with increasing powers, and the 13 indicates the modulo value.

You can change CAS mode settings directly from the configuration menu. Just press ▼ until the setting you want to choose is highlighted and then press OK.

Note that the configuration menu includes only those options that are not currently selected. For example, if Rigorous is a current setting, its opposite, Sloppy, will appear on the menu. If you choose Sloppy, then Rigorous appears in its place.

To return your CAS modes to their default settings, select Default cfg and press OK.

To close the configuration menu, select Quit config and press OK.

NOTE You can also change CAS mode settings from CAS MODES screen. See "CAS modes" on page 14-5 for information.

Online Help language

One CAS setting that only appears on the configuration menu is the setting that determines the language of the online help. Two languages are available: English and French. To choose French, select Francais and press OK. To return to English, select English and press OK.

Entering expressions and subexpressions

You type expressions in the Equation Writer is much the same way as you type them in the HOME screen, using the keys to directly enter numbers, letters and operators, and menus to select various functions and commands.

When you type an expression in the Equation Writer, the operator that you are typing always carries over to the adjacent or selected expression. You don't have to worry about where the parentheses go: they are automatically entered for you.

It will help you understand how the Equation Writer works if you view a mathematical expression as a tree, with the four arrow keys enabling you to move through the tree:

- the ▶ and ◀ keys enable you to move from one branch to another
- the ▲ and ▼ keys enable you to move up and down a particular tree
- the SHIFT ▲ and SHIFT ▼ key combinations enable you to make multiple selections.

How do I select?

There are two ways of going into selection mode:

- Pressing ▲ takes you into selection mode and selects the element adjacent to the cursor. For example:

  1+2+3+4 ▲

  selects 4. Pressing it again selects the entire tree: 1+2+3+4.

- Pressing ▶ takes you into selection mode and selects the branch adjacent to the cursor. Pressing it augments the selection, adding the next branch to the right. For example:

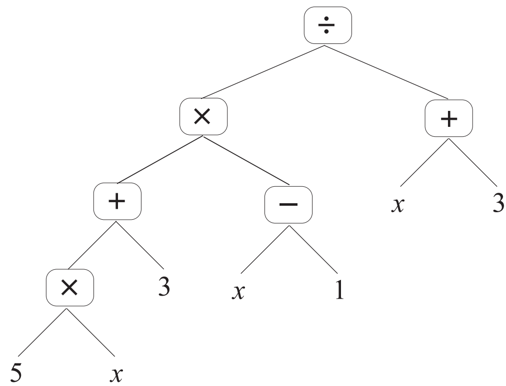
  1+2+3+4 ▶

selects 3+4. Pressing it again selects 2+3+4, and again selects 1+2+3+4.

NOTE: If you are typing a templated function with multiple arguments (such as Σ, $\int$,SUBST, etc.), pressing ▶ or ◀ enables you to move from one argument to another. In this case, you have to press [▲] to select elements in the expression.

The following illustration shows how an expression can be viewed as a tree in the Equation Writer. It illustrates a tree view of the expression:

$$\frac{(5x+3)\cdot(x-1)}{x+3}$$



Suppose that the cursor is positioned to the right of 3:

- If you press [▲] once, the 3 component is selected.
- If you press [▲] again, the selection moves up the tree, with $x + 3$ now selected.
- If you press [▲] again, the selection moves up the tree, and now the entire expression is selected.
- If you had pressed [►] instead of [▲] when the cursor was positioned to the right of 3, the leaves of the branch get selected (that is, $x + 3$).
- If you press [►] again, the selection moves up the tree, and now the entire expression is selected.
- If you now press [▼], just the numerator is selected.
- If you now press [▼] again, the top-most branch selected (that is, $(5x + 3)$).
- Continue pressing [▼] to select each top-most leaf in turn ($5x$ and then 5).

- Press ▲ again and again to progressively select more of the top-most branch, and then lower branches (5*x*, 5*x* + 3, and then the entire numerator and finally the entire expression).

More Examples

Example1

If you enter:

$$2 + X \times 3 - X$$

and press ▶ ▶ ▶ the entire expression is selected.

Pressing ENTER evaluates what is selected (that is, the entire expression) and returns:

$$2X + 2$$

If you enter the same expression as earlier but press ▶ after the first X, as in:

2 + X ▶ × 3 – X

the 2 + X is selected and the next operation, multiplication, is applied to to it. The expression becomes:

$$(2 + X) \times 3 - X$$

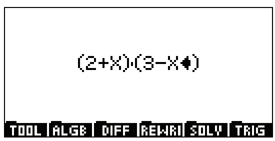
Pressing ▶ ▶ selects the entire expression, and pressing ENTER evaluates it, resulting in:

$$2X + 6$$

Now enter the same expression, but press ▲ after the 3, as in:

2 + X ▶ × 3 ▲ – X

Note that ▶ selects the expression so far entered (2 + X) thus making the next operation apply to the entire selection, not just the last entered term. The ▲ key selects just the last entry (3) and makes the next operation



(– X) apply to it. As a result, the entered expression is interpreted, and displayed, as (2 + X)(3 – X).

Select the entire expression by pressing [▶] [▶] [▶] and evaluate it by pressing [ENTER]. The result is:

$$-(X^2-X-6)$$

Example2

To enter X^2–3X+1, press:

[X,T,θ] [X^Y] 2 [▶] – 3 [X,T,θ] +1

If, instead, you had to enter $-x^2$–3X+1, you would need to press:

(–) [X,T,θ] [X^Y] 2 [▶] [▶] – 3 [X,T,θ] +1

Note that you press [▶] twice to ensure that the exponent applies to –X and not just to X.

Example 3

Suppose you want to enter:

$$\frac{1}{2}+\frac{1}{3}+\frac{1}{4}+\frac{1}{5}$$

Each fraction can be viewed as a separate branch on the equation tree. In the Equation Writer type the first branch:

1 ÷ 2

and then select this branch by pressing [▶].

Now type + and enter the second branch:

1 ÷ 3

Select the second branch by pressing [▶].

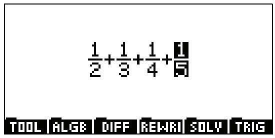
Now type + and enter the third branch:

1 ÷ 4

Likewise, select the third branch by pressing [▶], type + and then the fourth branch:

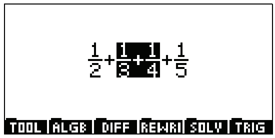
1 ÷ 5

Select the fifth branch by pressing [▶]. At this point, the desired expression is in the Equation Writer, as shown at the right.

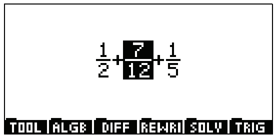


Suppose that you want to select the second and third branches, that is: $\frac{1}{3}+\frac{1}{4}$. First press [◀] [◀]. This selects $\frac{1}{3}$, the second term.

Now press [SHIFT] [▶]. This key combination enables you to select two contiguous branches, the one already selected and the one to the right of it.



If you want, you can evaluate the selected part by pressing [ENTER]. The result is shown at the right.



Suppose now you want to perform the partial calculation:

$$\frac{1}{2}+\frac{1}{5}$$

Because the two terms in this partial calculation are not contiguous (that is, side by side), you must first perform a permutation so that they are side by side.To do this, press:

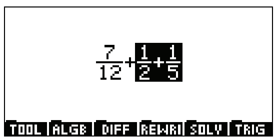
[SHIFT] [◀]

This exchanges the selected element with its neighbour to the left. The result is shown at the right.

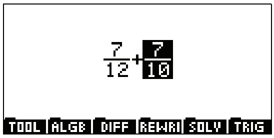
Now press:

[▶] [SHIFT] [▶]

to select just the branches you are interested in:



Pressing [ENTER] produces the result of the partial calculation.



Summing up

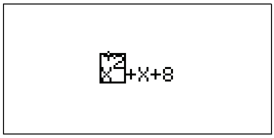
Pressing [SHIFT] [▶] enables you to select the current element and its neighbour to the right. [SHIFT] [◀] enables you to exchange the selected element with its neighbour to the left. The selected element remains selected after you move it.

Cursor mode

In cursor mode you can select a large expression quickly. To select cursor mode, press:

TOOL `Cursor mode` OK

As you press the arrow key, various parts of the expression are enclosed n in a box.



When what you want to select is enclosed, press [ENTER] to select it.

Changing the font

If you are entering a long expression, you may find it useful to reduce the size of the font used in the Equation Writer. Select `Change font` from the TOOL menu. This enables you to view a large expression in its entirety when you need to. Selecting `Change font` again returns the font size to its previous setting.

You can also see the selected expression or subexpression is a smaller or larger font size by pressing [VIEWS] and then TEXT (to use the smaller font) or GRAP (to use the larger font).

How to modify an expression

If you're typing an expression, the DEL key enables you to erase what you've typed. If you're selecting, you can:

- Cancel the selection without deleting the expression by pressing DEL . The cursor moves to the end of the deselected portion.
- Replace the selection with an expression, just by typing the desired expression.
- Transform the selected expression by applying a CAS function to it (which you can invoke from one of CAS menus along the bottom of the screen).
- Delete the selected expression by pressing:

  ALPHA SHIFT DEL

- Delete a selected unary operator at the top of the expression tree by pressing:

  SHIFT DEL

  For example, to replace SIN(expr) with COS(expr), select SIN(expr), press SHIFT DEL and then press COS.

- Delete a binary infix operator and one of its arguments by selecting the argument you want delete and pressing:

  SHIFT DEL

  For example, if you have the expression 1+2 and select 1, pressing SHIFT DEL deletes 1+ and leaves only 2. Similarly, to delete F(*x*)= in the expression F(*x*) = $x^2 - x + 1$, you select F(*x*) and then press SHIFT DEL . This produces $x = x^2 - x + 1$.

- Delete a binary operator by selecting:

  `Edit expr.`

  from the TOOL menu and then making the correction.

- Copy an element from CAS history. You access CAS history by pressing SYMB . See page 15-19 for details.

Accessing CAS functions

While you are in the Equation Writer, you can access all CAS functions, and you can access them in various ways.

General principle: When you have written an expression in the Equation Writer, all you have to do is press [ENTER] to evaluate whatever you have selected (or the entire expression, if nothing is selected).

How to type Σ and $\int$

Press [SHIFT] [+] to enter Σ and [SHIFT] [d/dx] to enter $\int$.

These symbols and are treated as prefix functions with multiple arguments. They are automatically placed before the selected element, if there is one (hence the term *prefix* functions).

You can move the cursor from argument to argument by pressing [▶] or [◀].

Enter the expressions according to the rules of selection explained earlier, but you must first go into selection mode by pressing [▲].

NOTE Do not use the index *i* to define a summation, because *i* designates the complex-number solution of $x^2 + 1 = 0$.

Σ performs exact calculations if its argument has a discrete primitive; otherwise it performs approximate calculations, even in exact mode. For example, in both approximate and exact mode:

$$\sum_{k=0}^{4} \frac{1}{k!} = 2.70833333334$$

whereas in exact mode:

$$1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} = \frac{65}{24}$$

Note that Σ can symbolically calculate summations of rational fractions and hypergeometric series that allow a discrete primitive. For example, if you type:

$$\sum_{K=1}^{4} \frac{1}{K \cdot (K+1)}$$

select the entire expression and press [ENTER], you obtain:

$$\frac{4}{5}$$

However, if you type:

$$\sum_{K=1}^{\infty} \frac{1}{K \cdot (K+1)}$$

select the entire expression and press [ENTER], you obtain 1.

How to enter infix functions

An infix function is one that is typed *between* its arguments. For example, AND, | and MOD are infix functions.You can either:

- type them in Alpha mode and then enter their arguments, or
- select them from a CAS menu or by pressing an appropriate key, provided that you have already written and selected the first argument.

  You move from one argument to the other by pressing [▶] and [◀]. The comma enables you to write a complex number: when you type (1,2), the parentheses are automatically placed when you type the comma. If you want to type (–1,2), you must select –1 before you type the comma.

How to enter prefix functions

A prefix function is one that is typed *before* its arguments. To enter a prefix function, you can:

- type the first argument, select it, then select the function from a menu, or
- you can select the function from a menu, or by directly entering it in Alpha mode, and then type the arguments.

The following example illustrates the various ways of entering a prefix function. Suppose you want to factor the expression $x^2 - 4$, then find its value for $x = 4$. FACTOR is the function for factoring, and it is found on the ALGB menu. SUBST is the function for substituting a value for a variable in an expression, and it is also found in the ALGB menu.

First option: function first, then arguments

In the Equation Writer, press ALGB, select FACTOR and then press [ENTER] or OK. FACTOR() is displayed in the Equation Writer, with the cursor between the parentheses (as shown at the right).

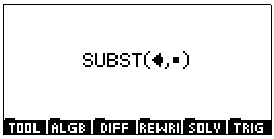
Enter your expression, using the rules of selection described earlier.

[X,T,θ] [X^Y] 2 [▶] [-] 4 [▶] [▶]

The entire expression is now selected.

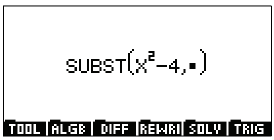
Press [ENTER] then produce the result.

With a blank Equation Writer screen, press ALGB, select SUBST and then press [ENTER] or OK.

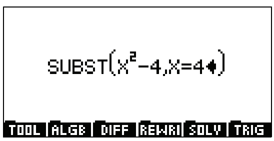


With the cursor between the parentheses at the location of the first argument, type your expression.

Note that SUBST has two arguments. When you have finished entering the first argument (the expression), press [▶] to move to the second argument.



Now enter the second argument, *x*=4.

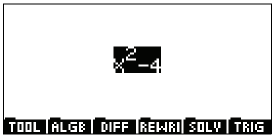


Press [ENTER] to obtain the an intermediate result ($4^2 - 4$) and [ENTER] again to evaluate the intermediate result. The final answer is 12.

Second option: arguments first, then function

Enter your expression, using the rules of selection described earlier.

[X,T,θ] [X^Y] 2 [▶] [-] 4 [▶] [▶] [▶]



The entire expression is now selected.

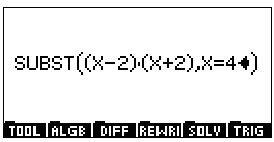
Now press ALGB and select `FACTOR`. Notice that the `FACTOR` is applied to whatever was selected (which is automatically placed in parentheses).

Press [ENTER] to evaluate the expression. The result is the factors of the expression.

Because the result of an evaluation is always selected, you can immediately apply another command to it.

To illustrate this, press ALGB, select `SUBST` and then press [ENTER] or OK. Note that `SUBST` is applied to whatever was selected (which is automatically placed in parentheses). Note too that the cursor is automatically placed in the position of the second argument.

Enter the second argument, x=4.



Press [ENTER] to obtain an intermediate result, (4– 2)(4 + 2), and [ENTER] again to evaluate the intermediate result. The final answer, as before, is 12.

Note If you call a CAS function while you're writing an expression, whatever is currently selected is copied to the function's first or main argument. If nothing is selected, the cursor is placed at the appropriate location for completing the arguments.

Equation Writer variables

You can store objects in variables, then access an object by using the name of its variable. However, you should note the following:

- Variables used in CAS cannot be used in HOME, and vice versa.
- In HOME or in the program editor, use STO to store an object in a variable.
- In CAS, use the STORE command (on the ALGB menu) to store a value in a variable.
- The [VARS] key displays a menu that contains all the available variables. Pressing [VARS] while you are in HOME displays the names of the variables defined in HOME and in the Aplets. Pressing [VARS] while you are in the Equation Writer displays the names of the variables defined in CAS (as explained on page 15-18).

Predefined CAS variables

- `VX` contains the name of the current symbolic variable. Generally, this is *X*, so you should not use *X* as the name of a numeric variable. Nor should you erase the contents of *X* with the `UNASSIGN` command (on the ALGB menu) after having done a symbolic calculation.
- `EPS` contains the value of epsilon used in the EPSX0 command.

- `MODULO` contains the value of *p* for performing symbolic calculations in *Z/pZ* or in *Z/pZ*[*X*]. You can change the value of *p* either with the `MODSTO` command on the `MODULAR` menu, (by typing, for example, MODSTO(*n*) to give *p* a value of *n*), or from CAS MODES screen (see page 14-5).
- `PERIOD` must contain the period of a function before you can find its Fourier coefficients.
- `PRIMIT` contains the primitive of the last integrated function.
- `REALASSUME` contains a list of the names of the symbolic variables that are considered reals. If you've chosen the `Cmplx vars` option on the `CFG` configuration menu, the defaults are *X*, *Y*, *t*, *S1 and S2*, as well as any integration variables that are in use.

  If you've chosen the `Real vars` option on the `CFG` configuration menu, all symbolic variables are considered reals. You can also use an assumption to define a variable such as X >1. In a case like this, you use the `ASSUME(X>1)` command to make `REALASSUME` contain X>1. The command `UNASSUME(X)` cancels all the assumptions you have previously made about *X*.

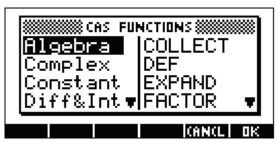
  To see these variables, as well as those that you've defined in CAS, press [VARS] in the Equation Editor (see "CAS variables" on page 14-4).

The keyboard in the Equation Writer

The keys mentioned in this section have different functions when pressed in the Equation Writer than when used elsewhere.

MATH key

The [MATH] key, if pressed in the Equation Writer, displays just those functions used in symbolic calculation. These functions are contained in the following menus:

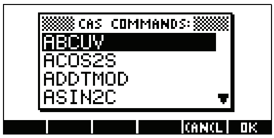


- The five function-containing Equation Writer menus outlined in the previous section: `Algebra` (ALGB), `Diff&Int` (**DIFF**), `Rewrite` (**REWR**), `Solve` (**SOLV**) and `Trig` (**TRIG**).

- The `Complex` menu, providing functions specific to manipulating with complex numbers.
- The `Constant` menu, containing e, i,∞ and π.
- The `Hyperb.` menu, containing hyperbolic functions.
- The `Integer` menu, containing functions that enable you to perform integer arithmetic.
- The `Modular` menu, containing functions that enable you to perform modular arithmetic (using the value contained in the `MODULO` variable).
- The `Polynom.`menu, containing functions that enable you to perform calculations with polynomials.
- The `Real` menu, containing functions specific to common real-number calculations
- The `Tests` menu, containing logic functions for working with hypotheses.

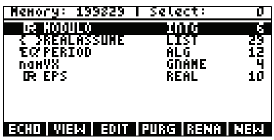
SHIFT MATH keys

The [SHIFT] [MATH] key combination opens an alphabetical menu of all CAS commands. You can enter a command by selecting it from this menu, so that you don't have to type it in ALPHA mode.



VARS key

Pressing [VARS] while you're in the Equation Writer displays the names of the variables defined in CAS. Take special note of `namVX`, which contains the name of the current variable.



The menu options on the variables screen are:

ECHO Press to copy the name of the highlighted variable to the position of the cursor in Equation Writer.

VIEW Press to see the contents of the highlighted variable.

EDIT Press to change the contents of the highlighted variable.

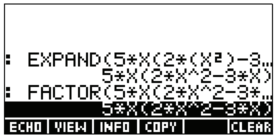
PURG Press to clear the value of the highlighted variable.

RENA Press to change the name of the highlighted variable.

NEW Press to define a new variable (which you do by specifying an object and a name for the object.

SYMB key

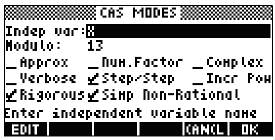
Pressing the [SYMB] key in the Equation Writer gives you access to CAS history. As in the HOME screen history, the calculations are written on the left and the results are written on the right. Using the arrow keys, you can scroll through the history.



Press COPY to copy the highlighted entry in history to the clipboard in order to paste it in the Equation Writer. Press [ENTER] or ECHO to replace the current selection in Equation Writer with the highlighted entry in CAS history. Press [ON] to leave CAS history without changing it in any way.

SHIFT SYMB or SHIFT HOME keys

While you are working in the Equation Writer, pressing [SHIFT] [SYMB] or [SHIFT] [HOME] opens CAS `MODES` screen. The various CAS modes are described in "CAS modes" on page 14-5.

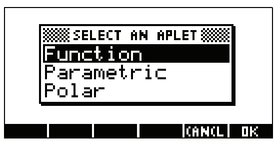


SHIFT , key

Pressing [SHIFT] followed by the comma key undoes (that is, cancels) your last operation.

PLOT key

Pressing [PLOT] in the Equation Writer displays a menu of plot types. You can choose to graph a function, a parametric curve, or a polar curve.



Depending on what you choose, the highlighted expression is copied into the appropriate aplet, to the destination that you specify.

NOTE This operation supposes that the current variable is also the variable of the function or curve you want to graph. When the expression is copied, it is evaluated, and the current variable (contained in VX) is changed to X, T, or θ, depending on the type of plot you chose.

If the function depends on a parameter, it is preferable to give the parameter a value before pressing [PLOT]. If, however, you want the parameterized expression to be copied with its parameter, then the name of the parameter must consist of a single letter other than X, T, or θ, so that there is no confusion. If the highlighted expression has real values, the Function, Aplet or Polar Aplet can be chosen, and the graph will be of Function or Polar type. If the highlighted expression has complex values, the Parametric Aplet must be chosen, and the graph will be of Parametric type.

To summarize. If you choose:

- the Function Aplet, the highlighted expression is copied into the chosen function `Fi`, and the current variable is changed to X.
- the Parametric Aplet, the real part and the imaginary part of the highlighted expression are copied into the chosen functions `Xi,Yi`, and the current variable is changed to T.
- the Polar Aplet, the highlighted expression is copied into the chosen function `R`i and the current variable is changed to θ.

NUM key

Pressing [NUM] in the Equation Writer causes the highlighted expression to be replaced by a numeric approximation. [NUM] puts the calculator into approximate mode.

SHIFT NUM key

Pressing [SHIFT] [NUM] in the Equation Writer causes the highlighted expression to be replaced by a rational number. [SHIFT] [NUM] puts the calculator into exact mode.

VIEWS key

Pressing [VIEWS] in the Equation Writer enables you to move the cursor with the [►] and [◄] arrow keys to see the entire highlighted expression. Press OK to return in the Equation Writer.

Short-cut keys

In the Equation Writer, the following are short-cut keys to the symbols indicated:

[SHIFT] 0 for ∞

[SHIFT] 1 for i

[SHIFT] 3 for π

[SHIFT] 5 for <

[SHIFT] 6 for >

[SHIFT] 8 for ≤

[SHIFT] 9 for ≥

16

Step-by-Step Examples

Introduction

This chapter illustrates the power of CAS, and the Equation Writer, by working though a number of examples. Some of these examples are variations on questions from senior math examination papers.

The examples are given in order of increasing difficulty.

Example 1

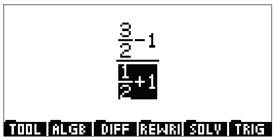
If *A* is:

$$\frac{\frac{3}{2}-1}{\frac{1}{2}+1}$$

calculate the result of *A* in the form of an irreducible fraction, showing each step of the calculation.

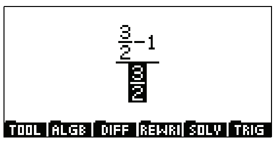
Solution: In the Equation Writer, enter *A* by typing:

3 [÷] 2 [▶] [−] 1 [▶]
[▶] [÷] 1 [÷] 2 [▶]
[+] 1

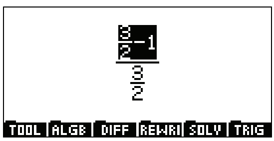


Now press [▶] to select the denominator (as shown above).

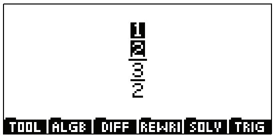
Press [ENTER] to simplify the denominator.



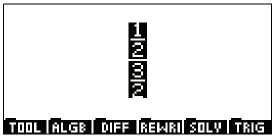
Now select the numerator by pressing [◀].



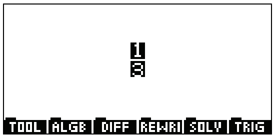
Press [ENTER] to simplify the numerator.



Press [▲] to select the entire fraction.



Press [ENTER] to simplify the selected fraction, giving the result shown at the right.



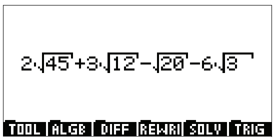
Example 2

Given that $C = 2\sqrt{45} + 3\sqrt{12} - \sqrt{20} - 6\sqrt{3}$

write *C* in the form $d\sqrt{5}$, where *d* is a whole number.

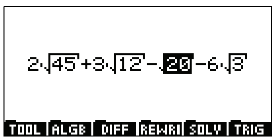
Solution: In the Equation Writer, enter C by typing:

2 [SHIFT] [X^2] 45 [▶] [▶] [+] 3 [SHIFT] [X^2] 12 [▶] [▶] [-] [SHIFT] [X^2] 20 [▶] [▶] [-] 6 [SHIFT] [X^2] 3



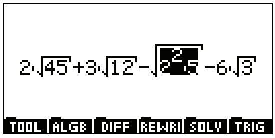
Press [▶] [▶] [▶] to select $-6\sqrt{3}$.

Press [◀] to select $-\sqrt{20}$ and [▼] [▼] to select 20.



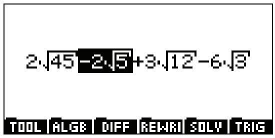
Now press ALGB, select FACTOR and press OK .

Press [ENTER] to factor 20 into $2^2 \cdot 5$.

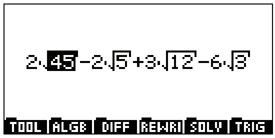


Press [▲] to select $\sqrt{2^2 \cdot 5}$ and [ENTER] to simplify it.

Press [▶] to select $-2\sqrt{5}$ *and* [SHIFT] [◀] to exchange $3\sqrt{12}$ with $-2\sqrt{5}$.



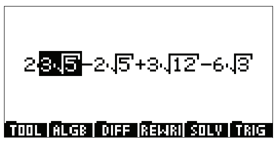
Press [◀] to select $2\sqrt{45}$ and [▼] [▶] [▼] to select 45.



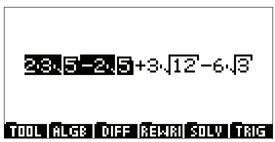
Press **ALGB**, select `FACTOR` and press **OK**.

Press [ENTER] to factor 45 into $3^2 \cdot 5$.

Press [▲] to select $\sqrt{3^2 \cdot 5}$ and [ENTER] to simplify the selection.



Press [▲] to select $2 \cdot 3\sqrt{5}$, and [SHIFT] [▶] to select $2 \cdot 3\sqrt{5} - 2\sqrt{5}$.



Press [ENTER] to evaluate the selection.

It remains to transform $3\sqrt{12}$ and combine it with $-6\sqrt{3}$. Follow the same procedure as undertaken a number of times above. You will find that $3\sqrt{12}$ is equal to $6\sqrt{3}$, and so the final two terms cancel each other out.

Hence the result is $C = 4\sqrt{5}$

Example 3

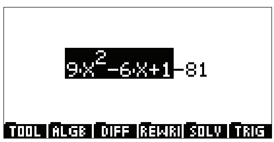
Given the expression $D = (3x-1)^2 - 81$:

- expand and reduce *D*
- factor *D*
- solve the equation $(3x-10)\cdot(3x+8) = 0$ and
- evaluate *D* for *x* = 5.

Solution: First, enter *D* using the Equation Writer:

3 [ALPHA] *X* [-] 1 [▶] [▶] [X^Y] 2 [▶] [-] 81

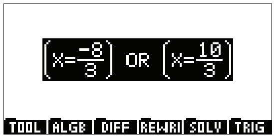
Press [▶] [◀] to select $(3X-1)^2$ and [ENTER] to expand the expression. This gives: $9x^2 - 6x + 1 - 81$



Press [▲] to select the entire equation, then press [ENTER] to reduce it to $9x^2 - 6x - 80$.

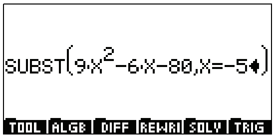
Press ALGB, select FACTOR, press OK and then [ENTER]. The result is as shown at the right.

Now press SOLV, select SOLVEVX, press OK and press [ENTER]. The result is shown at the right.

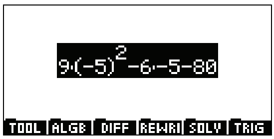


Press [SYMB] to display CAS history, select D or a version of it, and press [ENTER].

Press ALGB, select `SUBST`, press OK and, then complete the second argument: $x = -5$



Press [▶] [▶] [▶] to select the entire expression and then [ENTER] to obtain the intermediate result shown.



Press [ENTER] once more to yield the result: 175. Therefore, $D = 175$ when $x = -5$.

Example 4

A baker produces two assortments of biscuits and macaroons. A packet of the first assortment contains 17 biscuits and 20 macaroons. A packet of the second assortment contains 10 biscuits and 25 macaroons. Both packets cost 90 cents.

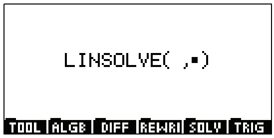
Calculate the price of one biscuit, and the price of one macaroon.

Solution: Let *x* be the price of one biscuit, and *y* the price of one macaroon. The problem is to solve:

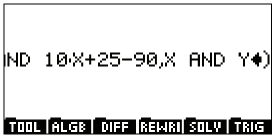
$$17x + 20y = 90$$

$$10x + 25y = 90$$

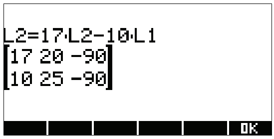
Press SOLV, select `LINSOLVE` and press OK.



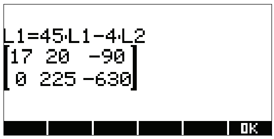
Enter 17 [ALPHA] X [+] 20 [ALPHA] Y [-] 90 [▲] [▶] [▶] [▶] [SHIFT] [(-)] 10 [ALPHA] X [+] 25 [ALPHA] Y [-] 90 [▶] [ALPHA] X [SHIFT] [(-)] [ALPHA] Y



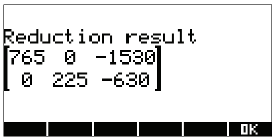
If you are working in step by step mode, pressing [ENTER] produces the result at the right.



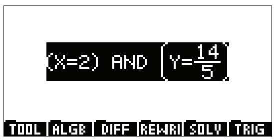
Press [ENTER] again to produce the next step in the solution:



Press [ENTER] again to produce the reduction result:



Pressing [ENTER] again produces the final result:



If you select $\frac{14}{5}$, and press [NUM] you get X = 2 and Y = 2.8. In other words, the price of one biscuit is 2 cents, and the price of one macaroon is 2.8 cents.

Exercise 5

Suppose that A and B are points having the coordinates (–1, 3) and (–3,–1) respectively, and where the unit of measure is the centimetre.

1. Find the exact length of *AB* in centimetres.
2. Determine the equation of the line *AB*.

First method

Type:

`STORE((-1,3),A)`

and press [ENTER].

Accept the change to `Complex` mode, if necessary.

Note that pressing [ENTER] returns the coordinates in complex form: –1+3i.

Now type:

`STORE((-3,-1),B)`

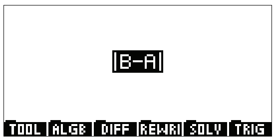
and press [ENTER].

The coordinates this time are represented as –3+–1·i.

The vector AB has coordinates B – A.

Type:

[SHIFT] [(] `(B - A)`



Press [ENTER]. The result is $2\sqrt{5}$.

Now apply the `DROITE` command to determine the equation of the line *AB*:

[MATH] `Complex`

`DROITE` [ALPHA] A [▶]

[ALPHA] B

Pressing [ENTER] gives an intermediate result.

Press [ENTER] again to simplify the result to Y = 2X+5.

Second method

Type:

```
(-3,-1 )-(-1,3)
```
[ENTER]

The answer is –(2+4i).

With the answer still selected, apply the `ABS` command by pressing [SHIFT] [(].

Pressing [ENTER] gives $2\sqrt{5}$, the same answer as with method 1 above.

You can also determi1ne the equation of the line AB by typing:

```
DROITE(( -1,3), (-3,-1))
```
[ENTER]

Pressing [ENTER] then gives the result obtained before: Y = –(2X+5).

Exercise 6

In this exercise, we consider some examples of integer arithmetic.

Part 1

For *n*, a strictly positive integer, we define:

$$a_n = 4 \times 10^n - 1, b_n = 2 \times 10^n - 1, c_n = 2 \times 10^n + 1$$

1. Compute a_1, b_1, c_1, a_2, b_2, c_2, a_3, b_3 and c_3.
2. Determine how many digits the decimal representations of a_n and c_n can have. Show that a_n and c_n are divisible by 3.
3. Using a list of prime numbers less than 100, show that b_3 is a prime.

4. Show that for every integer n > 0, $b_n \times c_n = a_{2n}$.
5. Deduce the prime factor decomposition of a_6.
6. Show that GCD(b_n,c_n) = GCD(c_n,2). Deduce that b_n and c_n are prime together.

Solution: Begin by entering the three definitions. Type:

DEF(A(N) = $4 \cdot 10^N - 1$)

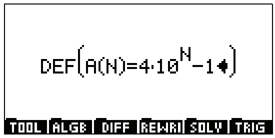
DEF(B(N) = $2 \cdot 10^N - 1$)

DEF(C(N) = $2 \cdot 10^N + 1$)

Here are the keystrokes for entering the first definition:

First select the `DEF` command by pressing ALGB ▼ OK.

Now press ALPHA A (ALPHA N ▶ SHIFT = 4 × 10 X^Y ALPHA N ▶ ▶ - 1



Finally press ENTER.

Do likewise to define the other two expressions.

You can now calculate various values of A(N), B(N) and C(N) simply by typing the defined variable and a value for N, and then pressing ENTER. For example:

A(1) ENTER yields 39

A(2) ENTER yields 399

A(3) ENTER yields 3999

B(1) ENTER yields 19

B(2) ENTER yields 199

B(3) ENTER yields 1999

and so on.

In determining the number of digits the decimal representations of a_n and c_n can have, the calculator is used only to try out different values of n.

Show that the whole numbers k such that:
$10^n \le k < 10^{n+1}$ have $(n+1)$ digits in decimal notation.

We have:

$$10^n < 3 \cdot 10^n < a_n < 4 \cdot 10^n < 10^{n+1}$$

$$10^n < b_n < 2 \cdot 10^n < 10^{n+1}$$

$$10^n < 2 \cdot 10^n < c_n < 3 \cdot 10^n < 10^{n+1}$$

so a_n, b_n, c_n have $(n+1)$ digits in decimal notation.

Moreover, $d_n = 10^n - 1$ is divisible by 9, since its decimal notation can only end in 9.

We also have:

$$a_n = 3 \cdot 10^n + d_n$$

and

$$c_n = 3 \cdot 10^n - d_n$$

so a_n and c_n are both divisible by 3.

Let's consider whether B(3) is a prime number.

Type `ISPRIME?(B(3))` and press ENTER. The result is 1, which means true. In other words, B(3) is a prime.

Note: `ISPRIME?` is not available from a CAS soft menu, but you can select it from from CAS `FUNCTIONS` menu while you are in the Equation Writer by pressing MATH, choosing the `INTEGER` menu, and scrolling to the `ISPRIME?` function.

To prove that $b_3 = 1999$ is a prime number, it is necessary to show that 1999 is not divisible by any of the prime numbers less than or equal to $\sqrt{1999}$. As $1999 < 2025 = 45^2$, that means testing the divisibility of 1999 by n = 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41. 1999 is not divisible by any of these numbers, so we can conclude that 1999 is prime.

Now consider the product of two of the definitions entered above: B(N) × C(N):

[ALPHA] B [(] [ALPHA] N [▶] [×] [ALPHA] C [(] [ALPHA] N [ENTER].

Press REWR, [▼] [▼] [▼] to select `EXP2POW` and press OK.

Press [ENTER] to evaluate the expression, yielding the result of B(N) × C(N).

Consider now the decomposition of A(6) into its prime factors.

Press ALGB, [▼] [▼] [▼] to select `FACTOR` and press OK.

Now press [ALPHA] A [(] 6.

Finally, press [ENTER] to get the result. The factors are listed, separated by a medial period. In this case, the factors are 3, 23, 29 and 1999.

Now let's consider whether b_n and c_n are relatively prime. Here, the calculator is useful only for trying out different values of n.

To show that b_n and c_n are relatively prime, it is enough to note that:

$$c_n = b_n + 2$$

That means that the common divisors of b_n and c_n are the common divisors of b_n and 2, as well as the common divisors of c_n and 2. b_n and 2 are relatively prime because b_n is a prime number other than 2. So:

$$GCD(c_n,b_n) = GCD(c_n,2) = GCD(b_n,2) = 1$$

Part 2

Given the equation:

$$b_3 \cdot x + c_3 \cdot y = 1 \qquad [1]$$

where the integers x and y are unknown and b_3 and c_3 are defined as in part 1 above:

1. Show that [1] has at least one solution.
2. Apply Euclid's algorithm to b_3 and c_3 and find a solution to [1].
3. Find all solutions of [1].

Solution: Equation [1] must have at least one solution, as it is actually a form of Bézout's Identity.

In effect, Bézout's Theorem states that if a and b are relatively prime, there exists an x and y such that:

$$a \cdot x + b \cdot y = 1$$

Therefore, the equation $b_3 \cdot x + c_3 \cdot y = 1$ has at least one solution.

Now enter `IEGCD(B(3), C(3))`.

Note that the `IEGCD` function can be found on the `INTEGER` submenu of the `MATH` menu.

Pressing [ENTER] a number of times returns the result shown at the right:

In other words:

$$b_3 \times 1000 + c_3 \times (-999) = 1$$

Therefore, we have a particular solution:

$$x = 1000,\ y = -999.$$

The rest can be done on paper:

$$c_3 = b_3 + 2\,,\ b_3 = 999 \times 2 + 1$$

so, $b_3 = 999 \times (c_3 - b_3) + 1$, or

$$b_3 \times 1000 + c_3 \times (-999) = 1$$

The calculator is not needed for finding the general solution to equation [1].

We started with $b_3 \cdot x + c_3 \cdot y = 1$

and have established that $b_3 \times 1000 + c_3 \times (-999) = 1$.

So, by subtraction we have:
$b_3 \cdot (x - 1000) + c_3 \cdot (y + 999) = 0$

or $b_3 \cdot (x - 1000) = -c_3 \cdot (y + 999)$

According to Gauss's Theorem, c_3 is prime with b_3, so c_3 is a divisor of $(x - 1000)$.

Hence there exists $k \in Z$ such that:

$$(x - 1000) = k \times c_3$$

and

$$-(y + 999) = k \times b_3$$

Solving for *x* and *y*, we get:

$$x = 1000 + k \times c_3$$

and

$$y = -999 - k \times b_3$$

for $k \in Z$.

This gives us:

$$b_3 \cdot x + c_3 \cdot y = b_3 \times 1000 + c_3 \times (-999) = 1$$

The general solution for all $k \in Z$ is therefore:

$$x = 1000 + k \times c_3$$

$$y = -999 - k \times b_3$$

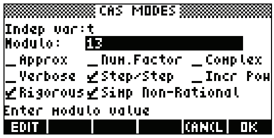
Exercise 7

Let *m* be a point on the circle *C* of center *O* and radius 1. Consider the image *M* of *m* defined on their affixes by the transformation $\mathrm{F} : z -> \frac{1}{2} \cdot z^2 - Z$. When *m* moves on the circle *C*, *M* will move on a curve Γ. In this exercise we will study and plot Γ.

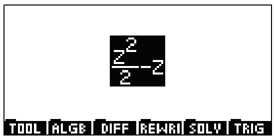
1. Let $t \notin [-\pi,\pi]$ and *m* be the point on *C* of affix $z = e^{i \cdot t}$. Find the coordinates of *M* in terms of *t*.
2. Compare x(–t) with x(t) and y(–t) with y(t).
3. Compute *x′*(*t*) and find the variations of *x* over [0, π].
4. Repeat step 3 for *y*.
5. Show the variations of *x* and *y* in the same table.
6. Put the points of Γ corresponding to *t* = 0, π/3, 2π/3 and π, and draw the tangent to Γ at these points.

Part 1

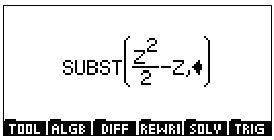
First go to CAS `MODES` screen and make *t* the VX variable. To do this, press CAS to open the Equation Writer, and then press [SHIFT] [HOME]. This opens CAS `MODES` screen. Press EDIT and delete the current variable. Type [SHIFT] [ALPHA] T and press OK.



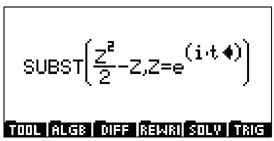
Now enter the expression $\frac{1}{2} \cdot z^2 - z$ and press [▶] [▶] to select it.



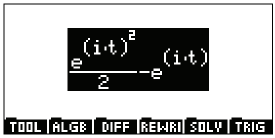
Now invoke the `SUBST` command from the ALGB menu. Because the expression was highlighted, the `SUBST` command is automatically applied to it.



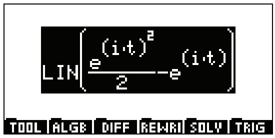
Note that the cursor is positioned in the second parameter. Since we know that $z = e^{i \cdot t}$, we can enter this as the second parameter.



Selecting the entire expression and pressing [ENTER] gives the result at the right:



Now linearize the result by applying the `LIN` command (which can be found on the REWRI menu).



The result, after accepting the switch to complex mode, is shown at the right:

Now store the result in variable M. Note that `STORE` is on the ALGB menu.

To calculate the real part of the expression, apply the `RE` command (available on the `COMPLEX` submenu of the `MATH` menu).

Pressing [ENTER] yields the result at the right:

We are now going to define this result as $x(t)$.

To do this, enter =X(t), highlight the X(t) by pressing [▶] and press [SHIFT] [◀] to swap the two parts of the expression, as shown at the right:

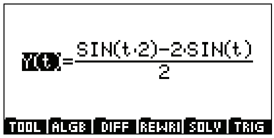
Now select the entire expression and apply the

DEF command to it. Press [ENTER] to complete the definition.

To calculate the real part of the expression, apply the IM command (available on the COMPLEX submenu of the MATH menu) to the stored variable M.

Press [ENTER] to get the result at the right:

Finally, define the result as Y(t) in the same way that you defined X(t): by firstly adding Y(t) = to the expression (as shown at the right) and then applying the DEF command.



We have now found the coordinates of *M* in terms of *t*.

Part 2

To find an axis of symmetry for Γ, calculate $x(-t)$ and $y(-t)$ by typing:

[ALPHA] *X* [(] [SHIFT] [ALPHA] *t* [▶] [(-)]

Press [▶] to highlight the expression.

Then press [ENTER] to produce the result at the right:

In other words,
$x(-t) = x(t)$

Now type [ALPHA] *Y* [(] [SHIFT] [ALPHA] *t* [▶] [(-)]

Press [▶] to highlight the expression.

Then press [ENTER] to produce the result at the right:

In other words, $y(-t) = -y(t)$.

If $M_1(x(t),y(t))$ is part of Γ , then $M_x(x(-t),y(-t))$ is also part of Γ .

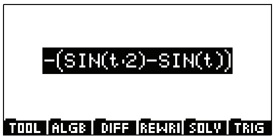
Since M_1 and M_2 are symmetrical with respect to the x-axis, we can deduce that the x-axis is an axis of symmetry for Γ .

Part 3

Calculate $x'(t)$ by typing:

DIFF DERVX OK
[ALPHA] X [(] [SHIFT]
[ALPHA] t. Press [▶] [▶]
to highlight the expression.

Pressing [ENTER] returns the result at the right:

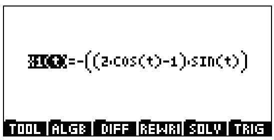


Press [ENTER] to simplify the result:

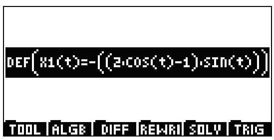
You can now define the function $x'(t)$ by invoking `DEF`.

Note: You will first need to type `=X1(t)` then exchange `X1(t)` with the previous expression.

To do this, highlight X1(t) and type [SHIFT] [◀].



Now select the entire expression and apply the `DEF` command to it:



Finally press [ENTER] to finish the definition.

Part 4

To calculate $y'(t)$, begin by typing: `DERVX(Y(t))`. Pressing [ENTER] returns:

Press [ENTER] again to simplify the result:

Select `FACTOR` and press [ENTER].

You can now define the function $y'(t)$ (in the same way that you defined $x'(t)$).

Part 5

To show the variations of $x(t)$ and $y(t)$, we will trace $x(t)$ and $y(t)$ on the same graph.

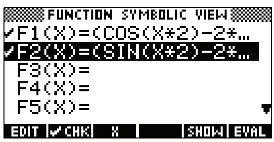
The independent variable must be t which it should be as a result of the previous calculations. (You can check this by pressing [SHIFT] [SYMB].)

Type `X(t)` in the Equation Writer and press [ENTER]. The corresponding expression is displayed.

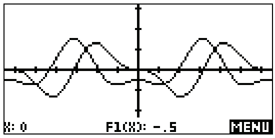
Now press [PLOT], select `Function`, press OK, select `F1` as the destination and press OK.

Now do the same thing with Y(t), making `F2` the destination.

To graph the functions, quit CAS (by pressing [HOME]), choose the `Function` aplet, and check `F1` and `F2`.



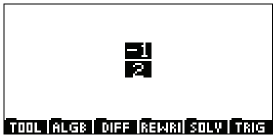
Now press [PLOT] to see the graphs.



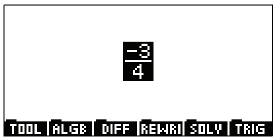
Part 6

To find the values of $x(t)$ and $y(t)$ for $t = 0, \frac{\pi}{3}, \frac{2 \cdot \pi}{3}, \pi$ return to CAS, type each function in turn and press [ENTER]. (You may need to press [ENTER] twice for further simplification).

For example, pressing [ALPHA] X [(] 0 [ENTER] gives the result at the right:



Likewise, pressing [ALPHA] X [(] [SHIFT] π [÷] 3 [ENTER] [ENTER] gives this answer at the right:



The other results are:

$$X\left(\frac{2\pi}{3}\right) = \frac{1}{4}$$

$$X(\pi) = \frac{3}{2}$$

$$Y(0) = 0$$

$$Y\left(\frac{\pi}{3}\right) = \frac{-\sqrt{3}}{4}$$

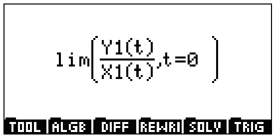
$$Y\left(\frac{2\pi}{3}\right) = \frac{-3 \cdot \sqrt{3}}{4}$$

$$Y(\pi) = 0$$

The slope of the tangents is $m = \frac{y'(t)}{x'(t)}$.

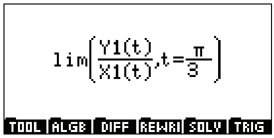
We can find the values of $\frac{y'(t)}{x'(t)}$ for $t = 0, \frac{\pi}{3}, \frac{2 \cdot \pi}{3}, \pi$ by using the `lim` command.

The example at the right shows the case for t = 0. Select the entire expression and press [ENTER] to get the answer:

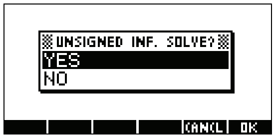


0

The example at the right shows the case for t = π/3.

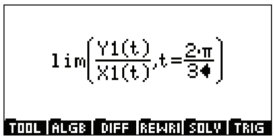


Selecting the entire expression and pressing [ENTER] displays the message shown at the right. Accept `YES` and press OK. Press [ENTER] again to get the result:



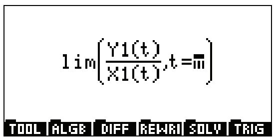
∞

The next example is for t = 2π/3. Selecting the entire expression and pressing [ENTER] displays the result:



0

The final example is for the case where t = π. Press [ENTER], accept `YES` to the message `UNSIGNED INF. SOLVE?`, press OK and press [ENTER] to get the result:



∞

Here, then, are the variations of $x(t)$ and $y(t)$:

t	0		$\frac{\pi}{3}$		$\frac{2\pi}{3}$		π
$x'(t)$	0	–	0	+	$\sqrt{3}$	+	0
$x(t)$	$\frac{-1}{2}$	$\downarrow$	$\frac{-3}{4}$	$\uparrow$	$\frac{1}{4}$	$\uparrow$	$\frac{3}{2}$
$y(t)$	0	$\downarrow$	$\frac{-\sqrt{3}}{4}$	$\downarrow$	$\frac{-3\sqrt{3}}{4}$	$\uparrow$	0
$y'(t)$	0	–	–1	–	0	+	2
m	0		∞		0		∞

Now we will graph Γ, which is a parametric curve.

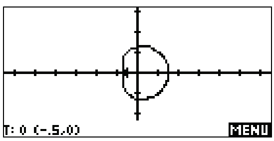
In the Equation Writer, type `X(t) + i × Y(t).`

Select the entire expression and press [ENTER].

Now press [PLOT], select `Parametric` and press OK. Select `X1,Y1` as the destination and press OK.

To make the graph of Γ, quit CAS and choose the `Parametric` aplet. Check `X1(T)` and `Y1(T)`.

Now press [PLOT] to see the graph.



Exercise 8

For this exercise, make sure that the calculator is in exact real mode with *X* as the current variable.

Part 1

For an integer, *n*, define the following:

$$u_n = \int_0^2 \frac{2x+3}{x+2} e^{\frac{x}{n}} dx$$

Define g over [0,2] where:

$$g(x) = \frac{2x+3}{x+2}$$

1. Find the variations of g over [0,2]. Show that for every real x in [0,2]:

$$\frac{3}{2} \le g(x) \le \frac{7}{4}$$

2. Show that for every real *x* in [0,2]:

$$\frac{3}{2} e^{\frac{x}{n}} \le g(x) e^{\frac{x}{n}} \le \frac{7}{4} e^{\frac{x}{n}}$$

3. After integration, show that:

$$\frac{3}{2}\left(n e^{\frac{2}{n}} - n\right) \le u_n \le \frac{7}{4}\left(n e^{\frac{2}{n}} - n\right)$$

4. Using:

$$\lim_{x \to 0} \frac{e^x - 1}{x} = 1$$

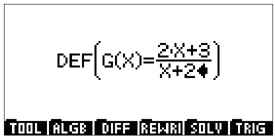
show that if u_n has a limit *L* as *n* approaches infinity, then:

$$3 \le L \le \frac{7}{2}$$

Solution 1

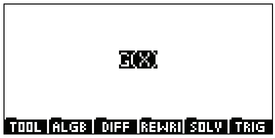
Start by defining G(X):

ALGB DEF [ALPHA] G [(] [ALPHA] X [▶] [SHIFT] = 2 [ALPHA] X [+] 3 [▶] [÷] [ALPHA] X [+] 2

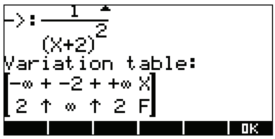


Now press [ENTER]:

Press [▼] and [▶] to select the numerator and denominator, and then press [SHIFT] [DEL]. This leaves G(X) displayed:



Finally, apply the `TABVAR` function:



DIFF `TABVAR` OK

and press [ENTER] a number of times until the variation table appears (shown above).

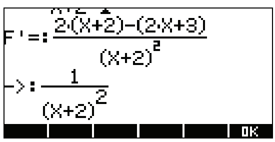
The first line of the variation table gives the sign of $g'(x)$ according to *x*, and the second line the variations of $g(x)$. Note that for `TABVAR` the function is always called `F`.

We can deduce, then, that *g*(*x*) increases over [0, 2].

If you had been in step-by-step mode, you would have obtained:

$$F = \frac{2 \cdot X + 3}{X + 2}$$

Press [ENTER] to get the result at the right.



Now press ▼ and scroll down the screen to:

$$\to \frac{1}{(x+2)^2}$$

Now press ENTER to obtain the table of variations.

If you are not in step-by -step mode, you can also get the calculation of the derivative by typing:

```
DERVX(G(X))
```

which produces the preceding result.

To prove the stated inequality, first calculate $g(0)$ by typing G(0) and pressing ENTER. The answer is: $\frac{3}{2}$.

Now calculate $g(2)$ by typing G(2) and pressing ENTER. The answer is $\frac{7}{4}$.

The two results prove that:

$$\frac{3}{2} \le g(x) \le \frac{7}{4} \text{ for } x \in [0,2]$$

Solution 2

The calculator is not needed here. Simply stating that:

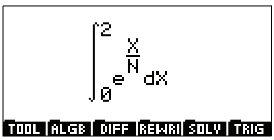
$$e^{\frac{x}{n}} \ge 0 \text{ for } x \in [0,2]$$

is sufficient to show that, for $x \in [0,2]$, we have:

$$\frac{3}{2}e^{\frac{x}{n}} \le g(x)e^{\frac{x}{n}} \le \frac{7}{4}e^{\frac{x}{n}}$$

Solution 3

To integrate the preceding inequality, type the expression at the right:



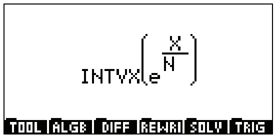
Pressing ENTER produces the result at the right:

We can now see that:

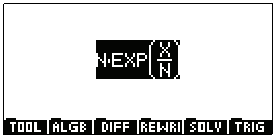
$$\frac{3}{2}\left(ne^{\frac{2}{n}}-n\right) \le u_n \le \frac{7}{4}\left(ne^{\frac{2}{n}}-n\right)$$

To justify the preceding calculation, we must assume that $n \cdot e^{\frac{x}{n}}$ is a primitive of $e^{\frac{x}{n}}$.

If you are not sure, you can use the `INTVX` function as illustrated at the right:



Note that the `INTVX` command is on the **DIFF** menu.

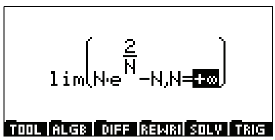


The simplified result, got by pressing [ENTER] twice, is shown at the right:

Solution 4

To find the limit of $\left(ne^{\frac{2}{n}}-n\right)$ when $n \to +\infty$, enter the expression at the right:

Note that the `lim` command is on the **DIFF** menu. The infinity sign can be selected from the character map, opened by pressing [SHIFT] [VARS].



Pressing [ENTER] once after selecting the infinity sign adds a "+" character to the infinity sign.

Select the entire expression ans press [ENTER] to get the result, which is:

2

NOTE: The variable `VX` is now set to `N`. Reset it to `X` by pressing [SHIFT] [SYMB] (to display CAS `MODES` screen) and change the `INDEP VAR` setting.

To check the result, we can say that:

$$\lim_{x \to 0} \frac{e^x - 1}{x} = 1$$

and that therefore:

$$\lim_{n \to +\infty} \frac{e^{\frac{2}{n}} - 1}{\frac{2}{n}} = 1$$

or, simplifying:

$$\lim_{n \to +\infty} \left(e^{\frac{2}{n}} - 1 \right) \cdot n = 2$$

If the limit L of u_n exists as n approaches $+\infty$ in the inequalities in solution 2 above, we get:

$$\frac{3}{2} \cdot 2 \le L \le \frac{7}{4} \cdot 2$$

Part 2

1. Show that for every *x* in [0,2]:

$$\frac{2x+3}{x+2} = 2 - \frac{1}{x+2}$$

2. Find the value of:

$$I = \int_0^2 \frac{2x+3}{x+2} dx$$

3. Show that for every *x* in [0,2]:

$$1 \le e^{\frac{x}{n}} \le e^{\frac{2}{n}}$$

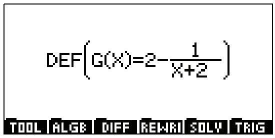
4. Deduce that:

$$1 \le u_n \le e^{\frac{2}{n}} \cdot I$$

5. Show that u_n is convergent and find its limit, *L*.

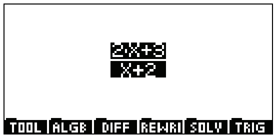
Solution 1

Start by defining the following: $g(x) = 2 - \frac{1}{x+2}$



Now type PROPFRAC(G(X)). Note that PROPFRAC can be found on the POLYNOMIAL submenu of the MATH menu.

Pressing [ENTER] yields the result shown at the right.

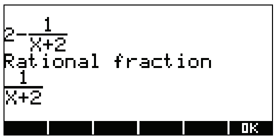


Solution 2

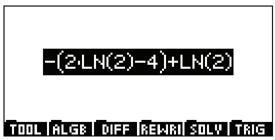
Enter the integral:

$$I = \int_0^2 g(x)dx\ .$$

Pressing [ENTER] yields the result shown at the right:



Pressing [ENTER] again yields:



Working by hand:

$2x + 3 = 2(x+2) - 1$, so: $g(x) = 2 - \frac{1}{x+2}$

Then, integrating term by term between 0 and 2 produces:

$$\int_0^2 g(x)dx = [2x - \ln(x+2)]\ \begin{matrix} x = 2 \\ x = 0 \end{matrix}$$

that is, since $\ln 4 = 2\ln 2$:

$$\int_0^2 g(x)dx = 4 - \ln 2$$

Solution 3

The calculator is not needed here. Simply stating that $e^{\frac{x}{n}}$ increases for $x \in [0,2]$ is sufficient to yield the inequality:

$$1 \le e^{\frac{x}{n}} \le e^{\frac{2}{n}}$$

Solution 4

Since $g(x)$ is positive over $[0, 2]$, through multiplication we get:

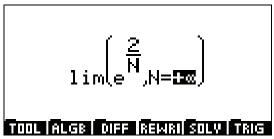
$$g(x) \le g(x)e^{\frac{x}{n}} \le g(x)e^{\frac{2}{n}}$$

and then, integrating:

$$I \le u_n \le e^{\frac{2}{n}} I$$

Solution 5

First find the limit of $e^{\frac{2}{n}}$ when $n \to +\infty$.



Note: pressing ENTER after you have selected the infinity sign from the character map places a "+" character in front of the infinity sign.

Selecting the entire expression and pressing ENTER yields:

1

In effect, $\frac{2}{n}$ tends to 0 as n tends to $+\infty$, so $e^{\frac{2}{n}}$ tends to $e^0 = 1$ as n tends to $+\infty$.

As n tends to $+\infty$, u_n is the portion between I and a quantity that tends to I.

Hence, u_n converges, and its limit is I.

We have therefore shown that: $L = I = 4 - \ln 2$

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Variables and memory management

Introduction

The HP 40gs has approximately 200K of user memory. The calculator uses this memory to store variables, perform computations, and store history.

A variable is an object that you create in memory to hold data. The HP 40gs has two types of variables, home variables and aplet variables.

- Home variables are available in all aplets. For example, you can store real numbers in variables *A* to *Z* and complex numbers in variables Z0 to Z9. These can be numbers you have entered, or the results of calculations. These variables are available within all aplets and within any programs.
- Aplet variables apply only to a single aplet. Aplets have specific variables allocated to them which vary from aplet to aplet.

You use the calculator's memory to store the following objects:

- copies of aplets with specific configurations
- new aplets that you download
- aplet variables
- home variables
- variables created through a catalog or editor, for example a matrix or a text note
- programs that you create.

You can use the Memory Manager (SHIFT *MEMORY*) to view the amount of memory available. The catalog views, which are accessible via the Memory Manager, can be used to transfer variables such as lists or matrices between calculators.

Storing and recalling variables

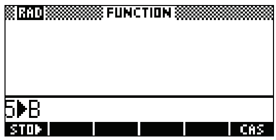
You can store numbers or expressions from a previous input or result into variables.

Numeric Precision

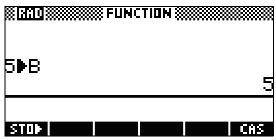
A number stored in a variable is always stored as a 12-digit mantissa with a 3-digit exponent. Numeric precision in the display, however, depends on the display mode (Standard, Fixed, Scientific, Engineering, or Fraction). A displayed number has only the precision that is displayed. If you copy it from the HOME view display history, you obtain only the precision displayed, not the full internal precision. On the other hand, the variable *Ans* always contains the most recent result to full precision.

To store a value

1. On the command line, enter the value or the calculation for the result you wish to store.



2. Press STO▶
3. Enter a name for the variable.
4. Press [ENTER].

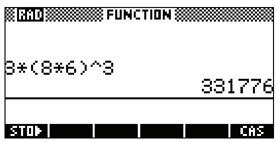


To store the results of a calculation

If the value you want to store is in the HOME view display history, for example the results of a previous calculation, you need to copy it to the command line, then store it.

1. Perform the calculation for the result you want to store.

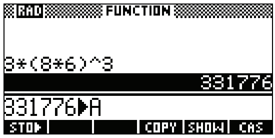
   3 [×] [(] 8 [×] 6 [)]
   [X^Y] 3 [ENTER]



2. Press [▲] to highlight to the result you wish to store.
3. Press COPY to copy the result to the command line.
4. Press STO▶ .

5. Enter a name for the variable.

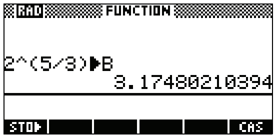
   [ALPHA] A



6. Press [ENTER] to store the result.

The results of a calculation can also be stored directly to a variable. For example:

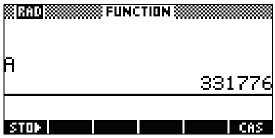
2 [X^Y] [(] 5 [÷] 3 [)]
STO▶ [ALPHA] B
[ENTER]



To recall a value

To recall a variable's value, type the name of the variable and press [ENTER].

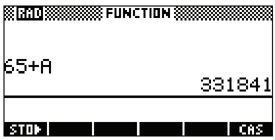
[ALPHA] A [ENTER]



To use variables in calculations

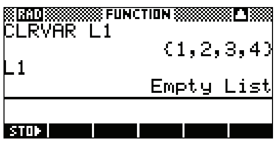
You can use variables in calculations. The calculator substitutes the variable's value in the calculation:

65 [+] [ALPHA] A [ENTER]



To clear a variable

You can use the CLRVAR command to clear a specified variable. For example, if you have stored {1,2,3,4} in variable L1, entering CLRVAR L1 [ENTER] will clear L1. (You can find the CLRVAR command by pressing [SHIFT] [MATH] and choosing the PROMPT category of commands.)



The VARS menu

You use the VARS menu to access all variables in the calculator. The VARS menu is organised by category. For each variable category in the left column, there is a list of variables in the right column. You select a variable category and then select a variable in the category.

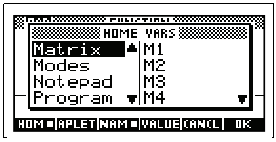
1. Open the VARS menu.

   [VARS]

2. Use the arrow keys or press the alpha key of the first letter in the category to select a variable category.

   For example, to select the Matrix category, press [)] *.*

   Note: In this instance, there is no need to press the ALPHA key.



3. Move the highlight to the variables column.

   [▶]

4. Use the arrow keys to select the variable that you want. For example, to select the M2 variable, press [▼] .

   [▼]

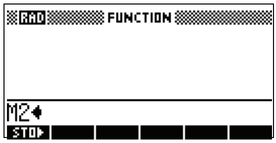
5. Choose whether to place the variable name or the variable value on the command line.

   – Press VALUE to indicate that you want the variable's contents to appear on the command line.

   – Press NAME to indicate that you want the variable's name to appear on the command line.

6. Press OK to place the value or name on the command line. The selected object appears on the command line.

   OK



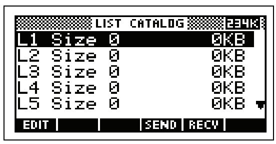
Note: The VARS menu can also be used to enter the names or values of variables into programs.

Example

This example demonstrates how to use the VARS menu to add the contents of two list variables, and to store the result in another list variable.

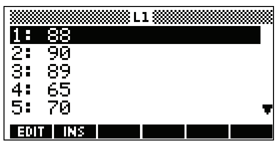
1. Display the List Catalog.

   SHIFT *LIST*
   to select L1
   EDIT



2. Enter the data for L1.

   88 OK 90 OK 89 OK
   65 OK 70 OK

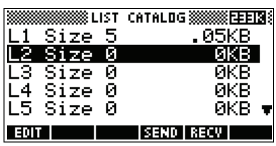


3. Return to the List Catalog to create L2.

   SHIFT *LIST*

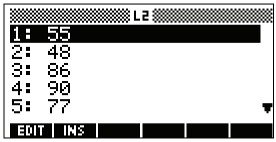
   ▼ *to select L2*

   EDIT



4. Enter data for L2.

   55 OK 48 OK 86 OK
   90 OK 77 OK

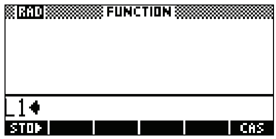


5. Press HOME to access HOME.
6. Open the variable menu and select L1.

   VARS ▼ ▼ ▼ ▶

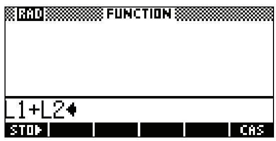
7. Copy it to the command line. *Note: Because the* NAM *option is highlighted, the variable's name, rather than its contents, is copied to the command line.*

   OK



8. Insert the + operator and select the L2 variable from the List variables.

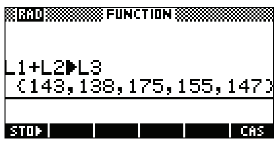
   + VARS
   ▼ ▼ ▼ ▶ ▼ OK



9. Store the answer in the List catalog L3 variable.

   STO▶ ALPHA *L3*
   ENTER

   Note: You can also type list names directly from the keyboard.



Home variables

It is not possible to store data of one type in a variable of another type. For example, you use the Matrix catalog to create matrices. You can create up to ten matrices, and you can store these in variables M0 to M9. You cannot store matrices in variables other than M0 to M9.

Category	Available names
Complex	Z0 to Z9 For example, *(1,2)* STO▸ Z0 or 2+3*i* STO▸ Z1. You can enter a complex number by typing *(r,i)*, where *r* represents the real part, and *i* represents the imaginary part.
Graphic	G0 to G9 See "Graphic commands" on page 21-21 for more information on storing graphic objects via programming commands. See "To store into a graphics variable" on page 20-5 for more information on storing graphic object via the sketch view.
Library	Aplet library variables can store aplets that you have created, either by saving a copy of a standard aplet, or downloading an aplet from another source.
List	L0 to L9 For example, {1,2,3} STO▸ L1.
Matrix	M0 to M9 can store matrices or vectors. For example, [[1,2],[3,4]] STO▸ M0.
Modes	Modes variables store the modes settings that you can configure using SHIFT *MODES*.
Notepad	Notepad variables store notes.
Program	Program variables store programs.
Real	A to Z and θ. For example, 7.45 STO▸ A.
Symbolic	E0…9, S1…S5, s1…s5 and n1…n5.

Aplet variables

Most aplet variables store values that are unique to a particular aplet. These include symbolic expressions and equations (see below), settings for the Plot and Numeric views, and the results of some calculations such as roots and intersections.

See the Reference Information chapter for more information about aplet variables.

Category	**Available names**
Function	F0 to F9 (Symbolic view). See “Function aplet variables” on page R-7.
Parametric	X0, Y0 to X9, Y9 (Symbolic view). See “Parametric aplet variables” on page R-8.
Polar	R0 to R9 (Symbolic view). See “Polar aplet variables” on page R-9.
Sequence	U0 to U9 (Symbolic view). See “Sequence aplet variables” on page R-10.
Solve	E0 to E9 (Symbolic view). See “Solve aplet variables” on page R-11.
Statistics	C0 to C9 (Numeric view). See “Statistics aplet variables” on page R-12.

To access an aplet variable

1. Open the aplet that contains the variable you want to recall.
2. Press VARS to display the VARS menu.
3. Use the arrow keys to select a variable category in the left column, then press ▶ to access the variables in the right column.
4. Use the arrow keys to select a variable in the right column.
5. To copy the name of the variable onto the edit line, press OK . (NAME▪ is the default setting.)
6. To copy the value of the variable into the edit line, press VALUE and press OK .

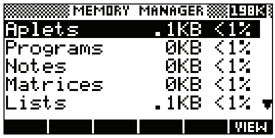
Memory Manager

You can use the Memory Manager to determine the amount of available memory on the calculator. You can also use Memory Manager to organize memory. For example, if the available memory is low, you can use the Memory Manager to determine which aplets or variables consume large amounts of memory. You can make deletions to free up memory.

Example

1. Start the Memory Manager. A list of variable categories is displayed.

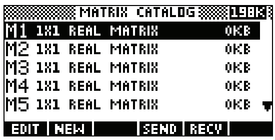
   SHIFT *MEMORY*

   Free memory is displayed in the top right corner and the body of the screen lists each category, the memory it uses, and the percentage of the total memory it uses.

2. Select the category with which you want to work and press VIEW. Memory Manager displays memory details of variables within the category.

   ▼ ▼ ▼ VIEW

3. To delete variables in a category:

   – Press DEL to delete the selected variable.

   – Press SHIFT *CLEAR* to delete all variables in the selected category.

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Matrices

Introduction

You can perform matrix calculations in HOME and in programs. The matrix *and each row* of a matrix appear in brackets, and the elements and rows are separated by commas. For example, the following matrix:

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$$

is displayed in the history as:
[[1,2,3],[4,5,6]]

(If the Decimal Mark mode is set to `Comma`, then separate each element and each row with a period.)

You can enter matrices directly in the command line, or create them in the matrix editor.

Vectors

Vectors are one-dimensional arrays. They are composed of just one row. A vector is represented with single brackets; for example, [1,2,3]. A vector can be a real number vector or a complex number vector, for example [(1,2), (7,3)].

Matrices

Matrices are two-dimensional arrays. They are composed of more than one row and more than one column. Two-dimensional matrices are represented with nested brackets; for example, [[1,2,3],[4,5,6]]. You can create complex matrices, for example, [[(1,2), (3,4)], [(4,5), (6,7)]].

Matrix Variables

There are ten matrix variables available, named M0 to M9. You can use them in calculations in HOME or in a program. You can retrieve the matrix names from the VARS menu, or just type their names from the keyboard.

Creating and storing matrices

You can create, edit, delete, send, and receive matrices in the Matrix catalog.

To open the Matrix catalog, press SHIFT *MATRIX*.

You can also create and store matrices—named or unnamed—-in HOME. For example, the command:

```
POLYROOT([1,0,-1,0])▶M1
```

stores the root of the complex vector of length 3 into the M1 variable. M1 now contains the three roots of $x^3 - x = 0$

Matrix Catalog keys

The table below lists the operations of the menu keys in the Matrix Catalog, as well as the use of Delete (DEL) and Clear (SHIFT *CLEAR*).

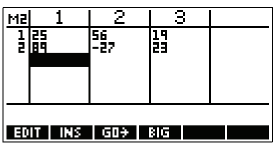
Key	Meaning
EDIT	Opens the highlighted matrix for editing.
NEW	Prompts for a matrix type, then opens an empty matrix with the highlighted name.
SEND	Transmits the highlighted matrix to another HP 40gs or a disk drive. See.
RECV	Receives a matrix from another HP 40gs or a disk drive. See .
DEL	Clears the highlighted matrix.
SHIFT *CLEAR*	Clears all matrices.
SHIFT ▼ or ▲	Moves to the end or the beginning of the catalog.

To create a matrix in the Matrix Catalog

1. Press SHIFT *MATRIX* to open the Matrix Catalog. The Matrix catalog lists the 10 available matrix variables, M0 to M9.

2. Highlight the matrix variable name you want to use and press **NEW**.
3. Select the type of matrix to create.
   – **For a vector (one-dimensional array)**, select `Real vector` or `Complex vector`. Certain operations (+, –, `CROSS`) do not recognize a one-dimensional matrix as a vector, so this selection is important.
   – **For a matrix (two-dimensional array),** select `Real matrix` or `Complex matrix`.
4. For each element in the matrix, type a number or an expression, and press [ENTER]. (The expression may not contain symbolic variable names.)

   For complex numbers, enter each number in complex form; that is, *(a, b)*, where *a* is the real part and *b* is the imaginary part. You must include the parentheses and the comma.
5. Use the cursor keys to move to a different row or column. You can change the direction of the highlight bar by pressing **GO**. The **GO** menu key toggles between the following three options:
   – **GO↓** specifies that the cursor moves to the cell below the current cell when you press [ENTER].
   – **GO→** specifies that the cursor moves to the cell to the right of the current cell when you press [ENTER].
   – **GO** specifies that the cursor stays in the current cell when you press [ENTER].
6. When done, press [SHIFT] *MATRIX* to see the Matrix catalog, or press [HOME] to return to HOME. The matrix entries are automatically stored.



A matrix is listed with two dimensions, even if it is 3×1. A vector is listed with the number of elements, such as 3.

To transmit a matrix

You can send matrices between calculators just as you can send aplets, programs, lists, and notes.

1. Connect the calculators using an appropriate cable.
2. Open the Matrix catalogs on both calculators.
3. Highlight the matrix to send.
4. Press **SEND** and choose the method of sending.
5. Press **RECV** on the receiving calculator and choose the method of receiving.

For more information on sending and receiving files, see "Sending and receiving aplets" on page 22-4.

Working with matrices

To edit a matrix

In the Matrix catalog, highlight the name of the matrix you want to edit and press **EDIT**.

Matrix edit keys

The following table lists the matrix edit key operations.

Key	Meaning
EDIT	Copies the highlighted element to the edit line.
INS	Inserts a row of zeros above, or a column of zeros to the left, of the highlighted cell. (You are prompted to choose row or column.)
GO	A three-way toggle for cursor advancement in the Matrix editor. **GO→** advances to the right, **GO↓**, advances downward, and **GO** does not advance at all.
BIG	Switches between larger and smaller font sizes.
DEL	Deletes the highlighted cells, row, or column (you are prompted to make a choice).
SHIFT *CLEAR*	Clears all elements from the matrix.

Key	Meaning (Continued)
SHIFT ▲ ▼ ▶ ◀	Moves to the first row, last row, first column, or last column respectively.

To display a matrix

- In the Matrix catalog (SHIFT *MATRIX*), highlight the matrix name and press **EDIT**.
- In HOME, enter the name of the matrix variable and press ENTER.

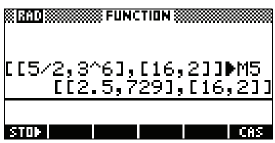
To display one element

In HOME, enter *matrixname*(*row,column*). For example, if `M2` is `[[3,4],[5,6]]`, then `M2(1,2)` ENTER returns `4`.

To create a matrix in HOME

1. Enter the matrix in the edit line. Start and end the matrix *and each row* with square brackets (the shifted 5 and 6 keys).
2. Separate each element *and each row* with a comma. Example: `[[1,2],[3,4]]`.
3. Press ENTER to enter and display the matrix.

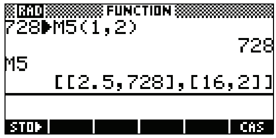
The left screen below shows the matrix `[[2.5,729],[16,2]]` being stored into M5. The screen on the right shows the vector `[66,33,11]` being stored into M6. Note that you can enter an expression (like 5/2) for an element of the matrix, and it will be evaluated.



To store one element

In HOME, enter, *value* STO▸ *matrixname*(*row*, *column*). For example, to change the element in the first row and second column of M5 to 728, then display the resulting matrix:

728 STO▸ [ALPHA]
M5 [(] 1 [,] 2 [)] [ENTER]
[ALPHA] M5 [ENTER] .



An attempt to store an element to a row or column beyond the size of the matrix results in an error message.

Matrix arithmetic

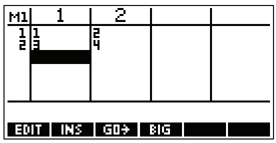
You can use the arithmetic functions (+, –, ×, / and powers) with matrix arguments. Division left-multiplies by the inverse of the divisor. You can enter the matrices themselves or enter the names of stored matrix variables. The matrices can be real or complex.

For the next examples, store [[1,2],[3,4]] into M1 and [[5,6],[7,8]] into M2.

Example

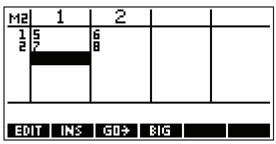
1. Create the first matrix.

   [SHIFT] *MATRIX* NEW
   OK 1 [ENTER] 2 [ENTER]
   [▼] 3 [ENTER] 4
   [ENTER]

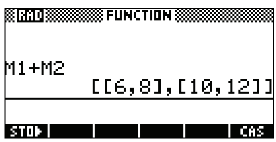


2. Create the second matrix.

   [SHIFT] *MATRIX* [▼]
   NEW OK 5 [ENTER] 6
   [ENTER] [▼] 7 [ENTER]
   8 [ENTER]



3. Add the matrices that you created.



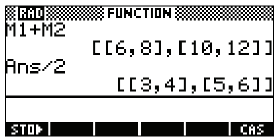
HOME ALPHA M1 + ALPHA M2 ENTER

To multiply and divide by a scalar

For division by a scalar, enter the matrix first, then the operator, then the scalar. For multiplication, the order of the operands does not matter.

The matrix and the scalar can be real or complex. For example, to divide the result of the previous example by 2, press the following keys:

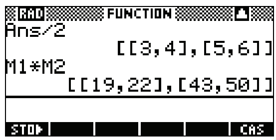
÷ 2 ENTER



To multiply two matrices

To multiply the two matrices M1 and M2 that you created for the previous example, press the following keys:

ALPHA M1 × ALPHA M 2 ENTER



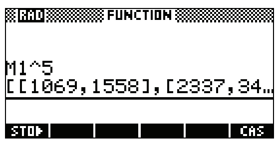
To multiply a matrix by a vector, enter the matrix first, then the vector. The number of elements in the vector must equal the number of columns in the matrix.

To raise a matrix to a power

You can raise a matrix to any power as long as the power is an integer. The following example shows the result of raising matrix M1, created earlier, to the power of 5.

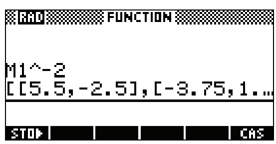
ALPHA M1 X^Y 5 ENTER

Note: You can also raise a matrix to a power without first storing it as a variable.



Matrices can be raised to negative powers. In this case, the result is equivalent to 1/[matrix]^ABS(power). In the following example, M1 is raised to the power of –2.

ALPHA M1 X^Y (-) 2 ENTER



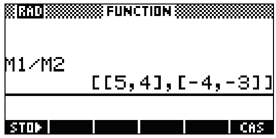
To divide by a square matrix

For division of a matrix or a vector by a square matrix, the number of rows of the dividend (or the number of elements, if it is a vector) must equal the number of rows in the divisor.

This operation is not a mathematical division: it is a left-multiplication by the inverse of the divisor. M1/M2 is equivalent to $M2^{-1} * M1$.

To divide the two matrices M1 and M2 that you created for the previous example, press the following keys:

ALPHA M1 ÷
ALPHA M2 ENTER



To invert a matrix

You can invert a *square matrix* in HOME by typing the matrix (or its variable name) and pressing SHIFT x^{-1} ENTER. Or you can use the matrix INVERSE command. Enter `INVERSE`(*matrixname*) in HOME and press ENTER.

To negate each element

You can change the sign of each element in a matrix by pressing (-) before the matrix name.

Solving systems of linear equations

Example

Solve the following linear system:

$$\begin{aligned} 2x + 3y + 4z &= 5 \\ x + y - z &= 7 \\ 4x - y + 2z &= 1 \end{aligned}$$

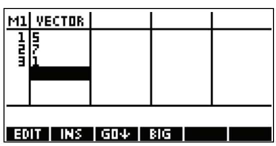
1. Open the Matrix catalog and create a vector.

   SHIFT *MATRIX* **NEW**

   ▼ ENTER

2. Create the vector of the constants in the linear system.

   5 ENTER 7 ENTER
   1 ENTER



3. Return to the Matrix Catalog.

   [SHIFT] *MATRIX*

   In this example, the vector you created is listed as M1.

4. Create a new matrix.

   [▼] **NEW**

   Select `Real matrix`

   OK

5. Enter the equation coefficients.

   2 [ENTER] 3 [ENTER]

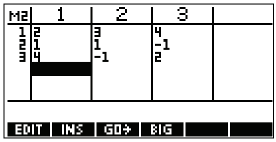
   4 [ENTER] [▼]

   1 [ENTER] 1 [ENTER]

   [(-)] 1 [ENTER] 4 [ENTER]

   [(-)] 1 [ENTER] 2 [ENTER]

   In this example, the matrix you created is listed as M2.

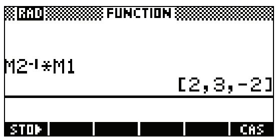


6. Return to HOME and enter the calculation to left-multiply the constants vector by the inverse of the coefficients matrix.

   [HOME] [ALPHA] M2

   [SHIFT] x^{-1} [×]

   [ALPHA] M1 [ENTER]



The result is a vector of the solutions $x = 2$, $y = 3$ and $z = -2$.

An alternative method, is to use the RREF function. See “RREF” on page 18-12.

Matrix functions and commands

About functions

- Functions can be used in any aplet or in HOME. They are listed in the MATH menu under the Matrix category. They can be used in mathematical expressions—primarily in HOME—as well as in programs.
- Functions always produce and display a result. They do not change any stored variables, such as a matrix variable.
- Functions have arguments that are enclosed in parentheses and separated by commas; for example, `CROSS`(*vector1*,*vector2*). The matrix input can be either a matrix variable name (such as `M1`) or the actual matrix data inside brackets. For example, `CROSS(M1,[1,2])`.

About commands

Matrix commands are listed in the CMDS menu (SHIFT *CMDS*), in the matrix category.

See “Matrix commands” on page 21-24 for details of the matrix commands available for use in programming.

Functions differ from commands in that a function can be used in an expression. Commands cannot be used in an expression.

Argument conventions

- For *row#* or *column#*, supply the number of the row (counting from the top, starting with 1) or the number of the column (counting from the left, starting with 1).
- The argument *matrix* can refer to either a vector or a matrix.

Matrix functions

COLNORM

Column Norm. Finds the maximum value (over all columns) of the sums of the absolute values of all elements in a column.

`COLNORM`(*matrix*)

COND Condition Number. Finds the 1-norm (column norm) of a square *matrix*.

`COND`(*matrix*)

CROSS Cross Product of *vector1* with *vector2*.

`CROSS`(*vector1*, *vector2*)

DET Determinant of a square *matrix*.

`DET`(*matrix*)

DOT Dot Product of two arrays, *matrix1 matrix2*.

`DOT`(*matrix1, matrix2*)

EIGENVAL Displays the eigenvalues in vector form for *matrix*.

`EIGENVAL`(*matrix*)

EIGENVV Eigenvectors and Eigenvalues for a square *matrix*. Displays a list of two arrays. The first contains the eigenvectors and the second contains the eigenvalues.

`EIGENVV`(*matrix*)

IDENMAT Identity matrix. Creates a square matrix of dimension *size* × *size* whose diagonal elements are 1 and off-diagonal elements are zero.

`IDENMAT`(*size*)

INVERSE Inverts a square matrix (real or complex).

`INVERSE`(*matrix*)

LQ LQ Factorization. Factors an $m \times n$ *matrix* into three matrices:
{[[$m \times n$ *lowertrapezoidal*]],[[$n \times n$ *orthogonal*]], [[$m \times m$ *permutation*]]}.

`LQ`(*matrix*)

LSQ Least Squares. Displays the minimum norm least squares *matrix* (or *vector*).

`LSQ`(*matrix1, matrix2*)

LU

LU Decomposition. Factors a square *matrix* into three matrices:
{[[*lowertriangular*]],[[*uppertriangular*]],[[*permutation*]]}
The *uppertriangular* has ones on its diagonal.

`LU`(*matrix*)

MAKEMAT

Make Matrix. Creates a matrix of dimension *rows* × *columns*, using *expression* to calculate each element. If *expression* contains the variables I and J, then the calculation for each element substitutes the current row number for I and the current column number for J.

`MAKEMAT`(*expression, rows, columns*)

Example

`MAKEMAT(0,3,3)` returns a 3×3 zero matrix, `[[0,0,0],[0,0,0],[0,0,0]]`.

QR

QR Factorization. Factors an *m*×*n matrix* into three matrices: {[[*m*×*m orthogonal*]],[[*m*×*n uppertrapezoidal*]],[[*n*×*n permutation*]]}.

`QR`(*matrix*)

RANK

Rank of a rectangular *matrix*.

`RANK`(*matrix*)

ROWNORM

Row Norm. Finds the maximum value (over all rows) for the sums of the absolute values of all elements in a row.

`ROWNORM`(*matrix*)

RREF

Reduced-Row Echelon Form. Changes a rectangular *matrix* to its reduced row-echelon form.

`RREF`(*matrix*)

SCHUR

Schur Decomposition. Factors a square *matrix* into two matrices. If *matrix* is real, then the result is
{[[*orthogonal*]],[[*upper-quasi triangular*]]}.
If *matrix* is complex, then the result is
{[[*unitary*]],[[*upper-triangular*]]}.

`SCHUR`(*matrix*)

SIZE

Dimensions of *matrix*. Returned as a list: {rows,columns}.

`SIZE`(*matrix*)

SPECNORM Spectral Norm of *matrix*.

`SPECNORM`(*matrix*)

SPECRAD Spectral Radius of a square *matrix*.

`SPECRAD`(*matrix*)

SVD Singular Value Decomposition. Factors an $m \times n$ *matrix* into two matrices and a vector: {[[$m \times m$ *square orthogonal*]],[[$n \times n$ *square orthogonal*]], [*real*]}.

`SVD`(*matrix*)

SVL Singular Values. Returns a vector containing the singular values of *matrix.*

`SVL`(*matrix*)

TRACE Finds the trace of a square *matrix.* The trace is equal to the sum of the diagonal elements. (It is also equal to the sum of the eigenvalues.)

`TRACE`(*matrix*)

TRN Transposes *matrix*. For a complex matrix, TRN finds the conjugate transpose.

`TRN`(*matrix*)

Examples

Identity Matrix

You can create an identity matrix with the IDENMAT function. For example, IDENMAT(2) creates the 2×2 identity matrix [[1,0],[0,1]].

You can also create an identity matrix using the MAKEMAT (*make matrix*) function. For example, entering MAKEMAT(I¼J,4,4) creates a 4 × 4 matrix showing the numeral 1 for all elements except zeros on the diagonal. The logical operator ¼ returns 0 when I (the row number) and J (the column number) are equal, and returns 1 when they are not equal.

Transposing a Matrix

The TRN function swaps the row-column and column-row elements of a matrix. For instance, element 1,2 (row 1, column 2) is swapped with element 2,1; element 2,3 is swapped with element 3,2; and so on.

For example, `TRN([[1,2],[3,4]])` creates the matrix `[[1,3],[2,4]]`.

Reduced-Row Echelon Form

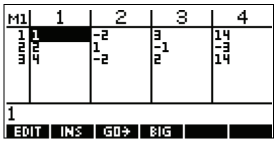
The following set of equations

$$\begin{aligned} x - 2y + 3z &= 14 \\ 2x + y - z &= -3 \\ 4x - 2y + 2z &= 14 \end{aligned}$$

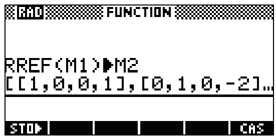
can be written as the augmented matrix

$$\left[\begin{array}{ccc|c} 1 & -2 & 3 & 14 \\ 2 & 1 & -1 & -3 \\ 4 & -2 & 2 & 14 \end{array}\right]$$

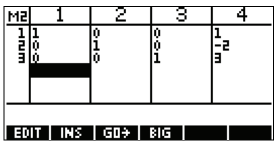
which can then stored as a 3×4 real matrix in any matrix variable. M1 is used in this example.



You can use the RREF function to change this to reduced row echelon form, storing it in any matrix variable. M2 is used in this example.



The reduced row echelon matrix gives the solution to the linear equation in the fourth column.

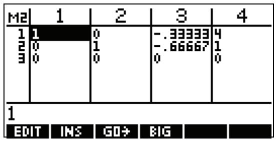


An advantage of using the RREF function is that it will also work with inconsistent matrices resulting from systems of equations which have no solution or infinite solutions.

For example, the following set of equations has an infinite number of solutions:

$$\begin{aligned} x + y - z &= 5 \\ 2x - y &= 7 \\ x - 2y + z &= 2 \end{aligned}$$

The final row of zeros in the reduced-row echelon form of the augmented matrix indicates an inconsistent system with infinite solutions.



19

Lists

You can do list operations in HOME and in programs. A list consists of comma-separated real or complex numbers, expressions, or matrices, all enclosed in braces. A list may, for example, contain a sequence of real numbers such as `{1,2,3}`. (If the Decimal Mark mode is set to `Comma`, then the separators are periods.) Lists represent a convenient way to group related objects.

There are ten list variables available, named L0 to L9. You can use them in calculations or expressions in HOME or in a program. Retrieve the list names from the VARS menu, or just type their names from the keyboard.

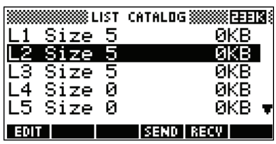
You can create, edit, delete, send, and receive named lists in the List catalog (SHIFT *LIST*). You can also create and store lists—named or unnnamed—in HOME lists

List variables are identical in behaviour to the columns C1.C0 in the Statistics aplet. You can store a statistics column to a list (or vice versa) and use any of the list functions on the statistics columns, or the statistics functions, on the list variables.

Create a list in the List Catalog

1. Open the List catalog.

   SHIFT *LIST*.

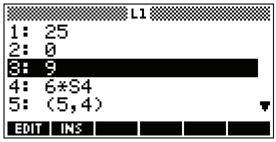


2. Highlight the list name you want to assign to the new list (L1, etc.) and press EDIT to display the List editor.

   EDIT

3. Enter the values you want in the list, pressing [ENTER] after each one.

   Values can be real or complex numbers (or an expression). If you enter a calculation, it is evaluated and the result is inserted in the list.



4. When done, press [SHIFT] *LIST* to see the List catalog, or press [HOME] to return to HOME.

List catalog keys

The list catalog keys are:

Key	Meaning
EDIT	Opens the highlighted list for editing.
SEND	Transmits the highlighted list to another HP 40gs or a PC. See “Sending and receiving aplets” on page 22-4 for further information.
RECV	Receives a list from another HP 40gs or a PC. See “Sending and receiving aplets” on page 22-4 for further information.
[DEL]	Clears the highlighted list.
[SHIFT] *CLEAR*	Clears all lists.
[SHIFT] [▼] or [▲]	Moves to the end or the beginning of the catalog.

List edit keys

When you press EDIT to create or change a list, the following keys are available to you:

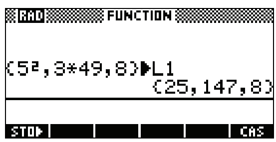
Key	Meaning
EDIT	Copies the highlighted list item into the edit line.
INS	Inserts a new value before the highlighted item.
DEL	Deletes the highlighted item from the list.
SHIFT *CLEAR*	Clears all elements from the list.
SHIFT ▼ or ▲	Moves to the end or the beginning of the list.

Create a list in HOME

1. Enter the list on the edit line. Start and end the list with braces (the shifted 8 and 9 keys) and separate each element with a comma.
2. Press ENTER to evaluate and display the list.

   Immediately after typing in the list, you can store it in a variable by pressing STO▶ *listname* ENTER. The list variable names are L0 through L9.

   This example stores the list {25,147,8} in L1. *Note: You can omit the final brace when entering a list.*



Displaying and editing lists

To display a list

- In the List catalog, highlight the list name and press EDIT.
- In HOME, enter the name of the list and press ENTER.

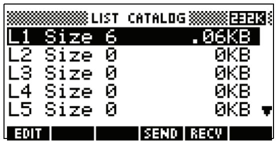
To display one element

In HOME, enter *listname*(*element#*). For example, if L2 is {3,4,5,6}, then `L2(2)` ENTER returns `4`.

To edit a list

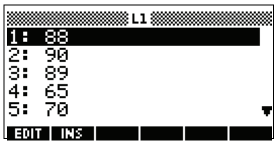
1. Open the List catalog.

   SHIFT *LIST*.



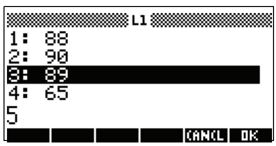
2. Press ▲ or ▼ to highlight the name of the list you want to edit (L1, etc.) and press EDIT to display the list contents.

   EDIT

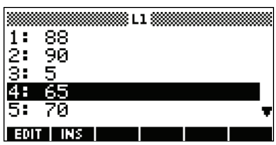


3. Press ▲ or ▼ to highlight the element you want to edit. In this example, edit the third element so that it has a value of 5.

   ▼ ▼ EDIT
   DEL DEL
   5



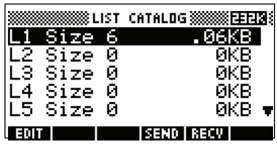
4. Press OK .



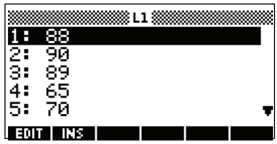
To insert an element in a list

1. Open the List catalog.

   SHIFT *LIST*.

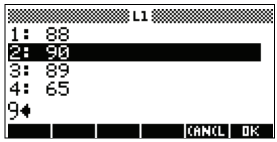


2. Press ▲ or ▼ to highlight the name of the list you want to edit (L1, etc.) and press EDIT to display the list contents.

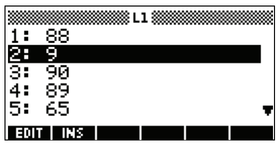


   New elements are inserted above the highlighted position. In this example, an element, with the value of 9, is inserted between the first and second elements in the list.

3. Press ▼ to the insertion position, then press INS, and press 9.



4. Press OK.



To store one element

In HOME, enter *value* STO▶ *listname*(*element*). For example, to store 148 as the second element in L1, type `148` STO▶ `L1(2)` ENTER.

Deleting lists

To delete a list

In the List catalog, highlight the list name and press [DEL]. You are prompted to confirm that you want to delete the contents of the highlighted list variable. Press [ENTER] to delete the contents.

To delete all lists

In the List catalog, press [SHIFT] *CLEAR*.

Transmitting lists

You can send lists to calculators or PCs just as you can aplets, programs, matrices, and notes.

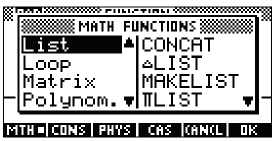
1. Connect the calculators using an appropriate cable).
2. Open the List catalogs on both calculators.
3. Highlight the list to send.
4. Press **SEND** and choose the method of sending.
5. Press **RECV** on the receiving calculator and choose the method of receiving.

For more information on sending and receiving files, see "Sending and receiving aplets" on page 22-4.

List functions

List functions are found in the MATH menu. You can use them in HOME, as well as in programs.

You can type in the name of the function, or you can copy the name of the function from the List category of the MATH menu. Press [MATH] [(] (the alpha L character key). This highlights the List category in the left column. Press [▶] to move the cursor to the right column which contain the List functions, select a function, and press **OK**.



List functions have the following syntax:

- Functions have arguments that are enclosed in parentheses and separated by commas. Example: `CONCAT(L1,L2)`. An argument can be either a list variable name (such as L1) *or* the actual list. For example, `REVERSE({1,2,3})`.

- If Decimal Mark in Modes is set to Comma, use periods to separate arguments. For example, `CONCAT(L1.L2)`.

Common operators like +, –, ×, and / can take lists as arguments. If there are two arguments and both are lists, then the lists must have the same length, since the calculation pairs the elements. If there are two arguments and one is a real number, then the calculation pairs the number with each element of the list.

Example

`5*{1,2,3}` returns `{5,10,15}`.

Besides the common operators that can take numbers, matrices, or lists as arguments, there are commands that can only operate on lists.

CONCAT

Concatenates two lists into a new list.

`CONCAT(`*list1*, *list2*`)`

Example

`CONCAT({1,2,3},{4})` returns `{1,2,3,4}`.

ΔLIST

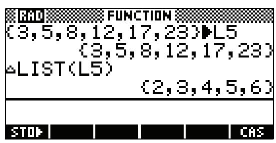
Creates a new list composed of the first differences, that is, the differences between the sequential elements in *list1*. The new list has one fewer elements than *list1*. The first differences for $\{x_1\ x_2\ ...\ x_n\}$ are $\{x_2{-}x_1\ ...\ x_n{-}x_{n-1}\}$.

`ΔLIST(`*list1*`)`

Example

In HOME, store {3,5,8,12,17,23} in L5 and find the first differences for the list.

[HOME] [SHIFT]
{3,5,8,12,17,23
[SHIFT]} STO▶ [ALPHA]
L 5 [ENTER]
[MATH] L [▶]
Select `ΔLIST` OK
[ALPHA] L5 [ENTER]



MAKELIST

Calculates a sequence of elements for a new list. Evaluates *expression* with *variable* from *begin* to *end* values, taken at *increment* steps.

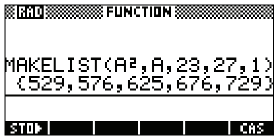
`MAKELIST(`*expression*, *variable*, *begin*, *end*, *increment*`)`

The MAKELIST function generates a series by automatically producing a list from the repeated evaluation of an expression.

Example

In HOME, generate a series of squares from 23 to 27.

MATH L ▶ *Select*
MAKELIST OK
ALPHA A X^2
, ALPHA A , 23 ,
27 , 1) ENTER



ΠLIST

Calculates the product of all elements in list.

`ΠLIST(`*list*`)`

Example

`ΠLIST({2,3,4})` returns `24`.

POS

Returns the position of an element within a list. The *element* can be a value, a variable, or an expression. If there is more than one instance of the element, the position of the first occurrence is returned. A value of 0 is returned if there is no occurrence of the specified element.

`POS(`*list, element*`)`

Example

`POS ({3, 7, 12, 19},12)` returns `3`

REVERSE

Creates a list by reversing the order of the elements in a list.

`REVERSE(`*list*`)`

SIZE

Calculates the number of elements in a list.

`SIZE(`*list*`)`

Also works with matrices.

ΣLIST

Calculates the sum of all elements in list.

`ΣLIST(`*list*`)`

Example

`ΣLIST({2,3,4})` returns `9`.

SORT

Sorts elements in ascending order.

`SORT(`*list*`)`

Finding statistical values for list elements

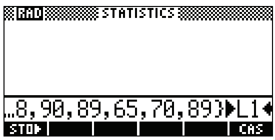
To find values such as the mean, median, maximum, and minimum values of the elements in a list, use the Statistics aplet.

Example

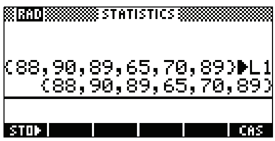
In this example, use the Statistics aplet to find the mean, median, maximum, and minimum values of the elements in the list, L1.

1. Create L1 with values 88, 90, 89, 65, 70, and 89.

   SHIFT { 88 , 90 , 89 , 65 , 70 , 89 SHIFT } STO▶ ALPHA L1

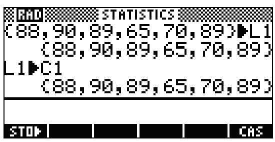


   ENTER



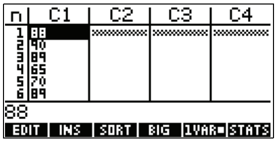
2. In HOME, store L1 into C1. You will then be able to see the list data in the Numeric view of the Statistics aplet.

   ALPHA L1
   STO▶ ALPHA C1
   ENTER



3. Start the Statistics aplet, and select 1-variable mode (press 2VAR, if necessary, to display 1VAR).

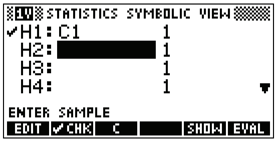
   APLET *Select* `Statistics` START



   Note: Your list values are now in column 1 (C1).

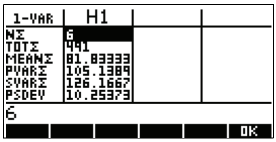
4. In the Symbolic view, define H1 (for example) as C1 (sample) and 1 (frequency).

   SYMB



5. Go to the Numeric view to display calculated statistics.

   NUM STATS



   See “One-variable” on page 10-14 for the meaning of each computed statistic.

20

Notes and sketches

Introduction

The HP 40gs has text and picture editors for entering notes and sketches.

- Each aplet has its own independent **Note view** and **Sketch view**. Notes and sketches that you create in these views are associated with the aplet. When you save the aplet, or send it to another calculator, the notes and sketches are saved or sent as well.
- The **Notepad** is a collection of notes independent of all aplets. These notes can also be sent to another calculator via the Notepad Catalog.

Aplet note view

You can attach text to an aplet in its Note view.

To write a note in Note view

1. In an aplet, press SHIFT *NOTE* for the Note view.
2. Use the note editing keys shown in the table in the following section.
3. Set Alpha lock (A...Z) for quick entry of letters. For *lowercase* Alpha lock, press SHIFT A...Z.
4. While Alpha lock is on:
   - To type a single letter of the opposite case, press SHIFT *letter*.
   - To type a single non-alpha character (such as 5 or [ ), press ALPHA first. (This turns off Alpha lock for one character.)

   Your work is automatically saved. Press any view key (NUM, SYMB, PLOT, VIEWS) or HOME to exit the Notes view.

Note edit keys

Key	Meaning
SPACE	Space key for text entry.
PAGE▼	Displays next page of a multi-page note.
A...Z	Alpha-lock for letter entry.
SHIFT A...Z	Lower-case alpha-lock for letter entry.
BKSP	Backspaces cursor and deletes character.
DEL	Deletes current character.
ENTER	Starts a new line.
SHIFT *CLEAR*	Erases the entire note.
VARS	Menu for entering variable names, and contents of variables.
MATH	Menu for entering math operations, and constants.
SHIFT *CMDS*	Menu for entering program commands.
SHIFT *CHARS*	Displays special characters. To type one, highlight it and press OK . To copy a character *without* closing the CHARS screen, press ECHO .

Aplet sketch view

You can attach pictures to an aplet in its Sketch view (SHIFT *SKETCH*). Your work is automatically saved with the aplet. Press any other view key or HOME to exit the Sketch view

Sketch keys

Key	Meaning
STO▶	Stores the specified portion of the current sketch to a graphics variable (G1 through G0).
NEWP	Adds a new, blank page to the current sketch set.
PAGE▼	Displays next sketch in the sketch set. Animates if held down.
TEXT	Opens the edit line to type a text label.
DRAW	Displays the menu-key labels for drawing.
DEL	Deletes the current sketch.
SHIFT *CLEAR*	Erases the entire sketch set.
-	Toggles menu key labels on and off. If menu key labels are hidden, - or any menu key, redisplays the menu key labels.

To draw a line

1. In an aplet, press SHIFT *SKETCH* for the Sketch view.
2. In Sketch view, press DRAW and move the cursor to where you want to start the line
3. Press LINE. This turns on line-drawing.
4. Move the cursor in any direction to the end point of the line by pressing the ▲, ▼, ▶, ◀ keys.
5. Press OK to finish the line.

To draw a box

1. In Sketch view, press DRAW and move the cursor to where you want any corner of the box to be.
2. Press BOX.
3. Move the cursor to mark the opposite corner for the box. You can adjust the size of the box by moving the cursor.
4. Press OK to finish the box.

To draw a circle

1. In Sketch view, press DRAW and move the cursor to where you want the center of the circle to be.
2. Press CIRCL. This turns on circle drawing.
3. Move the cursor the distance of the radius.
4. Press OK to draw the circle.

DRAW keys

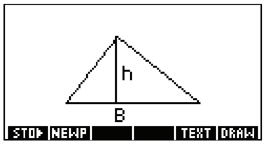
Key	Meaning
DOT+	Dot on. Turns pixels on as the cursor moves.
DOT-	Dot off. Turns pixels off as the cursor moves.
LINE	Draws a line from the cursor's starting position to the cursor's current position. Press OK when you have finished. You can draw a line at any angle.
BOX	Draws a box from the cursor's starting position to the cursor's current position. Press OK when you have finished.
CIRCL	Draws a circle with the cursor's starting position as the center. The radius is the distance between the cursor's starting and ending position. Press OK to draw the circle.

To label parts of a sketch

1. Press TEXT and type the text on the edit line. To lock the Alpha shift on, press A...Z (for uppercase) or SHIFT A...Z (for lowercase).

   To make the label a smaller character size, turn off BIG■ before pressing A...Z. (BIG is a toggle between small and large font size). The smaller character size cannot display lowercase letters.

2. Press OK .
3. Position the label where you want it by pressing the ▲, ▼, ▶, ◀ keys.
4. Press OK again to affix the label.
5. Press DRAW to continue drawing, or press HOME to exit the Sketch view.



To create a set of sketches

You can create a set of up to ten sketches. This allows for simple animation.

- After making a sketch, press NEWP to add a new, blank page. You can now make a new sketch, which becomes part of the current set of sketches.
- To view the next sketch in an existing set, press PAGE▼. Hold PAGE▼ down for animation.
- To remove the current page in the current sketch series, press DEL .

To store into a graphics variable

You can define a portion of a sketch inside a box, and then store that graphic into a graphics variable.

1. In the Sketch view, display the sketch you want to copy (store into a variable).
2. Press STO▶ .
3. Highlight the variable name you want to use and press OK .
4. Draw a box around the portion you want to copy: move the cursor to one corner, press OK , then move the cursor to the opposite corner, and press OK .

To import a graphics variable

You can copy the contents of a graphics variable into the Sketch view of an aplet.

1. Open the Sketch view of the aplet (SHIFT *SKETCH*). The graphic will be copied here.
2. Press VARS , HOME.
3. Highlight `Graphic`, then press ▶ and highlight the name of the variable (`G1`, etc.).
4. Press VALUE OK to recall the contents of the graphics variable.
5. Move the box to where you would like to copy the graphic, then press OK .

The notepad

Subject to available memory, you can store as many notes as you want in the Notepad (SHIFT *NOTEPAD*). These notes are independent of any aplet. The Notepad catalog lists the existing entries by name. *It does not include notes that were created in aplets' Note views, but these can be imported. See "To import a note" on page 20-8.*

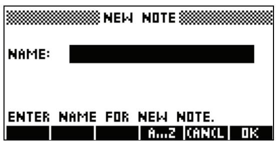
To create a note in the Notepad

1. Display the Notepad catalog.

   SHIFT *NOTEPAD*

2. Create a new note.

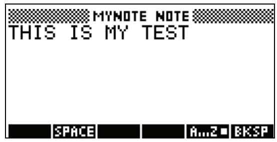
   NEW



3. Enter a name for your note.

   A...Z MYNOTE OK

4. Write your note.

   See “Note edit keys” on page 20-2 for more information on the entry and editing of notes.

5. When you are finished, press HOME or an aplet key to exit Notepad. Your work is automatically saved.

Notepad Catalog keys

Key	Meaning
EDIT	Opens the selected note for editing.
NEW	Begins a new note, and asks for a name.
SEND	Transmits the selected note to another HP 40gs or PC.
RECV	Receives a note being transmitted from another HP 40gs or PC.
DEL	Deletes the selected note.
SHIFT *CLEAR*	Deletes all notes in the catalog.

To import a note

You can import a note from the Notepad into an aplet's Note view, and vice versa. Suppose you want to copy a note named "Assignments" from the Notepad into the Function Note view:

1. In the Function aplet, display the Note view (SHIFT *NOTE*).
2. Press VARS HOME, highlight `Notepad` in the left column, then highlight the name "Assignments" in the right column.
3. Press VALUE OK to copy the contents of "Assignments" to the Function Note view.

   Note: To recall the name instead of the contents, press HOME *instead of* VALUE.

Suppose you want to copy the Note view from the current aplet into the note, Assignments, in the Notepad.

1. In the Notepad (SHIFT *NOTEPAD*), open the note, "Assignments".
2. Press VARS APLET, highlight `Note` in the left column, then press ▶ and highlight `NoteText` in the right column.
3. Press VALUE OK to recall the contents of the Note view into the note "Assignments".

21

Programming

Introduction

This chapter describes how to program using the HP 40gs. In this chapter you'll learn about:

- using the Program catalog to create and edit programs
- programming commands
- storing and retrieving variables in programs
- programming variables.

HINT More information on programming, including examples and special tools, can be found at HP's calculators web site:
http://www.hp.com/calculators

The Contents of a Program

An HP 40gs program contains a sequence of numbers, mathematical expressions, and commands that execute automatically to perform a task.

These items are separated by a colon (:). Commands that take multiple arguments have those arguments separated by a semicolon (;). For example,

`PIXON` *xposition* ; *yposition* :

Structured Programming

Inside a program you can use branching structures to control the execution flow. You can take advantage of structured programming by creating building-block programs. Each building-block program stands alone—and it can be called from other programs. *Note: If a program has a space in its name then you have to put quotes around it when you want to run it.*

Example

```
RUN GETVALUE: RUN CALCULATE: RUN
"SHOW ANSWER":
```

This program is separated into three main tasks, each an individual program. Within each program, the task can be simple—or it can be divided further into other programs that perform smaller tasks.

Program catalog

The Program catalog is where you create, edit, delete, send, receive, or run programs. This section describes how to

- open the Program catalog
- create a new program
- enter commands from the program commands menu
- enter functions from the MATH menu
- edit a program
- run and debug a program
- stop a program
- copy a program
- send and receive a program
- delete a program or its contents
- customize an aplet.

Open Program Catalog

1. Press SHIFT *PROGRM*.

   The Program Catalog displays a list of program names. The Program Catalog contains a built-in entry called `Editline`.

   `Editline` contains the last expression that you entered from the edit line in HOME, or the last data you entered in an input form. (If you press ENTER from HOME without entering any data, the HP 40gs runs the contents of `Editline`.)

   Before starting to work with programs, you should take a few minutes to become familiar with the Program catalog menu keys. You can use any of the following keys (both menu and keyboard), to perform tasks in the Program catalog.

Program catalog keys

The program catalog keys are:

Key	Meaning
EDIT	Opens the highlighted program for editing.
NEW	Prompts for a new program name, then opens an empty program.
SEND	Transmits the highlighted program to another HP 40gs or to a disk drive.
RECV	Receives the highlighted program from another HP 40gs or from a disk drive.
RUN	Runs the highlighted program.
SHIFT ▲ or ▼	Moves to the beginning or end of the Program catalog.
DEL	Deletes the highlighted program.
SHIFT *CLEAR*	Deletes all programs in the program catalog.

Creating and editing programs

Create a new program

1. Press SHIFT *PROGRM* to open the Program catalog.
2. Press NEW.

   The HP 40gs prompts you for a name.

   A program name can contain special characters, such as a space. However, if you use special characters and then run the program by typing it in HOME, you must enclose the program name in double quotes (" "). Don't use the " symbol within your program name.

3. Type your program name, then press OK .

   When you press OK , the Program Editor opens.

4. Enter your program. When done, start any other activity. Your work is saved automatically.

Enter commands

Until you become familiar with the HP 40gs commands, the easiest way to enter commands is to select them from the Commands menu from the Program editor. You can also type in commands using alpha characters.

1. From the Program editor, press SHIFT *CMDS* to open the Program Commands menu.

   SHIFT *CMDS*

2. On the left, use ▼ or ▲ to highlight a command category, then press ▶ to access the commands in the category. Select the command that you want.

   ▼ ▼ ▶ ▼

3. Press OK to paste the command into the program editor.

   OK

Edit a program

1. Press SHIFT *PROGRM* to open the Program catalog.

2. Use the arrow keys to highlight the program you want to edit, and press EDIT. The HP 40gs opens the Program Editor. The name of your program appears in the title bar of the display. You can use the following keys to edit your program.

Editing keys

The editing keys are:

Key	Meaning
STO ▶	Inserts the STO ▶ character at the editing point.
SPACE	Inserts space into text.
▲PAGE	Displays previous page of the program.
PAGE▼	Displays next page of the program.
▲ ▼	Moves up or down one line.
▶ ◀	Moves right or left one character.
A...Z	Alpha-lock for letter entry. Press SHIFT A...Z to lock lower case.
BKSP	Backspaces cursor and deletes character.
DEL	Deletes current character.
ENTER	Starts a new line.
SHIFT *CLEAR*	Erases the entire program.
VARS MATH	Displays menus for selecting variable names, contents of variables, math functions, and program constants.
SHIFT *CMDS*	Displays menus for selecting program conmmands.
SHIFT *CHARS*	Displays all characters. To type one, highlight it and press OK . To enter several characters in a row, use the ECHO menu key while in the *CHARS* menu.

Using programs

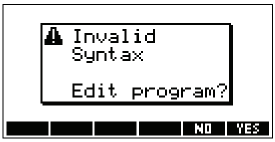
Run a program

From HOME, type `RUN` *program_name*.
or
From the Program catalog, highlight the program you want to run and press RUN

Regardless of where you start the program, all programs run in HOME. What you see will differ slightly depending on where you started the program. If you start the program from HOME, the HP 40gs displays the contents of *Ans* (Home variable containing the last result), when the program has finished. If you start the program from the Program catalog, the HP 40gs returns you to the Program catalog when the program ends.

Debug a program

If you run a program that contains errors, the program will stop and you will see an error message.



To debug the program:

1. Press YES to edit the program.

   The insert cursor appears in the program at the point where the error occurred.

2. Edit the program to fix the error.
3. Run the program.
4. Repeat the process until you correct all errors.

Stop a program

You can stop the running of a program at any time by pressing *CANCEL* (the [ON] key). *Note: You may have to press it a couple of times.*

Copy a program

You can use the following procedure if you want to make a copy of your work before editing—or if you want to use one program as a template for another.

1. Press SHIFT *PROGRM* to open the Program catalog.
2. Press NEW .
3. Type a new file name, then choose OK .

   The Program Editor opens with a new program.
4. Press VARS to open the variables menu.
5. Press 7 to quickly scroll to Program.
6. Press ▶, then highlight the program you want to copy.
7. Press VALUE , then press OK .

   The contents of the highlighted program are copied into the current program at the cursor location.

HINT If you use a programming routine often, save the routine under a different program name, then use the above method to copy it into your programs.

Transmit a program

You can send programs to, and receive programs from, other calculators just as you can send and receive aplets, matrices, lists, and notes.

After connecting the calculators with an appropriate cable, open the Program catalogs on both calculators. Highlight the program to send, then press SEND on the sending calculator and RECV on the receiving calculator.

You can also send programs to, and receive programs from, a remote storage device (aplet disk drive or computer). This takes place via a cable connection and requires an aplet disk drive or specialized software running on a PC (such as a connectivity kit).

Delete a program

To delete a program:

1. Press [SHIFT] *PROGRM* to open the Program catalog.
2. Highlight a program to delete, then press [DEL].

Delete all programs

You can delete all programs at once.

1. In the Program catalog, press [SHIFT] *CLEAR*.
2. Press YES.

Delete the contents of a program

You can clear the contents of a program without deleting the program name.

1. Press [SHIFT] *PROGRM* to open the Program catalog.
2. Highlight a program, then press EDIT.
3. Press [SHIFT] *CLEAR*, then press YES.
4. The contents of the program are deleted, but the program name remains.

Customizing an aplet

You can customize an aplet and develop a set of programs to work with the aplet.

Use the SETVIEWS command to create a custom VIEWS menu which links specially written programs to the new aplet.

A useful method for customizing an aplet is illustrated below:

1. Decide on the built-in aplet that you want to customize. For example you could customize the Function aplet or the Statistics aplet. The customized aplet inherits all the properties of the built-in aplet. Save the customized aplet with a unique name.
2. Customize the new aplet if you need to, for example by presetting axes or angle measures.
3. Develop the programs to work with your customized aplet. When you develop the aplet's programs, use the standard aplet naming convention. This allows you to keep track of the programs in the Program catalog that belong to each aplet. See "Aplet naming convention" on page 21-10.

4. Develop a program that uses the SETVIEWS command to modify the aplet's VIEWS menu. The menu options provide links to associated programs. You can specify any other programs that you want transferred with the aplet. See "SETVIEWS" on page 21-14 for information on the command.
5. Ensure that the customized aplet is selected, then run the menu configuration program to configure the aplet's VIEWS menu.
6. Test the customized aplet and debug the associated programs. (Refer to "Debug a program" on page 16-7).

Aplet naming convention

To assist users in keeping track of aplets and associated programs, use the following naming convention when setting up an aplet's programs:

- Start all program names with an abbreviation of the aplet name. We will use APL in this example.
- Name programs called by menu entries in the VIEWS menu number, after the entry, for example:
  - APL.ME1 for the program called by menu option 1
  - APL.ME2 for the program called by menu option 2
- Name the program that configures the new VIEWS menu option APL.SV where SV stands for SETVIEWS.

For example, a customized aplet called "Differentiation" might call programs called DIFF.ME1, DIFF.ME2, and DIFF.SV.

Example

This example aplet is designed to demonstrate the process of customizing an aplet. The new aplet is based on the Function aplet. *Note: This aplet is not intended to serve a serious use, merely to illustrate the process.*

Save the aplet

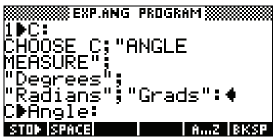
1. Open the Function aplet and save it as "EXPERIMENT". The new aplet appears in the Aplet library.

   [APLET] *Select*
   `Function` **SAVE**
   [ALPHA] EXPERIMENT
   OK

2. Create a program called EXP.ME1 with contents as shown. This program configures the plot ranges, then runs a program that allows you to set the angle format.

3. Create a program called EXP.ME2 with contents as shown. This program sets the numeric view options for the aplet, and runs the program that you can use to configure the angle mode.

4. Create a program called EXP.ANG which the previous two programs call.



5. Create a program called EXP.S which runs when you start the aplet, as shown. This program sets the angle mode to degrees, and sets up the initial function that the aplet plots.

Configuring the Setviews menu option programs

In this section we will begin by configuring the VIEWS menu by using the SETVIEWS command. We will then create the "helper" programs called by the VIEWS menu which will do the actual work.

6. Open the Program catalog and create a program named “EXP.SV”. Include the following code in the program.

   Each entry line after the command SETVIEWS is a trio that consists of a VIEWS menu text line (a space indicates none), a program name, and a number that defines the view to go to after the program has run its course. All programs listed here will transfer with an aplet when the aplet is transferred.

   ```
   SETVIEWS ″″;″″;18;
   ```

   Sets the first menu option to be “Auto scale”. This is the fourth standard Function aplet view menu option and the 18 “Auto scale”, specifies that it is to be included in the new menu. The empty quotes will ensure that the old name of “Auto scale” appears on the new menu. See “SETVIEWS” on page 21-14.

   ```
   ″My Entry1″;″EXP.ME1″;1;
   ```

   Sets the second menu option. This option runs program EXP.ME1, then returns to view 1, Plot view.

   ```
   ″My Entry2″;″EXP.ME2″;3;
   ```

   Sets the third menu option. This option runs the program EXP.ME2, then returns to view 3, the NUM view.

   ```
   ″ ″;″EXP.SV″;0;
   ```

   This line specifies that the program to set the View menu (this program) is transferred with the aplet. The space character between the first set of quotes in the trio specifies that no menu option appears for the entry. You do not need to transfer this program with the aplet, but it allows users to modify the aplet’s menu if they want to.

""; "EXP.ANG"; 0;

The program EXP.ANG is a small routine that is called by other programs that the aplet uses. This entry specifies that the program `EXP.ANG` is transferred when the aplet is transferred, but the space in the first quotes ensures that no entry appears on the menu.

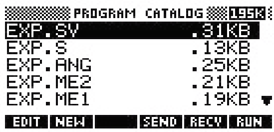
"Start"; "EXP.S"; 7:

This specifies the Start menu option. The program that is associated with this entry, `EXP.S`, runs automatically when you start the aplet. Because this menu option specifies view 7, the VIEWS menu opens when you start the aplet.

You only need to run this program once to configure your aplet's VIEWS menu. Once the aplet's VIEWS menu is configured, it remains that way until you run SETVIEWS again.

You do not need to include this program for your aplet to work, but it is useful to specify that the program is attached to the aplet, and transmitted when the aplet is transmitted.

7. Return to the program catalog. The programs that you created should appear as follows:



8. You must now RUN the program EXP.SV to execute the SETVIEWS command and create the modified VIEWS menu. Check that the name of the new aplet is highlighted in the Aplet view.
9. You can now return to the Aplet library and press START to run your new aplet.

Programming commands

This section describes the commands for programming with HP 40gs. You can enter these commands in your program by typing them or by accessing them from the Commands menu.

Aplet commands

CHECK

Checks (selects) the corresponding function in the current aplet. For example, Check 3 would check F3 if the current aplet is Function. Then a checkmark would appear next to F3 in Symbolic view, F3 would be plotted in Plot view, and evaluated in Numeric view.

`CHECK` *n*:

SELECT

Selects the named aplet and makes it the current aplet. *Note: Quotes are needed if the name contains spaces or other special characters.*

`SELECT` *apletname*:

SETVIEWS

The SETVIEWS command is used to define entries in the VIEWS menu for aplets that you customize. See "Customizing an aplet" on page 21-9 for an example of using the SETVIEWS command.

When you use the SETVIEWS command, the aplet's standard VIEWS menu is deleted and the customized menu is used in its place. You only need to apply the command to an aplet once. The VIEWS menu changes remain unless you apply the command again.

Typically, you develop a program that uses the SETVIEWS command only. The command contains a trio of arguments for each menu option to create, or program to attach. Keep the following points in mind when using this command:

- The SETVIEWS command deletes an aplet's standard Views menu options. If you want to use any of the standard options on your reconfigured VIEWS menu, you must include them in the configuration.
- When you invoke the SETVIEWS command, the changes to an aplet's VIEWS menu remain with the aplet. You need to invoke the command on the aplet again to change the VIEWS menu.
- All the programs that are called from the VIEWS menu are transferred when the aplet is transferred, for example to another calculator or to a PC.
- As part of the VIEWS menu configuration, you can specify programs that you want transferred with the aplet, but are not called as menu options. For example, these can be sub-programs that menu

options use, or the program that defines the aplet's VIEWS menu.

- You can include a "Start" option in the VIEWS menu to specify a program that you want to run automatically when the aplet starts. This program typically sets up the aplet's initial configuration. The START option on the menu is also useful for resetting the aplet.

Command syntax

The syntax for the command is as follows:

> `SETVIEWS`
> `"`*Prompt1*`";"`*ProgramName1*`";`*ViewNumber1*`;`
> `"`*Prompt2*`";"`*ProgramName2*`";`*ViewNumber2*`:`
> (You can repeat as many *Prompt/ProgramName/ViewNumber* trios of arguments as you like.)

Within each *Prompt/ProgramName/ViewNumber* trio, you separate each item with a semi-colon.

Prompt

Prompt is the text that is displayed for the corresponding entry in the Views menu. Enclose the prompt text in double quotes.

Associating programs with your aplet

If *Prompt* consists of a single space, then no entry appears in the view menu. The program specified in the *ProgramName* item is associated with the aplet and transferred whenever the aplet is transmitted. Typically, you do this if you want to transfer the Setviews program with the aplet, or you want to transfer a sub-program that other menu programs use.

Auto-run programs

If the *Prompt* item is "Start", then the *ProgramName* program runs whenever you start the aplet. This is useful for setting up a program to configure the aplet. Users can select the Start item from the VIEWS menu to reset the aplet if they change configurations.

You can also define a menu item called "Reset" which is auto-run if the user chooses the RESET button in the APLET view.

ProgramName

ProgramName is the name of the program that runs when the corresponding menu entry is selected. All programs that are identified in the aplet's SETVIEWS command are transferred when the aplet is transmitted.

ViewNumber

V*iewNumber* is the number of a view to start after the program finishes running. For example, if you want the menu option to display the Plot view when the associated program finishes, you would specify 1 as the *ViewNumber* value.

Including standard menu options

To include one of an aplet's standard VIEWS menu options in your customized menu, set up the arguments trio as follows:

- The first argument specifies the menu item name:
  - Leave the argument empty to use the standard Views menu name for the item, or
  - Enter a menu item name to replace the standard name.
- The second argument specifies the program to run:
  - Leave the argument empty to run the standard menu option.
  - Insert a program name to run the program before the standard menu option is executed.
- The third argument specifies the view and the menu number for the item. Determine the menu number from the View numbers table below.

  Note: SETVIEWS with no arguments resets the views to default of the base aplet.

View numbers

The Function aplet views are numbered as follows:

0	HOME	11	List Catalog
1	Plot	12	Matrix Catalog
2	Symbolic	13	Notepad Catalog
3	Numeric	14	Program Catalog
4	Plot-Setup	15	Plot-Detail
5	Symbolic-Setup	16	Plot-Table
6	Numeric-Setup	17	Overlay Plot
7	Views	18	Auto scale
8	Note	19	Decimal
9	Sketch view	20	Integer
10	Aplet Catalog	21	Trig

View numbers from 15 on will vary according to the parent aplet. The list shown above is for the Function aplet. Whatever the normal VIEWS menu for the parent aplet, the first entry will become number 15, the second number 16 and so on.

UNCHECK

Unchecks (unselects) the corresponding function in the current aplet. For example, Uncheck 3 would uncheck F3 if the current aplet is Function.

`UNCHECK` *n*:

Branch commands

Branch commands let a program make a decision based on the result of one or more tests. Unlike the other programming commands, the branch commands work in logical groups. Therefore, the commands are described together rather than each independently.

IF...THEN...END

Executes a sequence of commands in the *true-clause* only if the *test-clause* evaluates to true. Its syntax is:

`IF` *test-clause*

`THEN` *true-clause* `END`

Example

```
1▶A :
IF A==1
 THEN MSGBOX " A EQUALS 1" :
 END:
```

IF... THEN... ELSE... END

Executes the *true-clause* sequence of commands if the *test-clause* is true, or the *false-clause* sequence of commands if the *test-clause* is false.

`IF` *test-clause*

`THEN` *true-clause* `ELSE` *false-clause* `END`

Example

```
1▶A :
IF A==1 THEN
 MSGBOX "A EQUALS 1" :
ELSE
 MSGBOX "A IS NOT EQUAL TO 1" :
 A+1▶A :
END:
```

CASE...END

Executes a series of test-clause commands that execute the appropriate *true-clause* sequence of commands. Its syntax is:

CASE
IF *test-clause*$_1$ THEN *true-clause*$_1$ END
IF *test-clause*$_2$ THEN *true-clause*$_2$ END
.
.
.
IF *test-clause*$_n$ THEN *true-clause*$_n$ END
END:

When CASE is executed, *test-clause*$_1$ is evaluated. If the test is true, *true-clause*$_1$ is executed, and execution skips to END. If *test-clause*$_1$ if false, execution proceeds to *test-clause*$_2$. Execution with the CASE structure continues until a true-clause is executed (or until all the test-clauses evaluate to false).

IFERR... THEN... ELSE... END...

Many conditions are automatically recognized by the HP 40gs as *error conditions* and are automatically treated as errors in programs.

IFERR…THEN…ELSE…END allows a program to intercept error conditions that otherwise would cause the program to abort. Its syntax is:

```
IFERR trap-clause
THEN clause_1
ELSE clause_2
END:
```

Example

```
IFERR
 60/X ▶ Y:
THEN
 MSGBOX "Error: X is zero.":
ELSE
 MSGBOX "Value is "Y:
END:
```

RUN

Runs the named program. If your program name contains special characters, such as a space, then you must enclose the file name in double quotes (" ").

`RUN "`*program name*`":` or `RUN` *programname*`:`

STOP

Stops the current program.

```
STOP:
```

Drawing commands

The drawing commands act on the display. The scale of the display depends on the current aplet's Xmin, Xmax, Ymin, and Ymax values. *The following examples assume the HP 40gs default settings with the Function aplet as the current aplet.*

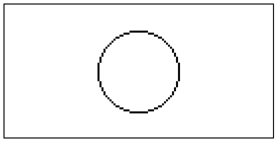
ARC

Draws a circular arc, of given radius, whose centre is at *(x,y)* The arc is drawn from *start_angle_measurement* to *end_angle_measurement*.

`ARC` *x;y;radius;start_angle_measurement;*
end_angle_measurement:

Example

```
ARC 0;0;2;0;2π:
FREEZE:
```



Draws a circle centered at (0,0) of radius 2. The FREEZE command causes the circle to remain displayed on the screen until you press a key.

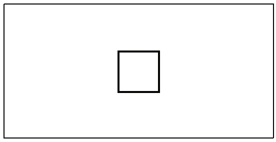
BOX

Draws a box with diagonally opposite corners (*x1,y1*) and (*x2,y2*).

BOX *x1*;*y1*;*x2*;*y2*:

Example

```
BOX -1;-1;1;1:
FREEZE:
```



Draws a box, lower corner at (–1,–1), upper corner at (1,1)

ERASE

Clears the display

```
ERASE:
```

FREEZE

Halts the program, freezing the current display. Execution resumes when any key is pressed.

LINE

Draws a line from *(x1, y1)* to (*x2, y2*).

LINE *x1;y1;x2;y2:*

PIXOFF

Turns off the pixel at the specified coordinates *(x,y)*.

PIXOFF *x;y:*

PIXON

Turns on the pixel at the specified coordinates *(x,y)*.

PIXON *x;y:*

TLINE

Toggles the pixels along the line from *(x1, y1)* to (*x2, y2*) on and off. Any pixel that was turned off, is turned on; any pixel that was turned on, is turned off. TLINE can be used to erase a line.

TLINE *x1;y1;x2;y2:*

Example

`TLINE 0;0;3;3:`
Erases previously drawn 45 degree line from (0,0) to (3,3), or draws that line if it doesn't already exist.

Graphic commands

The graphic commands use the graphics variables G0 through G9—or the Page variable from Sketch—as *graphicname* arguments. The *position* argument takes the form (x,y). Position coordinates depend on the current aplet's scale, which is specified by Xmin, Xmax, Ymin, and Ymax. The upper left corner of the target graphic (*graphic2*) is at (Xmin,Ymax).

You can capture the current display and store it in G0 by simultaneously pressing [ON] + [PLOT].

DISPLAY→

Stores the current display in *graphicname*.

`DISPLAY→` *graphicname*:

→DISPLAY

Displays graphic from *graphicname* in the display.

`→DISPLAY` *graphicname*:

→GROB

Creates a graphic from *expression*, using *font_size*, and stores the resulting graphic in *graphicname*. Font sizes are 1, 2, or 3. If the *fontsize* argument is 0, the HP 40gs creates a graphic display like that created by the `SHOW` operation.

`→GROB` *graphicname* ; *expression* ; *fontsize* :

GROBNOT

Replaces graphic in *graphicname* with bitwise-inverted graphic.

`GROBNOT` *graphicname* :

GROBOR

Using the logical OR, superimposes *graphicname2* onto *graphicname1*. The upper left corner of *graphicname2* is placed at *position*.

`GROBOR` *graphicname1* ; (*position*) ; *graphicname2* :

where position is expressed in terms of the current axes settings, not in terms of pixel postion.

GROBXOR

Using the logical XOR, superimposes *graphicname2* onto *graphicname1*. The upper left corner of *graphicname2* is placed at *position*.

`GROBXOR`
graphicname1 ; (*position*) ; *graphicname2* :

MAKEGROB

Creates graphic with given width, height, and hexadecimal data, and stores it in *graphicname*.

`MAKEGROB` *graphicname* ; *width* ; *height* ; *hexdata* :

PLOT→

Stores the Plot view display as a graphic in *graphicname*.

`PLOT→` *graphicname* :

`PLOT→` and `DISPLAY→` can be used to transfer a copy of the current PLOT view into the sketch view of the aplet for later use and editing.

Example

```
1 ▶PageNum:
PLOT→ Page:
→DISPLAY Page:
FREEZE:
```

This program stores the current PLOT view to the first page in the sketch view of the current aplet and then displays the sketch as a graphic object until any key is pressed.

→PLOT

Puts graph from *graphicname* into the Plot view display.

`→PLOT` *graphicname* :

REPLACE

Replaces portion of graphic in *graphicname1* with *graphicname2*, starting at *position*. `REPLACE` also works for lists and matrices.

`REPLACE`
graphicname1 ; (*position*) ; *graphicname2* :

SUB

Extracts a portion of the named graphic (or list or matrix), and stores it in a new variable, *name*. The portion is specified by *position* and *positions.*

`SUB` *name* ; *graphicname* ; (*position*) ; (*positions*) :

ZEROGROB

Creates a blank graphic with given *width* and *height*, and stores it in *graphicname*.

`ZEROGROB` *graphicname* ; *width* ; *height* :

Loop commands

Loop hp allow a program to execute a routine repeatedly. The HP 40gs has three loop structures. The example programs below illustrate each of these structures incrementing the variable A from 1 to 12.

DO…UNTIL …END

`Do` … `Until` … `End` is a loop command that executes the *loop-clause* repeatedly until *test-clause* returns a true (nonzero) result. Because the test is executed *after* the loop-clause, the loop-clause is always executed at least once. Its syntax is:

DO *loop-clause* UNTIL *test-clause* END

```
1 ▶ A:
DO
   A + 1 ▶ A:
   DISP 3;A:
UNTIL A == 12 END:
```

**WHILE…
REPEAT…
END**

`While` … `Repeat` … `End` is a loop command that repeatedly evaluates *test-clause* and executes *loop-clause* sequence if the test is true. Because the test-clause is executed before the loop-clause, the loop-clause is not executed if the test is initially false. Its syntax is:

WHILE *test-clause* REPEAT *loop-clause* END

```
1 ▶ A:
WHILE A < 12 REPEAT

    A+1 ▶ A:
    DISP 3;A:
END:
```

**FOR…TO…STEP
...END**

FOR *name=start-expression* TO *end-expression*
[STEP *increment*]; *loop-clause* END

```
FOR A=1 TO 12 STEP 1;

DISP 3;A:

END:
```

Note that the STEP parameter is optional. If it is omitted, a step value of 1 is assumed.

BREAK

Terminates loop.

```
BREAK:
```

Matrix commands

The matrix commands take variables M0–M9 as arguments.

ADDCOL

Add Column. Inserts *values* into a column before *column_number* in the specified matrix. You enter the *values* as a vector. The values must be separated by commas and the number of values must be the same as the number of rows in the matrix *name*.

`ADDCOL`
name `;` `[`*value*$_1$,...,*value*$_n$`]` `;` *column_number* `:`

ADDROW

Add Row. Inserts *values* into a row before *row_number* in the specified matrix. You enter the values as a vector. The values must be separated by commas and the number of values must be the same as the number of columns in the matrix *name*.

`ADDROW` *name* `;` `[`*value*$_1$,..., *value*$_n$`]` `;` *row_number* `:`

DELCOL

Delete Column. Deletes the specified column from the specified matrix.

`DELCOL` *name* `;` *column_number* `:`

DELROW

Delete Row. Deletes the specified row from the specified matrix.

`DELROW` *name* `;` *row_number* `:`

EDITMAT

Starts the Matrix Editor and displays the specified matrix. If used in programming, returns to the program when user presses OK .

`EDITMAT` *name* `:`

RANDMAT

Creates random matrix with a specified number of rows and columns and stores the result in *name* (*name* must be `M0...M9`). The entries will be integers ranging from –9 to 9.

`RANDMAT` *name* `;` *rows* `;` *columns* `:`

REDIM

Redimensions the specified matrix or vector to *size*. For a matrix, *size* is a list of two integers *{n1,n2}*. For a vector, *size* is a list containing one integer *{n}*.

`REDIM` *name* `;` *size* `:`

REPLACE

Replaces portion of a matrix or vector stored in *name* with an object starting at position *start*. *start* for a matrix is a list containing two numbers; for a vector, it is a single number. Replace also works with lists and graphics.

`REPLACE` *name* `;` *start* `;` *object* `:`

SCALE

Multiplies the specified *row_number* of the specified matrix by *value*.

`SCALE` *name* `;` *value* `;` *rownumber* `:`

SCALEADD

Multiplies the row of the matrix *name* by *value*, then adds this result to the second specified row.

`SCALEADD` *name* `;` *value* `;` *row1* `;` *row2* `:`

SUB

Extracts a *sub-object*—a portion of a list, matrix, or graphic from *object*—and stores it into *name*. *start* and *end* are each specified using a list with two numbers for a matrix, a number for vector or lists, or an ordered pair, (`X`,`Y`), for graphics.

`SUB` *name* `;` *object* `;` *start* `;` *end* `:`

SWAPCOL

Swaps Columns. Exchanges *column1* and *column2* of the specified matrix.

`SWAPCOL` *name* `;` *column1* `;` *column2* `:`

SWAPROW

Swap Rows. Exchanges *row1* and *row2* in the specified matrix.

`SWAPROW` *name* `;` *row1* `;` *row2* `:`

Print commands

These commands print to an HP infrared printer, for example the HP 82240B printer.

PRDISPLAY

Prints the contents of the display.

`PRDISPLAY:`

PRHISTORY

Prints all objects in the history.

`PRHISTORY:`

PRVAR

Prints name and contents of *variablename*.

PRVAR *variablename* :

You can also use the PRVAR command to print the contents of a program or a note.

PRVAR *programname* ; PROG:

PRVAR *notename* ; NOTE:

Prompt commands

BEEP

Beeps at the frequency and for the time you specify.

BEEP *frequency* ; *seconds* :

CHOOSE

Creates a choose box, which is a box containing a list of options from which the user chooses one. Each option is numbered, 1 through *n*. The result of the choose command is to store the number of the option chosen in a variable. The syntax is:

CHOOSE *variable_name* ; *title* ; $option_1$; $option_2$; ...$option_n$:

where *variable_name* is the name of a variable for storing a default option number, *title* is the text displayed in the title bar of the choose box, and $option_1...option_n$ are the options listed in the choose box.

By pre-storing a value into *variable_name* you can specify the default option number, as shown in the example below.

Example

```
3 ▶ A:CHOOSE A;
"COMIC STRIPS";
"DILBERT";
"CALVIN&HOBBES";
"BLONDIE":
```

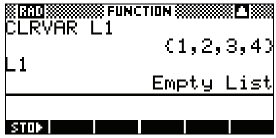
CLRVAR

Clears the specified variable. The syntax is:

CLRVAR *variable* :

Example

If you have stored {1,2,3,4} in variable L1, entering CLVAR L1 [ENTER] will clear L1.



DISP

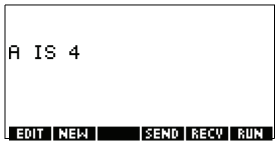
Displays *textitem* in a row of the display at the *line_number*. A text item consists of any number of expressions and quoted strings of text. The expressions are evaluated and turned into strings. Lines are numbered from the top of the screen, 1 being the top and 7 being the bottom.

`DISP` *line_number* ; *textitem* :

Example

`DISP 3;"A is" 2+2`

Result: `A is 4` (displayed on line 3)



DISPXY

Displays *object* at position (*x_pos*, *y_pos*) in size *font*. The syntax is:

`DISPXY` *x_pos* ; *y_pos*;*font*;*object* :

The value of *object* can be a text string, a variable, or a combination of both. *x_pos* `and` *y_pos* are relative to the current settings of Xmin, Xmax, Ymin and Ymax (which you set in the PLOT SETUP view). The value of *font* is either 1 (small) or 2 (large).

Example

```
DISPXY
-3.5;1.5;2;"HELLO
WORLD":
```

DISPTIME

Displays the current date and time.

`DISPTIME`

To set the date and time, simply store the correct settings in the date and time variables. Use the following formats: `M.DDYYYY` for the date and `H.MMSS` for the time.

Examples

`5.152000▶ DATE` (sets the date to May 15, 2000).

`10.1500▶ TIME` (sets the time to 10:15 am).

EDITMAT

Matrix Editor. Opens the Matrix editor for the specified matrix. Returns to the program when user presses OK

`EDITMAT` *matrixname* `:`

The `EDITMAT` command can also be used to create matrices.

1. Press [SHIFT] *CMDS* [)] [▶] [SIN] OK
2. Press [ALPHA] *M* 1, and then press [ENTER].

   The Matrix catalog opens with M1 available for editing.

`EDITMAT` *matrixname* is an alternative to opening the matrix editor with *matrixname*. It can be used in a program to enter a matrix.

FREEZE

This command prevents the display from being updated after the program runs. This allows you to view the graphics created by the program. Cancel `FREEZE` by pressing any key.

`FREEZE:`

GETKEY

Waits for a key, then stores the keycode rc.p in *name,* where r is row number, c is column number, and p is key-plane number. The key-planes numbers are: 1 for unshifted; 2 for shifted; 4 for alpha-shifted; and 5 for both alpha-shifted and shifted.

`GETKEY` *name* `:`

INPUT

Creates an input form with a title bar and one field. The field has a label and a default value. There is text help at the bottom of the form. The user enters a value and presses the OK menu key. The value that the user enters is stored in the variable *name*. The *title*, *label*, and *help* items are text strings and need to be enclosed in double quotes.

Use [SHIFT] *CHARS* to type the quote marks " ".

`INPUT` *name* `;` *title* `,` *label* `;` *help* `;` *default* `:`

Example

```
INPUT R; "Circular Area";
      "Radius";
      "Enter Number";1:
```

MSGBOX

Displays a message box containing *textitem*. A text item consists of any number of expressions and quoted strings of text. The expressions are evaluated and turned into strings of text.

For example, `"AREA IS:" 2+2` becomes `AREA IS: 4`. Use SHIFT *CHARS* to type the quote marks " ".

`MSGBOX` *textitem* :

Example

```
1 ▶ A:
MSGBOX "AREA IS: "π*A^2:
```

You can also use the NoteText variable to provide text arguments. This can be used to insert line breaks. For example, press SHIFT *NOTE* and type `AREA IS` ENTER.

The position line

```
MSGBOX NoteText " " π*A^2:
```

will display the same message box as the previous example.

PROMPT

Displays an input box with *name* as the title, and prompts for a value for *name*. *name* can be a variable such as A…Z, θ, L1…L9, C1…C9 or Z1…Z9..

`PROMPT` *name* :

WAIT

Halts program execution for the specified number of seconds.

`WAIT` *seconds* :

Stat-One and Stat-Two commands

The following commands are used for analyzing one-variable and two-variable statistical data.

Stat-One commands

DO1VSTATS

Calculates STATS using *datasetname* and stores the results in the corresponding variables: NΣ, TotΣ, MeanΣ, PVarΣ, SVarΣ, PSDev, SSDev, MinΣ, Q1, Median, Q3, and MaxΣ. *Datasetname* can be H1, H2, ..., or H5. *Datasetname* must include at least two data points.

`DO1VSTATS` *datasetname* **:**

SETFREQ

Sets *datasetname* frequency according to *column* or value. *Datasetname* can be H1, H2,..., or H5, *column* can be C0–C9 and value can be any positive integer.

`SETFREQ` *datasetname* **;** *column* **:**

or

`SETFREQ` *definition* **;** *value* **:**

SETSAMPLE

Sets *datasetname* sample according to *column.* *Datasetname* can be H1–H5, and column can be CO–C9.

`SETSAMPLE` *datasetname* **;** *column* **:**

Stat-Two commands

DO2VSTATS

Calculates STATS using *datasetname* and stores the results in corresponding variables: MeanX, ΣX, ΣX2, MeanY, ΣY, ΣY2, ΣXY, Corr, PCov, SCov, and RELERR. *Datasetname* can be SI, S2,..., or S5. *Datasetname* must include at least two pairs of data points.

`DO2VSTATS` *datasetname* **:**

SETDEPEND

Sets *datasetname* dependent *column*. *Datasetname* can be S1, S2, ..., or S5 and *column* can be C0–C9.

`SETDEPEND` *datasetname* **;** *column* **:**

SETINDEP

Sets *datasetname* independent *column*. *Datasetname* can be S1, S2,..., or S5 and *column* can be C0–C9.

`SETINDEP` *datasetname* **;** *column* **:**

Storing and retrieving variables in programs

The HP 40gs has both Home variables and Aplet variables. Home variables are used for real numbers, complex numbers, graphics, lists, and matrices. Home variables keep the same values in HOME and in aplets.

Aplet variables are those whose values depend on the current aplet. The aplet variables are used in programming to emulate the definitions and settings you make when working with aplets interactively.

You use the Variable menu (VARS) to retrieve either Home variables or aplet variables. See "The VARS menu" on page 17-4. Not all variables are available in every aplet. S1fit–S5fit, for example, are only available in the Statistics aplet. Under each variable name is a list of the aplets where the variable can be used.

Plot-view variables

Area
Function

Contains the last value found by the Area function in Plot-FCN menu.

Axes
All Aplets

Turns axes on or off.

From Plot Setup, check (or uncheck) __`AXES`.

or

In a program, type:

`1 ▶ Axes`—to turn axes on (default).
`0 ▶ Axes`—to turn axes off.

Connect
Function
Parametric
Polar
Solve
Statistics

Draws lines between successively plotted points.

From Plot Setup, check (or uncheck) __`CONNECT`.

or

In a program, type

`1 ▶ Connect`—to connect plotted points (default, except in Statistics where the default is off).
`0 ▶ Connect`—not to connect plotted points.

Coord
Function
Parametric
Polar
Sequence
Solve
Statistics

Turns the coordinate-display mode in Plot view on or off.

From Plot view, use the Menu mean key to toggle coordinate display on an off.

In a program, type

`1 ▶ Coord`—to turn coordinate display on (default).
`0 ▶ Coord`—to turn coordinate display off.

Extremum
Function

Contains the last value found by the Extremum operation in the Plot-FCN menu.

FastRes
Function
Solve

Toggles resolution between plotting in every other column (faster), or plotting in every column (more detail).

From Plot Setup, choose Faster or More Detail.

or

In a program, type

`1 ▶ FastRes`—for faster.
`0 ▶ FastRes`—for more detail (default).

Grid
All Aplets

Turns the background grid in Plot view on or off. From Plot setup, check (or uncheck) `__GRID`.

or

In a program, type

`1 ▶ Grid` to turn the grid on.
`0 ▶ Grid` to turn the grid off (default).

Hmin/Hmax
Statistics

Defines minimum and maximum values for histogram bars.

From Plot Setup for one-variable statistics, set values for `HRNG`.

or

In a program, type

n_1 ▶ `Hmin`

n_2 ▶ `Hmax`

where $n_2 > n_1$

Hwidth
Statistics

Sets the width of histogram bars.

From Plot Setup in 1VAR stats set a value for `Hwidth`

or

In a program, type

n ▶ `Hwidth`

Indep
All Aplets

Defines the value of the independent variable used in tracing mode.

In a program, type

n ▶ `Indep`

InvCross
All Aplets

Toggles between solid crosshairs or inverted crosshairs. (Inverted is useful if the background is solid).

From Plot Setup, check (or uncheck) __`InvCross`

or

In a program, type:

`1` ▶ `InvCross`—to invert the crosshairs.
`0` ▶ `InvCross` —for solid crosshairs (default).

Isect
Function

Contains the last value found by the Intersection function in the Plot-FCN menu.

Labels
All Aplets

Draws labels in Plot view showing X and Y ranges.

From Plot Setup, check (or uncheck) __`Labels`

or

In a program, type

`1` ▶`Labels`—to turn labels on.
`0` ▶`Labels`—to turn labels off (default).

Nmin / Nmax
Sequence

Defines the minimum and maximum independent variable values. Appears as the `NRNG` fields in the Plot Setup input form.

From Plot Setup, enter values for `NRNG`.

or

In a program, type

n_1 ▶`Nmin`

n_2 ▶`Nmax`

where $n_2 > n_1$

Recenter
All Aplets

Recenters at the crosshairs locations when zooming.

From Plot-Zoom-Set Factors, check (or uncheck) __ `Recenter`

or

In a program, type

`1 ▶ Recenter`— to turn recenter on (default).
`0 ▶ Recenter`—to turn recenter off.

Root
Function

Contains the last value found by the Root function in the Plot-FCN menu.

S1mark–S5mark
Statistics

Sets the mark to use for scatter plots.

From Plot Setup for two-variable statistics, `S1mark-S5mark`, then choose a mark.

or

In a program, type

`n ▶ S1mark`
where `n` is `1,2,3,...5`

SeqPlot
Sequence

Enables you to choose types of sequence plot: Stairstep or Cobweb.

From Plot Setup, select `SeqPlot`, then choose `Stairstep` or `Cobweb`.

or

In a program, type

`1 ▶ SeqPlot`—for Stairstep.

`2 ▶ SeqPlot`—for Cobweb.

Simult
Function
Parametric
Polar
Sequence

Enables you to choose between simultaneous and sequential graphing of all selected expressions.

From Plot Setup, check (or uncheck) `_SIMULT`

or
In a program, type

`1 ▶ Simult`—for simultaneous graphing (default).
`0 ▶ Simult`—for sequential graphing.

Slope
Function

Contains the last value found by the Slope function in the Plot-FCN menu.

StatPlot
Statistics

Enables you to choose types of 1-variable statistics plot between Histogram or Box-and-Whisker.

From Plot Setup, select `StatPlot`, then choose `Histogram` or `BoxWhisker`.

or

In a program, type

`1 ▶ StatPlot`—for Histogram.

`2 ▶ StatPlot`—for Box-and-Whisker.

Umin/Umax
Polar

Sets the minimum and maximum independent values. Appears as the `URNG` field in the Plot Setup input form.

From the Plot Setup input form, enter values for `URNG`.

or

In a program, type

n_1 ▶ `Umin`

n_2 ▶ `Umax`

where $n_2 > n_1$

Ustep
Polar

Sets the step size for an independent variable.

From the Plot Setup input form, enter values for `USTEP`.

or

In a program, type

n ▶ `Ustep`

where $n > 0$

Tmin / Tmax
Parametric

Sets the minimum and maximum independent variable values. Appears as the TRNG field in the Plot Setup input form.

From Plot Setup, enter values for TRNG.

or

In a program, type

n_1 ▶ Tmin

n_2 ▶ Tmax

where $n_2 > n_1$

Tracing
All Aplets

Turns the tracing mode on or off in Plot view.

In a program, type

1 ▶ Tracing—to turn Tracing mode on (default).
0 ▶ Tracing—to turn Tracing mode off.

Tstep
Parametric

Sets the step size for the independent variable.

From the Plot Setup input form, enter values for TSTEP.

or

In a program, type

n ▶ Tstep

where $n > 0$

Xcross
All Aplets

Sets the horizontal coordinate of the crosshairs. Only works with TRACE off.

In a program, type

n ▶ Xcross

Ycross
All Aplets

Sets the vertical coordinate of the crosshairs. Only works with TRACE off.

In a program, type

n ▶ Ycross

Xtick
AAll Aplets

Sets the distance between tick marks for the horizontal axis.

From the Plot Setup input form, enter a value for `Xtick`.

or

In a program, type

n ▶ `Xtick` where $n > 0$

Ytick
All Aplets

Sets the distance between tick marks for the vertical axis.

From the Plot Setup input form, enter a value for `Ytick`.

or

In a program, type

n ▶ `Ytick` where $n > 0$

Xmin / Xmax
All Aplets

Sets the minimum and maximum horizontal values of the plot screen. Appears as the `XRNG` fields (horizontal range) in the Plot Setup input form.

From Plot Setup, enter values for `XRNG`.

or

In a program, type

n_1 ▶ `Xmin`

n_2 ▶ `Xmax`

where $n_2 > n_1$

Ymin / Ymax
All Aplets

Sets the minimum and maximum vertical values of the plot screen. Appears as the `YRNG` fields (vertical range) in the Plot Setup input form.

From Plot Setup, enter the values for `YRNG`.

or

In a program, type

n_1 ▶ `Ymin`

n_2 ▶ `Ymax`

where $n_2 > n_1$

Xzoom
All Aplets

Sets the horizontal zoom factor.

From Plot-ZOOM-Set Factors, enter the value for `XZOOM`.

or

In a program, type

n ▶ `XZOOM`
where $n > 0$

The default value is 4.

Yzoom
All Aplets

Sets the vertical zoom factor.

From Plot-ZOOM-Set Factors, enter the value for `YZOOM`.

or
In a program, type

n ▶ `YZOOM`

The default value is 4.

Symbolic-view variables

Angle
All Aplets

Sets the angle mode.

From Symbolic Setup, choose `Degrees`, `Radians`, or `Grads` for angle measure.

or

In a program, type

`1` ▶ `Angle` —for Degrees.

`2` ▶ `Angle` —for Radians.

`3` ▶ `Angle`—for Grads.

F1...F9, F0
Function

Can contain any expression. Independent variable is *X*.

Example

`'SIN(`*X*`)'` ▶ `F1(`*X*`)`

You must put single quotes around an expression to keep it from being evaluated before it is stored. Use SHIFT *CHARS* to type the single quote mark.

X1, Y1...X9,Y9
X0,Y0
Parametric

Can contain any expression. Independent variable is T.

Example

`'SIN(4*T)' ▶ Y1(T):'2*SIN(6*T)' ▶ X1(T)`

R1...R9, R0
Polar

Can contain any expression. Independent variable is θ.

Example

`'2*SIN(2*θ)' ▶ R1(θ)`

U1...U9, U0
Sequence

Can contain any expression. Independent variable is N.

Example

`RECURSE (U,U(N-1)*N,1,2) ▶ U1(N)`

E1...E9, E0
Solve

Can contain any equation or expression. Independent variable is selected by highlighting it in Numeric View.

Example

`'X+Y*X-2=Y' ▶ E1`

S1fit...S5fit
Statistics

Sets the type of fit to be used by the FIT operation in drawing the regression line.

From Symbolic Setup view, specify the fit in the field for S1FIT, S2FIT, etc.
or
In a program, store one of the following constant numbers or names into a variable `S1fit`, `S2fit`, etc.

```
1 Linear
2 LogFit
3 ExpFit
4 Power
5 QuadFit
6 Cubic
7 Logist
8 ExptFit
9 TrigFit
10 User
```

Example

`Cubic ▶ S2fit`

or

`6 ▶ S2fit`

Numeric-view variables

The following aplet variables control the Numeric view. The value of the variable applies to the current aplet only.

C1...C9, C0
Statistics

`C0` through `C9`, for columns of data. Can contain lists.

Enter data in the Numeric view

or

In a program, type

`LIST ▶C`*n*

where *n* = `0, 1, 2, 3 ... 9`

Digits
All Aplets

Number of decimal places to use for Number format in the HOME view and for labeling axes in the Plot view.

From the Modes view, enter a value in the second field of `Number Format`.

or

In a program, type

n ▶ `Digits`

where $0 < n < 11$

Format
All Aplets

Defines the number display format to use for numeric format on the HOME view and for labeling axes in the Plot view.

From the Modes view, choose `Standard`, `Fixed`, `Scientific`, `Engineering`, `Fraction or Mixed Fraction` in the `Number Format` field.

or

In a program, store the constant number (or its name) into the variable `Format`.

1 Standard

2 Fixed

3 Sci

4 Eng

5 Fraction

6 MixFraction

Note: if `Fraction` or `Mixed Fraction` is chosen, the setting will be disregarded when labeling axes in the Plot view. A setting of `Scientific` will be used instead.

Example

`Scientific ▶ Format`

or

`3 ▶ Format`

NumCol
All Aplets except Statistics aplet

Sets the column to be highlighted in Numeric view.

In a program, type

n ▶ `NumCol`

where *n* can be `0, 1, 2, 3, 4, 5, 6, 7, 8, 9.`

NumFont
Function
Parametric
Polar
Sequence
Statistics

Enables you to choose the font size in Numeric view. Does not appear in the Num Setup input form. Corresponds to the BIG key in Numeric view.

In a program, type

`0 ▶ NumFont` for small (default).
`1 ▶ NumFont` for big.

NumIndep
Function
Parametric
Polar
Sequence

Specifies the list of independent values to be used by Build Your Own Table.

In a program, type

`LIST ▶ NumIndep`

NumRow
All Aplets except Statistics aplet

Sets the row to be highlighted in Numeric view.

In a program, type

n ▶ `NumRow`

where $n > 0$

NumStart
Function
Parametric
Polar
Sequence

Sets the starting value for a table in Numeric view.

From Num Setup, enter a value for `NUMSTART`.

or

In a program, type

n ▶ `NumStart`

NumStep
Function
Parametric
Polar
Sequence

Sets the step size (increment value) for an independent variable in Numeric view.

From Num Setup, enter a value for `NUMSTEP`.

or

In a program, type

n ▶ `NumStep`
where $n > 0$

NumType
Function
Parametric
Polar
Sequence

Sets the table format.

From Num Setup, choose `Automatic` or `Build Your Own`.

or

In a program, type

`0` ▶ `NumType` for Build Your Own.
`1` ▶ `NumType` for Automatic (default).

NumZoom
Function
Parametric
Polar
Sequence

Sets the zoom factor in the Numeric view.

From Num Setup, type in a value for `NUMZOOM`.

or

In a program, type

n ▶ `NumZoom`
where $n > 0$

StatMode
Statistics

Enables you to choose between 1-variable and 2-variable statistics in the Statistics aplet. Does not appear in the Plot Setup input form. Corresponds to the 1VAR and 2VAR menu keys in Numeric View.

In a program, store the constant name (or its number) into the variable StatMode. `1VAR=1`, `2VAR=2`.

Example

`1VAR ▶ StatMode`

or

`1 ▶ StatMode`

Note variables

The following aplet variable is available in Note view.

NoteText
All Aplets

Use `NoteText` to recall text previously entered in Note view.

Sketch variables

The following aplet variables are available in Sketch view.

Page
All Aplets

Sets a *page* in a sketch set. The graphics can be viewed one at a time using the ▲PAGE and PAGE▼ keys.

The Page variable refers to the currently displayed page of a sketch set.

In a program, type

graphicname ▶ `Page`

PageNum
All Aplets

Sets a number for referring to a particular page of the sketch set (in Sketch view).

In a program, type the page that is shown when SHIFT *SKETCH* is pressed.

n ▶ `PageNum`

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Extending aplets

Aplets are the application environments where you explore different classes of mathematical operations.

You can extend the capability of the HP 40gs in the following ways:

- Create new aplets, based on existing aplets, with specific configurations such as angle measure, graphical or tabular settings, and annotations.
- Transmit aplets between HP 40gs calculators via a serial or USB cable.
- Download e-lessons (teaching aplets) from Hewlett-Packard's Calculator web site.
- Program new aplets. See chapter 21, "Programming", for further details.

Creating new aplets based on existing aplets

You can create a new aplet based on an existing aplet. To create a new aplet, save an existing aplet under a new name, then modify the aplet to add the configurations and the functionality that you want.

Information that defines an aplet is saved automatically as it is entered into the calculator.

To keep as much memory available for storage as possible, delete any aplets you no longer need.

Example

This example demonstrates how to create a new aplet by saving a copy of the built-in Solve aplet. The new aplet is saved under the name "TRIANGLES" and contains the formulas commonly used in calculations involving right-angled triangles.

1. Open the Solve aplet and save it under the new name.

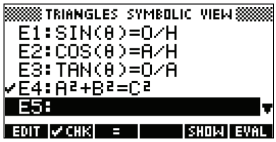
   APLET `Solve`

   SAVE | ALPHA
   T R I A N G L E S

   ENTER START

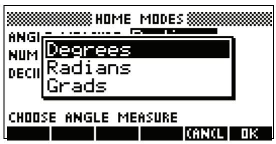
2. Enter the four formulas:

   SIN ALPHA θ
) = ALPHA O
   ÷ ALPHA H ENTER
   COS ALPHA θ) =
   ALPHA A ÷
   ALPHA H ENTER
   TAN ALPHA θ) =
   ALPHA O ÷ ALPHA A ENTER
   ALPHA A X^2 + ALPHA B X^2
   = ALPHA C X^2 ENTER



3. Decide whether you want the aplet to operate in Degrees, Radians, or Grads.

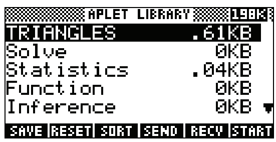
   SHIFT *MODES* CHOOS
   `Degrees`
   OK



4. View the Aplet Library. The "TRIANGLES" aplet is listed in the Aplet Library.

   APLET

   The Solve aplet can now be reset and used for other problems.



Using a customized aplet

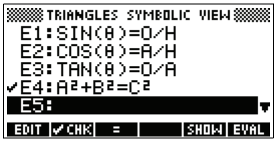
To use the “Triangles” aplet, simply select the appropriate formula, change to the Numeric view and solve for the missing variable.

Find the length of a ladder leaning against a vertical wall if it forms an angle of 35° with the horizontal and extends 5 metres up the wall.

1. Select the aplet.

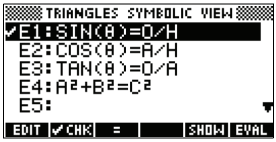
   APLET TRIANGLES

   START



2. Choose the sine formula in E1.

   ▲ ▲ ▲ ▲ ✓CHK

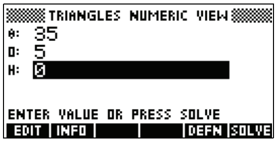


3. Change to the Numeric view and enter the known values.

   NUM

   35 ENTER

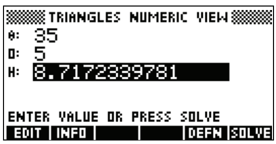
   5 ENTER



4. Solve for the missing value.

   SOLVE

   The length of the ladder is approximately 8.72 metres



Resetting an aplet

Resetting an aplet clears all data and resets all default settings.

To reset an aplet, open the Library, select the aplet and press RESET .

You can only reset an aplet that is based on a built-in aplet if the programmer who created it has provided a Reset option.

Annotating an aplet with notes

The Note view (SHIFT *NOTE*) attaches a note to the current aplet. See Chapter 20, “Notes and sketches”.

Annotating an aplet with sketches

The Sketch view (SHIFT *SKETCH*) attaches a picture to the current aplet. See chapter 20, “Notes and sketches”.

HINT Notes and sketches that you attach to an aplet become part of the aplet. When you transfer the aplet to another calculator, the associated note and sketch are transferred as well.

Downloading e-lessons from the web

In addition to the standard aplets that come with the calculator, you can download aplets from the world wide web. For example, Hewlett-Packard’s Calculators web site contains aplets that demonstrate certain mathematical concepts. Note that you need the Graphing Calculator Connectivity Kit in order to load aplets from a PC.

Hewlett-Packard’s Calculators web site can be found at:

http://www.hp.com/calculators

Sending and receiving aplets

A convenient way to distribute or share problems in class and to turn in homework is to transmit (copy) aplets directly from one HP 40gs to another. This can take place via a suitable cable. (You can use a serial cable with a 4-pin mini-USB connector, which plugs into the RS232 port on the calculator. The serial cable is available as a separate accessory.)

You can also send aplets to, and receive aplets from, a PC. This requires special software running on the PC (such as the PC Connectivity Kit). A USB cable with a 5-pin mini-USB connector is provided with the hp40gs for connecting with a PC. It plugs into the USB port on the calculator.

To transmit an aplet

1. Connect the PC or aplet disk drive to the calculator by an appropriate cable.

2. Sending calculator: Open the Library, highlight the aplet to send, and press **SEND**.
   – The **SEND TO** menu appears with the following options:

     HP39/40 (USB) = to send via the USB port

     HP39/40 (SER) = to send via the RS232 serial port

     USB DISK DRIVE = to send to a disk drive via the USB port

     SER. DISK DRIVE = to send to a disk drive via the RS232 serial port

     Note: choose a disk drive option if you are using the hp40gs connectivity kit to transfer the aplet.

     Highlight your selection and press **OK** .
   – If transmitting to a disk drive, you have the options of sending to the current (default) directory or to another directory.

3. Receiving calculator: Open the aplet library and press **RECV**.
   – The **RECEIVE FROM** menu appears with the following options:

     HP39/40 (USB) = to receive via the USB port

     HP39/40 (SER) = to receive via the RS232 serial port

     USB DISK DRIVE = to receive from a disk drive via the USB port

     SER. DISK DRIVE = to receive from a disk drive via the RS232 serial port

     Note: choose a disk drive option if you are using the hp40gs connectivity kit to transfer the aplet.

     Highlight your selection and press **OK** .

   The Transmit annunciator—»—is displayed until transmission is complete.

If you are using the PC Connectivity Kit to download aplets from a PC, you will see a list of aplets in the PC's current directory. Check as many items as you would like to receive.

Sorting items in the aplet library menu list

Once you have entered information into an aplet, you have defined a new version of an aplet. The information is automatically saved under the current aplet name, such as "Function." To create additional aplets of the same type, you must give the current aplet a new name.

The advantage of storing an aplet is to allow you to keep a copy of a working environment for later use.

The aplet library is where you go to manage your aplets. Press APLET. Highlight (using the arrow keys) the name of the aplet you want to act on.

To sort the aplet list

In the aplet library, press SORT. Select the sorting scheme and press ENTER.

- `Chronologically` produces a chronological order based on the date an aplet was last used. (The last-used aplet appears first, and so on.)
- `Alphabetically` produces an alphabetical order by aplet name.

To delete an aplet

You cannot delete a built-in aplet. You can only clear its data and reset its default settings.

To delete a customized aplet, open the aplet library, highlight the aplet to be deleted, and press DEL. To delete all custom aplets, press SHIFT *CLEAR*.

Reference information

Glossary

aplet	A small application, limited to one topic. The built-in aplet types are Function, Parametric, Polar, Sequence, Solve, Statistics, Inference, Finance, Trig Explorer, Quad Explorer, Linear Explorer and Triangle Solve. An aplet can be filled with the data and solutions for a specific problem. It is reusable (like a program, but easier to use) and it records all your settings and definitions.
command	An operation for use in programs. Commands can store results in variables, but do not display results. Arguments are separated by semi-colons, such as `DISP` *expression*; *line#*.
expression	A number, variable, or algebraic expression (numbers plus functions) that produces a value.
function	An operation, possibly with arguments, that returns a result. It does not store results in variables. The arguments must be enclosed in parentheses and separated with commas (or periods in Comma mode), such as `CROSS`(*matrix1*,*matrix2*).
HOME	The basic starting point of the calculator. Go to HOME to do calculations.
Library	For aplet management: to start, save, reset, send and receive aplets.

list	A set of values separated by commas (periods if the Decimal Mark mode is set to `Comma`) and enclosed in braces. Lists are commonly used to enter statistical data and to evaluate a function with multiple values. Created and manipulated by the List editor and catalog.
matrix	A two-dimensional array of values separated by commas (periods if the Decimal Mark mode is set to `Comma`) and enclosed in nested brackets. Created and manipulated by the Matrix catalog and editor. Vectors are also handled by the Matrix catalog and editor.
menu	A choice of options given in the display. It can appear as a list or as a set of *menu-key labels* across the bottom of the display.
menu keys	The top row of keys. Their operations depend on the current context. The labels along the bottom of the display show the current meanings.
note	Text that you write in the Notepad or in the Note view for a specific aplet.
program	A reusable set of instructions that you record using the Program editor.
sketch	A drawing that you make in the Sketch view for a specific aplet.
variable	The name of a number, list, matrix, note, or graphic that is stored in memory. Use STO▸ to store and use VARS to retrieve.
vector	A one-dimensional array of values separated by commas (periods if the Decimal Mark mode is set to `Comma`) and enclosed in single brackets. Created and manipulated by the Matrix catalog and editor.

views — The possible contexts for an aplet: Plot, Plot Setup, Numeric, Numeric Setup, Symbolic, Symbolic Setup, Sketch, Note, and special views like split screens.

Resetting the HP 40gs

If the calculator "locks up" and seems to be stuck, you must **reset** it. This is much like resetting a PC. It cancels certain operations, restores certain conditions, and clears temporary memory locations. However, it does *not* clear stored data (variables, aplet databases, programs) *unless* you use the procedure, "To erase all memory and reset defaults".

To reset using the keyboard

Press and hold the [ON] key and the third menu key simultaneously, then release them.

If the calculator does not respond to the above key sequence, then:

1. Turn the calculator over and locate the small hole in the back of the calculator.
2. Insert the end of a straightened metal paper clip into the hole as far as it will go. Hold it there for 1 second, then remove it.
3. Press [ON] If necessary, press [ON] and the first and last menu keys simultaneously. (Note: This will erase your calculator memory.)

To erase all memory and reset defaults

If the calculator does not respond to the above resetting procedures, you might need to restart it by erasing all of memory. *You will lose everything you have stored.* All factory-default settings are restored.

1. Press and hold the [ON] key, the first menu key, and the last menu key simultaneously.
2. Release all keys in the reverse order.

   Note: To cancel this process, release only the top-row keys, then press the third menu key.

If the calculator does not turn on

If the HP 40gs does not turn on follow the steps below until the calculator turns on. You may find that the calculator turns on before you have completed the procedure. If the calculator still does not turn on, please contact Customer Support for further information.

1. Press and hold the ON key for 10 seconds.
2. Press and hold the ON key and the third menu key simultaneously. Release the third menu key, then release the ON key.
3. Press and hold the ON key, the first menu key, and the sixth menu key simultaneously. Release the sixth menu key, then release the first menu key, and then release the ON key.
4. Locate the small hole in the back of the calculator. Insert the end of a straightened metal paper clip into the hole as far as it will go. Hold it there for 1 second, then remove it. Press the ON key.
5. Remove the batteries (see "Batteries" on page R-4), press and hold the ON key for 10 seconds, and then put the batteries back in. Press the ON key.

Operating details

Operating temperature: 0° to 45°C (32° to 113°F).

Storage temperature: –20° to 65°C (– 4° to 149°F).

Operating and storage humidity: 90% relative humidity at 40°C (104°F) maximum. *Avoid getting the calculator wet.*

Battery operates at 6.0V dc, 80mA maximum.

Batteries

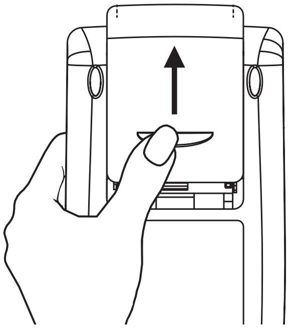
The calculator uses 4 AAA(LR03) batteries as main power and a CR2032 lithium battery for memory backup.

Before using the calculator, please install the batteries according to the following procedure.

To install the main batteries

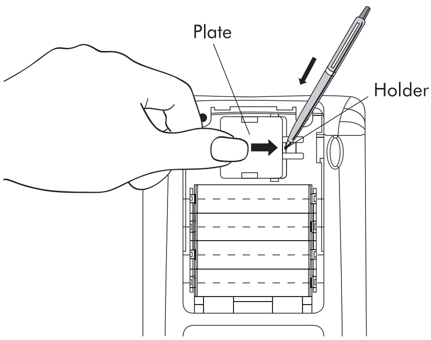
a. Slide up the battery compartment cover as illustrated.

b. Insert 4 new AAA (LR03) batteries into the main compartment. Make sure each battery is inserted in the indicated direction.



To install the backup battery

a. Press down the holder. Push the plate to the shown direction and lift it.



b. Insert a new CR2032 lithium battery. Make sure its positive (+) side is facing up.

c. Replace the plate and push it to the original place.

After installing the batteries, press ON to turn the power on.

Warning: It is recommended that you replace this battery every 5 years. When the low battery icon is displayed, you need to replace the batteries as soon as possible. However, avoid removing the backup battery and main batteries at the same time to avoid data lost.

Variables

Home variables

The home variables are:

Category	Available name
Complex	`Z1...Z9, Z0`
Graphic	`G1...G9, G0`

Library	`Function`
	`Parametric`
	`Polar`
	`Sequence`
	`Solve`
	`Statistics`
	User-named

List	`L1...L9, L0`
Matrix	`M1...M9, M0`

Modes	`Ans`
	`Date`
	`HAngle`
	`HDigits`
	`HFormat`
	`Ierr`
	`Time`

Notepad	*User-named*
Program	`Editline` *User-named*
Real	`A...Z`, θ

Function aplet variables

The function aplet variables are:

Category	Available name	

Plot	`Axes`
	`Connect`
	`Coord`
	`FastRes`
	`Grid`
	`Indep`
	`InvCross`
	`Labels`
	`Recenter`
	`Simult`
	`Tracing`
		`Xcross`
		`Ycross`
		`Xtick`
		`Ytick`
		`Xmin`
		`Xmax`
		`Ymin`
		`Ymax`
		`Xzoom`
		`Yxoom`

Plot-FCN	`Area`
	`Extremum`
	`Isect`
		`Root`
		`Slope`

Symbolic	`Angle`
	`F1`
	`F2`
	`F3`
	`F4`
	`F5`
		`F6`
		`F7`
		`F8`
		`F9`
		`F0`

Numeric	`Digits`
	`Format`
	`NumCol`
	`NumFont`
	`NumIndep`
		`NumRow`
		`NumStart`
		`NumStep`
		`NumType`
		`NumZoom`

Note	`NoteText`	
Sketch	`Page`	`PageNum`

Parametric aplet variables

The parametric aplet variables are:

Category	Available name	
Plot	Axes Connect Coord Grid Indep InvCross Labels Recenter Simult Tmin Tmax	Tracing Tstep Xcross Ycross Xtick Ytick Xmin Xmax Ymin Ymax Xzoom Yzoom
Symbolic	Angle X1 Y1 X2 Y2 X3 Y3 X4 Y4 X5	Y5 X6 Y6 X7 Y7 X8 Y8 X9 Y9 X0 Y0
Numeric	Digits Format NumCol NumFont NumIndep	NumRow NumStart NumStep NumType NumZoom
Note	NoteText	
Sketch	Page	PageNum

Polar aplet variables

The polar aplet variables are:

Category	Available names	
Plot	Axes	
	Connect	Xcross
	Coord	Ycross
	Grid	Xtick
	Indep	Ytick
	InvCross	Xmin
	Labels	Xmax
	Recenter	Ymin
	Simult	Ymax
	Umin	Xzoom
	Umax	Yxoom
	θstep	
	Tracing	
Symbolic	Angle	R6
	R1	R7
	R2	R8
	R3	R9
	R4	R0
	R5	
Numeric	Digits	NumRow
	Format	NumStart
	NumCol	NumStep
	NumFont	NumType
	NumIndep	NumZoom
Note	NoteText	
Sketch	Page	PageNum

Sequence aplet variables

The sequence aplet variables are:

Category	Available name	
Plot	Axes	Tracing
	Coord	Xcross
	Grid	Ycross
	Indep	Xtick
	InvCross	Ytick
	Labels	Xmin
	Nmin	Xmax
	Nmax	Ymin
	Recenter	Ymax
	SeqPlot	Xzoom
	Simult	Yzoom
Symbolic	Angle	U6
	U1	U7
	U2	U8
	U3	U9
	U4	U0
	U5	
Numeric	Digits	NumRow
	Format	NumStart
	NumCol	NumStep
	NumFont	NumType
	NumIndep	NumZoom
Note	NoteText	
Sketch	Page	PageNum

Solve aplet variables

The solve aplet variables are:

Category	Available name	
Plot	Axes	Xcross
	Connect	Ycross
	Coord	Xtick
	FastRes	Ytick
	Grid	Xmin
	Indep	Xmax
	InvCross	Ymin
	Labels	Ymax
	Recenter	Xzoom
	Tracing	Yxoom
Symbolic	Angle	E6
	E1	E7
	E2	E8
	E3	E9
	E4	E0
	E5	
Numeric	Digits	NumCol
	Format	NumRow
Note	NoteText	
Sketch	Page	PageNum

Statistics aplet variables

The statistics aplet variables are:

Category	Available name	
Plot	Axes Connect Coord Grid Hmin Hmax Hwidth Indep InvCross Labels Recenter S1mark S2mark S3mark	S4mark S5mark StatPlot Tracing Xcross Ycross Xtick Ytick Xmin Xmax Ymin Ymax Xzoom Yxoom
Symbolic	Angle S1fit S2fit	S3fit S4fit S5fit
Numeric	C0,...C9 Digits Format NumCol	NumFont NumRow StatMode
Stat-One	MaxΣ MeanΣ Median MinΣ NΣ Q1	Q3 PSDev SSDev PVarΣ SVarΣ TotΣ
Stat-Two	Corr Cov Fit MeanX MeanY RelErr	ΣX ΣX2 ΣXY ΣY ΣY2
Note	NoteText	
Sketch	Page	PageNum

MATH menu categories

Math functions

The math functions are:

Category	Available name	
Calculus	∂ ∫ TAYLOR	
Complex	ARG CONJ	IM RE
Constant	e i	MAXREAL MINREAL π
Hyperb.	ACOSH ASINH ATANH COSH SINH	TANH ALOG EXP EXPM1 LNP1
List	CONCAT ΔLIST MAKELIST πLIST POS	REVERSE SIZE ΣLIST SORT
Loop	ITERATE RECURSE Σ	

<table>
<tr><th>Category</th><th colspan="2">Available name (Continued)</th></tr>
<tr><td>Matrix</td><td>COLNORM</td><td>QR</td></tr>
<tr><td></td><td>COND</td><td>RANK</td></tr>
<tr><td></td><td>CROSS</td><td>ROWNORM</td></tr>
<tr><td></td><td>DET</td><td>RREF</td></tr>
<tr><td></td><td>DOT</td><td>SCHUR</td></tr>
<tr><td></td><td>EIGENVAL</td><td>SIZE</td></tr>
<tr><td></td><td>EIGENVV</td><td>SPECNORM</td></tr>
<tr><td></td><td>IDENMAT</td><td>SPECRAD</td></tr>
<tr><td></td><td>INVERSE</td><td>SVD</td></tr>
<tr><td></td><td>LQ</td><td>SVL</td></tr>
<tr><td></td><td>LSQ</td><td>TRACE</td></tr>
<tr><td></td><td>LU</td><td>TRN</td></tr>
<tr><td></td><td>MAKEMAT</td><td></td></tr>
<tr><td>Polynom.</td><td>POLYCOEF</td><td>POLYFORM</td></tr>
<tr><td></td><td>POLYEVAL</td><td>POLYROOT</td></tr>
<tr><td>Prob.</td><td>COMB</td><td>UTPC</td></tr>
<tr><td></td><td>!</td><td>UTPF</td></tr>
<tr><td></td><td>PERM</td><td>UTPN</td></tr>
<tr><td></td><td>RANDOM</td><td>UTPT</td></tr>
<tr><td>Real</td><td>CEILING</td><td>MIN</td></tr>
<tr><td></td><td>DEG→RAD</td><td>MOD</td></tr>
<tr><td></td><td>FLOOR</td><td>%</td></tr>
<tr><td></td><td>FNROOT</td><td>%CHANGE</td></tr>
<tr><td></td><td>FRAC</td><td>%TOTAL</td></tr>
<tr><td></td><td>HMS→</td><td>RAD→DEG</td></tr>
<tr><td></td><td>→HMS</td><td>ROUND</td></tr>
<tr><td></td><td>INT</td><td>SIGN</td></tr>
<tr><td></td><td>MANT</td><td>TRUNCATE</td></tr>
<tr><td></td><td>MAX</td><td>XPON</td></tr>
<tr><td>Stat-Two</td><td>PREDX</td><td></td></tr>
<tr><td></td><td>PREDY</td><td></td></tr>
<tr><td>Symbolic</td><td>=</td><td>QUAD</td></tr>
<tr><td></td><td>ISOLATE</td><td>QUOTE</td></tr>
<tr><td></td><td>LINEAR?</td><td>|</td></tr>
</table>

Category	Available name (Continued)	
Tests	< ≤ == ≠ > ≥	AND IFTE NOT OR XOR
Trig	ACOT ACSC ASEC	COT CSC SEC

Program constants

The program constants are:

Category	Available name	
Angle	Degrees Grads Radians	
Format	Standard Fixed	Sci Eng Fraction
SeqPlot	Cobweb Stairstep	
S1...5fit	Linear LogFit ExpFit Power Trigonometric	QuadFit Cubic Logist User Exponent
StatMode	Stat1Var Stat2Var	
StatPlot	Hist BoxW	

Physical Constants

The physical constants are:

Category	Available Name
Chemist	• `Avogadro` (Avagadro's Number, NA) • `Boltz.` (Boltmann, k) • `mol. vo...` (molar volume, Vm) • `univ gas` (universal gas, R) • `std temp` (standard temperature, St dT) • `std pres` (standard pressure, St dP)
Phyics	• `StefBolt` (Stefan-Boltzmann, σ) • `light s...` (speed of light, c) • `permitti` (permittivity, ε0) • `permeab` (permeability, μ0) • `acce gr...` (acceleration of gravity, g) • `gravita...` (gravitation, G)
Quantum	• `Plank's` (Plank's constant, h) • `Dirac's` (Dirac's, hbar) • `e charge` (electronic charge, q) • `e mass` (electron mass, me) • `q/me ra...` (q/me ratio, qme) • `proton m` (proton mass, mp) • `mp/me r...` (mp/me ratio, mpme) • `fine str` (fine structure, α) • `mag flux` (magnetic flux, ϕ) • `Faraday` (Faraday, F) • `Rydberg` (Rydberg, R∞) • `Bohr rad` (Bohr radius, a0) • `Bohr mag` (Bohr magneton, μB) • `nuc. mag` (nuclear magneton, μN) • `photon...` (photon wavelength, λ) • `photon...` (photon frequency, f0) • `Compt w...` (Compton wavelength, λc)

CAS functions

CAS functions are:

Category	Function	
Algebra	COLLECT DEF EXPAND FACTOR PARTFRAC QUOTE	STORE | SUBST TEXPAND UNASSIGN
Complex	i ABS ARG CONJ DROITE	IM – RE SIGN
Constant	e i	∞ π
Diff & Int	DERIV DERVX DIVPC FOURIER IBP INTVX lim	PREVAL RISCH SERIES TABVAR TAYLOR0 TRUNC
Hyperb.	ACOSH ASINH ATANH	COSH SINH TANH
Integer	DIVIS EULER FACTOR GCD IDIV2 IEGCD IQUOT	IREMAINDER ISPRIME? LCM MOD NEXTPRIME PREVPRIME
Modular	ADDTMOD DIVMOD EXPANDMOD FACTORMOD GCDMOD	INVMOD MODSTO MULTMOD POWMOD SUBTMOD

Category	Function (Continued)	
Polynom.	EGCD FACTOR GCD HERMITE LCM LEGENDRE	PARTFRAC PROPFRAC PTAYL QUOT REMAINDER TCHEBYCHEFF
Real	CEILING FLOOR FRAC	INT MAX MIN
Rewrite	DISTRIB EPSX0 EXPLN EXP2POW FDISTRIB LIN LNCOLLECT	POWEXPAND SINCOS SIMPLIFY XNUM XQ
Solve	DESOLVE ISOLATE LDEC	LINSOLVE SOLVE SOLVEVX
Tests	ASSUME UNASSUME > ≥ < ≤	== ≠ AND OR NOT IFTE
Trig	ACOS2S ASIN2C ASIN2T ATAN2S HALFTAN SINCOS TAN2CS2 TAN2SC	TAN2SC2 TCOLLECT TEXPAMD TLIN TRIG TRIGCOS TRIGSIN TRIGTAN

Program commands

The program commands are:

Category	Command	
Aplet	CHECK SELECT SETVIEWS UNCHECK	
Branch	IF THEN ELSE END	CASE IFERR RUN STOP
Drawing	ARC BOX ERASE FREEZE	LINE PIXOFF PIXON TLINE
Graphic	DISPLAY→ →DISPLAY →GROB GROBNOT GROBOR GROBXOR	MAKEGROB PLOT→ →PLOT REPLACE SUB ZEROGROB
Loop	FOR = TO STEP END DO	UNTIL END WHILE REPEAT END BREAK
Matrix	ADDCOL ADDROW DELCOL DELROW EDITMAT RANDMAT	REDIM REPLACE SCALE SCALEADD SUB SWAPCOL SWAPROW
Print	PRDISPLAY PRHISTORY PRVAR	
Prompt	BEEP CHOOSE CLRVAR DISP DISPXY DISPTIME EDITMAT	FREEZE GETKEY INPUT MSGBOX PROMPT WAIT
Stat-One	DO1VSTATS RANDSEED	SETFREQ SETSAMPLE

Category	Command (Continued)

Stat-Two	`DO2VSTATS`
	`SETDEPEND`
	`SETINDEP`

Status messages

Message	Meaning
Bad Argument Type	Incorrect input for this operation.
Bad Argument Value	The value is out of range for this operation.
Infinite Result	Math exception, such as 1/0.
Insufficient Memory	You must recover some memory to continue operation. Delete one or more matrices, lists, notes, or programs (using catalogs), or custom (not built-in) aplets (using SHIFT *MEMORY*).
Insufficient Statistics Data	Not enough data points for the calculation. For two-variable statistics there must be two columns of data, and each column must have at least four numbers.
Invalid Dimension	Array argument had wrong dimensions.
Invalid Statistics Data	Need two columns with equal numbers of data values.

Message	Meaning (Continued)
Invalid Syntax	The function or command you entered does not include the proper arguments or order of arguments. The delimiters (parentheses, commas, periods, and semi-colons) must also be correct. Look up the function name in the index to find its proper syntax.
Name Conflict	The | (where) function attempted to assign a value to the variable of integration or summation index.
No Equations Checked	You must enter and check an equation (Symbolic view) before evaluating this function.
(OFF SCREEN)	Function value, root, extremum, or intersection is not visible in the current screen.
Receive Error	Problem with data reception from another calculator. Re-send the data.
Too Few Arguments	The command requires more arguments than you supplied.
Undefined Name	The global variable named does not exist.
Undefined Result	The calculation has a mathematically undefined result (such as 0/0).
Out of Memory	You must recover a lot of memory to continue operation. Delete one or more matrices, lists, notes, or programs (using catalogs), or custom (not built-in) aplets (using SHIFT *MEMORY*).

Limited Warranty

HP 40gs Graphing Calculator; Warranty period: 12 months

1. HP warrants to you, the end-user customer, that HP hardware, accessories and supplies will be free from defects in materials and workmanship after the date of purchase, for the period specified above. If HP receives notice of such defects during the warranty period, HP will, at its option, either repair or replace products which prove to be defective. Replacement products may be either new or like-new.
2. HP warrants to you that HP software will not fail to execute its programming instructions after the date of purchase, for the period specified above, due to defects in material and workmanship when properly installed and used. If HP receives notice of such defects during the warranty period, HP will replace software media which does not execute its programming instructions due to such defects.
3. HP does not warrant that the operation of HP products will be uninterrupted or error free. If HP is unable, within a reasonable time, to repair or replace any product to a condition as warranted, you will be entitled to a refund of the purchase price upon prompt return of the product with proof of purchase.
4. HP products may contain remanufactured parts equivalent to new in performance or may have been subject to incidental use.
5. Warranty does not apply to defects resulting from (a) improper or inadequate maintenance or calibration, (b) software, interfacing, parts or supplies not supplied by HP, (c) unauthorized modification or misuse, (d) operation outside of the published environmental specifications for the product, or (e) improper site preparation or maintenance.

6. HP MAKES NO OTHER EXPRESS WARRANTY OR CONDITION WHETHER WRITTEN OR ORAL. TO THE EXTENT ALLOWED BY LOCAL LAW, ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY, SATISFACTORY QUALITY, OR FITNESS FOR A PARTICULAR PURPOSE IS LIMITED TO THE DURATION OF THE EXPRESS WARRANTY SET FORTH ABOVE. Some countries, states or provinces do not allow limitations on the duration of an implied warranty, so the above limitation or exclusion might not apply to you. This warranty gives you specific legal rights and you might also have other rights that vary from country to country, state to state, or province to province.
7. TO THE EXTENT ALLOWED BY LOCAL LAW, THE REMEDIES IN THIS WARRANTY STATEMENT ARE YOUR SOLE AND EXCLUSIVE REMEDIES. EXCEPT AS INDICATED ABOVE, IN NO EVENT WILL HP OR ITS SUPPLIERS BE LIABLE FOR LOSS OF DATA OR FOR DIRECT, SPECIAL, INCIDENTAL, CONSEQUENTIAL (INCLUDING LOST PROFIT OR DATA), OR OTHER DAMAGE, WHETHER BASED IN CONTRACT, TORT, OR OTHERWISE. Some countries, States or provinces do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.
8. The only warranties for HP products and services are set forth in the express warranty statements accompanying such products and services . HP shall not be liable for technical or editorial errors or omissions contained herein.

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Service

Europe

Country :	Telephone numbers
Austria	+43-1-3602771203
Belgium	+32-2-7126219
Denmark	+45-8-2332844
Eastern Europe countries	+420-5-41422523
Finland	+35-89640009
France	+33-1-49939006
Germany	+49-69-95307103
Greece	+420-5-41422523
Holland	+31-2-06545301
Italy	+39-02-75419782
Norway	+47-63849309
Portugal	+351-229570200
Spain	+34-915-642095
Sweden	+46-851992065
Switzerland	+41-1-4395358 (German) +41-22-8278780 (French) +39-02-75419782 (Italian)
Turkey	+420-5-41422523
UK	+44-207-4580161
Czech Republic	+420-5-41422523
South Africa	+27-11-2376200
Luxembourg	+32-2-7126219
Other European countries	+420-5-41422523

Asia Pacific

Country :	Telephone numbers
Australia	+61-3-9841-5211
Singapore	+61-3-9841-5211

L.America

Country:	Telephone numbers
Argentina	0-810-555-5520
Brazil	Sao Paulo 3747-7799; ROTC 0-800-157751
Mexico	Mx City 5258-9922; ROTC 01-800-472-6684
Venezuela	0800-4746-8368
Chile	800-360999
Columbia	9-800-114726
Peru	0-800-10111
Central America & Caribbean	1-800-711-2884
Guatemala	1-800-999-5105
Puerto Rico	1-877-232-0589
Costa Rica	0-800-011-0524

N.America

Country :	Telephone numbers
U.S.	1800-HP INVENT
Canada	(905) 206-4663 or 800- HP INVENT

ROTC = Rest of the country

Please logon to http://www.hp.com for the latest service and support information.h

Regulatory Notices

Federal Communications Commission Notice

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio or television technician for help.

Modifications

The FCC requires the user to be notified that any changes or modifications made to this device that are not expressly approved by Hewlett-Packard Company may void the user's authority to operate the equipment.

Cables

Connections to this device must be made with shielded cables with metallic RFI/EMI connector hoods to maintain compliance with FCC rules and regulations.

Declaration of Conformity for Products Marked with FCC Logo, United States Only

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

For questions regarding your product, contact:

Hewlett-Packard Company
P. O. Box 692000, Mail Stop 530113
Houston, Texas 77269-2000
Or, call
1-800-474-6836
For questions regarding this FCC declaration, contact:
Hewlett-Packard Company
P. O. Box 692000, Mail Stop 510101
Houston, Texas 77269-2000
Or, call
1-281-514-3333
To identify this product, refer to the part, series, or model number found on the product.

Canadian Notice

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Avis Canadien

Cet appareil numérique de la classe B respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

European Union Regulatory Notice

This product complies with the following EU Directives:

- Low Voltage Directive 73/23/EEC
- EMC Directive 89/336/EEC

Compliance with these directives implies conformity to applicable harmonized European standards (European Norms) which are listed on the EU Declaration of Conformity issued by Hewlett-Packard for this product or product family.

This compliance is indicated by the following conformity marking placed on the product:

This marking is valid for non-Telecom products and EU harmonized Telecom products (e.g. Bluetooth).

XXXX*

This marking is valid for EU non-harmonized Telecom products .
*Notified body number (used only if applicable - refer to the product label)

Japanese Notice

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　取り扱い説明書に従って正しい取り扱いをしてください。

Korean Notice

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주거지역에서는 물론 모든지역에서 사용할 수 있습니다.

Disposal of Waste Equipment by Users in Private Household in the European Union

This symbol on the product or on its packaging indicates that this product must not be disposed of with your other household waste. Instead, it is your responsibility to dispose of your waste equipment by handing it over to a designated collection point for the recycling of waste electrical and electronic equipment. The separate collection and recycling of your waste equipment at the time of disposal will help to conserve natural resources and ensure that it is recycled in a manner that protects human health and the environment. For more information about where you can drop off your waste equipment for recycling, please contact your local city office, your household waste disposal service or the shop where you purchased the product.

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