HP Prime Graphing Calculator

User Guide

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Preface

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 operations.

- A key that initiates an unshifted function is represented by an image of that key:

  SIN, EEX, Settings, etc.

- A key combination that initiates a shifted unction (or inserts a character) is represented by the appropriate shift key (Shift or ALPHA) followed by the key for that function or character:

  Shift LN initiates the natural exponential function and ALPHA 3 inserts the pound character (#)

  The name of the shifted function may also be given in parentheses after the key combination:

  Shift Esc (Clear), Shift Symb (Setup)

- A key pressed to insert a digit is represented by that digit:

  5, 7, 8, etc.

- All fixed on-screen text—such as screen and field names—appear in bold:

  CAS Settings, **XSTEP**, **Decimal Mark**, etc.

- A menu item selected by touching the screen is represented by an image of that item:

  Sto ▸, OK, Cancel.

  Note that you must use your finger to select a menu item. Using a stylus or something similar will not select whatever is touched.

- Items you can select from a list, and characters on the entry line, are set in a non-proportional font, as follows:

  `Function`, `Polar`, `Parametric`, `Ans`, etc.

- Cursor keys are represented by ▲, ▼, ▶, and ◀. You use these keys to move from field to field on a screen, or from one option to another in a list of options.

- Error messages are enclosed in quotation marks:

  “Syntax Error”

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1

Getting started

The HP Prime Graphing Calculator is an easy-to-use yet powerful graphing calculator designed for secondary mathematics education and beyond. It offers hundreds of functions and commands, and includes a computer algebra system (CAS) for symbolic calculations.

In addition to an extensive library of functions and commands, the calculator comes with a set of HP apps. An HP app is a special application designed to help you explore a particular branch of mathematics or to solve a problem of a particular type. For example, there is a HP app that will help you explore geometry and another to help you explore parametric equations. There are also apps to help you solve systems of linear equations and to solve time-value-of-money problems.

The HP Prime also has its own programming language you can use to explore and solve mathematical problems.

Functions, commands, apps and programming are covered in detail later in this guide. In this chapter, the general features of the calculator are explained, along with common interactions and basic mathematical operations.

Before starting

Charge the battery fully before using the calculator for the first time. To charge the battery, either:

- Connect the calculator to a computer using the USB cable that came in the package with your HP Prime. (The PC needs to be on for charging to occur.)
- Connect the calculator to a wall outlet using the HP-provided wall adapter.

When the calculator is on, a battery symbol appears in the title bar of the screen. Its appearance will indicate how much power the battery has. A flat battery will take approximately 4 hours to become fully charged.

⚠ Battery Warning

- To reduce the risk of fire or burns, do not disassemble, crush or puncture the battery; do not short the external contacts; and do not dispose of the battery in fire or water.
- To reduce potential safety risks, only use the battery provided with the calculator, a replacement battery provided by HP, or a compatible battery recommended by HP.
- Keep the battery away from children.
- If you encounter problems when charging the calculator, stop charging and contact HP immediately.

⚠ Adapter Warning

- To reduce the risk of electric shock or damage to equipment, only plug the AC adapter into an AC outlet that is easily accessible at all times.
- To reduce potential safety risks, only use the AC adapter provided with the calculator, a replacement AC adapter provided by HP, or an AC adapter purchased as an accessory from HP.

On/off, cancel operations

To turn on

Press [On Off] to turn on the calculator.

To cancel

When the calculator is on, pressing the [Esc Clear] key cancels the current operation. For example, it will clear whatever you have entered on the entry line. It will also close a menu and a screen.

To turn off

Press [Shift] [On Off](Off) turn the calculator off.

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

The Home View

Home view is the starting point for many calculations. Most mathematical functions are available in the Home view. Some additional functions are available in the computer algebra system (CAS). A history of your previous calculations is retained and you can re-use a previous calculation or its result.

To display Home view, press ⌂ Settings.

The CAS View

CAS view enables you to perform symbolic calculations. It is largely identical to Home view—it even has its own history of past calculations—but the CAS view offers some additional functions.

To display CAS view, press CAS Settings.

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 ensure that you do not misplace 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

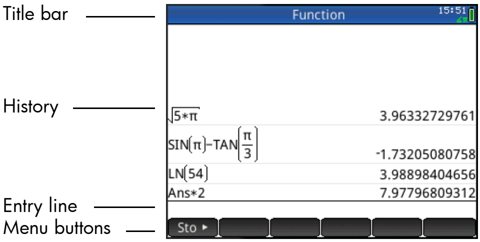
To adjust the brightness

To adjust the brightness of the display, press and hold On Off, then press the + Ans ; or − Base : key to increase or decrease the brightness. The brightness will change with each press of the + Ans ; or − Base : key.

To clear the display

- Press Esc Clear or On Off to clear the entry line.
- Press Shift Esc Clear (Clear) to clear the entry line and the history.

Sections of the display



```
√5*π                          3.96332729761
SIN(π)-TAN(π/3)              -1.73205080758
LN(54)                        3.98898404656
Ans*2                         7.97796809312
```

Home view has four sections (shown above). The **title bar** shows either the screen name or the name of the app you are currently using—`Function` in the example above. It also shows the time, a battery power indicator, and a number of symbols that indicate various calculator settings. These are explained below. The **history** displays a record of your past calculations. The **entry line** displays the object you are currently entering or modifying. The **menu buttons** are options that are relevant to the current display. These options are selected by tapping the corresponding menu button. You close a menu, without making a selection from it, by pressing Esc Clear.

Annunciators. Annunciators are symbols or characters that appear in the title bar. They indicate current settings, and also provide time and battery power information.

Annunciator	Meaning
∡° [Lime green]	The angle mode setting is currently degrees.
∡π [Lime green]	The angle mode setting is currently radians.
⬆S [Cyan]	The Shift key is active. The function shown in blue on a key will be activated when a key is pressed. Press Shift to cancel shift mode.

Annunciator	Meaning (Continued)
CAS [White]	You are working in CAS view, not Home view.
A...Z [orange]	**In Home view** The Alpha key is active. The character shown in orange on a key will be entered in *uppercase* when a key is pressed. See "Adding text" on page 23 for more information. **In CAS view** The Alpha–Shift key combination is active. The character shown in orange on a key will be entered in *uppercase* when a key is pressed. See "Adding text" on page 23 for more information.
a...z [orange]	**In Home view** The Alpha–Shift key combination is active. The character shown in orange on a key will be entered in *lowercase* when a key is pressed. See "Adding text" on page 23 for more information. **In CAS view** The Alpha key is active. The character shown in orange on a key will be entered in *lowercase* when a key is pressed. See "Adding text" on page 23 for more information.
↑U [Yellow]	The user keyboard is active. All the following key presses will enter the customized objects associated with the key. See "The User Keyboard: Customizing key presses" on page 516 for more information.

Annunciator	Meaning (Continued)
1U [Yellow]	The user keyboard is active. The next key press will enter the customized object associated with the key. See “The User Keyboard: Customizing key presses” on page 516 for more information.
[Time]	Current time. The default is 24-hour format, but you can choose AM–PM format. See “Home settings” on page 30 for more information.
🔋 [Green with gray border]	Battery-charge indicator.

Navigation

The HP Prime offers two modes of navigation: touch and keys. In many cases, you can tap on an icon, field, menu, or object to select (or deselect) it. For example, you can open the Function app by tapping once on its icon in the Application Library. However, to open the Application Library, you will need to press a key: Apps Info.

Instead of tapping an icon in the Application Library, you can also press the cursor keys—▲, ▼, ◀, ▶—until the app you want to open is highlighted, and then press Enter ≈. In the Application Library, you can also type the first one or two letters of an app’s name to highlight the app. Then either tap the app’s icon or press Enter ≈ to open it.

Sometimes a touch or key–touch combination is available. For example, you can deselect a toggle option either by tapping twice on it, or by using the arrow keys to move to the field and then tapping a touch button along the bottom of the screen (in this case √).

Note that you must use your finger or a capacitive stylus to select an item by touch.

Touch gestures

In addition to selection by tapping, there are other touch-related operations available to you:

To quickly move from page to page, **flick**:

> Place a finger on the screen and quickly swipe it in the desired direction (up or down).

To pan, **drag** your finger horizontally or vertically across the screen.

To quickly zoom in, make an **open pinch**:

> Place the thumb and a finger close together on the screen and move them apart. Only lift them from the screen when you reach the desired magnification.

To quickly zoom out, make an **closed pinch**:

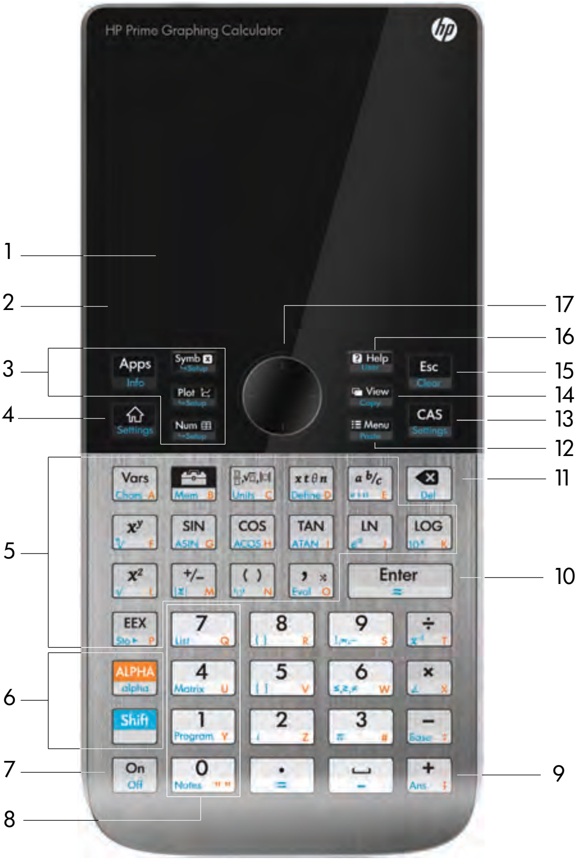
> Place the thumb and a finger some distance apart on the screen and move them toward each other. Only lift them from the screen when you reach the desired magnification.

Note that pinching to zoom only works in applications that feature zooming (such as where graphs are plotted). In other applications, pinching will do nothing, or do something other than zooming. For example, in the Spreadsheet app, pinching will change the width of a column or the height of a row.

The keyboard

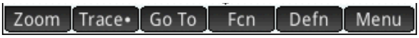
The numbers in the legend below refer to the parts of the keyboard described in the illustration on the next page.

Number	Feature
1	LCD and touch-screen: 320 × 240 pixels
2	Context-sensitive touch-button menu
3	HP Apps keys
4	Home view and preference settings
5	Common math and science functions
6	Alpha and Shift keys
7	On, Cancel and Off key
8	List, matrix, program, and note catalogs
9	Last Answer key (Ans)
10	Enter key
11	Backspace and Delete key
12	Menu (and Paste) key
13	CAS (and CAS preferences) key
14	View (and Copy) key
15	Escape (and Clear) key
16	Help key
17	Rocker wheel (for cursor movement)



Context-sensitive menu

A context-sensitive menu occupies the bottom line of the screen.



The options available depend on the context, that is, the view you are in. Note that the menu items are activated by touch.

There are two types of buttons on the context-sensitive menu:

- menu button: tap to display a pop-up menu. These buttons have square corners along their top (such as Zoom in the illustration above).
- command button: tap to initiate a command. These buttons have rounded corners (such as Go To in the illustration above).

Entry and edit keys

The primary entry and edit keys are:

Keys	**Purpose**
0 to 9	Enter numbers
On or Esc	Cancels the current operation or clears the entry line.
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.
+/−	For entering a negative number. For example, to enter –25, press +/− 25. *Note: this is not the same operation that is performed by the subtraction key (−).*
▯,√▯,|▯|	Math template: Displays a palette of pre-formatted templates representing common arithmetic expressions.
xtθn	Enters the independent variable (that is, either *X*, *T*, θ, or *N*, depending on the app that is currently active).

Keys	Purpose (Continued)
Shift 6	Relations palette: Displays a palette of comparison operators and Boolean operators.
Shift 9	Special symbols palette: Displays a palette of common math and Greek characters.
Shift a b/c	Automatically inserts the degree, minute, or second symbol according to the context.
Del	Backspace. Deletes the character to the left of the cursor. It will also return the highlighted field to its default value, if it has one.
Shift Del	Delete. Deletes the character to the right of the cursor.
Shift Esc Clear (Clear)	Clears all data on the screen (including the history). On a settings screen—for example Plot Setup—returns all settings to their default values.
◀ ▶ ▲ ▼	Cursor keys: Moves the cursor around the display. Press Shift ▼ to move to the end of a menu or screen, or Shift ▲ to move to the start. (These keys represent the directions of the rocker wheel.)

Keys	Purpose (Continued)
Shift Vars	Displays all the available characters. To enter a character, use the cursor keys to highlight it, and then tap OK. To select multiple characters, select one, tap Echo, and continue likewise before pressing OK. There are many pages of characters. You can jump to a particular Unicode block by tapping More and selecting the block. You can also flick from page to page.

Shift keys

There are two shift keys that you use to access the operations and characters printed on the bottom of the keys: Shift and ALPHA.

Key	Purpose
Shift	Press Shift to access the operations printed in blue on a key. For instance, to access the settings for Home view, press Shift Settings.
ALPHA	Press the ALPHA key to access the characters printed in orange on a key. For instance, to type Z in Home view, press ALPHA and then press 2. For a lowercase letter, press ALPHA Shift and then the letter. In CAS view, ALPHA and another key gives a lowercase letter, and ALPHA Shift and another letter gives an uppercase letter.

Adding text

The text you can enter directly is shown by the orange characters on the keys. These characters can only be entered in conjunction with the ALPHA and Shift keys. Both uppercase and lowercase characters can be entered, and the method is exactly the opposite in CAS view than in Home view.

Keys	Effect in Home view	Effect in CAS view
ALPHA	Makes the next character uppercase	Makes the next character lowercase
ALPHA ALPHA	Lock mode: makes all characters uppercase until the mode is reset	Lock mode: makes all characters lowercase until the mode is reset
Shift	With uppercase locked, makes the next character lowercase	With lowercase locked, makes the next character uppercase
ALPHA Shift	Makes the next character lowercase	Makes the next character uppercase
ALPHA Shift ALPHA	Lock mode: makes all characters lowercase until the mode is reset	Lock mode: makes all characters uppercase until the mode is reset
Shift	With lowercase locked, makes the next character uppercase	With uppercase locked, makes the next character lowercase
Shift ALPHA	With lowercase locked, makes all characters uppercase until the mode is reset	With uppercase locked, makes all characters lowercase until the mode is reset
ALPHA	Reset uppercase lock mode	Reset lowercase lock mode
ALPHA ALPHA ALPHA ALPHA	Reset lowercase lock mode	Reset uppercase lock mode

You can also enter text (and other characters) by displaying the characters palette: Shift Vars.

Math keys

The most common math functions have their own keys on the keyboard (or a key in combination with the Shift key).

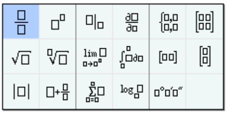
Example 1: To calculate SIN(10), press SIN 10 and press Enter. The answer displayed is –0.544… (if your angle measure setting is radians).

Example 2: To find the square root of 256, press Shift x^2 256 and press Enter. The answer displayed is 16. Notice that the Shift key initiates the operator represented in blue on the next key pressed (in this case √ on the x^2 key).

The mathematical functions not represented on the keyboard are on the **Math**, **CAS**, and **Catlg** menus (see chapter 21, "Functions and commands", starting on page 307).

Note that the order in which you enter operands and operators is determined by the entry mode. By default, the entry mode is *textbook*, which means that you enter operands and operators just as you would if you were writing the expression on paper. If your preferred entry mode is Reverse Polish Notation, the order of entry is different. (See chapter 2, "Reverse Polish Notation (RPN)", starting on page 47.)

Math template



The math template key (Units) helps you insert the framework for common calculations (and for vectors, matrices, and hexagesimal numbers). It displays a palette of pre-formatted outlines to which you add the constants, variables, and so on. Just tap on the template you want (or use the arrow keys to highlight it and press Enter). Then enter the components needed to complete the calculation.

Example: Suppose you want to find the cube root of 945:

1. In Home view, press Units.
2. Select $\sqrt[\square]{\square}$.

   The skeleton or framework for your calculation now appears on the entry line: $\sqrt[\square]{\blacksquare}$

3. Each box on the template needs to be completed:

   3▶945

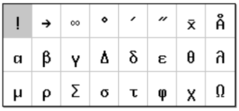
4. Press Enter to display the result: 9.813…

The template palette can save you a lot of time, especially with calculus calculations.

You can display the palette at any stage in defining an expression. In other words, you don't need to start out with a template. Rather, you can embed one or more templates at any point in the definition of an expression.

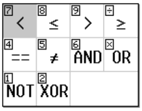
Math shortcuts

As well as the math template, there are other similar screens that offer a palette of special characters. For example, pressing Shift 9 displays the special symbols palette, shown at the right. Select a character by tapping it (or scrolling to it and pressing Enter).



!	→	∞	°	′	″	x̄	Å
α	β	γ	Δ	δ	ε	θ	λ
μ	ρ	Σ	σ	τ	φ	χ	Ω

A similar palette—the relations palette—is displayed if you press Shift 6. The palette displays operators useful in math and programming. Again, just tap the character you want.



7 <	8 ≤	9 >	÷ ≥
4 ==	5 ≠	6 AND	× OR
1 NOT	2 XOR		

Other math shortcut keys include $xt\theta n$. Pressing this key inserts an *X*, *T*, θ, or *N* depending on what app you are using. (This is explained further in the chapters describing the apps.)

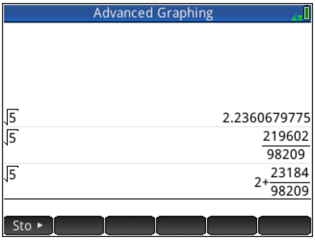
Similarly, pressing Shift a b/c enters a degree, minute, or second character. It enters ° if no degree symbol is part of your expression; enters ′ if the previous entry is a value in degrees; and enters ″ if the previous entry is a value in minutes. Thus entering:

36 Shift a b/c 40 Shift a b/c 20 Shift a b/c

yields 36°40′20″. See “Hexagesimal numbers” on page 26 for more information.

Fractions

The fraction key (a b/c) cycles through thee varieties of fractional display. If the current answer is the decimal fraction 5.25, pressing a b/c converts the answer to the common fraction 21/4. If you press a b/c again, the answer is converted to a mixed number (5 + 1/4). If pressed again, the display returns to the decimal fraction (5.25).



```
√5                2.2360679775
√5                219602/98209
√5                2+23184/98209
```

The HP Prime will approximate fraction and mixed number representations in cases where it cannot find exact ones. For example, enter $\sqrt{5}$ to see the decimal approximation: 2.236…. Press a b/c once to see $\frac{219602}{98209}$ and again to see $2+\frac{23184}{98209}$. Pressing a b/c a third time will cycle back to the original decimal representation.

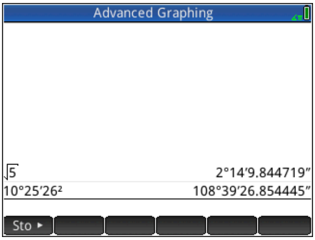
Hexagesimal numbers

Any decimal result can de displayed in hexagesimal format; that is, in units subdivided into groups of 60. This includes degrees, minutes, and seconds as well as hours, minutes, and seconds. For example, enter $\frac{11}{8}$ to see the decimal result: 1.375. Now press Shift a b/c to see 1°22′30. Press Shift a b/c again to return to the decimal representation.

HP Prime will produce the best approximation in cases where an exact result is not possible. Enter $\sqrt{5}$ to see the decimal approximation: 2.236… Press Shift a b/c to see 2°14′9.84472.

Note that the degree and minute entries must be integers, and the minute and second entries must be positive. Decimals are not allowed, except in the seconds.

Note too that the HP Prime treats a value in hexgesimal format as a single entity. Hence any operation performed on a hexagesimal value is performed on the entire value. For example, if you enter 10°25′26″^{2}, the whole value is squared, not just the seconds component. The result in this case is 108°39′26.8544″.



```
Advanced Graphing
√5                          2°14'9.844719"
10°25'26²                 108°39'26.854445"
Sto ▸
```

EEX key (powers of 10)

Numbers like 5×10^4 and 3.21×10^{-7} are expressed in *scientific notation*, that is, in terms of powers of ten. This is simpler to work with than 50 000 or 0.000 000 321. To enter numbers like these, use the EEX functionality. This is easier than using × 10 x^y.

Example: Suppose you want to calculate

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

First select `Scientific` as the number format.

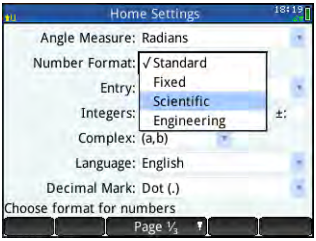
1. Open the **Home Settings** window.

   Shift Settings

2. Select `Scientific` from the **Number Format** menu.

3. Return home: Settings

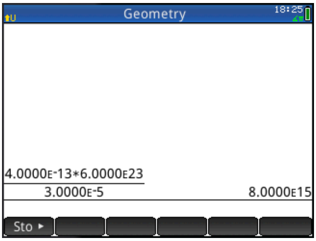
4. Enter 4 EEX +/– 13 × 6 EEX 23 ÷ 3 EEX +/– 5



```
Home Settings                      18:19
  Angle Measure: Radians
  Number Format: √Standard
          Entry:  Fixed
                  Scientific
       Integers:  Engineering      ±:
        Complex: (a,b)
       Language: English
   Decimal Mark: Dot (.)
Choose format for numbers
                 Page 1/3
```

5. Press Enter

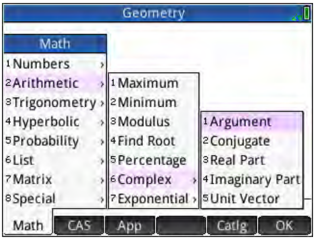
   The result is `8.0000E15`. This is equivalent to 8 × 10^{15}.



```
4.0000E-13*6.0000E23
         3.0000E-5                        8.0000E15
```

Menus

A menu offers you a choice of items. As in the case shown at the right, some menus have sub-menus and sub-sub-menus.



To select from a menu

There are two techniques for selecting an item from a menu:

- direct tapping and
- using the arrow keys to highlight the item you want and then either tapping OK or pressing Enter.

Note that the menu of buttons along the bottom of the screen can only be activated by tapping.

Shortcuts

- Press ▲ when you are at the top of the menu to immediately display the last item in the menu.
- Press ▼ when you are at the bottom of the menu to immediately display the first item in the menu.
- Press Shift ▼ to jump straight to the bottom of the menu.
- Press Shift ▲ to jump straight to the top of the menu.
- Enter the first few characters of the item’s name to jump straight to that item.
- Enter the number of the item shown in the menu to jump straight to that item.

To close a menu

A menu will close automatically when you select an item from it. If you want to close a menu without selecting anything from it, press On Off or Esc Clear.

Toolbox menus

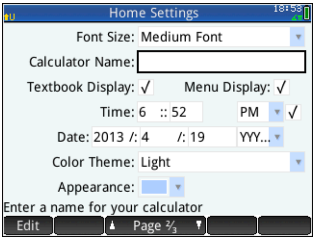
The Toolbox menus (Mem B) are a collection of menus offering functions and commands useful in mathematics and programming. The **Math**, **CAS**, and **Catlg** menus offer over 400 functions and commands. The items on these menus are described in detail in chapter 21, "Functions and commands", starting on page 307.

Input forms

An input form is a screen that provides one or more fields for you to enter data or select an option. It is another name for a dialog box.

- If a field allows you to enter data of your choice, you can select it, add your data, and tap OK. (There is no need to tap Edit first.)
- If a field allows you to choose an item from a menu, you can tap on it (the field or the label for the field), tap on it again to display the options, and tap on the item you want. (You can also choose an item from an open list by pressing the cursor keys and pressing Enter ≈ when the option you want is highlighted.)
- If a field is a toggle field—one that is either selected or not selected—tap on it to select the field and tap on it again to select the alternate option. (Alternatively, select the field and tap √.)

The illustration at the right shows an input form with all three types of field: **Calculator Name** is a free-form data-entry field, **Font Size** provides a menu of options, and **Textbook Display** is a toggle field.



Home Settings 18:53

Font Size: Medium Font

Calculator Name:

Textbook Display: √ Menu Display: √

Time: 6 :: 52 PM √

Date: 2013 /: 4 /: 19 YYY...

Color Theme: Light

Appearance:

Enter a name for your calculator

Reset input form fields

To reset a field to its default value, highlight the field and press Del. To reset all fields to their default values, press Shift Esc Clear (Clear).

System-wide settings

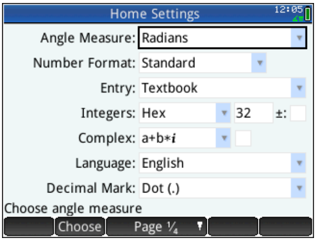
System-wide settings are values that determine the appearance of windows, the format of numbers, the scale of plots, the units used by default in calculations, and much more.

There are two system-wide settings: Home settings and CAS settings. Home settings control Home view and the apps. CAS settings control how calculations are done in the computer algebra system. CAS settings are discussed in chapter 3.

Although Home settings control the apps, you can override certain Home settings once inside an app. For example, you can set the angle measure to radians in the Home settings but choose degrees as the angle measure once inside the Polar app. Degrees then remains the angle measure until you open another app that has a different angle measure.

Home settings

You use the **Home Settings** input form to specify the settings for Home view (and the default settings for the apps). Press Shift Settings (Settings) to open the **Home Settings** input form. There are four pages of settings.



Home Settings

Angle Measure: Radians

Number Format: Standard

Entry: Textbook

Integers: Hex 32 ±: □

Complex: a+b*i □

Language: English

Decimal Mark: Dot (.)

Choose angle measure

Page 1

Setting	Options
Angle Measure	**Degrees**: 360 degrees in a circle. **Radians**: 2π radians in a circle. The angle mode you set is the angle setting used in both Home view and the current app. This is to ensure that trigonometric calculations done in the current app and Home view give the same result.
Number Format	The number format you set is the format used in all Home view calculations. **Standard**: Full-precision display. **Fixed**: Displays results rounded to a number of decimal places. If you choose this option, a new field appears for you to enter the number of decimal places. For example, `123.456789` becomes `123.46` in `Fixed 2` format. **Scientific:** Displays results with an one-digit exponent to the left of the decimal point, and the specified number of decimal places. For example, `123.456789` becomes `1.23E2` in `Scientific 2` format. **Engineering**: Displays results 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.

Setting	Options (Continued)
Entry	**Textbook**: An expression is entered in much the same way as if you were writing it on paper (with some arguments above or below others). In other words, your entry could be two-dimensional. **Algebraic**: An expression is entered on a single line. Your entry is always one-dimensional. **RPN**: Reverse Polish Notation. The arguments of the expression are entered first followed by the operator. The entry of an operator automatically evaluates what has already been entered.
Integers	Sets the default base for integer arithmetic: binary, octal, decimal, or hex. You can also set the number of bits per integer and whether integers are to be signed.
Complex	Choose one of two formats for displaying complex numbers: `(a,b)` or `a+b*i`. To the right of this field is an unnamed checkbox. Check it if you want to allow complex output from real input.
Language	Choose the language you want for menus, input forms, and the online help.

Setting	**Options (Continued)**
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 semicolons as separators in these contexts.

Page 2

Setting	**Options**
Font Size	Choose between small, medium, and large font for general display.
Calculator Name	Enter a name for the calculator.
Textbook Display	If selected, expressions and results are displayed in textbook format (that is, much as you would see in textbooks). If not selected, expressions and results are displayed in algebraic format (that is, in one-dimensional format). For example, $\begin{bmatrix}4 & 5\\6 & 2\end{bmatrix}$ is displayed as `[[4,5],[6,2]]` in algebraic format.
Menu Display	This setting determines whether the commands on the **Math** and **CAS** menus are presented descriptively or in common mathematical shorthand. The default is to provide the descriptive names for the functions. If you prefer the functions to be presented in mathematical shorthand, deselect this option.

Setting	Options (Continued)
Time	Set the time and choose a format: 24-hour or AM–PM format. The checkbox at the far right lets you choose whether to show or hide the time on the title bar of screens.
Date	Set the date and choose a format: `YYYY/MM/DD`, `DD/MM/YYYY`, or `MM/DD/YYYY`.
Color Theme	**Light**: black text on a light background **Dark**: white text on a dark background At the far right is a option for you to choose a color for the shading (such as the color of the highlight).

Page 3

Page 3 of the **Home Settings** input form is for setting Exam mode. This mode enables certain functions of the calculator to be disabled for a set period, with the disabling controlled by a password. This feature will primarily be of interest to those who supervise examinations and who need to ensure that the calculator is used appropriately by students sitting an examination. It is described in detail in chapter 4, "Exam Mode", starting on page 61.

Page 4

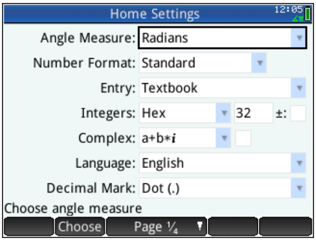
Page 4 of the **Home Settings** input form is for configuring your HP Prime to work with the HP Prime Wireless Kit. Visit www.hp.com/support for further information.

Specifying a Home setting

This example demonstrates how to change the number format from the default setting—Standard—to Scientific with two decimal places.

1. Press Shift Settings (Settings) to open the **Home Settings** input form.

   The **Angle Measure** field is highlighted.

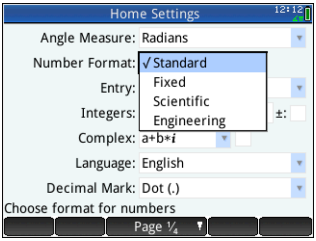


Home Settings 12:05

Angle Measure: Radians
Number Format: Standard
Entry: Textbook
Integers: Hex 32 ±: □
Complex: a+b*i □
Language: English
Decimal Mark: Dot (.)
Choose angle measure

2. Tap on **Number Format** (either the field label or the field). This selects the field. (You could also have pressed ▼ to select it.)

3. Tap on **Number Format** again. A menu of number format options appears.

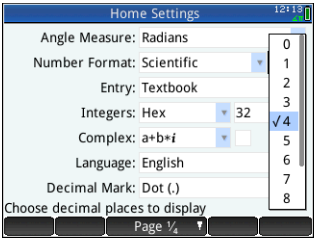


Home Settings 12:12

Angle Measure: Radians
Number Format: √Standard
Entry:
Integers: ±: □
Complex: a+b*i □
Language: English
Decimal Mark: Dot (.)
Choose format for numbers

4. Tap on **Scientific**. The option is chosen and the menu closes. (You can also choose an item by pressing the cursor keys and pressing Enter ≈ when the option you want is highlighted.)

5. Notice that a number appears to the right of the **Number Format** field. This is the number of decimal places currently set. To change the number to 2, tap on it twice, and then tap on 2 in the menu that appears.



Home Settings 12:13

Angle Measure: Radians
Number Format: Scientific
Entry: Textbook
Integers: Hex 32
Complex: a+b*i □
Language: English
Decimal Mark: Dot (.)
Choose decimal places to display

6. Press Settings to return to Home view.

Mathematical calculations

The most commonly used math operations are available from the keyboard (see “Math keys” on page 24). Access to the rest of the math functions is via various menus (see “Menus” on page 28).

Note that the HP Prime represents all numbers smaller than 1 × $10^{–499}$ as zero. The largest number displayed is 9.99999999999 × 10^{499}. A greater result is displayed as this number.

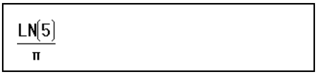
Where to start

The home base for the calculator is the Home view (Settings). You can do all your non-symbolic calculations here. You can also do calculations in CAS view, which uses the computer algebra system (see chapter 3, “Computer algebra system (CAS)”, starting on page 53). In fact, you can use functions from the **CAS** menu (one of the Toolbox menus) in an expression you are entering in Home view, and use functions from the **Math** menu (another of the Toolbox menus) in an expression you are entering in CAS view.

Choosing an entry type

The first choice you need to make is the style of entry. The three types are:

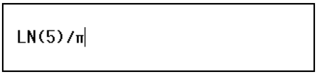
- Textbook



$\frac{LN(5)}{\pi}$

An expression is entered in much the same way as if you were writing it on paper (with some arguments above or below others). In other words, your entry could be two-dimensional, as in the example above.

- Algebraic



```
LN(5)/π
```

An expression is entered on a single line. Your entry is always one-dimensional.

- RPN (*Reverse Polish Notation*). [Not available in CAS view.]

  The arguments of the expression are entered first followed by the operator. The entry of an operator automatically evaluates what has already been entered. Thus you will need to enter a two-operator expression (as in the example above) in two steps, one for each operator:

  Step 1: 5 LN – the natural logarithm of 5 is calculated and displayed in history.

  Step 2: Shift 3 ÷ – π is entered as a divisor and applied to the previous result.

  More information about RPN mode can be found in chapter 2, "Reverse Polish Notation (RPN)", starting on page 47.

Note that on page 2 of the **Home Settings** screen, you can specify whether you want to display your calculations in Textbook format or not. This refers to the *appearance* of your calculations in the history section of both Home view and CAS view. This is a different setting from the *Entry* setting discussed above.

Entering expressions

The examples that follow assume that the entry mode is `Textbook`.

- An *expression* can contain numbers, functions, and variables.
- To enter a function, press the appropriate key, or open a Toolbox menu and select the function. You can also enter a function by using the alpha keys to spell out its name.
- When you have finished entering the expression, press Enter to evaluate it.

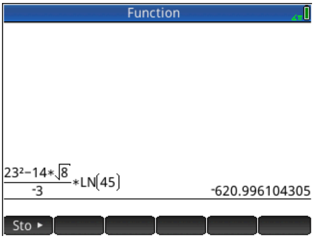
If you make a mistake while entering an expression, you can:

- delete the character to the left of the cursor by pressing Del
- delete the character to the right of the cursor by pressing Shift Del
- clear the entire entry line by pressing On Off or Esc Clear.

Example

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

( ) 23 x^2 − 14 Shift x^2 8 ▶ ▶ ÷ +/− 3 ▶ LN 45 Enter ≈



$\frac{23^2-14*\sqrt{8}}{-3}*LN(45)$ -620.996104305

This example illustrates a number of important points to be aware of:

- the importance of delimiters (such as parentheses)
- how to enter negative numbers
- the use of implied versus explicit multiplication.

Parentheses

As the example above shows, parentheses are automatically added to enclose the arguments of functions, as in `LN()`. However, you will need to manually add parentheses—by pressing ( )—to enclose a group of objects you want operated on as a single unit. Parentheses provide a way of avoiding arithmetic ambiguity. In the example above we wanted the entire numerator divided by –3, thus the entire numerator was enclosed in parentheses. Without the parentheses, only `14√8` would have been divided by –3.

The following examples show the use of parentheses, and the use of the cursor keys to move outside a group of objects enclosed within parentheses.

Entering ...	**Calculates ...**
SIN 45 + Shift 3	$\sin(45+\pi)$
SIN 45 ▶ + Shift 3	$\sin(45)+\pi$
Shift x^2 85 ▶ × 9	$\sqrt{85}\times 9$
Shift x^2 85 × 9	$\sqrt{85\times 9}$

Algebraic precedence

The HP Prime calculates according to the following order of precedence. Functions at the same level of precedence are evaluated in order from left to right.

1. Expressions within parentheses. Nested parentheses are evaluated from inner to outer.
2. !, √, reciprocal, square
3. nth root
4. Power, 10^{n}
5. Negation, multiplication, division, and modulo
6. Addition and subtraction
7. Relational operators (<, >, ≤, ≥, ==, ≠, =)
8. AND and NOT
9. OR and XOR
10. Left argument of | (where)
11. Assign to variable (:=)

Negative numbers

It is best to press +/− to start a negative number or to insert a negative sign. Pressing − instead will, in some situations, be interpreted as an operation to subtract the next number you enter from the last result. (This is explained in “To reuse the last result” on page 41.)

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

Explicit and implied multiplication

Implied multiplication takes place when two operands appear with no operator between them. If you enter `AB`, for example, the result is `A*B`. Notice in the example on page 38 that we entered 14 Shift x^y 8 without the multiplication operator after 14. For the sake of clarity, the calculator adds the operator to the expression in history, but it is not strictly necessary when you are entering the expression. You can, though, enter the operator if you wish (as was done in the examples on page 39). The result will be the same.

Large results

If the result is too long or too tall to be seen in its entirety—for example, a many-rowed matrix—highlight it and then press Show. The result is displayed in full-screen view. You can now press ▲ and ▼ (as well as ▶and ◀) to bring hidden parts of the result into view. Tap OK to return to the previous view.

Reusing previous expressions and results

Being able to retrieve and reuse an expression provides a quick way of repeating a calculation that requires only a few minor changes to its parameters. You can retrieve and reuse any expression that is in history. You can also retrieve and reuse any result that is in history.

To retrieve an *expression* and place it on the entry line for editing, either:

- tap twice on it, or
- use the cursor keys to highlight the expression and then either tap on it or tap Copy.

To retrieve a *result* and place it on the entry line, use the cursor keys to highlight it and then tap Copy.

If the expression or result you want is not showing, press ▲ repeatedly to step through the entries and reveal those that are not showing. You can also swipe the screen to quickly scroll through history.

Tip Pressing Shift ▲ takes you straight to the very first entry in history, and pressing Shift ▼ takes you straight to the most recent entry.

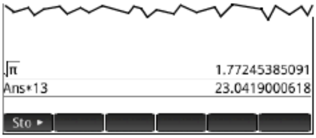
Using the clipboard

Your last four expressions are always copied to the clipboard and can easily be retrieved by pressing Shift Menu Paste. This opens the clipboard from where you can quickly choose the one you want.

Note that expressions and not results are available from the clipboard. Note too that the last four expressions remain on the clipboard even if you have cleared history.

To reuse the last result

Press Shift + Ans (Ans) to retrieve your last answer for use in another calculation. `Ans` appears on the entry line. This is a shorthand for your last answer and it can be part of a new expression. You could now enter other components of a calculation—such as operators, number, variables, etc.—and create a new calculation.



```
√π                        1.77245385091
Ans*13                    23.0419000618
```

Tip You don't need to first select `Ans` before it can be part of a new calculation. If you press a binary operator key to begin a new calculation, `Ans` is automatically added to the entry line as the first component of the new calculation. For example, to multiply the last answer by 13, you could enter Shift + Ans × 13 Enter. But the first two keystrokes are unnecessary. All you need to enter is × 13 Enter.

The variable `Ans` is always stored with full precision whereas the results in history will only have the precision determined by the current Number Format setting (see page 31). In other words, when you retrieve the number assigned to `Ans`, you get the result to its full precision; but when you retrieve a number from history, you get exactly what was displayed.

You can repeat the previous calculation simply by pressing Enter. This can be useful if the previous calculation involved `Ans`. For example, suppose you want to calculate the *n*th root of 2 when *n* is 2, 4, 8, 16, 32, and so on.

1. Calculate the square root of 2.

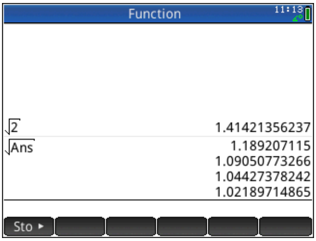
   Shift x^2 2 Enter

2. Now enter √`Ans`.

   Shift x^2 Shift + Enter

   This calculates the fourth root of 2.

3. Press Enter repeatedly. Each time you press, the root is twice the previous root. The last answer shown in the illustration at the right is $\sqrt[32]{2}$.



```
√2                    1.41421356237
√Ans                    1.189207115
                      1.09050773266
                      1.04427378242
                      1.02189714865
```

To reuse an expression or result from the CAS

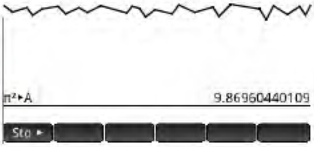
When your are working in Home view, you can retrieve an expression or result from the CAS by tapping Menu Paste and selecting `Get from CAS`. The CAS opens. Press ▲ or ▼ until the item you want to retrieve is highlighted and press Enter. The highlighted item is copied to the cursor point in Home view.

Storing a value in a variable

You can store a value in a variable (that is, assign a value to a variable). Then when you want to use that value in a calculation, you can refer to it by the variable's name. You can create your own variables, or you can take advantage of the built-in variables in Home view (named *A* to *Z* and θ) and in the CAS (named *a* to *z*, and a few others). CAS variables can be used in calculations in Home view, and Home variables can be used in calculations in the CAS. There are also built-in app variables and geometry variables. These can also be used in calculations.

Example: To assign π² to to the variable *A*:

Shift 3 x^2 Sto ▸ ALPHA Vars Enter


π²▸A 9.86960440109

Sto ▸

Your stored value appears as shown at the right. If you then wanted to multiply your stored value by 5, you could enter: ALPHA Vars × 5 Enter.

You can also create your own variables in Home view. For example, suppose you wanted to create a variable called `ME` and assign π² to it. You would enter:

Shift 3 x^2 Sto ▸ ALPHA +/– ALPHA a b/c Enter

A message appears asking if you want to create a variable called ME. Tap OK or press Enter to confirm your intention. You can now use that variable in subsequent calculations: `ME*3` will yield 29.6088132033, for example.

You can also create variables in CAS view in the same way. However, the built-in CAS variables must be entered in lowercase. However, the variables you create yourself can be uppercase or lowercase.

See chapter 22, "Variables", starting on page 423 for more information.

As well as built-in Home and CAS variables, and the variables you create yourself, each app has variables that you can access and use in calculations. See "App functions and variables" on page 109 for more information.

Complex numbers

You can perform arithmetic operations using complex numbers. Complex numbers can be entered in the following forms, where *x* is the real part, *y* is the imaginary part, and *i* is the imaginary constant, $\sqrt{-1}$:

- (x, y)
- $x + yi$ (except in RPN mode)
- $x - yi$ (except in RPN mode)
- $x + iy$ (except in RPN mode), or
- $x - iy$ (except in RPN mode)

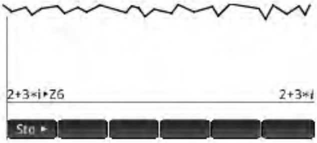
To enter *i*:

- press ALPHA Shift TAN

  or

- press Shift 2.

There are 10 built-in variables available for storing complex numbers. These are labeled `Z0` to `Z9`. You can also assign a complex number to a variable you create yourself.



```
2+3×i▸Z6                                2+3×i
```

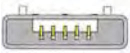
To store a complex number in a variable, enter the complex number, press Sto ▸, enter the variable that you want to assign the complex number to, and then press Enter. For example, to store `2+3i` in variable `Z6`:

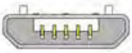
( ) 2 × 3 ▶ Sto ▸ ALPHA 2 6 Enter

Sharing data

As well as giving you access to many types of mathematical calculations, the HP Prime enables you to create various objects that can be saved and used over and over again. For example, you can create apps, lists, matrices, programs, and notes. You can also send these objects to other HP Primes. Whenever you encounter a screen with Send as a menu item, you can select an item on that screen to send it to another HP Prime.

You use one of the supplied USB cables to send objects from one HP Prime to another.


Micro-A: sender


Micro-B: receiver

This is the micro-A–micro B USB cable. Note that the connectors on the ends of the USB cable are slightly different. The micro-A connector has a rectangular end and the micro-B connector has a trapezoidal end. To share objects with another HP Prime, the micro-A connector must be inserted into the USB port on the *sending* calculator, with the micro-B connector inserted into the USB port on the *receiving* calculator.

General procedure

The general procedure for sharing objects is as follows:

1. Navigate to the screen that lists the object you want to send.

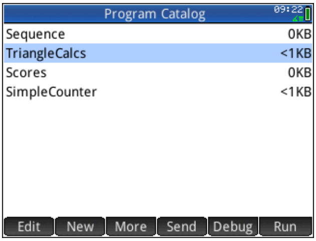
   This will be the Application Library for apps, the List Catalog for lists, the Matrix Catalog for matrices, the Program Catalog for programs, and the Notes Catalog for notes.

2. Connect the USB cable between the two calculators.

   The micro-A connector—with the rectangular end—must be inserted into the USB port on the *sending* calculator.

3. On the sending calculator, highlight the object you want to send and tap Send.

   In the illustration at the right, a program named `TriangleCalcs` has been selected in the Program Catalog and will be sent to the connected calculator when Send is tapped.


Program Catalog

Sequence	0KB
TriangleCalcs	<1KB
Scores	0KB
SimpleCounter	<1KB

Online Help

Press Help to open the online help. The help initially provided is context-sensitive, that is, it is always about the current view and its menu items.

For example, to get help on the Function app, press Apps, select Function, and press Help.

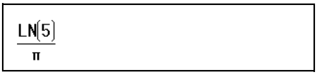
From within the help system, tapping Tree displays a hierarchical directory of all the help topics. You can navigate through the directory to other help topics, or use the search facility to quickly find a topic. You can find help on any key, view, or command.

Reverse Polish Notation (RPN)

The HP Prime provides you with three ways of entering objects in Home view:

- Textbook

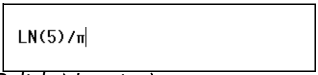
  An expression is entered in much the same way was if you were writing it on paper (with some arguments above or below others). In other words, your entry could be two-dimensional, as in the following example:



$\frac{LN(5)}{\pi}$

- Algebraic

  An expression is entered on a single line. Your entry is always one-dimensional. The same calculation as above would appear like this is algebraic entry mode:



```
LN(5)/π
```

- RPN (*Reverse Polish Notation*).

  The arguments of the expression are entered first followed by the operator. The entry of an operator automatically evaluates what has already been entered. Thus you will need to enter a two-operator expression (as in the example above) in two steps, one for each operator:

  Step 1: 5 LN – the natural logarithm of 5 is calculated and displayed in history.

  Step 2: Shift 3 ÷ – π is entered as a divisor and applied to the previous result.

You choose your preferred entry method from page 1 of the **Home Settings** screen (Shift Settings). See "System-wide settings", starting on page 30 for instructions on how to choose settings.

RPN is available in Home view, but not in CAS view.

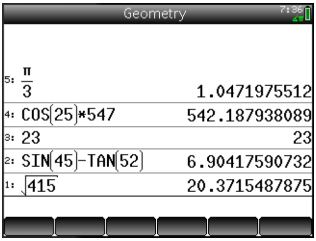
The same entry-line editing tools are available in RPN mode as in algebraic and textbook mode:

- Press Del to delete the character to the left of the cursor.
- Press Shift Del to delete the character to the right of the cursor.
- Press Esc Clear to clear the entire entry line.
- Press Shift Esc Clear to clear the entire entry line.

History in RPN mode

The results of your calculations are kept in history. This history is displayed above the entry line (and by scrolling up to calculations that are no longer immediately visible). The calculator offers three histories: one for the CAS view and two for Home view. CAS history is discussed in chapter 3. The two histories in Home view are:

- non-RPN: visible if you have chosen algebraic or textbook as your preferred entry technique
- RPN: visible only if you have chosen RPN as your preferred entry technique. The RPN history is also called the *stack*. As shown in the illustration below, each entry in the stack is given a number. This is the stack level number.



```
                 Geometry                  7:36
5: π/3                          1.0471975512
4: COS(25)*547                  542.187938089
3: 23                                      23
2: SIN(45)-TAN(52)              6.90417590732
1: √415                         20.3715487875
```

As more calculations are added, an entry's stack level number increases.

If you switch from RPN to algebraic or textbook entry, your history is not lost. It is just not visible. If you switch back to RPN, your RPN history is redisplayed. Likewise, if you switch to RPN, your non-RPN history is not lost.

When you are not in RPN mode, your history is ordered chronologically: oldest calculations at the top, most recent at the bottom. In RPN mode, your history is ordered chronologically by default, but you can change the order of the items in history. (This is explained in “Manipulating the stack” on page 51.)

Re-using results

There are two ways to re-use a result in history. Method 1 deselects the copied result after copying; method 2 keeps the copied item selected.

Method 1

1. Select the result to be copied. You can do this by pressing ▲ or ▼ until the result is highlighted, or by tapping on it.
2. Press Enter. The result is copied to the entry line and is deselected.

Method 2

1. Select the result to be copied. You can do this by pressing ▲ or ▼ until the result is highlighted, or by tapping on it.
2. Tap Stack and select `ECHO`. The result is copied to the entry line and remains selected.

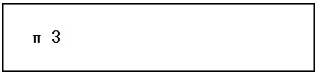
Note that while you can copy an item from the CAS history to use in a Home calculation (and copy an item from the Home history to use in a CAS calculation), you cannot copy items from or to the RPN history. You can, however, use CAS commands and functions when working in RPN mode.

Sample calculations

The general philosophy behind RPN is that arguments are placed before operators. The arguments can be on the entry line (each separated by a space) or they can be in history. For example, to multiply π by 3, you could enter:

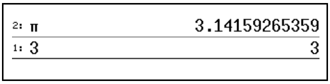
Shift 3 ⎵ 3

on the entry line and then enter the operator (×). Thus your entry line would look like this before entering the operator:



π 3

However, you could also have entered the arguments separately and then, with a blank entry line, entered the operator (×). Your history would look like this before entering the operator:

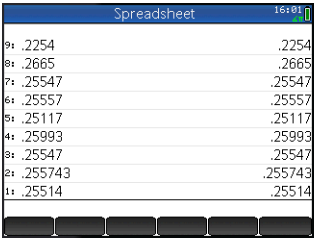


```
2: π                3.14159265359
1: 3                            3
```

If there are no entries in history and you enter an operator or function, an error message appears. An error message will also appear if there is an entry on a stack level that an operator needs but it is not an appropriate argument for that operator. For example, pressing COS when there is a string on level 1 displays an error message.

An operator or function will work only on the minimum number of arguments necessary to produce a result. Thus if you enter on the entry line `2 4 6 8` and press ×, stack level 1 shows `48`. Multiplication needs only two arguments, so the two arguments last entered are the ones that get multiplied. The entries `2` and `4` are not ignored: `2` is placed on stack level 3 and `4` on stack level 2.

Where a function can accept a variable number of arguments, you need to specify how many arguments you want it to include in its operation. You do this by specifying the number in parentheses straight after the function name. You then press Enter to evaluate the function. For example, suppose your stack looks like this:

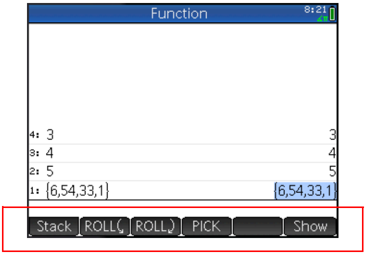


```
9: .2254          .2254
8: .2665          .2665
7: .25547        .25547
6: .25557        .25557
5: .25117        .25117
4: .25993        .25993
3: .25547        .25547
2: .255743      .255743
1: .25514        .25514
```

Suppose further that you want to determine the minimum of just the numbers on stack levels 1, 2, and 3. You choose the `MIN` function from the MATH menu and complete the entry as `MIN(3)`. When you press Enter, the minimum of just the last three items on the stack is displayed.

Manipulating the stack

A number of stack-manipulation options are available. Most appear as menu items across the bottom the screen. To see these items, you must first select an item in history:



PICK

Copies the selected item to stack level 1. The item below the one that is copied is then highlighted. Thus if you tapped PICK four times, four consecutive items will be moved to the bottom four stack levels (levels 1–4).

ROLL

There are two roll commads:

- Tap ROLL↲ to move the selected item to stack level 1. This is similar to PICK, but PICK duplicates the item, with the duplicate being placed on stack level1. However, ROLL doesn't duplicate an item. It simply moves it.
- Tap ROLL↳ to move the item on stack level 1 to the currently highlighted level

Swap

You can swap the position of the objects on stack level 1 with those on stack level 2. Just press , Eval. The level of other objects remains unchanged. Note that the entry line must not be active at the time, otherwise a comma will be entered.

Stack

Tapping Stack displays further stack-manipulation tools.

DROPN

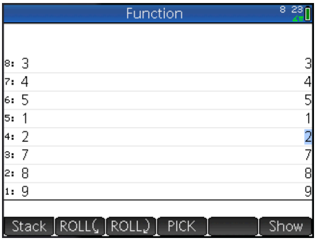
Deletes all items in the stack from the highlighted item down to and including the item on stack level 1. Items above the highlighted item drop down to fill the levels of the deleted items.

If you just want to delete a single item from the stack, see “Delete an item” below.

DUPN Duplicates all items between (and including) the highlighted item and the item on stack level 1. If, for example, you have selected the item on stack level 3, selecting `DUPN` duplicates it and the two items below it, places them on stack levels 1 to 3, and moves the items that were duplicated up to stack levels 4 to 6.

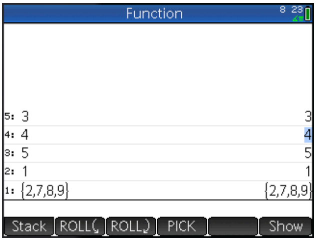
Echo Places a copy of the selected result on the entry line and leaves the source result highlighted.

→LIST Creates a list of results, with the highlighted result the first element in the list and the item on stack level 1 the last.



```
Function                     8 23
8: 3                            3
7: 4                            4
6: 5                            5
5: 1                            1
4: 2                            2
3: 7                            7
2: 8                            8
1: 9                            9
Stack ROLL↶ ROLL↷ PICK       Show
```

Before



```
Function                     8 23
5: 3                            3
4: 4                            4
3: 5                            5
2: 1                            1
1: {2,7,8,9}            {2,7,8,9}
Stack ROLL↶ ROLL↷ PICK       Show
```

After

Show an item

To show a result in full-screen textbook format, tap Show.

Tap OK to return to the history.

Delete an item

To delete an item from the stack:

1. Select it. You can do this by pressing ▲ or ▼ until the item is highlighted, or by tapping on it.
2. Press Del.

Delete all items

To delete all items, thereby clearing the history, press Shift Esc Clear.

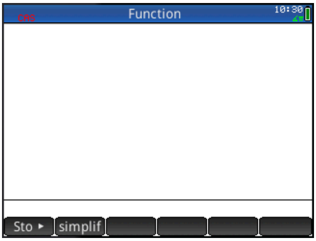
3

Computer algebra system (CAS)

A computer algebra system (CAS) enables you to perform symbolic calculations. By default, 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 app, are numerical calculations and are often approximations limited by the precision of the calculator (to 12 significant digits in the case of the HP Prime). For example, $\frac{1}{3}+\frac{2}{7}$ yields the approximate answer .619047619047 in Home view (with Standard numerical format), but yields the exact answer $\frac{13}{21}$ in the CAS.

The CAS offers many hundreds of functions, covering algebra, calculus, equation solving, polynomials, and more. You select a function from the **CAS** menu, one of the Toolbox menus discussed in chapter 21, “Functions and commands”, beginning on page 307. Consult that chapter for a description of all the CAS functions and commands.

CAS view



CAS calculations are done in CAS view. CAS view is almost identical to Home view. A history of calculations is built and you can select and copy previous calculations just as you can in Home view, as well as store objects in variables.

To open CAS view, press CAS Settings. **CAS** appears in red at the left of the title bar to indicate that you are in CAS view rather than Home view.

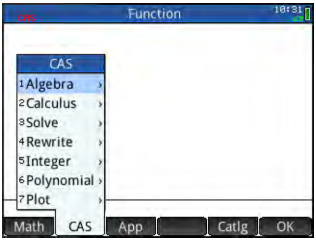
The menu buttons in CAS view are:

- Sto ▸ : assigns an object to a variable
- simplif : applies common simplification rules to reduce an expression to its simplest form. For example, `simplify(`$e^{a + LN(b*e^{c})}$`)` yields b * `EXP(`a`)` * `EXP(`c`)`.
- Copy : copies a selected entry in history to the entry line
- Show : displays the selected entry in full-screen mode, with horizontal and vertical scrolling enabled. The entry is also presented in textbook format.

CAS calculations

With one exception, you perform calculations in CAS view just as you do in Home view. (The exception is that there is no RPN entry mode in CAS view, just algebraic and textbook modes). All the operator and function keys work in the same way in CAS view as Home view (although all the alpha characters are lowercase rather than uppercase). But the primary difference is that the default display of answers is symbolic rather than numeric.

You can also use the template key (Units) to help you insert the framework for common calculations (and for vectors and matrices). This is explained in detail in “Math template” on page 24.



The most commonly used CAS functions are available from the CAS menu, one of the Toolbox menus. To display the menu, press Mem. (If the CAS menu is not open by default, tap CAS .) Other CAS commands are available from the Catlg menu (another of the Toolbox menus).

To choose a function, select a category and then a command.

Example 1

To find the roots of $2x^2 + 3x - 2$:

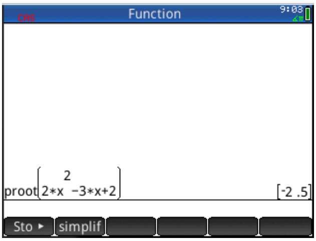
1. With the CAS menu open, select **Polynomial** and then **Find Roots**.

   The function `proot()` appears on the entry line.

2. Between the parentheses, enter:

   2 ALPHA alpha × X x² L + Ans 3 ALPHA alpha × X − Base 2

3. Press Enter ≈.



```
proot(2*x^2 -3*x+2)                    [-2 .5]
```

Example 2

To find the area under the graph of $5x^2 - 6$ between $x = 1$ and $x = 3$:

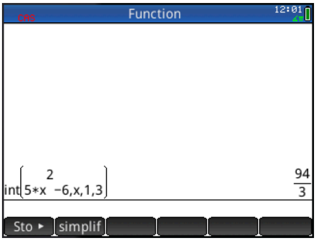
1. With the CAS menu open, select **Calculus** and then **Integrate**.

   The function `int()` appears on the entry line.

2. Between the parentheses, enter:

   5 ALPHA alpha × X x² L − Base 6 , Eval ALPHA alpha × X , Eval 1 , Eval 3

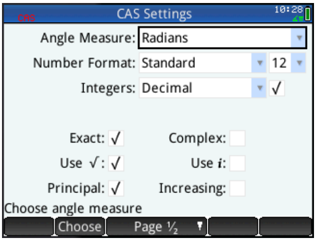
3. Press Enter ≈.



```
int(5*x^2 -6,x,1,3)                    94/3
```

Settings

Various settings allow you to configure how the CAS works. To display the settings, press Shift CAS Settings. The modes are spread across two pages.



CAS Settings

Angle Measure: Radians

Number Format: Standard 12

Integers: Decimal √

Exact: √ Complex: □

Use √: √ Use *i*: □

Principal: √ Increasing: □

Choose angle measure

Page 1

Setting	Purpose
Angle Measure	Select the units for angle measurements: `Radians` or `Degrees`.
Number Format (first drop-down list)	Select the number format for displayed solutions: `Standard` or `Scientific` or `Engineering`
Number Format (second drop-down list)	Select the number of digits to display in approximate mode (mantissa + exponent).
Integers (drop-down list)	Select the integer base: `Decimal` (base 10) `Hex` (base 16) `Octal` (base 8)
Integers (check box)	If checked, any real number equivalent to an integer in a non-CAS environment will be converted to an integer in the CAS. (Real numbers not equivalent to integers are treated as real numbers in CAS whether or not this option is selected.)
Simplify	Select the level of automatic simplification: None: do not simplify automatically (use simplif for manual simplification) Minimum: do basic simplifications Maximum: always try to simplify
Exact	If checked, the calculator is in exact mode and solutions will be symbolic. If not checked, the calculator is in approximate mode and solutions will be approximate. For example, 26 ÷ 5 yields $\frac{26}{5}$ in exact mode and 5.2 in approximate mode.

Setting	Purpose (Cont.)
Complex	Select this to allow complex results in variables.
Use √	If checked, second order polynomials are factorized in complex mode or in real mode if the discriminant is positive.
Use *i*	If checked, the calculator is in complex mode and complex solutions will be displayed when they exist. If not checked, the calculator is in real mode and only real solutions will be displayed. For example, factors(x^4–1) yields (x–1),(x+1),(x+i),(x–i) in complex mode and (x–1),(x+1),(x^2+1) in real mode.
Principal	If checked, the principal solutions to trigonometric functions will be displayed. If not checked, the general solutions to trigonometric functions will be displayed.
Increasing	If checked, polynomials will be displayed with increasing powers (for example, –4+x+3x^2+x^3). If not checked, polynomials will be displayed with decreasing powers (for example, x^3+3x^2+x–4).

Page 2

Setting	Purpose
Recursive Evaluation	Specify the maximum number of embedded variables allowed in an interactive evaluation. See also `Recursive Replacement` below.

Setting	Purpose (Cont.)
Recursive Replacement	Specify the maximum number of embedded variables allowed in a single evaluation in a program. See also `Recursive Evaluation` above.
Recursive Function	Specify the maximum number of embedded function calls allowed.
Epsilon	Any number smaller than the value specified for epsilon will be shown as zero.
Probability	Specify the maximum probability of an answer being wrong for non-deterministic algorithms. Set this to zero for deterministic algorithms.
Newton	Specify the maximum number of iterations when using the Newtonian method to find the roots of a quadratic.

Setting the form of menu items

One setting that affects the CAS is made outside the **CAS Settings** screen. This setting determines whether the commands on the CAS menu are presented descriptively or by their command name. Here are some examples of identical functions that are presented differently depending on what presentation mode you select:

Descriptive name	Command name
Factor List	ifactors
Complex Zeros	cZeros
Groebner Basis	gbasis
Factor by Degree	factor_xn
Find Roots	proot

The default menu presentation mode is to provide the descriptive names for the CAS functions. If you prefer the functions to be presented by their command name, deselect the **Menu Display** option on the second page of the **Home Settings** screen (see “Home settings” on page 30).

To use an expression or result from Home view

When your are working in CAS, you can retrieve an expression or result from Home view by tapping Menu Paste and selecting `Get from Home`. Home view opens. Press ▲ or ▼ until the item you want to retrieve is highlighted and press Enter ≈. The highlighted item is copied to the cursor point in CAS.

To use a Home variable in CAS

You can access Home variables from within the CAS. Home variables are assigned uppercase letters; CAS variables are assigned lowercase letters. Thus SIN(x) and SIN(X) will yield different results.

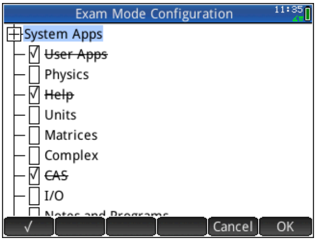
To use a Home variable in the CAS, simply include its name in a calculation. For example, suppose in Home view you have assigned variable *Q* to 100. Suppose too that you have assigned variable *q* to 1000 in the CAS. If you are in the CAS and enter 5**q*, the result is 5000. If you had entered 5**Q* instead, the result would have been 500.

In a similar way, CAS variables can be used in calculations in Home view. Thus you can enter 5**q* in Home view and get 5000, even though q is a CAS variable.

4

Exam Mode

The HP Prime can be precisely configured for an examination, with any number of features or functions disabled for a set period of time. Configuring a HP Prime for an examination is called *exam mode configuration*. You can create and save multiple exam mode configurations, each with its own subset of functionality disabled. You can set each configuration for its own time period, with or without a password. An exam mode configuration can be activated from an HP Prime, sent from one HP Prime to another via USB cable, or sent to one or more HP Primes via the Connectivity Kit.


Exam Mode Configuration

11:35

System Apps

- ☑ ~~User Apps~~
- ☐ Physics
- ☑ ~~Help~~
- ☐ Units
- ☐ Matrices
- ☐ Complex
- ☑ ~~CAS~~
- ☐ I/O
- ☐ Notes and Programs

Exam mode configuration will primarily be of interest to teachers, proctors, and invigilators who want to ensure that the calculator is used appropriately by students sitting for an examination. In the illustration to the right, user-customized apps, the help system and the computer algebra system have been selected for disabling.

As part of an exam mode configuration, you can choose to activate 3 lights on the calculator that will flash periodically during exam mode. The lights are on the top edge of the calculator. The lights will help the supervisor of the examination detect if any particular calculator has dropped out of exam mode. The flashing of lights on all calculators placed in exam mode will be synchronized so that all will flash the same pattern at the same time.

Modifying the default configuration

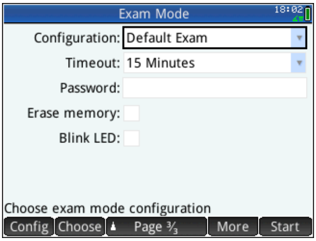
A configuration named `Default Exam` appears when you first access the **Exam Mode** screen. This configuration has no functions disabled. If only one configuration is needed, you can simply modify the default exam configuration. If you envisage the need for a number of configurations—different ones for different examinations, for example—modify the default configuration so that it matches the settings you will most often need, and then create other configurations for the settings you will need less often. There are two ways to access the screen for configuring and activating exam mode:

- press On Off + ALPHA alpha + a b/c
- choose the third page of the **Home Settings** screen.

The procedure below illustrates the second method.

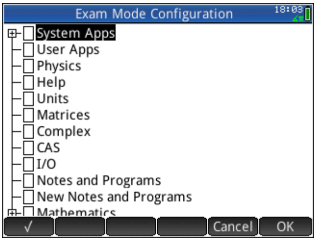
1. Press Shift Settings. The **Home Settings** screen appears.
2. Tap Page ¼ ▼.
3. Tap ▲ Page ¾ ▼.

   The **Exam Mode** screen appears. You use this screen to activate a particular configuration (just before an examination begins, for example).



Configuration: Default Exam ▾
Timeout: 15 Minutes ▾
Password:
Erase memory: □
Blink LED: □
Choose exam mode configuration

4. Tap Config. The **Exam Mode Configuration** screen appears.



⊞□ System Apps
□ User Apps
□ Physics
□ Help
□ Units
□ Matrices
□ Complex
□ CAS
□ I/O
□ Notes and Programs
□ New Notes and Programs
⊞□ Mathematics

5. Select those features you want disabled, and make sure that those features you don't want disabled are not selected.

An expand box at the left of a feature indicates that it is a category with sub-items that you can individually disable. (Notice that there is an expand box beside **System Apps** in the example shown above.) Tap on the expand box to see the sub-items. You can then select the sub-items individually. If you want to disable all the sub-item, just select the category.

You can select (or deselect) an option either by tapping on the check box beside it, or by using the cursor keys to scroll to it and tapping √.

6. When you have finished selecting the features to be disabled, tap OK.

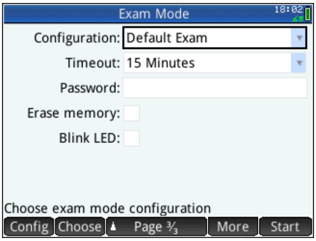
   If you want to activate exam mode now, continue with "Activating Exam Mode" below.

Creating a new configuration

You can modify the default exam configuration when new circumstances require a different set of disabled functions. Alternatively, you can retain the default configuration and create a new configuration. When you create a new configuration, you choose an existing configuration on which to base it.

1. Press Shift Settings. The **Home Settings screen** appears.
2. Tap Page ¼ ▼.
3. Tap ▲ Page ²⁄₄ ▼.

   The **Exam Mode** screen appears.



Configuration: Default Exam

Timeout: 15 Minutes

Password:

Erase memory: □

Blink LED: □

Choose exam mode configuration

4. Choose a base configuration from the **Configuration** list. If you have not created any exam mode configurations before, the only base configuration will be `Default Exam`.

5. Tap More, select `Copy` from the menu and enter a name for the new configuration.

   See “Adding text” on page 23 if you need help with entering alphabetic characters.

6. Tap OK twice.
7. Tap Config. The **Exam Mode Configuration** screen appears.
8. Select those features you want disabled, and make sure that those features you don’t want disabled are not selected.
9. When you have finished selecting the features to be disabled, tap OK.

   Note that you can create exam mode configurations using the Connectivity Kit in much the same way you create them on an HP Prime. You can then activate them on multiple HP Primes, either via USB or by broadcasting them to a class using the wireless modules. For more information, install and launch the HP Connectivity Kit that came on your product CD. From the Connectivity Kit menu, click **Help** and select **HP Connectivity Kit User Guide**.

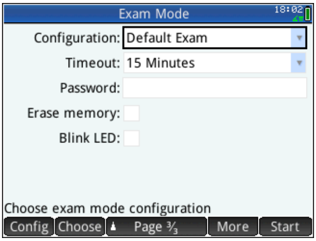
   If you want to activate exam mode now, continue with “Activating Exam Mode” below.

Activating Exam Mode

When you activate exam mode you prevent users of the calculator from accessing those features you have disabled. The features become accessible again at the end of the specified time-out period or on entry of the exam-mode password, whichever occurs sooner.

To activate exam mode:

1. If the **Exam Mode** screen is not showing, press Shift Settings, tap Page 1/4 ▼ and tap ▲ Page 2/4 ▼.



Exam Mode

Configuration: Default Exam

Timeout: 15 Minutes

Password:

Erase memory: □

Blink LED: □

Choose exam mode configuration

2. If a configuration other than `Default Exam` is required, choose it from the **Configuration** list.
3. Select a time-out period from the **Timeout** list.

   Note that 8 hours is the maximum period. If you are preparing to supervise a student examination, make sure that the time-out period chosen is greater than the duration of the examination.
4. Enter a password of between 1 and 10 characters. The password must be entered if you—or another user—wants to cancel exam mode before the time-out period has elapsed.
5. If you want to erase the memory of the calculator, select **Erase memory**. This will erase all user entries and return the calculator to its factory default settings.
6. If you want the exam mode indicator to flash periodically while the calculator is in exam mode, select **Blink LED**.
7. Using the supplied USB cable, connect a student's calculator.

   Insert the micro-A connector—the one with the rectangular end—into the USB port on the sending calculator, and the other connector into the USB port on the receiving calculator.
8. To activate the configuration on an attached calculator, tap Start. The **Exam Mode** screen closes. The connected calculator is now in exam

mode, with the specified disabled features not accessible to the user of that calculator.

9. Repeat from step 7 for each calculator that needs to have its functionality limited.

Cancelling exam mode

If you want to cancel exam mode before the set time period has elapsed, you will need to enter the password for the current exam mode activation.

1. If the **Exam Mode** screen is not showing, press Shift Settings, tap Page 1/4 ▼ and tap ▲ Page 2/4 ▼.
2. Enter the password for the current exam mode activation and tap OK twice.

You can also cancel exam mode using the Connectivity Kit. See the *HP Connectivity Kit User Guide* for more details.

Modifying configurations

Exam mode configurations can be changed. You can also delete a configuration and restore the default configuration.

To change a configuration

1. If the **Exam Mode** screen is not showing, press Shift Settings, tap Page 1/4 ▼ and tap ▲ Page 2/4 ▼.
2. Select the configuration you want to change from the Configuration list.
3. Tap Config.
4. Make whatever changes are necessary and then tap OK.

To return to the default configuration

1. Press Shift Settings. The **Home Settings screen** appears.
2. Tap Page ¼ ▼.
3. Tap ▲ Page 2/4 ▼.

   The **Exam Mode** screen appears.
4. Choose `Default Exam` from the **Configuration** list.
5. Tap More, select `Reset` from the menu and tap OK to confirm your intention to return the configuration to its default settings.

Deleting configurations

You cannot delete the default exam configuration (even if you have modified it). You can only delete those that you have created. To delete a configuration:

1. If the **Exam Mode** screen is not showing, press Shift Settings, tap Page ¼ ▼ and tap ▲ Page 2/4 ▼.
2. Select the configuration you want to delete from the **Configuration** list.
3. Tap More and choose `Delete`.
4. When asked to confirm the deletion, tap OK or press Enter ≈.

5

An introduction to HP apps

Much of the functionality of the HP Prime is provided in packages called HP apps. The HP Prime comes with 18 HP apps: 10 dedicated to mathematical topics or tasks, three specialized Solvers, three function Explorers, a spreadsheet, and an app for recording data streamed to the calculator from an external sensing device. You launch an app by first pressing Apps Info (which displays the **Application Library** screen) and tapping on the icon for the app you want.

What each app enables you to do is outlined in the following, where the apps are listed in alphabetical order.

App name	**Use this app to:**
Advanced Graphing	Explore the graphs of symbolic open sentences in *x* and y. Example: $x^2 + y^2 = 64$
DataStreamer	Collect real-world data from scientific sensors and export it to a statistics app for analysis.
Finance	Solve time-value-of-money (TVM) problems and amortization problems.
Function	Explore real-valued, rectangular functions of *y* in terms of *x*. Example: $y = 2x^2 + 3x + 5$
Geometry	Explore geometric constructions and perform geometric calculations.
Inference	Explore confidence intervals and hypothesis tests based on the Normal and Student's t-distributions.
Linear Explorer	Explore the properties of linear equations and test your knowledge.

App name	Use this app to: (Cont.)
Linear Solver	Find solutions to sets of two or three linear equations.
Parametric	Explore parametric functions of *x* and *y* in terms of *t*. Example: $x = \cos(t)$ and $y = \sin(t)$.
Polar	Explore polar functions of *r* in terms of an angle θ. Example: $r = 2\cos(4\theta)$
Quadratic Explorer	Explore the properties of quadratic equations and test your knowledge.
Sequence	Explore sequence functions, where *U* is defined 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	Explore equations in one or more real-valued variables, and systems of equations. Example: $x + 1 = x^2 - x - 2$
Spreadsheet	To solve problems or represent data best suited to a spreadsheet.
Statistics 1Var	Calculate one-variable statistical data (*x*)
Statistics 2Var	Calculate two-variable statistical data (*x* and *y*)
Triangle Solver	Find the unknown values for the lengths and angles of triangles.
Trig Explorer	Explore the properties of sinusoidal equations and test your knowledge.

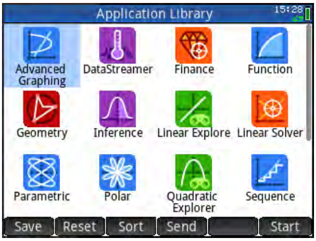
As you use an app to explore a lesson or solve a problem, you add data and definitions in one or more of the app's views. All this information is automatically saved in the app. You can come back to the app at any time and all the information is still there. You can also save a version of the app with a name you give it and then use the original app for another problem or purpose. See "Creating an app" on page 107 for more information about customizing and saving apps.

With one exception, all the apps mentioned above are described in detail in this user guide. The exception is the DataStreamer app. A brief introduction to this app is given in the HP Prime *Quick Start Guide*. Full details can be found in the *HP StreamSmart 410 User Guide*.

Application Library

Apps are stored in the Application Library, displayed by pressing Apps Info.

To open an app



1. Open the Application Library.
2. Find the app's icon and tap on it.

   You can also use the cursor keys to scroll to the app and, when it is highlighted, either tap Start or press Enter ≈.

To reset an app

You can leave an app at any time and all the data and settings in it are retained. When you return to the app, you can continue as you left off.

However, if you don't want to use the previous data and settings, you can return the app to its default state, that is, the state it was in when you opened it for the first time. To do this:

1. Open the Application Library.
2. Use the cursor keys to highlight the app.
3. Tap Reset.
4. Tap OK to confirm your intention.

You can also reset an app from within the app. From the main view of the app—which is usually, but not always, the Symbolic view—press Shift Esc Clear and tap OK to confirm your intention.

To sort apps

By default, the built-in apps in the Application Library are sorted chronologically, with the most recently used app shown first. (Customized apps always appear after the built-in apps.)

You can change the sort order of the built-in apps to:

- Alphabetically

  The app icons are sorted alphabetically by name, and in ascending order: A to Z.

- Fixed

  Apps are displayed in their default order: Function, Advanced Graphing, Geometry … Polar, and Sequence. Customized apps are placed at the end, after all the built-in apps. They appear in chronological order: oldest to most recent.

To change the sort order:

1. Open the Application Library.
2. Tap Sort.
3. From the **Sort Apps** list, choose the option you want.

To delete an app

The apps that come with the HP Prime are built-in and cannot be deleted, but you can delete an app you have created. To delete an app:

1. Open the Application Library.
2. Use the cursor keys to highlight the app.
3. Tap Delete.
4. Tap OK to confirm your intention.

Other options

The other options available in the Application Library are:

- Save

  Enables you to save a copy of an app under a new name. See “Creating an app” on page 107.

- Send

  Enables you to send an app to another HP Prime. See “Sharing data” on page 44.

App views

Most apps have three major views: Symbolic, Plot, and Numeric. These views are based on the symbolic, graphic, and numeric representations of mathematical objects. They are accessed through the Symb, Plot, and Num keys near the top left of the keyboard. Typically these views enable you to define a mathematical object—such as an expression or an open sentence—plot it, and see the values generated by it.

Each of these views has an accompanying setup view, a view that enables you to configure the appearance of the data in the accompanying major view. These views are called Symbolic Setup, Plot Setup, and Numeric Setup. They are accessed by pressing Esc Symb, Esc Plot, and Esc Num.

Not all apps have all the six views outlined above. The scope and complexity of each app determines its particular set of views. For example, the Spreadsheet app has no Plot view or Plot Setup view, and the Quadratic Explorer has only a Plot view. What views are available in each app is outlined in the next six sections.

Note that the DataStreamer app is not covered in this chapter. See *HP StreamSmart 410 User Guide* for information about this app.

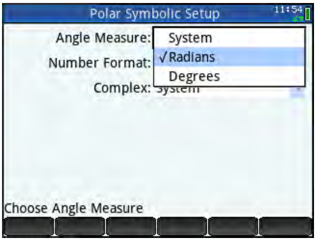
Symbolic view

The table below outlines what is done in the Symbolic view of each app.

App	**Use the Symbolic view to:**
Advanced Graphing	Specify up to 10 open sentences.
Finance	Not used
Function	Specify up to 10 real-valued, rectangular functions of *y* in terms of *x*.
Geometry	View the symbolic definition of geometric constructions.
Inference	Choose to conduct a hypothesis test or test a confidence level, and select a type of test.
Linear Explorer	Not used

App	Use the Symbolic view to: (Cont.)
Linear Solver	Not used
Parametric	Specify up to 10 parametric functions of *x* and *y* in terms of *t*.
Polar	Specify up to 10 polar functions of *r* in terms of an angle θ.
Quadratics Explorer	Not used
Sequence	Specify up to 10 sequence functions.
Solve	Specify up to 10 equations.
Spreadsheet	Not used
Statistics 1Var	Specify up to 5 univariate analyses.
Statistics 2Var	Specify up to 5 multivariate analyses.
Triangle Solver	Not used
Trig Explorer	Not used

Symbolic Setup view



Angle Measure: System
√Radians
Degrees

Number Format:

Complex: System

Choose Angle Measure

The Symbolic Setup view is the same for each app. It enables you to override the system-wide settings for angle measure, number format, and complex-number entry. The override applies only to the current app.

To change the settings for all apps, see "System-wide settings" on page 30.

Plot view

The table below outlines what is done in the Plot view of each app.

App	Use the Plot view to:
Advanced Graphing	Plot and explore the open sentences selected in Symbolic view.
Finance	Display an amortization graph.
Function	Plot and explore the functions selected in Symbolic view.
Geometry	Create and manipulate geometric constructions.
Inference	View a plot of the test results.
Linear Explorer	Explore linear equations and test your knowledge of them.
Linear Solver	Not used
Parametric	Plot and explore the functions selected in Symbolic view.
Polar	Plot and explore the functions selected in Symbolic view.
Quadratics Explorer	Explore quadratic equations and test your knowledge of them.
Sequence	Plot and explore the sequences selected in Symbolic view.
Solve	Plot and explore a single function selected in Symbolic view.
Spreadsheet	Not used
Statistics 1Var	Plot and explore the analyses selected in Symbolic view.
Statistics 2Var	Plot and explore the analyses selected in Symbolic view.
Triangle Solver	Not used
Trig Explorer	Explore sinusoidal equations and test your knowledge of them.

Plot Setup view

The table below outlines what is done in the Plot Setup view of each app.

App	Use the Plot Setup view to:
Advanced Graphing	Modify the appearance of plots and the plot environment.
Finance	Not used
Function	Modify the appearance of plots and the plot environment.
Geometry	Modify the appearance of the drawing environment.
Inference	Not used
Linear Explorer	Not used
Linear Solver	Not used
Parametric	Modify the appearance of plots and the plot environment.
Polar	Modify the appearance of plots and the plot environment.
Quadratics Explorer	Not used
Sequence	Modify the appearance of plots and the plot environment.
Solve	Modify the appearance of plots and the plot environment.
Spreadsheet	Not used
Statistics 1Var	Modify the appearance of plots and the plot environment.
Statistics 2Var	Modify the appearance of plots and the plot environment.
Triangle Solver	Not used
Trig Explorer	Not used

Numeric view

The table below outlines what is done in the Numeric view of each app.

App	Use the Numeric view to:
Advanced Graphing	View a table of numbers generated by the open sentences selected in Symbolic view.
Finance	Enter values for time-value-of-money calculations.
Function	View a table of numbers generated by the functions selected in Symbolic view.
Geometry	Perform calculations on the geometric objects drawn in Plot view.
Inference	Specify the statistics needed to perform the test selected in Symbolic view.
Linear Explorer	Not used
Linear Solver	Specify the coefficients of the linear equations to be solved.
Parametric	View a table of numbers generated by the functions selected in Symbolic view.
Polar	View a table of numbers generated by the functions selected in Symbolic view.
Quadratics Explorer	Not used
Sequence	View a table of numbers generated by the sequences selected in Symbolic view.
Solve	Enter the known values and solve for the unknown value.
Spreadsheet	Enter numbers, text, formulas, etc. The Numeric view is the primary view for this app.
Statistics 1Var	Enter data for analysis.
Statistics 2Var	Enter data for analysis.

App	Use the Numeric view to: (Cont.)
Triangle Solver	Enter known data about a triangle and solve for the unknown data.
Trig Explorer	Not used

Numeric Setup view

The table below outlines what is done in the Numeric Setup view of each app.

App	Use the Numeric Setup view to:
Advanced Graphing	Specify the numbers to be calculated according to the open sentences specified in Symbolic view, and set the zoom factor.
Finance	Not used.
Function	Specify the numbers to be calculated according to the functions specified in Symbolic view, and set the zoom factor.
Geometry	Not used
Inference	Not used
Linear Explorer	Not used
Linear Solver	Not used
Parametric	Specify the numbers to be calculated according to the functions specified in Symbolic view, and set the zoom factor.
Polar	Specify the numbers to be calculated according to the functions specified in Symbolic view, and set the zoom factor.
Quadratics Explorer	Not used.
Sequence	Specify the numbers to be calculated according to the sequences specified in Symbolic view, and set the zoom factor.
Solve	Not used

App	Use the Numeric Setup view to: (Cont.)
Spreadsheet	Not used
Statistics 1Var	Not used
Statistics 2Var	Not used
Triangle Solver	Not used
Trig Explorer	Not used

Quick example

The following example uses all six app views and should give you an idea of the typical workflow involved in working with an app. The Polar app is used as the sample app.

Open the app

1. Open the Application Library by pressing Apps Info.
2. Tap once on the icon of the Polar app.

   The Polar app opens in Symbolic View.

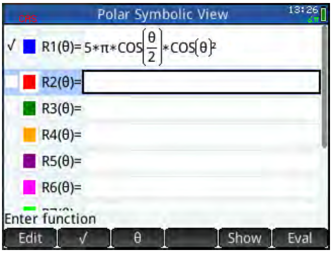
Symbolic view

The Symbolic view of the Polar app is where you define or specify the polar equation you want to plot and explore. In this example we will plot and explore the equation $r = 4\pi\cos(\theta/2)\cos(\theta)^2$.

3. Define the equation $r = 4\pi\cos(\theta/2)\cos(\theta)^2$ by entering:

   4 Shift 3 COS θ ÷ 2 ▶ ▶ COS θ ▶ x² Enter

   (If you are using algebraic entry mode, you would enter 4 Shift 3 COS ÷ 2 ▶ COS θ θ ▶ x² Enter.)



Polar Symbolic View

✓ 🟦 R1(θ)= 5*π*COS(θ/2)*COS(θ)²

🟥 R2(θ)=

🟩 R3(θ)=

🟧 R4(θ)=

🟪 R5(θ)=

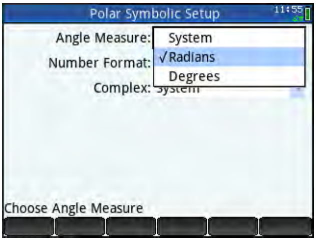
🟪 R6(θ)=

Enter function

This equation will draw symmetrical petals provided that the angle measure is set to radians. The angle measure for this app is set in the Symbolic Setup view.

Symbolic Setup view

4. Press Shift Symb.
5. Select `Radians` from the **Angle Measure** menu.



Polar Symbolic Setup 11:55

Angle Measure: System / √Radians / Degrees

Number Format:

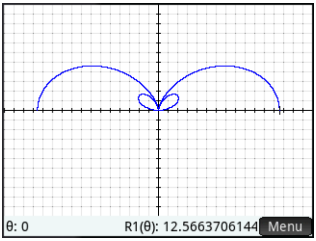
Complex: System

Choose Angle Measure

Plot view

6. Press Plot.

   A graph of the equation is plotted. However, as the illustration at the right shows, only a part of the petals is visible. To see the rest you will need to change the plot setup parameters.

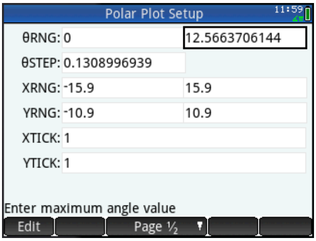


θ: 0 R1(θ): 12.5663706144 Menu

Plot Setup View

7. Press Shift Plot.
8. Set the second θ**RNG** field to 4π by entering:

   ▶ 4 Shift π 3 # (π) OK



Polar Plot Setup 11:59

θRNG: 0 12.5663706144

θSTEP: 0.1308996939

XRNG: -15.9 15.9

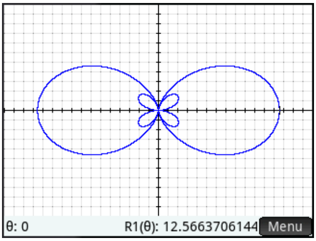
YRNG: -10.9 10.9

XTICK: 1

YTICK: 1

Enter maximum angle value

9. Press Plot to return to Plot view and see the complete plot.

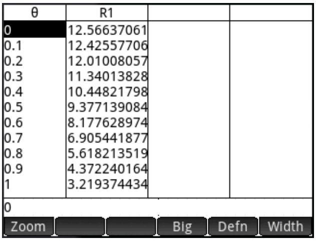


θ: 0 R1(θ): 12.5663706144 Menu

Numeric View

The values generated by the equation can be seen in Numeric view.

10. Press Num Setup .



θ	R1		
0	12.56637061		
0.1	12.42557706		
0.2	12.01008057		
0.3	11.34013828		
0.4	10.44821798		
0.5	9.377139084		
0.6	8.177628974		
0.7	6.905441877		
0.8	5.618213519		
0.9	4.372240164		
1	3.219374434		

0

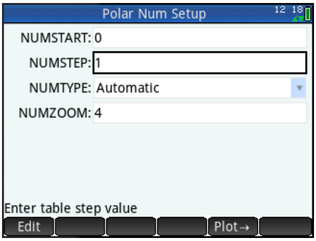
Suppose you want to see just whole numbers for θ; in other words, you want the increment between consecutive values in the θ column to be 1. You set this up in the Numeric Setup view.

Numeric Setup View

11. Press Shift Num Setup .

12. Change the **NUMSTEP** field to 1.

13. Press Num Setup to return to Numeric view.



Polar Num Setup

NUMSTART: 0

NUMSTEP: 1

NUMTYPE: Automatic

NUMZOOM: 4

Enter table step value

You will see that the θ column now contains consecutive integers starting from zero, and the corresponding values calculated by the equation specified in Symbolic view are listed in the R1 column.

Common operations in Symbolic view

[Scope: Advanced Graphing, Function, Parametric, Polar, Sequence, Solve. See dedicated app chapters for information about the other apps.]

Symbolic view is typically used to define a function or open sentence that you want to explore (by plotting and/or evaluating). In this section, the term *definition* will be used to cover both functions and open sentences.

Press Symb Setup to open Symbolic view.

Add a definition

With the exception of the Parametric app, there are 10 fields for entering definitions. In the Parametric app there are 20 fields, two for each paired definition.

1. Highlight an empty field you want to use, either by tapping on it or scrolling to it.
2. Enter your definition.

   If you need help, see “Definitional building blocks” on page 82.
3. Tap OK or press Enter when you have finished.

   Your new definition is added to the list of definitions.

   Note that variables used in definitions must be in uppercase. A variable entered in lowercase will cause an error message to appear.

Modify a definition

1. Highlight the definition you want to modify, either by tapping on it or scrolling to it.
2. Tap Edit.

   The definition is copied to the entry line.
3. Modify the definition.
4. Tap OK or press Enter when you have finished.

Definitional building blocks

The components that make up a symbolic definition can come from a number of sources.

- From the keyboard

  You can enter components directly from the keyboard. To enter $2X^2 – 3$, just press 2 ALPHA X x^2 − 3.

- From user variables

  If, for example, you have created a variable called COST, you could incorporate that into a definition either by typing it or choosing it from the **User** menu (one of the sub-menus of the Variables menu). Thus you could have a definition that reads `F1(X)=X²+COST`.

  To select a user variable, press Vars, tap User, select **User Variables**, and then select the variable of interest.

- From Home variables

  Some Home variables can be incorporated into a symbolic definition. To access a Home variable, press Vars, tap Home, select a category of variable, and select the variable of interest. Thus you could have a definition that reads F1(X)=X^2+Q. (Q is on the **Real** sub-menu of the **Home** menu.)

  Home variables are discussed in detail in chapter 28, “Troubleshooting”, beginning on page 507.

- From app variables

  All settings, definitions, and results, for all apps, are stored as variables. Many of these variables can be incorporated into a symbolic definition. To access app variables, press Vars, tap App, select the app, select the category of variable, and then select the variable of interest. You could, for instance, have a definition that reads F2(X)=X^2+X−Root. The value of the last root calculated in the Function app is substituted for Root when this definition is evaluated.

  App variables are discussed in detail in chapter 28, “Troubleshooting”, beginning on page 507.

- From math functions

  Some of the functions on the **Math** menu can be incorporated into a definition. The **Math** menu is one of the Toolbox menus (Mem). The following definition combines a math function (Size) with a Home variable (L1): F4(X)=X^2−SIZE(L1). It is equivalent to $x^2 – n$ where *n* is the number of elements in the list named L1. (Size is an option on the **List** menu, which is a sub-menu of the **Math** menu.)

- From CAS functions

  Some of the functions on the **CAS** menu can be incorporated into a definition. The **CAS** menu is one of the Toolbox menus (Mem). The following definition incorporates the CAS function irem: F5(X)=X^2+CAS.irem(45,7). (irem is entered by choosing Remainder, an option on the **Division** menu, which is a sub-menu of the **Integer** menu. Note that any CAS command or function selected to operate outside the CAS is given the CAS. prefix.)

- From app functions

  Some of the functions on the **App** menu can be incorporated into a definition. The **App** menu is one of the Toolbox menus (Mem). The following definition incorporates the app function PredY:

  F9(X)=X^2+Statistics_2Var.PredY(6).

- From the **Catlg** menu

  Some of the functions on the **Catlg** menu can be incorporated into a definition. The **Catlg** menu is one of the Toolbox menus (Mem). The following definition incorporates a command from that menu and an app variable: F6(X)=X^2+INT(Root). The integer value of the last root calculated in the Function app is substituted for INT(Root) when this definition is evaluated.

- From other definitions

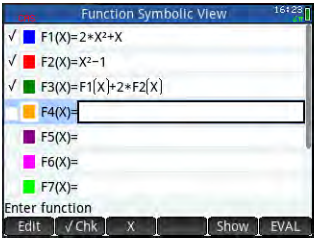
  You could, for example, define F3(X) as F1(X)*F2(X).

Evaluate a dependent definition

If you have a dependent definition—that is, one defined in terms of another definition—you can combine all the definitions into one by evaluating the dependent definition.

1. Select the dependent expression.
2. Tap Eval.

Consider the example at the right. Notice that F3(X) is defined in terms of two other functions. It is a dependent definition and can be evaluated. If you highlight F3(X) and tap Eval, F3(X) becomes 2*X^2+X+ 2*(X^2–1).



Function Symbolic View

√ F1(X)=2*X^2+X

√ F2(X)=X^2–1

√ F3(X)=F1(X)+2*F2(X)

F4(X)=

F5(X)=

F6(X)=

F7(X)=

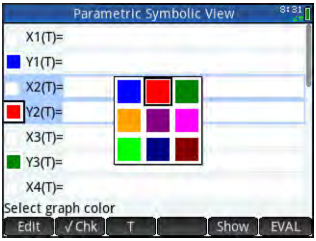
Enter function

Select or deselect a definition to explore

In the Advanced Graphing, Function, Parametric, Polar, Sequence, and Solve apps you can enter up to 10 definitions. However, only those definitions that are selected in Symbolic view will be plotted in Plot view and evaluated in Numeric view.

You can tell if a definition is selected by the tick (or checkmark) beside it. A checkmark is added by default as soon as you create a definition. So if you don't want to plot or evaluate a particular definition, highlight it and tap √. (Do likewise if you want to re-select a deselected function.)

Choose a color for plots


Parametric Symbolic View 8:31
X1(T)=
🟦 Y1(T)=
X2(T)=
🟥 Y2(T)=
X3(T)=
🟩 Y3(T)=
X4(T)=
Select graph color

Each function and open sentence can be plotted in a different color. If you want to change the default color of a plot:

1. Tap the colored square to the left of the function's definition.

   You can also select the square by pressing Enter while the definition is selected. Pressing Enter moves the selection from the definition to the colored square and from the colored square to the definition.

2. tap Choose.
3. Select the desired color from the color-picker.

Delete a definition

To delete a single definition:

1. Tap once on it (or highlight it using the cursor keys).
2. Press Del.

To delete all the definitions:

1. Press Shift Esc Clear.
2. Tap OK or press Enter to confirm your intention.

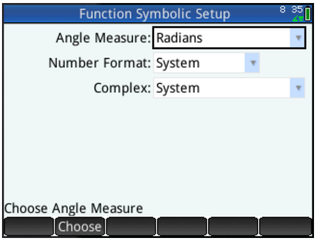
Symbolic view: Summary of menu buttons

Button	Purpose
Edit	Copies the highlighted definition to the entry line for editing. Tap OK when done. To add a new definition—even one that is replacing an existing one—highlight the field and just start entering your new definition.
√	Selects (or deselects) a definition.
X [Function only]	Enters the independent variable in the Function app. You can also press xtθn.
X [Advanced Graphing only]	Enters an X in the Advanced Graphing app. You can also press xtθn.
Y [Advanced Graphing only]	Enters an Y in the Advanced Graphing app.
T [Parametric only]	Enters the independent variable in the Parametric app. You can also press xtθn.
θ [Polar only]	Enters the independent variable in the Polar app. You can also press xtθn.
N [Sequence only]	Enters the independent variable in the Sequence app. You can also press xtθn.
= [Solve only]	Enters the equals sign in the Solve app. A shortcut equivalent to pressing Shift ≐.
Show	Displays the selected definition in full-screen mode. See “Large results” on page 40 for more information.
Eval	Evaluates dependent definitions. See “Evaluate a dependent definition” on page 84.

Common operations in Symbolic Setup view

[Scope: all apps]

The Symbolic Setup view is the same for all apps. Its primary purpose is to allow you to override three of the system-wide settings specified on the **Home Settings** window.


Function Symbolic Setup

Angle Measure: Radians

Number Format: System

Complex: System

Choose Angle Measure

Press Shift Symb Setup to open Symbolic Setup view.

Override system-wide settings

1. Tap once on the setting you want to change.

   You can tap on the field name or the field.

2. Tap again on the setting.

   A menu of options appears.

3. Select the new setting.

   Note that selecting the `Fixed`, `Scientific`, or `Engineering` option on the **Number Format** menu displays a second field for you to enter the required number of significant digits.

You could also select a field, tap Choose, and select the new setting.

Restore default settings

To restore default settings is to return precedence to the settings on the **Home Settings** screen.

To restore one field to its default setting:

1. Select the field.
2. Press Del.

To restore all default settings, press Shift Esc Clear.

Common operations in Plot view

Plot view functionality that is common to many apps is described in detail in this section. Functionality that is available only in a particular app is described in the chapter dedicated to that app.

Press Plot Setup to open Plot view.

Zoom

[Scope: Advanced Graphing, Function, Parametric, Polar, Sequence, Solve, Statistics 1 Var, and Statistics 2Var. Also, to a limited degree, Geometry.]

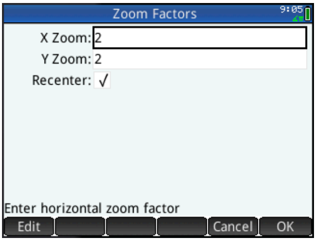
Zooming redraws the plot on a larger or smaller scale. It is a shortcut for changing the range settings in Plot Setup view. The extent of most zooms is determined by two zoom factors: a horizontal and a vertical factor. By default, these factors are both 2. Zooming out *multiplies* the scale by the factor, 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.

Zoom factors

To change the default zoom factors:

1. Open the Plot view of the app (Plot Setup).
2. Tap Menu to open the Plot view menu.
3. Tap Zoom to open the Zoom menu.
4. Scroll and select **Set Factors.**

   The **Zoom Factors** screen appears.



Zoom Factors

X Zoom: 2

Y Zoom: 2

Recenter: ✓

Enter horizontal zoom factor

5. Change one or both zoom factors.
6. If you want the plot to be centered around the current position of the cursor in Plot view, select **Recenter**.
7. Tap OK or press Enter ≈.

Zoom options

Zoom options are available from three sources:

- the keyboard
- the Zoom menu in Plot view
- the **Views** menu (View Copy).

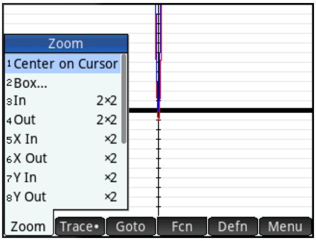
Zoom keys

There are two zoom keys: pressing + zooms in and pressing − zooms out. The extent of the scaling is determined by the **ZOOM FACTOR** settings (explained above).

Zoom menu

In Plot view, tap Zoom and tap an option. (If Zoom is not displayed, tap Menu.)

The zoom options are explained in the following table. Examples are provided on "Zoom examples" on page 91.



Option	Result
Center on Cursor	Redraws the plot so that the cursor is in the center of the screen. No scaling occurs.
Box	Explained in "Box zoom" on page 90.
In	Divides the horizontal and vertical scales by **X Zoom** and **Y Zoom** (values set with the **Set Factors** option explained on page 88). For instance, if both zoom factors are 4, then zooming in results in 1/4 as many units depicted per pixel. (Shortcut: press +.)
Out	Multiplies the horizontal and vertical scales by the **X Zoom** and **Y Zoom** settings. (Shortcut: press −.)
X In	Divides the horizontal scale only, using the **X Zoom** setting.
X Out	Multiplies the horizontal scale only, using the **X Zoom** setting.
Y In	Divides the vertical scale only, using the **Y Zoom** setting.
Y Out	Multiplies the vertical scale only, using the **Y Zoom** setting.

Option	Result (Cont.)
Square	Changes the vertical scale to match the horizontal scale. This is useful after you have done a box zoom, X zoom or Y zoom.
Autoscale	Rescales the vertical axis so that the display shows a representative piece of the plot given the supplied *x* axis settings. (For Sequence, Polar, parametric, and Statistics apps, autoscaling rescales both axes.) The autoscale process uses the first selected function to determine the best scale to use.
Decimal	Rescales both axes so each pixel is 0.1 units. This is equivalent to resetting the default values for **XRNG** and **YRNG**.
Integer	Rescales the horizontal axis only, making each pixel equal to 1 unit.
Trig	Rescales the horizontal axis so that 1 pixel equals π/24 radians or 7.5 degrees; rescales the vertical axis so that 1 pixel equals 0.1 units.
Undo Zoom	Returns the display to the previous zoom, or if there has been only one zoom, displays the graph with the original plot settings.

Box zoom

A box zoom enables you to zoom in on an area of the screen that you specify.

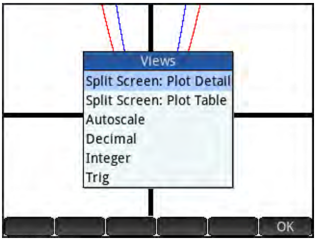
1. With the Plot view menu open, tap Zoom and select `Box`.
2. Tap one corner of the area you want to zoom in on and then tap OK.
3. Tap the diagonally opposite corner of the area you want to zoom in on and then tap OK.

   The screen fills with the area you specified. To return to the default view, tap Zoom and select `Decimal`.

You can also use the cursor keys to specify the area you want to zoom in on.

Views menu

The most commonly used zoom options are also available on the **Views** menu. These are:

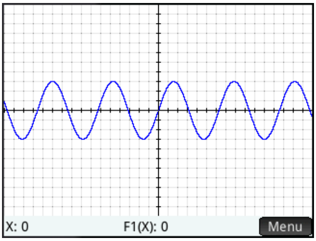


- Autoscale
- Decimal
- Integer
- Trig.

These options—which can be applied whatever view you are currently working in—are explained in the table immediately above.

Testing a zoom with split-screen viewing

A useful way of testing a zoom is to divide the screen into two halves, with each half showing the plot, and then to apply a zoom only to one side of the screen. The illustration at the right is a plot of $y = 3\sin x$. To split the screen into two halves:

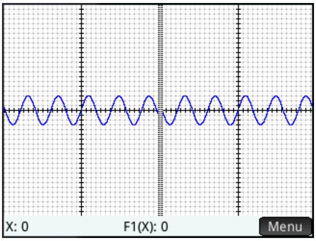


1. Open the **Views** menu.

   Press View Copy

2. Select `Split Screen: Plot Detail.`

   The result is shown at the right. Any zoom operation you undertake will be applied only to the copy of the plot in the right-hand half of the screen. This will help you test and then choose an appropriate zoom.



Note that you can replace the original plot on the left with the zoomed plot on the right by tapping ←Plot.

To un-split the screen, press Plot Setup.

Zoom examples

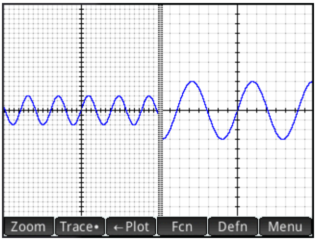
The following examples show the effects of the zooming options on a plot of $3\sin x$ using the default zoom factors (2 × 2). Split-screen mode (described above) has been used to help you see the effect of zooming.

Note that there is an Unzoom option on the **Zoom** menu. Use this to return a plot to its pre-zoom state. If the **Zoom** menu is not shown, tap Menu.

Zoom In

Zoom In

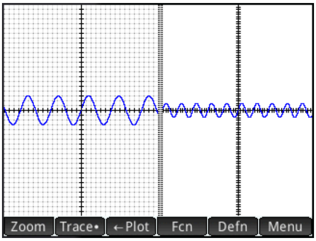
Shortcut: press +



Zoom Out

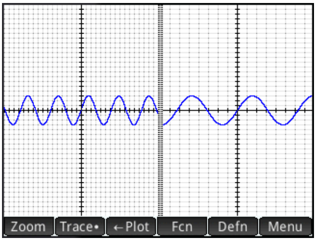
Menu Zoom Out

Shortcut: press −



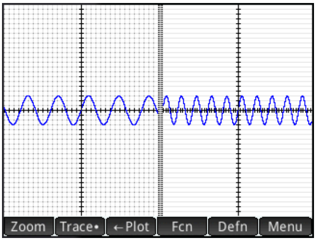
X In

Zoom X In



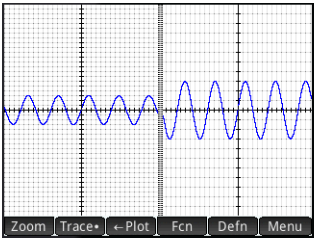
X Out

Zoom X Out



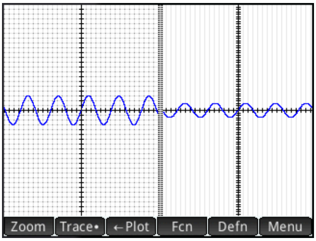
Y In

Zoom Y In



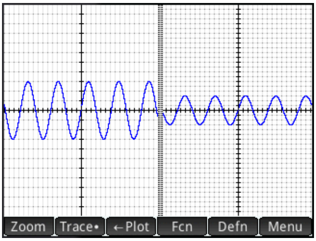
Y Out

Zoom Y Out



Square

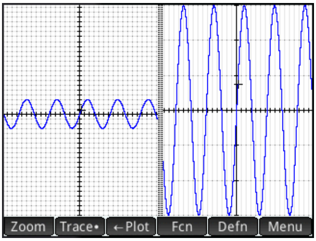
Zoom Square



Notice that in this example, the plot on left has had a Y In zoom applied to it. The Square zoom has returned the plot to its default state where the X and Y scales are equal.

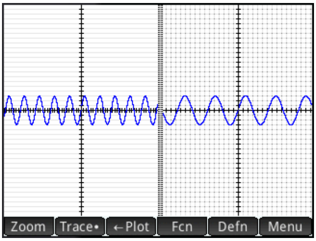
Autoscale

Zoom Autoscale



Decimal

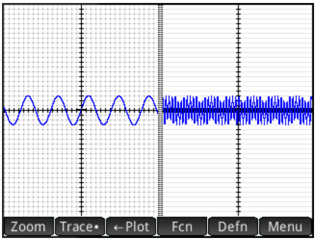
Zoom Decimal



Notice that in this example, the plot on left has had a X In zoom applied to it. The Decimal zoom has reset the default values for the *x*-range and *y*-range.

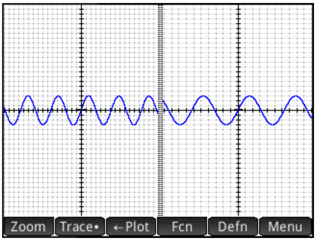
Integer

Zoom Integer



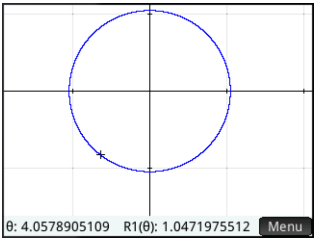
Trig

Zoom Trig



Trace

[Scope: Advanced Graphing, Function, Parametric, Polar, Sequence, Solve, Statistics 1 Var, and Statistics 2Var.]



The tracing functionality enables you to move a cursor (the *trace cursor*) along the current graph. You move the trace cursor by pressing ◀ or ▶. You can also move the trace cursor by tapping on or near the current plot. The trace cursor jumps to the point on the plot that is closest point to where you tapped.

The current coordinates of the cursor are shown at the bottom of the screen. (If menu buttons are hiding the coordinates, tap Menu to hide the buttons.)

Trace mode and coordinate display are automatically turned on when a plot is drawn.

To select a plot

Except in the Advanced Graphing app, if there is more than one plot displayed, press ▲ or ▼ until the trace cursor is on the plot you are interested in.

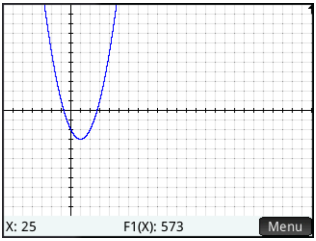
In the Advanced Graphing app, tap-and-hold on the plot you are interested in. Either the plot is selected, or a menu of plots appears for you select one.

To evaluate a definition

One of the primary uses of the trace functionality is to evaluate a plotted definition. Suppose in Symbolic view you have defined `F1(X)` as $(X-1)^2-3$. Suppose further that you want to know what the value of that function is when X is 25.

1. Open Plot view (Plot Setup).
2. If the menu at the bottom of the screen is not open, tap Menu.
3. If more than one definition is plotted, ensure that the trace cursor is on the plot of the definition you want to evaluate. You can press Defn to see the definition of a plot, and press ▲ or ▼ to move the trace cursor from plot to plot.
4. If you pressed Defn to see the definition of a plot, the menu at the bottom of the screen will be closed. Tap Menu to re-open it.
5. Tap Go To.
6. Enter 25 and tap OK.
7. Tap Menu.

   The value of `F1(X)` when X is 25 as shown at the bottom of the screen.


X: 25 F1(X): 573

This is one of many ways the HP Prime provides for you to evaluate a function for a specific independent variable. You can also evaluate a function in Numeric view (see page 102). Moreover, any expression you define in Symbolic view can be evaluated in Home view. For example, suppose `F1(X)` is defined as $(x-1)^2-3$. If you enter `F1(4)` in Home view and press Enter ≈ you get 6, since $(4-1)^2-3 = 6$.

To turn tracing on or off

- To turn off tracing, tap Trace•.
- To turn on tracing, tap Trace.

If these options are not displayed, tap Menu.

When tracing is off, pressing the cursor keys no longer constrains the cursor to a plot.

Plot view: Summary of menu buttons

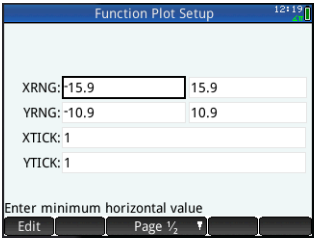
Button	Purpose
Zoom	Displays a menu of zoom options. See “Zoom options” on page 88.
Trace•/Trace	A toggle button for turning off and turning on trace functionality. See “Trace” on page 94.
Go To	Displays an input form for you to specify a value you want the cursor to jump to. The value you enter is the value of the independent variable.
Fcn [Function only]	Displays a menu of options for analyzing a plot. See “Analyzing functions” on page 118.
Defn	Displays the definition responsible for generating the selected plot.
Menu	A toggle button that shows and hides the other buttons across the bottom of the screen.

Common operations in Plot Setup view

This section covers only operations common to the apps mentioned. See the chapter dedicated to an app for the app-specific operations done in Plot Setup view.

Press Shift Plot Setup to open Plot Setup view.

Configure Plot view


Function Plot Setup

XRNG: -15.9 15.9
YRNG: -10.9 10.9
XTICK: 1
YTICK: 1

Enter minimum horizontal value

[Scope: Advanced Graphing, Function, Parametric, Polar, Sequence, Statistics 1 Var, Statistics 2Var]

The Plot Setup view is used to configure the appearance of Plot view and to set the method by which graphs are plotted. The configuration options are spread across two pages. Tap Page ½ ▼ to move from the first to the second page, and ▲ Page ²⁄₂ to return to the first page.

Tip When you go to Plot view to see the graph of a definition selected in Symbolic view, there may be no graph shown. The likely cause of this is that the spread of plotted values is outside the range settings in Plot Setup view. A quick way to bring the graph into view is to press View Copy and select `Autoscale`. This also changes the range settings in Plot Setup view.

Page 1

Setup field	Purpose
TRNG [Parametric only]	Sets the range of T-values to be plotted. Note that here are two fields: one for the minimum and one for the maximum value.
TSTEP [Parametric only]	Sets the increment between consecutive T-values.
θ**RNG** [Polar only]	Sets the range of angle values to be plotted. Note that here are two fields: one for the minimum and one for the maximum value.
θ**STEP** [Polar only]	Sets the increment between consecutive angle values.
SEQPLOT [Sequence only]	Sets the type of plot: Stairstep or Cobweb.
NRNG [Sequence only]	Sets the range of N-values to be plotted. Note that here are two fields: one for the minimum and one for the maximum value.
HWIDTH [Stats 1 Var only]	Sets the width of the bars in a histogram.
HRNG [Stats 1 Var only]	Sets the range of values to be included in a histogram. Note that here are two fields: one for the minimum and one for the maximum value.

Setup field	Purpose (Cont.)
S*MARK [Stats 2 Var only]	Sets the graphic that will be used to represent a data point in a scatter plot. A different graphic can be used for each of the five analyses that can be plotted together.
XRNG	Sets the initial range of the *x*-axis. Note that here are two fields: one for the minimum and one for the maximum value. In Plot view the range can be changed by panning and zooming.
YRNG	Sets the initial range of the *y*-axis. Note that there are two fields: one for the minimum and one for the maximum value. In Plot view the range can be changed by panning and zooming.
XTICK	Sets the increment between tickmarks on the *x*-axis.
YTICK	Sets the increment between tickmarks on the *y*-axis.

Page 2

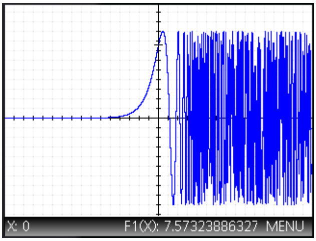
Setup field	Purpose
AXES	Shows or hides the axes.
LABELS	Places values at the ends of each axis to show the current range of values.
GRID DOTS	Places a dot at the intersection of each horizontal and vertical grid line.
GRID LINES	Draws a horizontal and vertical grid line at each integer *x*-value and *y*-value.
CURSOR	Sets the appearance of the trace cursor: standard, inverting, or blinking.
CONNECT [Stats 2 Var only]	Connects the data points with straight segments.

Setup field	**Purpose (Cont.)**
METHOD [Not in either statistics app]	Sets the graphing method to adaptive, fixed-step segments, or fixed-step dots. Explained below.

Graphing methods

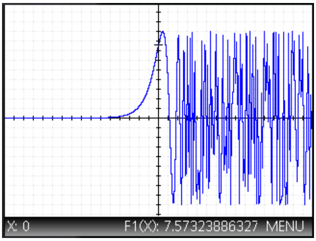
The HP Prime gives you the option of choosing one of three graphing methods. The methods are described below, with each applied to the function f(x) = 9*sin(e^x).

- *adaptive*: this gives very accurate results and is used by default. With this method active, some complex functions may take a while to plot. In these cases, Stop appears on the menu bar, enabling you to stop the plotting process if you wish.



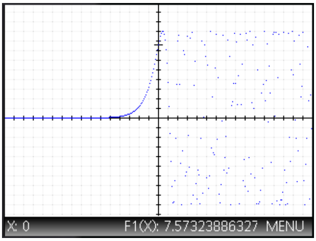
X: 0 F1(X): 7.57323886327

- *fixed-step segments*: this method samples *x*-values, computes their corresponding *y*-values, and then plots and connects the points.



X: 0 F1(X): 7.57323886327

- *fixed-step dots*: this works like fixed-step segments method but does not connect the points.



X: 0 F1(X): 7.57323886327

Restore default settings

[Scope: Advanced Graphing, Function, Parametric, Polar, Sequence, Solve, Statistics 1 Var, Statistics 2Var, Geometry.]

To restore one field to its default setting:

1. Select the field.
2. Press Del.

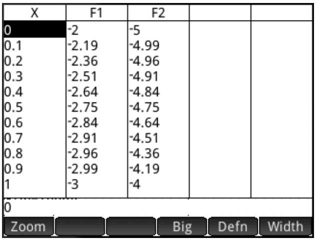
To restore all default settings, press Shift Esc Clear.

Common operations in Numeric view

[Scope: Advanced Graphing, Function, Parametric, Polar]

Numeric view functionality that is common to many apps is described in detail in this section. Functionality that is available only in a particular app is described in the chapter dedicated to that app.

Numeric view provides a table of evaluations. Each definition in Symbolic view is evaluated for a range of values for the independent variable. You can set the range and fineness of the independent variable, or leave it to the default settings.



X	F1	F2		
0	-2	-5		
0.1	-2.19	-4.99		
0.2	-2.36	-4.96		
0.3	-2.51	-4.91		
0.4	-2.64	-4.84		
0.5	-2.75	-4.75		
0.6	-2.84	-4.64		
0.7	-2.91	-4.51		
0.8	-2.96	-4.36		
0.9	-2.99	-4.19		
1	-3	-4		

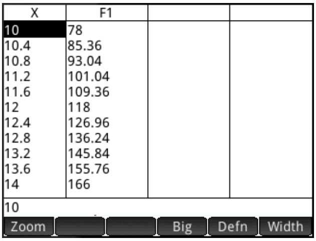
0

Press Num Setup to open Numeric view.

Zoom

Unlike in Plot view, zooming in Numeric view does not affect the size of what is displayed. Instead, it changes the increment between consecutive values of the independent variable (that is, the **NUMSTEP** setting in the Numeric Setup view: see page 105). Zooming in decreases the increment; zooming out increases the increment. The row that was highlighted before the zoom remains unchanged.

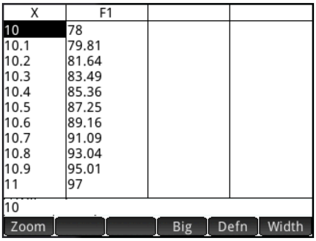
For the ordinary zoom in and zoom out options, the degree of zooming is determined by the zoom factor. In Numeric view this is the **NUMZOOM** field in the Numeric Setup view. The default value is 4. Thus if the current increment (that is, the **NUMSTEP** value) is 0.4, zooming in will further divide that interval by four smaller intervals. So instead of *x*-values of 10, 10.4, 10,8, 11.2 etc., the *x*-values will be 10, 10.1, 10.2, 10.3, 10.4, etc. (Zooming out does the opposite: 10, 10.4, 10,8, 11.2 etc. becomes10, 11.6, 13.2, 14.8, 16.4, etc.).



X	F1		
10	78		
10.4	85.36		
10.8	93.04		
11.2	101.04		
11.6	109.36		
12	118		
12.4	126.96		
12.8	136.24		
13.2	145.84		
13.6	155.76		
14	166		

10

Before zooming



X	F1		
10	78		
10.1	79.81		
10.2	81.64		
10.3	83.49		
10.4	85.36		
10.5	87.25		
10.6	89.16		
10.7	91.09		
10.8	93.04		
10.9	95.01		
11	97		

10

After zooming

Zoom options

In Numeric view, zoom options are available from two sources:

- the keyboard
- the Zoom menu in Numeric view.

Note that any zooming you do in Numeric view does not affect Plot view, and vice versa. However, if you choose a zoom option from the **Views** menu (View Copy) while you are in Numeric view, Plot view is displayed with the plots zoomed accordingly. In other words, the zoom options on the **Views** menu apply only to Plot view.

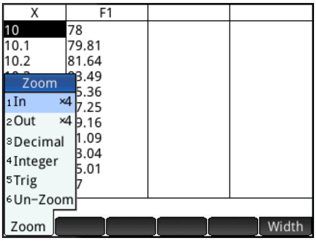
Zooming in Numeric view automatically changes the **NUMSTEP** value in the Numeric Setup view.

Zoom keys

There are two zoom keys: pressing + zooms in and pressing − zooms out. The extent of the scaling is determined by the **NUMZOOM** setting (explained above).

Zoom menu

In Numeric view, tap Zoom and tap an option.



X	F1		
10	78		
10.1	79.81		
10.2	81.64		

The zoom options are explained in the following table.

Option	Result
In	The increment between consecutive values of the independent variable becomes the current value divided by the **NUMZOOM** setting. (Shortcut: press +.)
Out	The increment between consecutive values of the independent variable becomes the current value multiplied by the **NUMZOOM** setting. (Shortcut: press −.)
Decimal	Restores the default **NUMSTART** and **NUMSTEP** values: 0 and 0.1 respectively.
Integer	The increment between consecutive values of the independent variable is set to 1.
Trig	• If the angle measure setting is radians, sets the increment between consecutive values of the independent variable to π/24 (approximately 0.1309). • If the angle measure setting is degrees, sets the increment between consecutive values of the independent variable to 7.5.
Undo Zoom	Returns the display to the previous zoom, or if there has been only one zoom, displays the graph with the original plot settings.

Evaluating

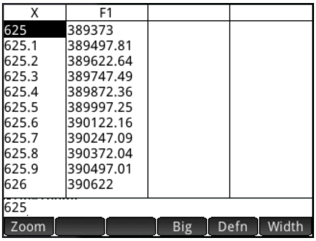
You can step through the table of evaluations in Numeric view by pressing ▲ or ▼. You can also quickly jump to an evaluation by entering the independent variable of interest in the independent variable column and tapping OK.

For example, suppose in the Symbolic view of the Function app, you have defined `F1(X)` as $(X-1)^2-3$. Suppose further that you want to know what the value of that function is when X is 625.

1. Open Numeric view (Num).
2. Anywhere in the independent column—the left-most column—enter 625.

3. Tap OK.

   Numeric view is refreshed, with the value you entered in the first row and the result of the evaluation in a cell to the right. In this example, the result is 389373.



X	F1		
625	389373		
625.1	389497.81		
625.2	389622.64		
625.3	389747.49		
625.4	389872.36		
625.5	389997.25		
625.6	390122.16		
625.7	390247.09		
625.8	390372.04		
625.9	390497.01		
626	390622		

625

Custom tables

If you choose `Automatic` for the **NUMTYPE** setting, the table of evaluations in Numeric view will follow the settings in the Numeric Setup view. That is, the independent variable will start with the **NUMSTART** setting and increment by the **NUMSTEP** setting. (These settings are explained in “Common operations in Numeric Setup view” on page 105.) However, you can choose to build your own table where just the values you enter appear as independent variables.

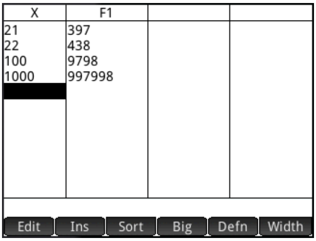
1. Open Numeric Setup view.

   Shift Num Setup

2. Choose `BuildYourOwn` from the **NUMTYPE** menu.
3. Open Numeric view.

   Numeric view will be empty.

4. In the independent column—the left-most column—enter a value of interest.
5. Tap OK.
6. If you still have other values to evaluate, repeat from step 4.



X	F1		
21	397		
22	438		
100	9798		
1000	997998		

Deleting data

To delete one row of data in your custom table, place the cursor in that row and press Del.

To delete all the data in your custom table:

1. Press Shift Esc Clear.
2. Tap OK or press Enter ≈ to confirm your intention.

Numeric view: Summary of menu buttons

Button	**Purpose**
Zoom	To modify the increment between consecutive values of the independent variable in the table of evaluations. See page 100.
Edit [BuildYourOwn only]	To edit the value in the selected cell. To overwrite the value in the selected cell, you can just start entering a new value without first tapping Edit . Only visible if **NUMTYPE** is set to `BuildYourOwn`. See "Custom tables" on page 103.
Ins [BuildYourOwn only]	To create a new row above the currently highlighted cell, with zero as the independent value. You can immediately start typing a new value. Only visible if **NUMTYPE** is set to `BuildYourOwn`. See "Custom tables" on page 103.
Sort [BuildYourOwn only]	To sort the values in the selected column in ascending or descending order. Move the cursor to the column of interest, tap Sort , select `Ascending` or `Descending`, and tap OK . Only visible if **NUMTYPE** is set to `BuildYourOwn`. See "Custom tables" on page 103.
Size	Lets you choose between small, medium, and large font.
Defn	Toggles between showing the value of the cell and the definition that generated the value.

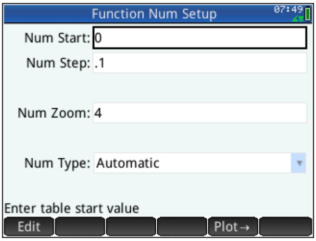
Button	Purpose (Cont.)
Column	Displays a menu for you to choose to display the evaluations of 1, 2, 3, or 4 defintions. If you have more than four definitions seelcted in Symbolic view, you can press ▶ to scroll rightwards and see more columns. Pressing ◀ scrolls the columns leftwards.

Common operations in Numeric Setup view

[Scope: Advanced Graphing, Function, Parametric, Polar, Sequence]

Press Shift Num Setup to open Numeric Setup view.

The Numeric Setup view is used to:


Function Num Setup

Num Start: 0

Num Step: .1

Num Zoom: 4

Num Type: Automatic

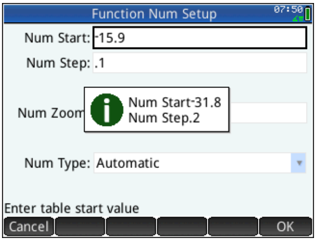
Enter table start value

- set the starting number for the independent variable in automatic tables displayed in Numeric view: the **Num Start** field.
- set the increment between consecutive numbers in automatic tables displayed in Numeric view: the **Num Step** field.
- specify whether the table of data to be displayed in Numeric view is to be based on the specified starting number and increment (automatic table) or to based on particular numbers for the independent variable that your specify (build-your-own table): the **Num Type** field.
- set the zoom factor for zooming in or out on the table displayed in Numeric view: the **Num Zoom** field.

Modifying Numeric Setup

Select the field you want to change and either specify a new value, or if you are choosing a type of table for Numeric view—automatic or build-your-own—choose the appropriate option from the **Num Type** menu.

To help you set a starting number and increment that matches the current Plot view, tap Plot→.


Function Num Setup

Num Start: -15.9

Num Step: .1

Num Zoom

Num Start-31.8
Num Step.2

Num Type: Automatic

Enter table start value

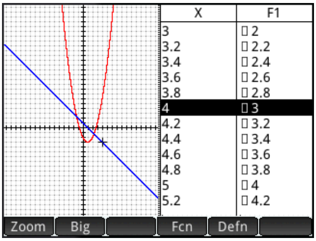
Restore default settings

To restore one field to its default setting:

1. Select the field.
2. Press Del.

To restore all default settings, press Shift Esc Clear.

Combining Plot and Numeric Views


X	F1
3	□2
3.2	□2.2
3.4	□2.4
3.6	□2.6
3.8	□2.8
4	□3
4.2	□3.2
4.4	□3.4
4.6	□3.6
4.8	□3.8
5	□4
5.2	□4.2

You can display Plot view and Numeric view side-by-side. Moving the tracing cursor causes the table of values in Numeric view to scroll. You can also enter a value in the `X` column. The table scrolls to that value, and the tracing cursor jumps to the corresponding point on the selected plot.

To combine Plot and Numeric view in a split screen, press View Copy and select `Split Screen: Plot Table`.

To return to Plot view, press Num Setup. To return to Numeric view by pressing Num Setup.

Adding a note to an app

You can add a note to an app. Unlike general notes—those created via the Note Catalog: see chapter 26—an app note is not listed in the Note Catalog. It can only be accessed when the app is open.

An app note remains with the app if the app is sent to another calculator.

To add a note to an app:

1. Open the app.
2. Press Shift Apps Info (Info).

   If a note has already been created for this app, its contents are displayed.
3. Tap Edit and start writing (or editing) your note.

   The format and bullet options available are the same as those in the Note Editor (described in "The Note Editor" on page 490).
4. To exit the note screen, press any key. Your note is automatically saved.

Creating an app

The apps that come with the HP Prime are built in and cannot be deleted. They are always available (simply by pressing Apps Info). However, you can create any number of customized instances of most apps. You can also create an instance of an app that is based on a previously customized app. Customized apps are opened from the application library in the same way that you open a built-in app.

The advantage of creating a customized instance of an app is that you can continue to use the built-in app for some other problem and return to the customized app at any time with all its data still in place. For example, you could create a customized version of the Sequence app that enables you to generate and explore the Fibonacci series. You could continue to use the built-in Sequence app to build and explore other sequences and return, as needed, to your special version of the Sequence app when you next want to explore the Fibonacci series. Or you could create a customized version of the Solve app—named, for example, `Triangles`—in which you set up, just once, the equations for solving common problems involving right-angled triangles (such as `H=O/SIN(θ)`, `A=H*COS(θ)`, `O=A*TAN(θ)`, etc.). You could continue to use the Solve app to solve other types of problems but use your Triangle app to solve problems involving right-angled triangles. Just open Triangles, select which equation to use—you won't need to re-enter them—enter the variables you know, and then solve for the unknown variable.

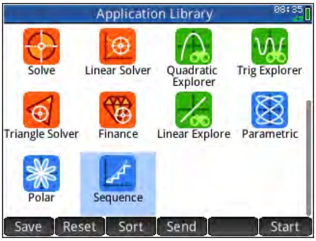
Like built-in apps, customized apps can be sent to another HP Prime calculator. This is explained in “Sharing data” on page 44. Customized apps can also be reset, deleted, and sorted just as built-in apps can (as explained earlier in this chapter).

Note that the only apps that cannot be customized are the:

- Linear Explorer
- Quadratic Explorer and
- Trig Explorer apps.

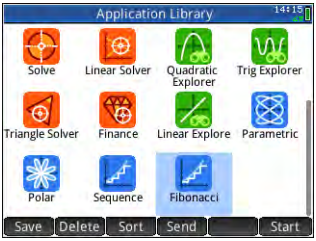
Example

Suppose you want to create a customized app that is based on the built-in Sequence app. The app will enable you to generate and explore the Fibonacci series.



1. Press Apps Info and use the cursor keys to highlight the Sequence app. Don’t open the app.
2. Tap Save . This enables you to create a copy of the built-in app and save it under a new name. Any data already in the built-in app is retained, and you can return to it later by opening the Sequence app.
3. In the **Name** field, enter a name for your new app—say, `Fibonacci`—and press Enter ≈ twice.

   Your new app is added to the Application Library. Note that it has the same icon as the parent app—Sequence—but with the name you gave it: `Fibonacci` in this example.



4. You are now ready to use this app just as you would the built-in Sequence app. Tap on the icon of your new app to open it. You will see in it all the same views and options as in the parent app.

In this example we have used the Fibonacci series as a potential topic for a customized app. To see how to create the Fibonacci series once inside the Sequence app—or an app based on the

Sequence app—see chapter 17, “Sequence app”, beginning on page 281.

As well as cloning a built-in app—as described above—you can modify the internal workings of a customized app using the HP Prime programming language. See “Customizing an app” on page 522.

App functions and variables

Functions

App functions are used in HP apps to perform common calculations. For example, in the Function app, the Plot view **Fcn** menu has a function called `SLOPE` that calculates the slope of a given function at a given point. The `SLOPE` function can also be used from the Home view or a program.

For example, suppose you want to find the derivative of $x^2 - 5$ at $x = 2$. One way, using an app function, is as follows:

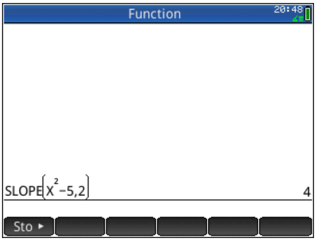
1. Press ⌂.
2. Tap App and select `Function` > `SLOPE`.

   `SLOPE()` appears on the entry line, ready for you to specify the function and the *x*-value.
3. Enter the function:

   ALPHA X x^2 − 5
4. Enter the parameter separator:

   ,
5. Enter the *x*-value and press Enter.

   The slope (that is the derivative) at $x = 2$ is calculated: 4.



SLOPE(X²−5,2) 4

All the app functions are described in “App menu”, beginning on page 347.

Variables

All apps have variables, that is, placeholders for various values that are unique to a particular app. These include symbolic expressions and equations, settings for the Plot and Numeric views, and the results of some calculations such as roots and intersections.

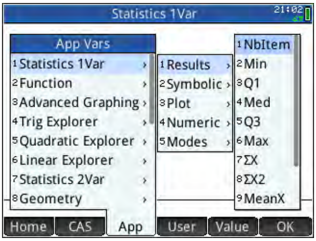
Suppose you are in Home view and want to retrieve the `mean` of a data set recently calculated in the Statistics 1Var app.

1. Press Vars.

   This opens the Variables menu. From here you can access Home variables, user-defined variables, and app variables.

2. Tap App.

   This opens a menu of app variables.



3. Select `Statistics 1Var > results > MeanX`.

   The current value of the variable you chose now appears on the entry line. You can press Enter to see its value. Or you can include the variable in an expression that you are building. For example, if you wanted to calculate the square root of the mean computed in the Statistics 1Var app, you would first press Shift x^2, follow steps 1 to 3 above, and then press Enter.

See appendix A, “Glossary”, beginning on page 587 for a complete list of app variables.

Qualifying variables

You can qualify the name of any app variable so that it can be accessed from anywhere on the HP Prime. For example, both the Function app and the Parametric app have an variable named `Xmin`. If the app you last had open was the Parametric app and enter `Xmin` in Home view, you will get the value of `Xmin` from the Parametric app. To get the value of `Xmin` in the Function app instead, you could open the Function app and then return to Home view. Alternatively, you could qualify the name of the variable by preceding it with the app name and a period, as in `Function.Xmin`.

6

Function app

The Function app enables you to explore up to 10 real-valued, rectangular functions of y in terms of x; for example, $y = 1 - x$ and $y = (x-1)^2 - 3$.

Once you have defined a function you can:

- create graphs to find roots, intercepts, slope, signed area, and extrema, and
- create tables that show how functions are evaluated at particular values.

This chapter demonstrates the basic functionality of the Function app by stepping you through an example. More-complex functionality is described in chapter 5, "An introduction to HP apps", beginning on page 69.

Getting started with the Function app

The Function app uses the customary app views: Symbolic, Plot and Numeric described in chapter 5.

For a description of the menu buttons available in this app, see:

- "Symbolic view: Summary of menu buttons" on page 86
- "Plot view: Summary of menu buttons" on page 96, and
- "Numeric view: Summary of menu buttons" on page 104.

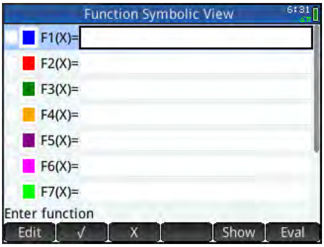
Throughout this chapter, we will explore the linear function $y = 1 - x$ and the quadratic function $y = (x-1)^2 - 3$.

Open the Function app

1. Open the Function app.

   Apps Info Select `Function`

   Recall that you can open an app just by tapping its icon. You can also open it by using the cursor keys to highlight it and then pressing Enter ≈.



Function Symbolic View 6:31

F1(X)=

F2(X)=

F3(X)=

F4(X)=

F5(X)=

F6(X)=

F7(X)=

Enter function

The Function app starts in Symbolic view. This is the *defining view*. It is where you symbolically define (that is, specify) the functions you want to explore.

The graphical and numerical data you see in Plot view and Numeric view are derived from the symbolic expressions defined here.

Define the expressions

There are 10 fields for defining functions. These are labeled `F1(X)` through `F9(X)` and `F0(X)`.

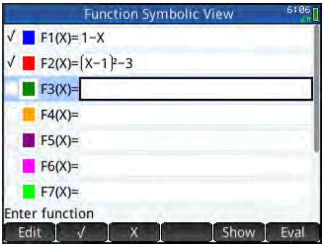
2. Highlight the field you want to use, either by tapping on it or scrolling to it. If you are entering a new expression, just start typing. If you are editing an existing expression, tap Edit and make your changes. When you have finished defining or changing the expression, press Enter ≈.

3. Enter the linear function in `F1(X)`.

   1 − xtθn Enter ≈

4. Enter the quadratic function in `F2(X)`.

   ( ) xtθn − 1 ▶ x^2 − 3 Enter ≈



Function Symbolic View 6:06

√ F1(X)=1−X

√ F2(X)=$(X-1)^2-3$

F3(X)=

F4(X)=

F5(X)=

F6(X)=

F7(X)=

Enter function

Note You can tap the X button to assist in the entry of equations. In the Function app, it has the same effect as pressing xtθn. (In other apps, xtθn enters a different character.)

5. Decide if you want to:

   – give one or more function a custom color when it is plotted

   – evaluate a dependent function

   – deselect a definition that you don’t want to explore

   – incorporate variables, math commands and CAS commands in a definition.

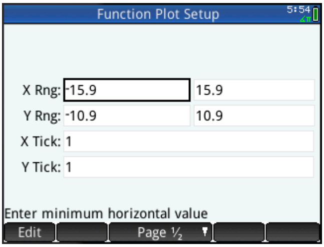
   For the sake of simplicity we can ignore these operations in this example. However, they can be useful and are described in detail in “Common operations in Symbolic view” on page 81.

Set up the plot

You can change the range of the *x*- and y-axes and the spacing of the tick marks along the axes

6. Display Plot Setup view.

   Shift Plot Setup (Setup)


Function Plot Setup

X Rng: -15.9 15.9
Y Rng: -10.9 10.9
X Tick: 1
Y Tick: 1

Enter minimum horizontal value

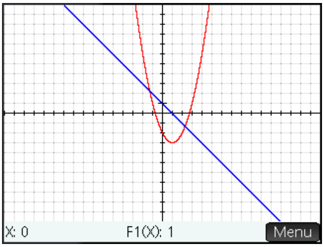
For this example, you can leave the plot settings at their default values. If your settings do not match those in the illustration above, press Shift Esc Clear (Clear) to restore the default values.

See “Common operations in Plot Setup view” on page 96 for more information about setting the appearance of plots.

Plot the functions

7. Plot the functions.

   Plot Setup



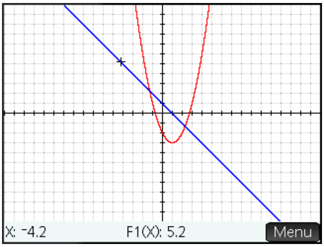
Trace a graph

By default, the trace functionality is active. This enables you to move a cursor along a graph. If more than two graphs are shown, the graph that is the highest in the list of functions in Symbolic view is the graph that will be traced by default. Since the linear equation is higher than the quadratic function in Symbolic view, it is the graph on which the tracing cursor appears by default.

8. Trace the linear function.

   ▶ or ◀

   Note how a cursor moves along the plot as you press the buttons. Note too that the coordinates of the cursor appear at the bottom of the screen and change as you move the cursor.



X: -4.2 F1(X): 5.2

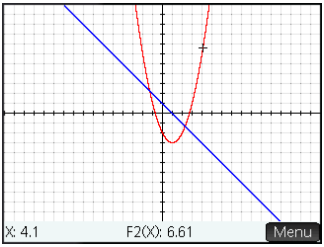
9. Move the tracing cursor from the linear function to the quadratic function.

   ▲ or ▼

10. Trace the quadratic function.

    ▶ or ◀

    Again notice how the coordinates of the cursor appear at the bottom of the screen and change as you move the cursor.



X: 4.1 F2(X): 6.61

Tracing is explained in more detail in “Trace” on page 94.

Change the scale

You can change the scale to see more or less of your graph. This can be done in four ways:

- Press [+ Ans] to zoom in or [− Base] to zoom out on the current cursor position. This method uses the zoom factors set in the **Zoom** menu. The default for both x and y is 2.
- Use the Plot Setup view to specify the exact x-range (`XRNG`) and y-range (`YRNG`) you want.

- Use options on the **Zoom** menu to zoom in or out, horizontally or vertically, or both, etc.
- Use options on the **View** menu (View Copy) to select a pre-defined view. Note that the `Autoscale` option attempts to provide a best fit, showing as many of the critical features of each plot as possible.

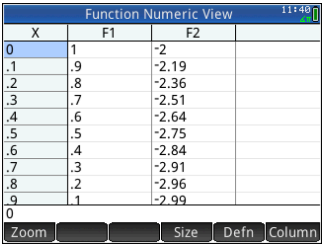
Note By dragging a finger horizontally or vertically across the screen, you can quickly see parts of the plot that are initially outside the set x and y ranges. This is easier than resetting the range of an axis.

Zoom options—with numerous examples—are explained in more detail in “Zoom” on page 88.

Display Numeric view

11. Display the Numeric view:

Num Setup


Function Numeric View

X	F1	F2
0	1	-2
.1	.9	-2.19
.2	.8	-2.36
.3	.7	-2.51
.4	.6	-2.64
.5	.5	-2.75
.6	.4	-2.84
.7	.3	-2.91
.8	.2	-2.96
.9	.1	-2.99

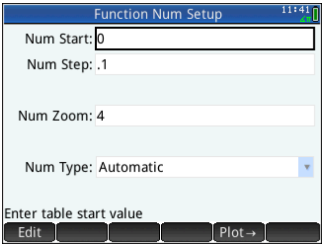
0

The Numeric view displays data generated by the expressions you defined in Symbolic view. For each expression selected in Symbolic view, Numeric view displays the value that results when the expression is evaluated for various *x*-values.

Set up Numeric view

12. Display the Numeric Setup view:

Shift Num Setup (Setup)


Function Num Setup

Num Start: 0

Num Step: .1

Num Zoom: 4

Num Type: Automatic

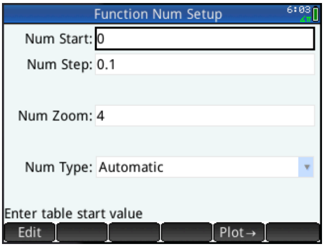
Enter table start value

You can set the starting value and step value (that is, the increment) for the *x*-column, as well as the zoom factor for zooming in or out on a row of the table. Note that in Numeric view, zooming does not affect the size of what is displayed. Instead, it changes the **Num Step** setting (that is, the increment between consecutive *x*-values). Zooming in decreases the increment; zooming out increases the increment. This is further explained in “Zoom” on page 100.

You can also choose whether the table of data in Numeric view is automatically populated or whether it is populated by you typing in the particular *x*-values you are interested in. These options—`Automatic` or `BuildYourOwn`—are available from the **Num Type** list. They are explained in detail in “Custom tables” on page 103.

13. Press Shift Esc Clear (Clear) to reset all the settings to their defaults.

14. Make the Numeric view X-column settings (**Num Start** and **Num Step**) match the tracer x-values (Xmin and pixel width) in Plot view:



Function Num Setup 6:03

Num Start: 0

Num Step: 0.1

Num Zoom: 4

Num Type: Automatic

Enter table start value

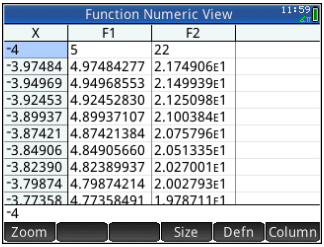
Tap Plot→ OK.

For example, if you have zoomed in on the plot in Plot view so that the visible x-range is now –4 to 4, this option will set **Num Start** to –4 and **Num Step** to 0.025…

Explore Numeric view

15. Re-display Numeric view:

Num Setup

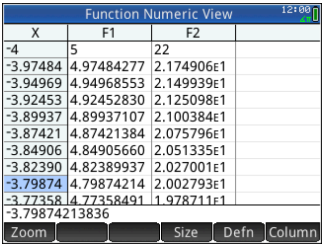


Function Numeric View 11:59

X	F1	F2
-4	5	22
-3.97484	4.97484277	2.174906E1
-3.94969	4.94968553	2.149939E1
-3.92453	4.92452830	2.125098E1
-3.89937	4.89937107	2.100384E1
-3.87421	4.87421384	2.075796E1
-3.84906	4.84905660	2.051335E1
-3.82390	4.82389937	2.027001E1
-3.79874	4.79874214	2.002793E1
-3.77358	4.77358491	1.978711E1

-4

To navigate around a table



Function Numeric View 12:00

X	F1	F2
-4	5	22
-3.97484	4.97484277	2.174906E1
-3.94969	4.94968553	2.149939E1
-3.92453	4.92452830	2.125098E1
-3.89937	4.89937107	2.100384E1
-3.87421	4.87421384	2.075796E1
-3.84906	4.84905660	2.051335E1
-3.82390	4.82389937	2.027001E1
-3.79874	4.79874214	2.002793E1
-3.77358	4.77358491	1.978711E1

-3.79874213836

16. Using the cursor keys, scroll through the values in the independent column (column `X`). Note that the values in the `F1` and `F2` columns match what you would get if you substituted the values in the `X` column for *x* in the

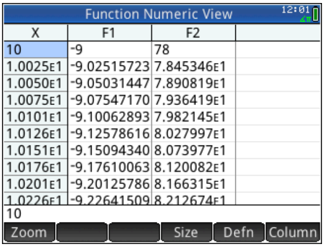
expressions selected in Symbolic view: `1−x` and `(x−1)`^{2}`−3`. You can also scroll through the columns of the dependant variables (labeled `F1` and `F2` in the illustration above).

You can also scroll the table vertically or horizontally using tap and drag gestures.

To go directly to a value

17. Place the cursor in the `X` column and type the desired value. For example, to jump straight to the row where *x* = 10:

    1 0 OK



X	F1	F2	
10	-9	78	
1.0025E1	-9.02515723	7.845346E1	
1.0050E1	-9.05031447	7.890819E1	
1.0075E1	-9.07547170	7.936419E1	
1.0101E1	-9.10062893	7.982145E1	
1.0126E1	-9.12578616	8.027997E1	
1.0151E1	-9.15094340	8.073977E1	
1.0176E1	-9.17610063	8.120082E1	
1.0201E1	-9.20125786	8.166315E1	
1.0226E1	-9.22641509	8.212674E1	

10

To access the zoom options

Numerous zoom options are available by tapping Zoom. These are explained in “Zoom” on page 100. A quick way to zoom in (or zoom out) is to press + (or −). This zooms in (or out) by the **Num Zoom** value set in the Numeric Setup view (see page 115). The default value is 4. Thus if the current increment (that is, the **Num Step** value) is 0.4, zooming in on the row whose x-value is 10 will further divide that interval into four smaller intervals. So instead of x-values of 10, 10.4, 10,8, 11.2 etc., the x-values will be 10, 10.1, 10.2, 10.3, 10.4, etc. (Zooming out does the opposite: 10, 10.4, 10,8, 11.2 etc. become 10, 11.6, 13.2, 14.8, 16.4, etc.)

Other options

As explained on page page 104, you can also:

- change the size of the font: small, medium, or large
- display the definition responsible for generating a column of values
- choose to show 1, 2, 3, or 4 columns of function values.

You can also combine Plot and Numeric view. See “Custom tables” on page 103.

Analyzing functions

The **Function** menu (Fcn) in Plot view enables you to find roots, intersections, slopes, signed areas, and extrema for any function defined in the Function app. If you have more than one function plotted, you may need to choose the function of interest beforehand.

Display the Plot view menu

The **Function** menu is a sub-menu of the Plot view menu. First, display the Plot view menu:

Plot Setup Menu

To find a root of the quadratic function

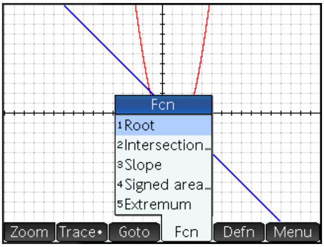
Suppose you want to find the root of the quadratic equation defined earlier. Since a quadratic equation can have more than one root, you will need to move the cursor closer to the root you are interested in than to any other root. In this example, you will find the root of the quadratic close to where *x* = 3.

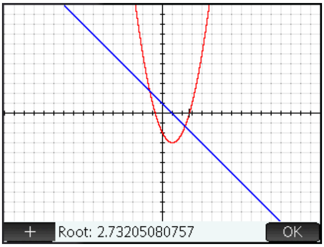
1. If it is not already selected, select the quadratic equation:

   ▲ or ▼

2. Press ▶ or ◀ to move the cursor near to where *x* = 3.

3. Tap Fcn and select `Root`

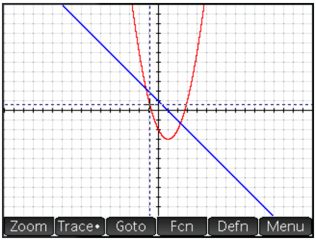




Root: 2.73205080757

The root is displayed at the bottom of the screen.

If you now move the trace cursor close to *x* = –1 (the other place where the quadratic crosses the *x*-axis) and select `Root` again, the other root is displayed.



Note the + button. If you tap this button, vertical and horizontal dotted lines are drawn through the current position of the tracer to highlight its position. Use this feature to draw attention to the cursor location. You can also choose a blinking cursor in Plot Setup. Note that the functions in the **Fcn** menu all use the current function being traced as the function of interest and the current tracer x-coordinate as an initial value. Finally, note that you can tap anywhere in Plot view and the tracer will move to the point on the current function that has the same x-value as the location you tapped. This is a faster way of choosing a point of interest than using the trace cursor. (You can move this tracing cursor using the cursor keys if you need finer precision.)

To find an intersection of two functions

Just as there are two roots of the quadratic equation, there are two points at which both functions intersect. As with roots, you need to position your cursor closer to the point you are interested in. In this example, the intersection close to $x = -1$ will be determined.

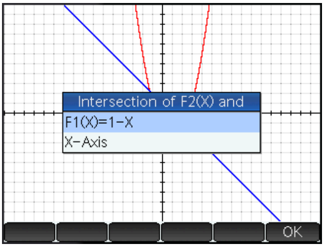
The **Go To** command is another way of moving the trace cursor to a particular point.

1. Tap OK to re-display the menu, tap Go To, enter +/− 1, and tap OK.

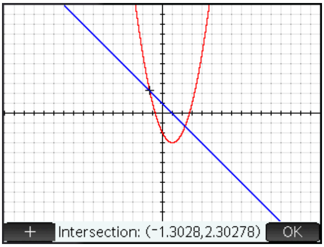
   The tracing cursor will now be on one of the functions at $x = 1$.

2. Tap Fcn and select `Intersection`.

   A list appears giving you a choice of functions and axes.


Intersection of F2(X) and
F1(X)=1−X
X−Axis

3. Choose the function whose point of intersection with the currently selected function you wish to find.

   Intersection: (-1.3028,2.30278)

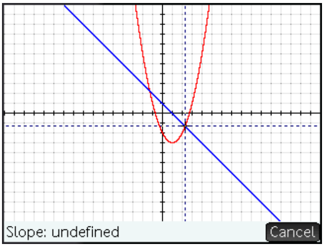
   The coordinates of the intersection are displayed at the bottom of the screen.

   Tap + on the screen near the intersection, and repeat from step 2. The coordinates of the intersection nearest to where you tapped are displayed at the bottom of the screen.

To find the slope of the quadratic function

We will now find the slope of the quadratic function at the intersection point.

1. Tap OK to re-display the menu, tap Fcn and select `Slope`.

   Slope: undefined

   The slope (that is, the gradient) of the function at the intersection point is displayed at the bottom of the screen.

   You can press ◀ or ▶ to trace along the curve and see the slope at other points. You can also press ▲ or ▼ to jump to another function and see the slope at points on it.

2. Press Cancel to re-display the Plot menu.

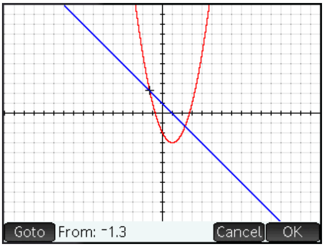
To find the signed area between the two functions

We'll now find the area between the two functions in the range $-1.3 \le x \le 2.3$.

1. Tap Fcn and select `Signed area`.

2. Specify the start value for *x*:

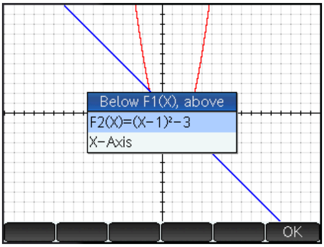
   Tap Go To and press +/– 1 . 3 Enter .



From: −1.3

3. Tap OK .

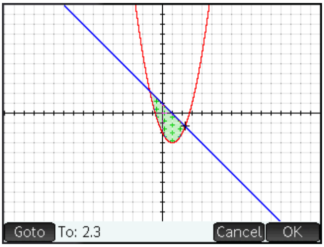
4. Select the other function as the boundary for the integral. (If F1(X) is the currently selected function, you would choose F2(X) here, and vice versa.)



5. Specify the end value for *x*:

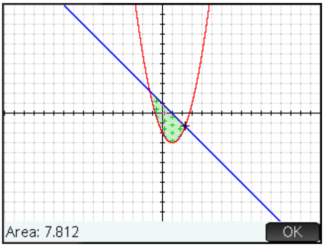
   Tap Go To and press 2 . 3 Enter .

   The cursor jumps to *x* = 2.3 and the area between the two functions is shaded.



To: 2.3

6. To display the numerical value of the integral, tap OK .



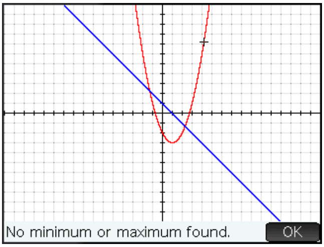
Area: 7.812

7. Tap OK to return to the Plot menu. Note that the sign of the area calculated depends both on which function you are tracing and whether you enter the endpoints from left to right or right to left.

Shortcut. When the **Goto** option is available, you can display the **Go To** screen simply by typing a number. The number you type appears on the entry line. Just tap OK to accept it.

To find the extremum of the quadratic

1. To calculate the coordinates of the extremum of the quadratic equation, move the tracing cursor near the extremum of interest (if necessary), tap Fcn and select `Extremum`.


No minimum or maximum found.

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

Note The `ROOT`, `INTERSECTION`, and `EXTREMUM` operations return only one value even if the function in question has more than one root, intersection, or extremum. The app will only return values that are closest to the cursor. You will need to move the cursor closer to other roots, intersections, or extrema if you want the app to calculate values for those.

The Function Variables

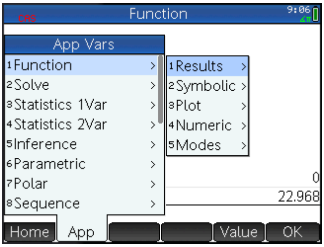
The result of each numerical analysis in the Function app is assigned to a variable. These variables are named:

- `Root`
- `Isect` (for Intersection)
- `Slope`
- `SignedArea`
- `Extremum`

The result of each new analysis overwrites the previous result. For example, if you find the second root of a quadratic equation after finding the first, the value of `Root` changes form the first to the second root.

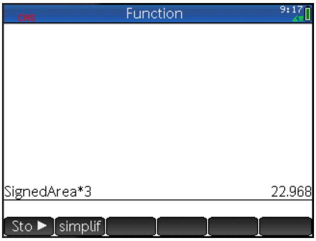
To access Function variables

The Function variables are available in Home view and in the CAS, where they can be included as arguments in calculations. They are also available in Symbolic view.



1. To access the variables, press Vars, tap App and select `Function`.
2. Select `Results` and then the variable of interest.

The variable's name is copied to the insertion point and its value is used in evaluating the expression that contains it. You can also enter the value of the variable instead of its name by tapping Value.



```
SignedArea*3                    22.968
```

For example, in Home view or the CAS you could select `SignedArea` from the **Vars** menus, press × 3 Enter and get the current value of `SignedArea` multiplied by three.

Function variables can also be made part of a function's definition in Symbolic view. For example, you could define a function as $x^2 - x - \text{Root}$.

The full range of variables, and their use in calculations, is covered in detail in chapter 22, "Variables", beginning on page 423.

Summary of FCN operations

Operation	Description
Root	Select Root to find the root of the current function nearest to the tracing cursor. If no root is found, but only an extremum, then the result is labeled Extremum instead of Root. 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 to the tracing cursor. The cursor moves to the extremum and the coordinate values are displayed. The resulting x-value is saved in a variable named Extremum.
Slope	Select Slope to find the numeric derivative of the current function at the current position of the tracing 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 and an ending point. The result is saved in a variable named SignedArea.
Intersection	Select Intersection to find the intersection of the graph you are currently tracing and another graph. You need to have at least two selected expressions in Symbolic view. Finds the intersection closest to the tracing cursor. Displays the coordinate values and moves the cursor to the intersection. The resulting x-value is saved in a variable named Isect.

7

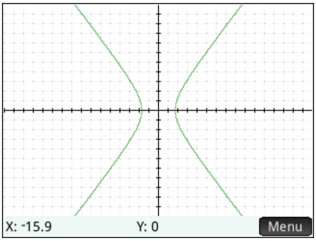
Advanced Graphing app

The Advanced Graphing app enables you to define and explore the graphs of symbolic open sentences in *x*, *y*, both or neither. You can plot conic sections, polynomials in standard or general form, inequalities, and functions. The following are examples of the sorts of open sentences you can plot:

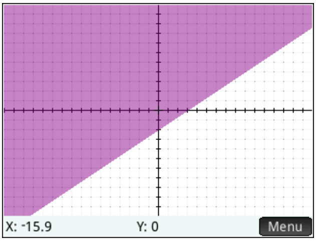
1. $x^2/3 - y^2/5 = 1$
2. $2x - 3y \le 6$
3. mod $x = 3$
4. $\sin((\sqrt{x^2 + y^2} - 5)^2) > \sin\left(8 \cdot \operatorname{atan}\left(\frac{y}{x}\right)\right)$
5. $x^2 + 4x = -4$
6. $1 > 0$

The illustrations below show what these open sentences look like when plotted:

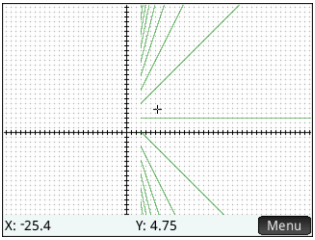
Example 1



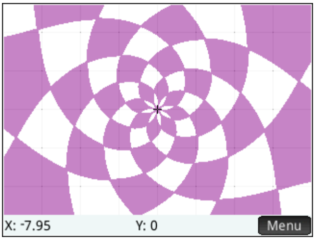
Example 2



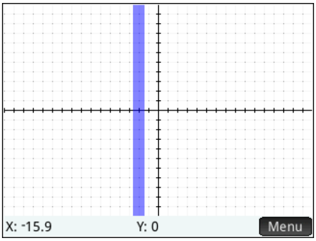
Example 3



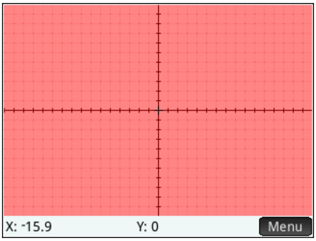
Example 4



Example 5



Example 6



Getting started with the Advanced Graphing app

The Advanced Graphing app uses the customary app views: Symbolic, Plot, and Numeric described in chapter 5.

For a description of the menu buttons available in this app, see:

- "Symbolic view: Summary of menu buttons" on page 86
- "Plot view: Summary of menu buttons" on page 96, and
- "Numeric view: Summary of menu buttons" on page 104.

The Trace option in the Advanced Graphing app works differently than in other apps and is described in detail in this chapter.

In this chapter, we will explore the rotated conic defined by:

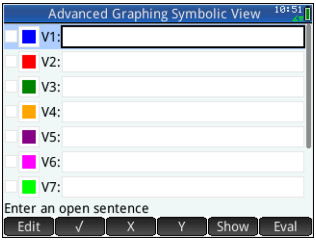
$$\frac{x^2}{2} - \frac{7xy}{10} + \frac{3y^2}{4} - \frac{x}{10} + \frac{y}{5} - 10 < 0$$

Open the app

1. Open the Advanced Graphing app:

   Apps Info Select `Advanced Graphing`

   The app opens in the Symbolic view.



Advanced Graphing Symbolic View 10:51

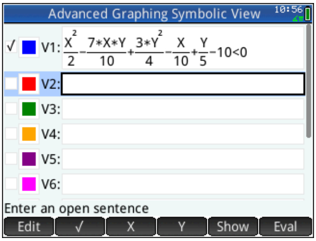
- □ 🟦 V1:
- □ 🟥 V2:
- □ 🟩 V3:
- □ 🟧 V4:
- □ 🟪 V5:
- □ V6:
- □ 🟩 V7:

Enter an open sentence

Define the open sentence

2. Define the open sentence:

   X x² ÷ 2 ► − 7 X Y ÷ 10 ► + 3 Y x² ÷ 4 ► − X ÷ 10 ► + Y ÷ 5 ► − 10 ≤,≥,≠ < 0 Enter



Advanced Graphing Symbolic View 10:56

- ✓ 🟦 V1: $\frac{X^2}{2}-\frac{7*X*Y}{10}+\frac{3*Y^2}{4}-\frac{X}{10}+\frac{Y}{5}-10<0$
- □ 🟥 V2:
- □ 🟩 V3:
- □ 🟧 V4:
- □ 🟪 V5:
- □ V6:

Enter an open sentence

   Note that ≤,≥,≠ displays the relations palette from which relational operators can be easily selected. This is the same palette that appears if you press Shift 6.

3. Decide if you want to:

   – give an open sentence a custom color when it is plotted

   – evaluate a dependent function

   – deselect a definition that you don’t want to explore

   – incorporate variables, math commands and CAS commands in a definition.

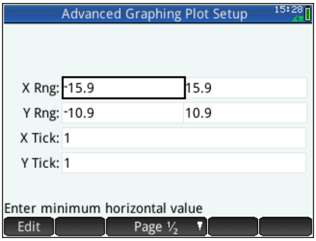
   For the sake of simplicity we can ignore these operations in this example. However, they can be useful and are described in detail in “Common operations in Symbolic view” on page 81.

Set up the plot

You can change the range of the *x*- and *y*-axes and the spacing of the interval marks along the axes.

4. Display Plot Setup view:

   Shift Plot ↳Setup (Setup)



Advanced Graphing Plot Setup

X Rng: -15.9 15.9

Y Rng: -10.9 10.9

X Tick: 1

Y Tick: 1

Enter minimum horizontal value

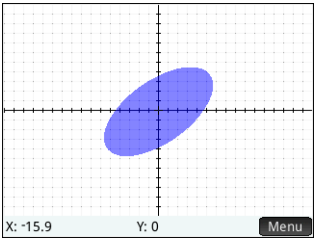
For this example, you can leave the plot settings at their default values. If your settings do not match those in the illustration at the right, press Shift Esc Clear (Clear) to restore the default values.

See "Common operations in Plot Setup view" on page 96 for more information about setting the appearance of plots.

Plot the selected definitions

5. Plot the selected definitions:

   Plot ↳Setup



Explore the graph

6. Display the Plot view menu items:

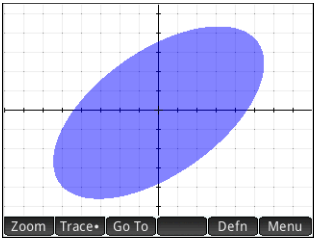
   Menu

   Note that you have options to zoom, trace, go to a specified point, and display the definition of the selected graph.

   You can use the zoom and split screen functionality discussed in chapter 6. You can tap and drag to scroll the Plot view, or use + Ans and − Base to zoom in and out on the cursor position, respectively.

7. Tap Zoom and select `In`.

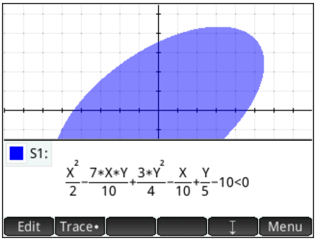
   A special feature of the Advanced Graphing app enables you to edit the definition of a graph from within the Plot view.



8. Tap Defn. The definition as you entered it in Symbolic view appears at the bottom of the screen.

9. Tap Edit.

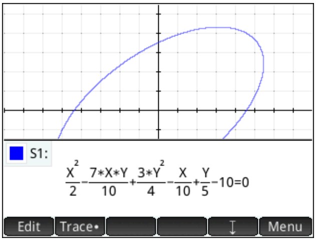
   The definition is now editable.



S1: $\frac{X^2}{2}-\frac{7*X*Y}{10}+\frac{3*Y^2}{4}-\frac{X}{10}+\frac{Y}{5}-10<0$

10. Change the < to = and tap OK.

    Notice that the graph changes to match the new definition. The definition in Symbolic view also changes.



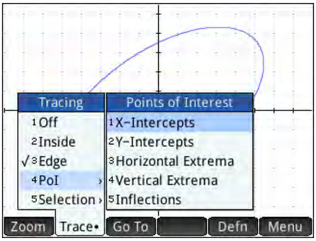
S1: $\frac{X^2}{2}-\frac{7*X*Y}{10}+\frac{3*Y^2}{4}-\frac{X}{10}+\frac{Y}{5}-10=0$

11. Tap ↧ to drop the definition to the bottom of the screen so that you can see the full graph. The definition is converted from textbook mode to algebraic mode to save screen space.

Trace in Plot view

In most HP apps, the Plot view contains Trace•, a toggle to turn tracing a function on and off. In the Advanced Graphing app, the relations plotted in Plot view may or may not be functions. So, instead of a toggle, Trace• becomes a menu for selecting how the tracer will behave. The Trace menu contains the following options:

- Off
- Inside
- PoI (Points of Interest)
  - X-Intercepts
  - Y-intercepts
  - Horizontal Extrema
  - Vertical Extrema
  - Inflections
- Selection



The tracer does not extend beyond the current Plot view window. The table below contains brief descriptions of each option.

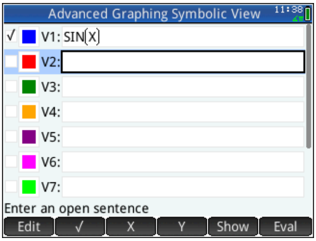
Trace option	**Description**
Off	Turns tracing off so that you can move the cursor freely in Plot view
Inside	Constrains the tracer to move within a region where the current relation is true. You can move in any direction within the region. Use this option for inequalities, for example.
Edge	Constrains the tracer to move along an edge of the current relation, if one can be found. Use this option for functions as well as for inequalities, etc.
PoI > X-Intercepts	Jumps from one x-intercept to another on the current graph
PoI > Y-Intercepts	Jumps from one y-intercept to another on the current graph
PoI > Horizontal Extrema	Jumps between the horizontal extrema on the current graph
PoI > Vertical Extrema	Jumps between the vertical extrema on the current graph
PoI > Inflections	Jumps from one inflection point to another on the current graph
Selection	Opens a menu so you can select which relation to trace. This option is needed because ▲ and ▼ no longer jump from relation to relation for tracing. All four cursor keys are needed for moving the tracer in the Advanced Graphing app.

Numeric view

The Numeric view of most HP apps is designed to explore 2-variable relations using numerical tables. Because the Advanced Graphing app expands this design to relations that are not necessarily functions, the Numeric view of this app becomes significantly different, though its purpose is still the same. The unique features of the Numeric view are illustrated in the following sections.

12. Press Symb ↳Setup to return to Symbolic view and define `V1` as `Y=SIN(X)`.

    Note that you don't have to erase the previous definition first. Just enter the new definition and tap OK.



Advanced Graphing Symbolic View 11:38

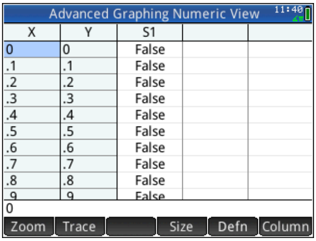
✓	🟦	V1: SIN(X)
□	🟥	V2:
□	🟩	V3:
□	🟧	V4:
□	🟪	V5:
□	🟪	V6:
□	🟩	V7:

Enter an open sentence

Display the Numeric view

13. Press Num ↳Setup to display the Numeric view.

    By default, the Numeric view displays rows of x- and y-values. In each row, the 2 values are followed by a column that tells whether or not the x–y pair satisfies each open sentence (True or False).



Advanced Graphing Numeric View 11:40

X	Y	S1		
0	0	False		
.1	.1	False		
.2	.2	False		
.3	.3	False		
.4	.4	False		
.5	.5	False		
.6	.6	False		
.7	.7	False		
.8	.8	False		
.9	.9	False		

0

Explore Numeric view

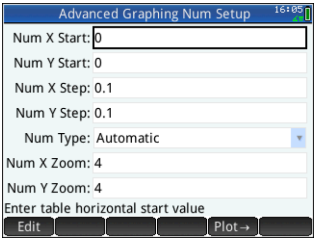
14. With the cursor in the X column, type a new value and tap OK. The table scrolls to the value you entered.

    You can also enter a value in the Y column and tap OK. Press ◀ and ▶ to move between the columns in Numeric view.

    You can also zoom in or out on the X-variable or Y-variable. Note that in Numeric view, zooming does not affect the size of what is displayed. Instead, it decreases or increases the increment between consecutive x- and y-values. Zooming in decreases the increment; zooming out increases the increment. This and other options are explained in "Common operations in Numeric view" on page 100.

Numeric Setup

Although you can configure the X- and Y-values shown in Numeric view by entering values and zooming in or out, you can also directly set the values shown using Numeric setup.



Advanced Graphing Num Setup

Num X Start: 0

Num Y Start: 0

Num X Step: 0.1

Num Y Step: 0.1

Num Type: Automatic

Num X Zoom: 4

Num Y Zoom: 4

Enter table horizontal start value

15. Display the Numeric Setup view:

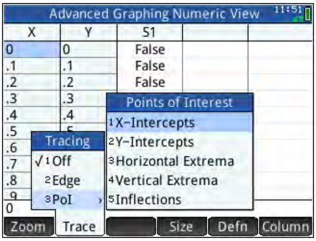
    Shift Num Setup (Setup)

You can set the starting value and step value (that is, the increment) for both the X-column and the Y-column, as well as the zoom factor for zooming in or out on a row of the table. You can also choose whether the table of data in Numeric view is automatically populated or whether it is populated by you typing in the particular x-values and y-values you are interested in. These options—Automatic or BuildYourOwn—are available from the **Num Type** list. They are explained in detail in “Custom tables” on page 103.

Trace in Numeric view

Besides the default configuration of the table in Numeric view, there are other options available in the Trace menu. The trace options in Numeric view mirror the trace options in Plot view. Both are designed to help you investigate the properties of relations numerically using a tabular format. Specifically, the table can be configured to show any of the following:

- edge values (controlled by X or Y)
- points of interest (PoI):
  - X-intercepts
  - Y-intercepts
  - horizontal extrema
  - vertical extrema
  - inflections



Advanced Graphing Numeric View

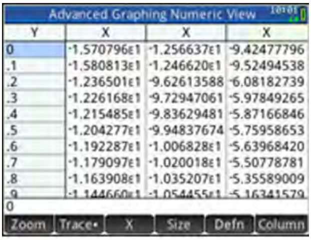
X	Y	S1
0	0	False
.1	.1	False
.2	.2	False
.3	.3	
.4	.4	
.5		
.6		
.7		
.8		
.9		
0		

The values shown using the Trace options depend on the Plot view window; that is, the values shown in the table are restricted to points visible in Plot view. Zoom in or out in Plot view to get the values you want to see in the table in Numeric view.

Trace Edge

16. Tap Trace• and select `Edge`.

Now the table shows (if possible) pairs of values that make the relation true. By default, the first column is the Y-column and there are multiple X-columns in case more than one X-value can be paired with the Y-value to make the relation true.



Y	X	X	X
0	-1.570796E1	-1.256637E1	-9.42477796
.1	-1.580813E1	-1.246620E1	-9.52494538
.2	-1.236501E1	-9.62613588	-6.08182739
.3	-1.226168E1	-9.72947061	-5.97849265
.4	-1.215485E1	-9.83629481	-5.87166846
.5	-1.204277E1	-9.94837674	-5.75958653
.6	-1.192287E1	-1.006828E1	-5.63968420
.7	-1.179097E1	-1.020018E1	-5.50778781
.8	-1.163908E1	-1.035207E1	-5.35589009
.9	-1.144660E1	-1.054455E1	-5.16341579

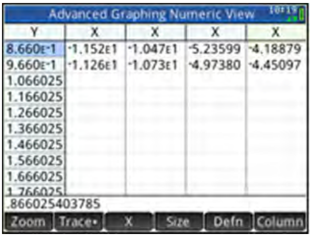
0

Tap X to make the first column an X-column followed by a set of Y-columns. In the figure above, for Y=0, there are 10 values of X in the default Plot view that make the relation `Y=SIN(X)` true. These are shown in the first row of the table. It can be clearly seen that the sequence of X-values have a common difference of π.

Again, you can enter a value for Y that is of interest.

17. With 0 highlighted in the Y-column, enter $\frac{\sqrt{3}}{2}$:

    Shift x^2 3 ÷ 2
    Enter



Y	X	X	X	X
8.660E-1	-1.152E1	-1.047E1	-5.23599	-4.18879
9.660E-1	-1.126E1	-1.073E1	-4.97380	-4.45097
1.066025				
1.166025				
1.266025				
1.366025				
1.466025				
1.566025				
1.666025				
1.766025				

.866025403785

18. Tap Column and select `4`.

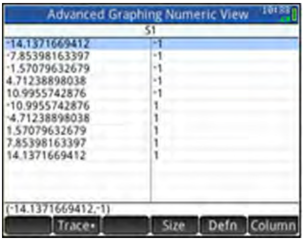
The first row of the table now illustrates that there are two branches of solutions. In each branch, the consecutive solution values are 2π apart.

Trace PoI

19. Tap Trace•, select `PoI` and select `Vertical Extrema` to see the extrema listed in the table.

20. Tap Size and select `Small` for a small font size.

21. Tap Column and select `2` to see just two columns.



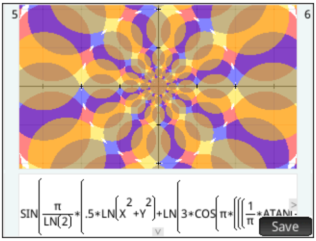
S1	
-14.1371669412	-1
-7.85398163397	-1
-1.57079632679	-1
4.71238898038	-1
10.9955742876	-1
-10.9955742876	1
-4.71238898038	1
1.57079632679	1
7.85398163397	1
14.1371669412	1

(-14.1371669412,-1)

The table lists the 5 minima visible in Plot view, followed by the 5 maxima.

Plot Gallery

A gallery of interesting graphs—and the equations that generated them—is provided with the calculator. You open the gallery from Plot view:


5
6
$SIN\left(\frac{\pi}{LN(2)}*\left(.5*LN\left(X^{2}+Y^{2}\right)+LN\left(3*COS\left(\pi*\left(\left(\left(\frac{1}{\pi}*ATAN\right.\right.\right.\right.\right.\right.\right.$
Save

1. With Plot view open, press the **Menu** key.
   Note that you press the Menu key here, not the Menu touch button on the screen.
2. From the menu, select **Visit Plot Gallery**. The first graph in the Gallery appears, along with its equation.
3. Press ▶ to display the next graph in the Gallery, and continue likewise until you want to close the Gallery.
4. To close the Gallery and return to Plot view, press Plot ↳Setup.

Exploring a plot from the Plot Gallery

If a particular plot in the Plot Gallery interests you, you can save a copy of it. The copy is saved as a new app—a customized instance of the Advanced Graphing app. You can modify and explore the app as you would with built-in version of the Advanced Graphing app.

To save a plot from the Plot Gallery:

1. With the plot of interest displayed, tap Save.
2. Enter a name for your new app and tap OK.
3. Tap OK again. Your new app opens, with the equations that generated the plot displayed in Symbolic view. The app is also added to the Application Library so that you can return to it later.

8

Geometry

The Geometry app enables you to draw and explore geometric constructions. A geometric construction can be composed of any number of geometric objects, such as points, lines, polygons, curves, tangents, and so on. You can take measurements (such as areas and distances), manipulate objects, and note how measurements change.

There are five app views:

- Plot view: provides drawing tools for you to construct geometric objects
- Symbolic view: provides editable definitions of the objects in Plot view
- Numeric view: for making calculations about the objects in Plot view
- Plot Setup view: for customizing the appearance of Plot view
- Symbolic Setup view: for overriding certain system-wide settings

There is no Numeric Setup view in this app.

To open the Geometry app, press Apps Info and select **Geometry**. The app opens in Plot view.

Getting started with the Geometry app

The following example shows how you can graphically represent the derivative of a curve, and have the value of the derivative automatically update as you move a point of tangency along the curve. The curve to be explored is $y =$ 3sin(x).

Since the accuracy of our calculation in this example is not too important, we will first change the number format to fixed at 3 decimal places. This will also help keep our geometry workspace uncluttered.

Preparation

1. Press Shift Settings.
2. On the **Home Setting** screen set the number format to `Fixed` and the number of decimal places to 3.

Open the app and plot the graph

3. Press Apps Info and select **Geometry**.

   If there are objects showing that you don't need, press Shift Esc Clear and confirm your intention by tapping OK.

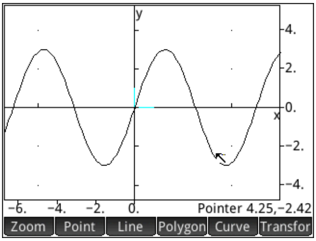
4. Select the type of graph you want to plot. In this example we are plotting a simple sinusoidal function, so choose:

   Curve > `Plot` > `Function`

5. With `plotfunc(` on the entry line, enter 3*sin(*x*):

   3 × SIN ASIN ALPHA alpha Shift × Enter ≈

   Note that *x* must be entered in lowercase in the Geometry app.

   If your graph doesn't resemble the illustration at the right, adjust the **X Rng** and **Y Rng** values in Plot Setup view (Shift Plot Setup).

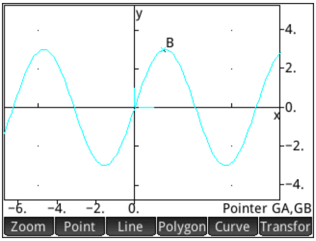
   We'll now add a point to the curve, a point that will be constrained always to follow the contour of the curve.

Add a constrained point

6. Tap Point and select `Point On`.

   Choosing `Point On` rather than `Point` means that the point will be constrained to whatever it is placed on.

7. Tap anywhere on the graph, press Enter ≈ and then press Esc Clear.

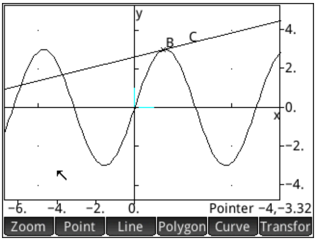
   Notice that a point is added to the graph and given a name (`B` in this example). Tap a blank area of the screen to deselect everything. (Objects colored cyan are selected.)

Add a tangent

8. We will now add a tangent to the curve, making point `B` the point of tangency:

   Line > `More` > `Tangent`

9. Tap on point `B`, press Enter and then press Esc.

   A tangent is drawn through point `B`. (Depending on where you placed point `B`, your illustration might be different from the one at the right.)

   We'll now make the tangent stand out by giving it a bright color.

10. If the curve is selected, tap a blank area of the screen to deselect, and then tap on the tangent to select it.

11. Press Menu and select `Change Color`.

12. Pick a color from the color-picker, press Enter and then tap on a blank area of the screen. Your tangent should now be colored.

13. Press Enter to select point `B`.

    If there is only one point on the screen, pressing Enter automatically selects it. If there is more than one point, a menu will appear asking you to choose a point.

14. With point `B` selected, use the cursor keys to move it about.

    Note that whatever you do, point `B` remains constrained to the curve. Moreover, as you move point `B`, the tangent moves as well. (If it moves off the screen, you can always bring it back by dragging your finger across the screen in the appropriate direction.)

15. Press Enter to deselect point `B`.

Note that there are two ways to move a point after it is selected: (a) using the cursor keys, as described above, and (b) using your finger. If you use the cursor keys, pressing Esc will cancel the move and put the point back where it was, while pressing Enter will accept the move and deselect the point. If you use your finger to move the point, lifting your finger completes the move and deselects the point. In this case there is no way to cancel the move unless you have activated keyboard shortcuts, which provides you with an undo function. (Shortcuts are described on page 147.)

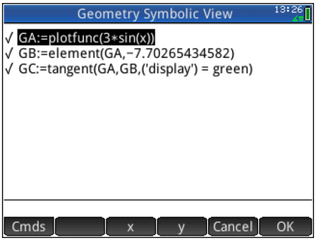
Create a derivative point

The derivative of a graph at any point is the slope of its tangent at that point. We'll now create a new point that will be constrained to point `B` and whose ordinate value is the derivative of the graph at point `B`. We'll constrain it by forcing its *x* coordinate (that is, its abscissa) to always match that of point `B`, and its *y* coordinate (that is, its ordinate) to always equal the slope of the tangent at that point.

16. To define a point in terms of the attributes of other geometric objects, you need to go to Symbolic view:

    Symb ↳Setup

    Note that each object you have so far created is listed in Symbolic view. Note too that the name for an object in Symbolic view is the name it was given in Plot view but prefixed with a "G". Thus the graph—labeled `A` in Plot view—is labeled `GA` in Symbolic view.



Geometry Symbolic View 13:26

```
√ GA:=plotfunc(3*sin(x))
√ GB:=element(GA,-7.70265434582)
√ GC:=tangent(GA,GB,('display') = green)
```

17. Highlight *GC* and tap New.

    When creating objects that are dependent on other objects, the order in which they appear in Symbolic view is important. Objects are drawn in Plot view in the order in which they appear in Symbolic view. Since we are about to create a new point that is dependent on the attributes of `GB` and `GC`, it is important that we place its definition after that of both `GB` and `GC`. That is why we made sure we were at the bottom the list of definitions before tapping New. If our new definition appeared higher up in Symbolic view, the point we are about to create wouldn't be drawn in Plot view.

18. Tap Cmds and choose `Point` > `point`

    You now need to specify the *x* and *y* coordinates of the new point. The former is to be constrained to abscissa of point B (referred to as GB in Symbolic view) and the later is to constrained to the slope of C (referred to as GC in Symbolic view).

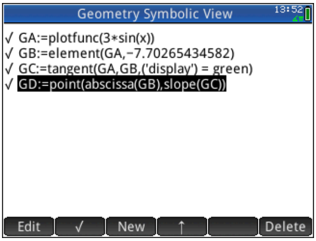
19. You should have `point()` on the entry line. Between the parentheses, add:

    `abscissa(GB),slope(GC)`

You can enter the commands by hand, or choose them from one of two Toolbox menus: **App** > **Measure**, or **Catlg**.

20. Tap OK.

    The definition of your new point is added to Symbolic view. When you return to Plot view, you will see a point named D and it will have the same *x*-coordinate as point B.

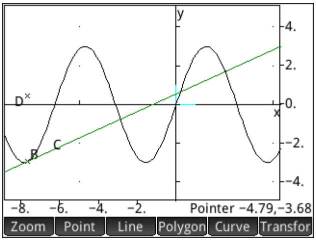


Geometry Symbolic View 13:52

√ GA:=plotfunc(3*sin(x))
√ GB:=element(GA,−7.70265434582)
√ GC:=tangent(GA,GB,('display') = green)
√ GD:=point(abscissa(GB),slope(GC))

21. Press Plot Setup.

    If you can't see point D, pan until it comes into view. The y coordinate of D will be the derivative of the curve at point B.



Since its difficult to read coordinates off the screen, we'll add a calculation that will give the exact derivative (to three decimal places) and which we can display in Plot view.

Add some calculations

22. Press Num Setup.

    Numeric view is where you enter calculations.

23. Tap New.

24. Tap Cmds and choose `Measure > slope`

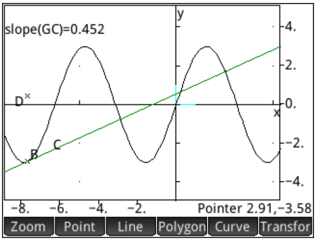
25. Between parentheses, add the name of the tangent, namely GC, and tap OK.

    Notice that the current slope is calculated and displayed. The value here is dynamic, that is, if the slope of the tangent changes in Plot view, the value of the slope is automatically updated in Numeric view.

26. With the new calculation highlighted in Numeric view, tap √.

    Selecting a calculation in Numeric view means that it will also be displayed in Plot view.

27. Press Plot Setup to return to Plot view.



slope(GC)=0.452

    Notice the calculation that you have just created in Numeric view is displayed at the top left of the screen.

    Let's now add two more calculations to Numeric view and have them displayed in Plot view.

28. Press Num Setup to return to Numeric view.

29. Tap New, enter `GB`, and tap OK.

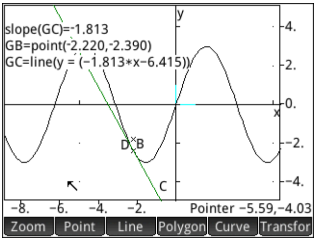
    Entering just the name of a point will show its coordinates.

30. Tap New, enter `GC`, and tap OK.

    Entering just the name of a line will show its equation.

31. Make sure both of these new equations are selected (by choosing each one and pressing √).

32. Press Plot Setup to return to Plot view.



slope(GC)=-1.813
GB=point(-2.220,-2.390)
GC=line(y = (-1.813*x-6.415))

    Notice that your new calculations are displayed.

33. Press Enter ≈ and choose point `GB`.

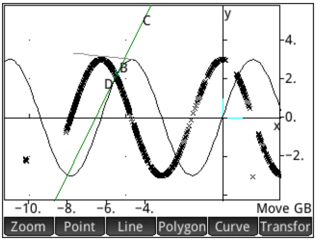
34. Use the cursor keys to move point `B` along the graph. Note that with each move, the results of the calculations shown at the top left of the screen change.

Trace the derivative

Point D is the point whose ordinate value matches the derivative of the curve at point B. It is easier to see how the derivative changes by looking at a plot of it rather than comparing subsequent calculations. We can do that by tracing point D as it moves in response to movements of point B.

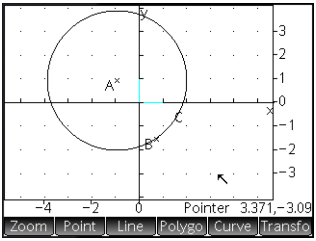
First we'll hide the calculations so that we can better see the trace curve.

35. Press Num Setup to return to Numeric view.
36. Select each calculation in turn and tap √. All calculations should now be deselected.
37. Press Plot Setup to return to Plot view.
38. Press Enter ≈ and select point GD.
39. Tap Point and select More > Trace
40. Press Enter ≈ and select point GB.
41. Using the cursor keys, move B along the curve. You will notice that a shadow curve is traced out as you move B. This is the curve of the derivative of 3sin(*x*).



Plot view in detail

In Plot view you can directly draw objects on the screen using various drawing tools. For example, to draw a circle, tap Curve and select Circle. Now tap where you want the center of the circle to be and press Enter ≈. Next, tap a point that is to be on the circumference and press Enter ≈. A circle is drawn with a center at the location of your first tap, and with a radius equal to the distance between your first tap and second tap.



Creating or selecting an object always involves at least two steps: tap and press Enter. Only by pressing Enter do you confirm your intention to create the point or select an object. When creating a point, you can tap on the screen and then use the cursor keys to accurately position the point before pressing Enter.

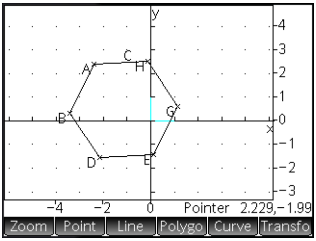
Note that there are on-screen instructions to help you. For example, `Hit Center` means tap where you want the center of your object to be, and `Hit Point 1` means tap at the location of the first point you want to add.

You can draw any number of geometric objects in Plot view. See "Geometric objects" on page 153 for a list of the objects you can draw. The drawing tool you choose—line, circle, hexagon, etc.—remains selected until you deselect it. This enables you to quickly draw a number of objects of the same type (such as a number of hexagons). Once you have finished drawing objects of a particular type, deselect the drawing tool by press Esc. (You can tell if a drawing tool is still active by the presence of on-screen help at the top left-side corner of the screen, help such as `Hit Point 1`.)

An object in Plot view can be manipulated in numerous ways, and its mathematical properties can be easily determined (see page 150).

Object naming

Each geometric object you create is given a name. In the example shown on page 141, note that the circle has been named `C`. Each defining point is also been named: the center point has been named `A`, and the point tapped to set the radius of the circle has been named `B`.



It is not only the points that define a geometric object that are given a name. Every component of the object that has any geometric significance is also named. If, for example, you create a hexagon, the hexagon is given a name as is each point at each vertex. In the example at the right, the pentagon is named C, the points used to define the hexagon are named A and B, and the remaining four vertices are named D, E, G, and H. Moreover, each of the six segments is also given a name: I, J, K, L, M, and N. These names are not displayed in Plot view, but you can see them if you go to Symbolic view (see “Symbolic view in detail” on page 148).

Naming objects and parts of objects enables you to refer to them in calculations. This is explained in “Numeric view in detail” on page 150.

You can rename an object. See “Symbolic Setup view” on page 150.

Selecting an object

To select an object, just tap on it. The color of a selected item changes to cyan.

To select a point in Plot view, just press Enter. A list of all the points appears. Select the one you want.

Hiding names

You can choose to hide the name of an object in Plot view:

1. Select the object whose label (that is, caption) you want to hide.
2. Press Menu.
3. Select `Toggle Caption`.
4. Press Esc.

Redisplay a hidden name by repeating this procedure.

Moving objects

Points To move a point press Enter. A list of all the points appears. Select the one you want to move, then tap on the new location for it, and press Enter.

You can also select a point by tapping on it.

In addition to tapping a new location for a selected point, you can press the arrow keys to move the point to a new location, or use a finger to drag the point to a new location.

A point can also be selected directly by tapping on it. (If the bottom-right of the screen shows the name of the point, you have accurately tapped the point; otherwise the pointer coordinates are shown, indicating that the point is not selected.)

Composite objects To move a multi-point object, see “Translation” on page 161.

Coloring objects

An object is colored black by default (and cyan when it is selected). If you want to change the color of an object:

1. Select the object whose color you want to change.
2. Press Menu Paste.
3. Select `Change Color`.

   The **Choose Color** palette appears.
4. Select the color you want.
5. Press Esc Clear.

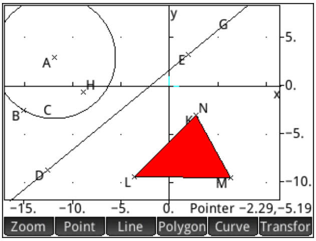
Filling objects

An object with closed contours (such as a circle or polygon) can be filled with color.

1. Press Menu Paste.
2. Select `Fill with Color`.

   The **Select Object** menu appears.
3. Select the object you want to fill.

   The object is highlighted.



1. Press Menu Paste.
2. Select `Change Color`.

   The **Choose Color** palette appears.
3. Select the color you want.
4. Press Esc Clear.

Removing fill

To remove the fill from an object:

1. Press Menu Paste.
2. Select `Fill with Color`.

   The **Select Object** menu appears.
3. Select the object.

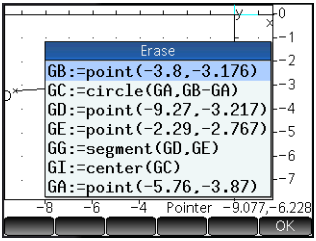
Undoing

You can undo your last addition or change to Plot view by pressing 4 Matrix U. However, you must have keyboard shortcuts activated for this to work. See page 147.

Clearing an object

To clear one object, select it and tap Del. Note that an object is distinct from the points you entered to create it. Thus deleting the object does not delete the points that define it. Those points remain in the app. For example, if you select a circle and press Del, the circle is deleted but the center point and radius point remain.

If you tap Del when no object is selected, a list of objects appears. Tap on the one you want to delete. (If you don't want to delete an object, press Esc to close the list.) If other objects are dependent on the one you have selected for deletion, you will be asked to confirm your intention. Tap OK to do so, otherwise tap Cancel.



```
Erase
GB:=point(-3.8,-3.176)
GC:=circle(GA,GB-GA)
GD:=point(-9.27,-3.217)
GE:=point(-2.29,-2.767)
GG:=segment(GD,GE)
GI:=center(GC)
GA:=point(-5.76,-3.87)
```

Pointer -9.077,-6.228

Note that points you add to an object once the object has been defined are cleared when you clear the object. Thus if you place a point (say D) on a circle and delete the circle, the circle and D are deleted, but the defining points—the center and radius points—remain.

Clearing all objects

To clear the app of all geometric objects, press Shift Esc. You will be asked to confirm your intention to do so. Tap OK to clear all objects defined in Symbolic view or Cancel to keep the app as it is. You can clear all measurements and calculations in Numeric view in the same way.

Moving about the Plot view

You can pan by dragging a finger across the screen: either up, down, left, or right. You can also use the cursor keys to pan once the cursor is at the edge of the screen.

Zooming

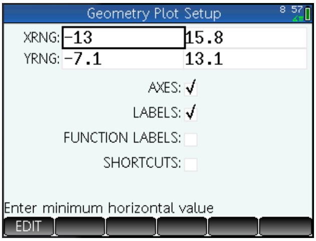
You can zoom by tapping Zoom and choosing a zoom option. The zoom options are the same as you find in the Plot view of many apps in the calculator (see "Zoom" on page 88).

Plot view: buttons and keys

Button or key	Purpose
Zoom	Various scaling options. See “Zoom” on page 88.
Point	Tools for creating various types of points. See “Points” on page 153
Line	Tools for creating various types of lines. See “Line” on page 156
Polygon	Tools for creating various types of polygons. See “Polygon” on page 157
Curve	Tools for creating various types of curves and plots. See “Curve” on page 158
Transfor	Tools for geometric transformations of various kinds. See “Geometric transformations” on page 161.
⌫ Del	Deletes a selected object (or the character to the left of the cursor if the entry line is active).
Esc Clear	De-activate the current drawing tool
Shift Esc Clear	Clears the Plot view of all geometric objects or the Numeric view of all measurements and calculations.
Shortcut keys	To quickly add an object, and undo what you’ve done. See page 147.

Plot Setup view

The Plot Setup view enables you to configure the appearance of Plot view and to take advantage of keyboard shortcuts.


Geometry Plot Setup

XRNG: -13 15.8

YRNG: -7.1 13.1

AXES: ✓

LABELS: ✓

FUNCTION LABELS: □

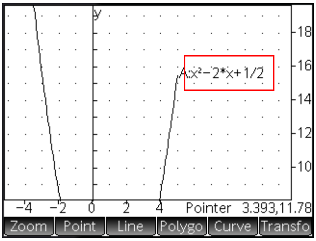
SHORTCUTS: □

Enter minimum horizontal value

The fields and options are:

- **X Rng**: Two fields for entering the minimum and maximum x-values, thereby giving the default horizontal range. As well as changing this range on the **Geometry Plot Setup** screen, you can change it by panning and zooming.
- **Y Rng**: Two fields for entering the minimum and maximum y-values, thereby giving the default vertical range. As well as changing this range on the **Geometry Plot Setup** screen, you can change it by panning and zooming.
- **Axes**: A toggle option to hide (or reshow) the axes in Plot view.

  Keyboard shortcut: Vars Chars A
- **Labels**: A toggle option to hide (or reshow) the names of the geometric objects (A, B, C, etc.) in Plot view.
- **Function Labels**: A toggle option to hide (or reshow) the expression that generated a plot with the plot. These should not be confused with calculation labels. You can show function labels without also showing calculation labels and vice versa).

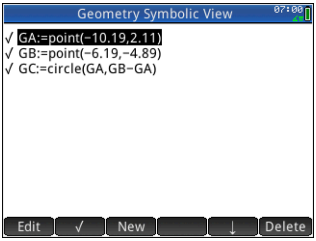


- **Shortcuts**: A toggle option to enable (or disable) keyboard shortcuts (that is, hot keys) in Plot view. With this option enabled, the following shortcuts become available:

Key	Result in Plot view
Vars Chars A	Hide (or reshow) the axes.
$\frac{\square}{\square}$,$\sqrt{\square}$,$\lvert\square\rvert$ Units C	Selects the circle drawing tool. Follow the instructions on the screen (or see page 158).
a b/c ° ′ ″ E	Erases all trace lines (see page 154)

Key	Result in Plot view (Continued)
TAN ATAN I	Selects the intersection drawing tool. Follow the instructions on the screen (or see page 154).
x^2 √ L	Selects the line drawing tool. Follow the instructions on the screen (or see page 156).
EEX Sto▸ P	Selects the point drawing tool. Follow the instructions on the screen (or see page 153).
9 !,∞,→ S	Selects the segment drawing tool. Follow the instructions on the screen (or see page 156).
÷ x^{-1} T	Selects the triangle drawing tool. Follow the instructions on the screen (or see page 157).
4 Matrix U	Undo.

Symbolic view in detail



√ GA:=point(−10.19,2.11)
√ GB:=point(−6.19,−4.89)
√ GC:=circle(GA,GB−GA)

Every object—whether a point, segment, line, polygon, or curve—is given a name, and its definition is displayed in Symbolic view (Symb Setup). The name is the name for it you see in Plot view, but prefixed by "G". Thus a point labeled A in Plot view is given the name GA in Symbolic view.

The G-prefixed name is a variable that can be read by the computer algebra system (CAS). Thus in the CAS you can include such variables in calculations. Note in the illustration above that GC is the name of the variable that represents a circle drawn in Plot view. If you are working in the CAS and wanted to know what the area of that circle is, you could enter `area(GC)` and press Enter ≈. (The CAS is explained in chapter 3.)

Note Calculations referencing geometry variables can be made in the CAS or in the Numeric view of the Geometry app (explained below on page 150).

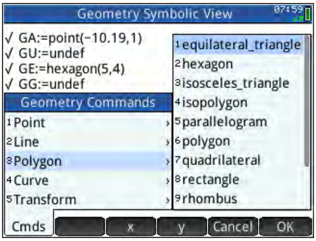
You can change the definition of an object by selecting it, tapping Edit, and altering one or more of its defining parameters. The object is modified accordingly in Plot view. For example, if you selected point `GB` in the illustration above, tapped Edit, changed one or both of the point's coordinates, and tapped OK, you would find, on returning to Plot view, a circle of a different size.

Creating objects

You can also create an object in Symbolic view. Tap New, define the object—for example, `point(4,6)`—and press Enter. The object is created and can be seen in Plot view.

Another example: to draw aline through points P and Q, enter `line(GP,GQ)` in Symbolic view and press Enter. When you return to Plot view, you will see a line passing through points P and Q.

The object-creation commands available in Symbolic view can be seen by tapping Cmds. The syntax for each command is given in "Geometry functions and commands" on page 165.



```
√ GA:=point(−10.19,1)
√ GU:=undef
√ GE:=hexagon(5,4)
√ GG:=undef
```

Re-ordering entries

You can re-order the entries in Symbolic view. Objects are drawn in Plot view in the order in which they are defined in Symbolic view. To change the position of an entry, highlight it and tap either ↓ (to move it down the list) or ↑ (to move it up).

Hiding an object

To prevent an object displaying in Plot view, deselect it in Symbolic view:

1. Highlight the item to be hidden.
2. Tap √.

Repeat the procedure to make the object visible again.

Deleting an object

As well as deleting an object in Plot view (see page 145) you can delete an object in Symbolic view.

1. Highlight the definition of the object you want to delete.
2. Tap Delete or press Del.

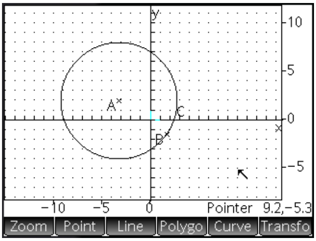
To delete all objects, press Shift Esc Clear.

Symbolic Setup view

The Symbolic view of the Geometry app is common with many apps. It is used to override certain system-wide settings. For details, see “Symbolic Setup view” on page 74.

Numeric view in detail

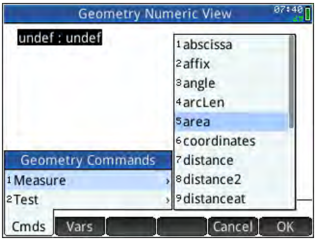
Numeric view (Num Setup) enables you to do calculations in the Geometry app. The results displayed are dynamic—if you manipulate an object in Plot view or Symbolic view, any calculations in Numeric view that refer to that object are automatically updated to reflect the new properties of that object.



Consider circle `C` in the illustration at the right. To calculate the area and radius of `C`:

1. Press Num Setup to open Numeric view.
2. Tap New.
3. Tap Cmds and choose `Measure > Area`.

   Note that `area()` appears on the entry line, ready for you to specify the object whose area you are interested in.


Geometry Numeric View

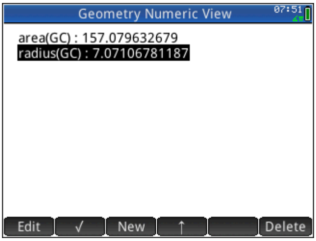
undef : undef

4. Tap Vars, choose `Curves` and then the curve whose area you are interested in.

   The name of the object is placed between the parentheses.

You could have entered the command and object name manually, that is, without choosing them from menus. If you enter object names manually, remember that the name of the object in Plot view must be given a "G" prefix if it is used in any calculation. Thus the circle named `C` in Plot view must be referred to as `GC` in Numeric view and Symbolic view.

5. Press Enter ≈ or tap OK. The area is displayed.
6. Tap New.
7. Enter `radius(GC)` and tap OK. The radius is displayed.



area(GC) : 157.079632679
radius(GC) : 7.07106781187

   Note that the syntax used here is the same as you use in the CAS to calculate the properties of geometric objects.

   The Geometry functions and their syntax are described in "Geometry functions and commands" on page 165.

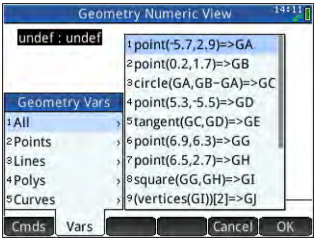
8. Press Plot Setup to go back to Plot view. Now manipulate the circle is some way that changes its area and radius. For example, select the center point (`A`) and use the cursor keys to move it to a new location. (Remember to press Enter ≈ when you have finished.)
9. Press Num Setup to go back to Numeric view. Notice that the area and radius calculations have been automatically updated.

Note

If an entry in Numeric view is too long for the screen, you can press ▶ to scroll the rest of the entry into view. Press ◀ to scroll back to the original view.

Listing all objects

When you are creating a new calculation in Numeric view, the Vars menu item appears. Tapping Vars gives you a list of all the objects in your Geometry workspace. These are also



undef : undef

1 point(-5.7,2.9)=>GA
2 point(0.2,1.7)=>GB
3 circle(GA,GB-GA)=>GC
4 point(5.3,-5.5)=>GD
5 tangent(GC,GD)=>GE
6 point(6.9,6.3)=>GG
7 point(6.5,2.7)=>GH
8 square(GG,GH)=>GI
9 (vertices(GI))[2]=>GJ

grouped according to their type, with each group given its own menu.

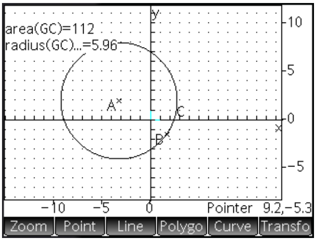
If you are building a calculation, you can select an object from one of these variables menus. The name of the selected object is placed at the insertion point on the entry line.

Getting object properties

As well as employing functions to make calculations in Numeric view, you can also get various parameters of objects just by tapping New and specifying the object's name. For example, you can get the coordinates of a point by entering the point and pressing Enter ≈. Another example: you can get the formula for a line just by entering its name, or the center point and radius of a circle just by entering the name of the circle.

Displaying calculations in Plot view

To have a calculation made in Numeric view appear in Plot view, just highlight it in Numeric view and tap √. A checkmark appears beside the calculation.



Repeat the procedure to prevent the calculation being displayed in Plot view. The checkmark is cleared.

Editing a calculation

1. Highlight the calculation you want to delete.
2. Tap Edit.
3. Make your change and tap OK.

Deleting a calculation

1. Highlight the calculation you want to delete.
2. Tap Delete.

To delete all calculations, press Shift Esc Clear. Note that deleting a calculation does not delete any geometric objects from Plot or Symbolic view.

Geometric objects

The geometric objects discussed in this section are those that can be created in Plot view. Objects can also be created in Symbolic view—more, in fact, than in Plot view—but these are discussed in "Geometry functions and commands" on page 165.

In Plot view, you choose a drawing tool to draw an object. The tools are listed in this section. Note that once you select a drawing tool, it remains selected until you deselect it. This enables you to quickly draw a number of objects of the same type (such as a number of circles). To deselect the current drawing tool, press Esc Clear. (You can tell if a drawing tool is still active by the presence of on-screen help in the top left-side corner of the screen, help such as `Hit Point 1`.)

The steps provided in this section are based on touch entry. For example, to add a point, the steps will tell you to *tap* on the screen where you want the point to be and press Enter ≈. However, you can also use the cursor keys to position the cursor where you want the point to be and then press Enter ≈.

The drawing tools for the geometric objects listed in this section can be selected from the menu buttons at the bottom of the screen. Some objects can also be entered using a keyboard shortcut. For example, you can select the triangle drawing tool by pressing x^{-1} ÷ T. (Keyboard shortcuts are only available if they have been turned on in Plot Setup view. See page 146.)

Points

Tap Point to display a menu and submenus of options for entering various types of points. The menus and submenus are:

Point

Tap where you want the point to be and press Enter ≈.

Keyboard shortcut: EEX Sto▸ P

Point On

Tap the object where you want the new point to be and press Enter ≈. If you select a point that has been placed on an object and then move that point, the point will be constrained to the object on which it was placed. For example, a point placed on a circle will remain on that circle regardless of how you move the point.

If there is no object where you tap, a point is created if you then press Enter.

Midpoint

Tap where you want one point to be and press Enter. Tap where you want the other point to be and press Enter. A point is automatically created midway between those two points.

If you choose an object first—such as a segment—choosing the Midpoint tool and pressing Enter adds a point midway between the ends of that object. (In the case of a circle, the midpoint is created at the circle's center.)

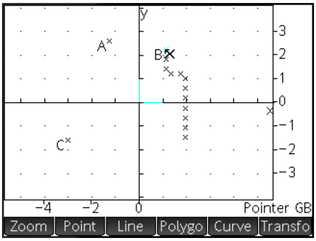
Intersection

Tap the desired intersection and press Enter. A point is created at one of the points of intersection.

Keyboard shortcut: TAN ATAN

More

Trace



Displays a list of points for you to choose the one you want to trace. If you subsequently move that point, a trace line is drawn on the screen to show its path. In the example at the right, point B was chosen to be traced. When that point was moved—up and to the left—a path of its movement was created.

Trace creates an entry in Symbolic view. In the example above, the entry is `Trace(GB)`.

Stop Trace

Turns off tracing and deletes the definition of the trace point from Symbolic view. If more than one point is being traced, a menu of trace points appears so that you can choose which one to untrace.

`Stop Trace` does not erase any existing trace lines. It merely prevents any further tracing should the point be moved again.

Erase Trace

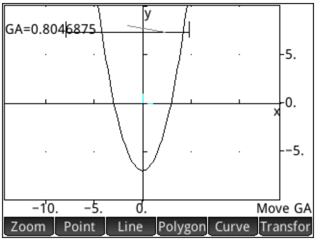
Erases all trace lines, but leaves the definition of the trace points in Symbolic view. While a Trace definition is still in Symbolic view, if you move the point again, a new trace line is created.

Center

Tap a circle and press Enter. A point is created at the center of the circle.

Element 0 .. 1

`Element 0 .. 1` has a number of uses. You can use it to place a constrained point on a object (whether previously created or not). For example, if in Symbolic view you define GA as `element(circle(),2))`, go to Plot view, turn on tracing, select GA and move it, you will see that GA is constrained to move in a circle centered on the origin and of radius 2.



You can also use `Element 0 .. 1` to generate values that can then be used as coefficients in functions you subsequently plot. For example, in Plot view select `Element 0 .. 1`. Notice that a label is added to the screen—GA, for example—and given a value of 0.5. You can now use that label as a coefficient in a function to be plotted. For example, you could choose `Curve` > `Plot` > `Function` and define a function as GA*x^2–7. A plot of 0.5x^2–7 appears in Plot view. Now select the label (GA, in this example) and press Enter. An interval bar appears on the screen. Tap anywhere along the interval bar (or press ◀ or ▶). The value of GA—and the shape of the graph—change to match the value along the at which you tapped.

Intersections

Tap one object other than a point and press Enter. Tap another object and press Enter. The point(s) where the two objects intersect are created and named. Note that an intersections object is created in Symbolic view even if the two objects selected do not intersect.

Random pts

Displays a palette for you to choose to add 1, 2, 3, or 4 points. The points are placed randomly.

Line

Segment

Tap where you want one endpoint to be and press Enter. Tap where you want the other endpoint to be and press Enter. A segment is drawn between the two end points.

Keyboard shortcut: 9

Ray

Tap where you want the endpoint to be and press Enter. Tap a point that you want the ray to pass through and press Enter. A ray is drawn from the first point and through the second point.

Line

Tap at a point you want the line to pass through and press Enter. Tap at another point you want the line to pass through and press Enter. A line is drawn through the two points.

Keyboard shortcut: x^2

Vector

Tap where you want one endpoint to be and press Enter. Tap where you want the other endpoint to be and press Enter. A vector is drawn between the two end points.

Angle bisector

1 ∡ Bisector

Tap the point that is the vertex of the angle to be bisected (A) and press Enter. Tap another point (B) and press Enter. Tap a third point (C) and press Enter. A line is drawn through A bisecting the angle formed by $\overline{AB}$ and $\overline{AC}$.

Perpendicular bisector

2 ⊥ Bisector

Tap one point and press Enter. Tap another point and press Enter. These two points define a segment. A line is drawn perpendicular to the segment through its midpoint. It does not matter if the segment is actually defined in the Symbolic view or not. Alternately, tap to select a segment and press Enter.

If you are drawing a perpendicular bisector to a segment, choose the segment first and then select **Perp. Bisector** from the **Line** menu. The bisector is drawn immediately without you having to select any points. Just press Enter to save the bisector.

Parallel

3∥

Tap on a point (*P*) and press Enter. Tap on a line (*L*) and press Enter. A new line is draw parallel to *L* and passing through *P*.

Perpendicular

4⊥

Tap on a point (*P*) and press Enter. Tap on a line (*L*) and press Enter. A new line is draw perpendicular to *L* and passing through *P*.

Tangent

Tap on a curve (*C*) and press Enter. Tap on a point (*P*) and press Enter. If the point (*P*) is on the curve (*C*), then a single tangent is drawn. If the point *(P*) is not on the curve (*C*), then zero or more tangents may be drawn.

Median

Tap on a point (A) and press Enter. Tap on a segment and press Enter. A line is drawn through the point (A) and the midpoint of the segment.

Altitude

Tap on a point (A) and press Enter. Tap on a segment and press Enter. A line is drawn through the point (A) perpendicular to the segment (or its extension).

Polygon

The **Polygon** menu provides tools for drawing various polygons.

Triangle

Tap at each vertex, pressing Enter after each tap.

Keyboard shortcut: ÷

Quadrilateral

Tap at each vertex, pressing Enter after each tap.

Ngon

Polygon5

Produces a pentagon. Tap at each vertex, pressing Enter after each tap.

Polygon6

Produces a hexagon. Tap at each vertex, pressing Enter after each tap.

Hexagon

Produces a regular hexagon (that is, one with sides of equal length and angles of equal measure). Tap on a point and press Enter. Tap on a second point to define the length of one side of the regular hexagon and press Enter. The other four vertices are automatically calculated and the regular hexagon is drawn.

Special

Eq. triangle

1 Equilateral △

Produces an equilateral triangle. Tap at one vertex and press Enter. Tap at another vertex and press Enter. The location of the third vertex is automatically calculated and the triangle is drawn.

Square

Tap at one vertex and press Enter. Tap at another vertex and press Enter. The location of the third and fourth vertices are automatically calculated and the square is drawn.

Parallelogram

Tap at one vertex and press Enter. Tap at another vertex and press Enter. Tap at a third vertex and press Enter. The location of the fourth vertex is automatically calculated and the parallelogram is drawn.

Curve

Circle

Tap at the center of the circle and press Enter. Tap at a point on the circumference and press Enter. A circle is drawn about the center point with a radius equal to the distance between the two tapped points.

Keyboard shortcut: Units

You can also create a circle by first defining it in Symbolic view. The syntax is `circle(GA,GB)` where `A` and `B` are two points. A circle is drawn in Plot view such that `A` and `B` define the diameter of the circle.

Ellipse

Tap at one focus point and press Enter. Tap at the second focus point and press Enter. Tap at point on the circumference and press Enter.

Hyperbola

Tap at one focus point and press Enter. Tap at the second focus point and press Enter. Tap at point on one branch of the hyperbola and press Enter.

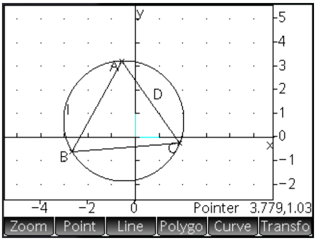
Parabola

Tap at the focus point and press Enter. Tap either on a line (the directrix) or a ray or segment nd press Enter.

Special

Circumcircle

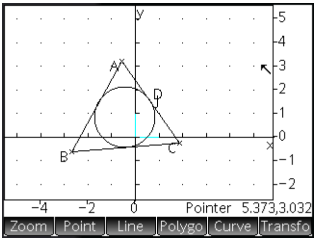
A circumcircle is the circle that passes through each of the triangle’s three vertices, thus enclosing the triangle.



Tap at each vertex of the triangle, pressing Enter after each tap.

Incircle

An incircle is a circle that is tangent to each of a polygon’s sides. The HP Prime can draw an incircle that is tangent to the sides of a triangle.

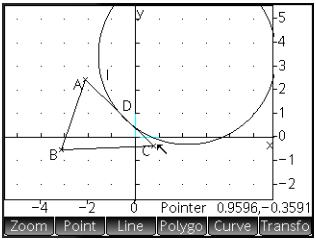


Tap at each vertex of the triangle, pressing Enter after each tap.

Excircle

An excircle is a circle that is tangent to one segment of a triangle and also tangent to the rays through the segment’s endpoints from the vertex of the triangle opposite the segment.

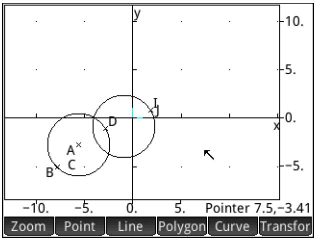
Tap at each vertex of the triangle, pressing Enter after each tap.



The excircle is drawn tangent to the side defined by the last two vertices tapped. In the example at the right, the last two vertices tapped were A and C (or C and A). Thus the excircle is drawn tangent to the segment $\overline{AC}$.

Locus

Takes two points as its arguments: the first is the point whose possible locations form the locus; the second is a point on an object. This second point drives the first through its locus as the second moves on its object.

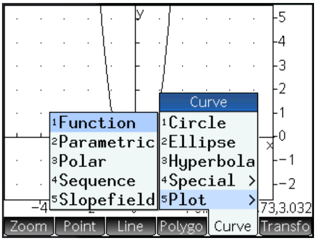


In the example at the right, circle C has been drawn and point D is a point placed on C (using the `Point On` function described above). Point I is a translation of point D. Choosing `Curve` > `Special` > `Locus` places `locus(` on the entry line. Complete the command as `locus(GI,GD)` and point I traces a path (its locus) that parallels point D as it moves around the circle to which it is constrained.

Plot

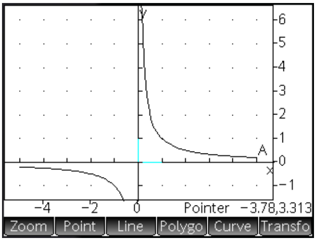
You can plot expressions of the following types in Plot view:

- Function
- Parametric
- Polar
- Sequence



Tap Curve, select **Plot**, and then the type of expression you want to plot. The entry line is enabled for you to define the expression.

Note that the variables you specify for an expression must be in lowercase.



In this example, **Function** has been selected as the plot type and the graph of y = 1/ x is plotted.

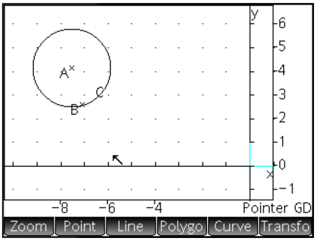
Geometric transformations

The **Transform** menu—displayed by tapping Transfor—provides numerous tools for you to perform transformations on geometric objects in Plot view. You can also define transformations in Symbolic view

Translation

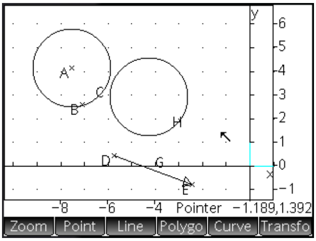
A translation is a transformation of a set of points that moves each point the same distance in the same direction. T: (x,y) → (x+a, y+b). You must create a vector to indicate the distance and direction of the translation. You then choose the vector and the object to be translated.

Suppose you want to translate circle B at the right down a little and to the right:



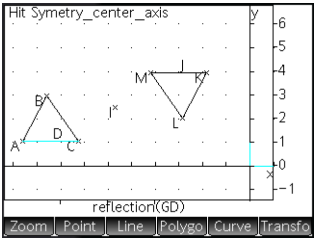
1. Tap Line and select **Vector**.
2. Draw a vector in the direction you want to translate the circle and of the same length as move you intend. (If you need help, see "Vector" on page 156.)
3. Tap Transfor and select `Translation`.
4. Tap the vector and press Enter ≈.
5. Tap the object to be moved and press Enter ≈.

   The object is moved the same length as the vector and in the same direction. The original object is left in place.



Reflection

A reflection is a transformation which maps an object or set of points onto its mirror image, where the mirror is either a point or a line. A reflection through a point is sometimes called a half-turn. In either case, each point on the mirror image is the same distance from the mirror as the corresponding point on the original. In the example at the right, the original triangle D is reflected through point I.


Hit Symetry_center_axis

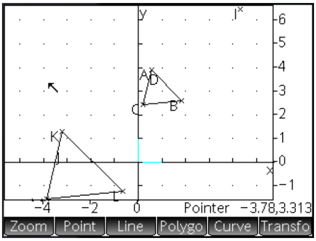
reflection(GD)

1. Tap Transfor and select **Reflection**.
2. Tap the point or straight object (segment, ray, or line) that will be the symmetry axis (that is, the mirror) and press Enter.
3. Tap the object that is to be reflected across the symmetry axis and press Enter. The object is reflected across the symmetry axis defined in step 2.

Dilation

A dilation (also called a homothety or uniform scaling) is a transformation where an object is enlarged or reduced by a given scale factor around a given point as center.

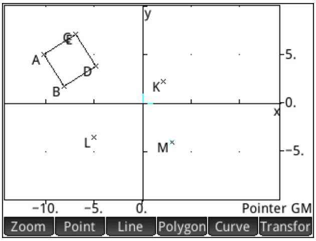
In the illustration at the right, the scale factor is 2 and the center of dilation is indicated by a point near the top right of the screen (named *I*). Each point on the new triangle is collinear with its corresponding point on the original triangle and point I. Further, the distance from point *I* to each new point will be twice the distance to the original point (since the scale factor is 2).


Pointer −3.78,3.313

1. Tap Transfor and select **Dilation**.
2. Tap the point that is to be the center of dilation and press Enter.
3. Enter the scale factor and press Enter.
4. Tap the object that is to be dilated and press Enter.

Rotation

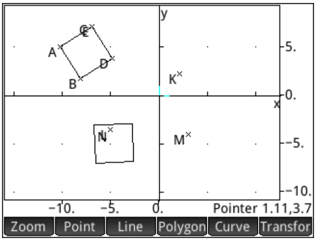
A rotation is a mapping that rotates each point by a fixed angle around a center point. The angle is defined using the `angle()` command, with the vertex of the angle as the first argument. Suppose you wish to rotate the square (GC) around point K (GK) through ∡ LKM in the figure to the right.



1. Press Symb and tap New.
2. Tap Cmds and select `Transform` > `Rotation`.

   `rotation()` appears on the entry line.
3. Between the parentheses, enter:

   `GK,angle(GK,GL,GM),GC`
4. Press Enter or tap OK.
5. Press Plot to return to Plot view to see the rotated square.



More

Projection

A projection is a mapping of one or more points onto an object such that the line passing through the point and its image is perpendicular to the object at the image point.

1. Tap Transfor and select **Projection**.
2. Tap the object onto which points are to be projected and press Enter.
3. Tap the point that is to be projected and press Enter.

   Note the new point added to the target object.

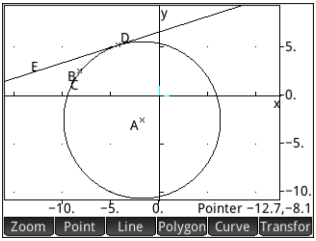
Inversion

An inversion is a mapping involving a center point and a scale factor. Specifically, the inversion of point A through center C, with scale factor k, maps A onto A′, such that A′ is on line CA and CA*CA′=k, where CA and CA′ denote the lengths of the corresponding segments. If k=1, then the lengths CA and CA' are reciprocals.

Suppose you wish to find the inversion of a circle (GC) with a point on the circle (GD) as center.

1. Tap Transfor and select `More > Inversion`.
2. Tap the point that is to be the center (GD) of the inversion circle and press Enter.
3. Enter the inversion ratio—use the default value of 1—and press Enter.
4. Tap on the circle(GC) and press Enter.

   You will see that the inversion is a line.

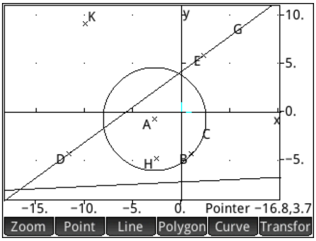


Reciprocation

A reciprocation is a special case of inversion involving circles. A reciprocation with respect to a circle transforms each point in the plane into its polar line. Conversely, the reciprocation with respect to a circle maps each line in the plane into its pole.

1. Tap Transfor and select `More > Reciprocation`.
2. Tap the circle and press Enter.
3. Tap a point and press Enter to see its polar line.
4. Tap a line and press Enter to see its pole.

   In the illustration to the right, point K is the reciprocation of line DE (G) and Line I (at the bottom of the display) is the reciprocation of point H.



Geometry functions and commands

The list of geometry-specific functions and commands in this section covers those that can be found by tapping Cmds in both Symbolic and Numeric view and those that are only available from the Catlg menu.

The sample syntax provided has been simplified. Geometric objects are referred to by a single uppercase character (such as A, B,C and so on). However, calculations referring to geometric objects—in the Numeric view of the Geometry app and in the CAS—must use the G-prefixed name given for it in Symbolic view. For example:

> `altitude(A,B,C)` is the simplified form given in this section
>
> `altitude(GA,GB,GC)` is the form you need to use in calculations

Further, in many cases the specified parameters in the syntax below—A, B, C etc.—can be the name of a point (such as GA) or a complex number representing a point. Thus `angle(A,B,C)` could be:

- `angle(GP,GR,GB)`
- `angle(3+2i,1−2i,5+i)` or
- a combination of named points and points defined by a complex number, as in `angle(GP,i1−2i,i).`

Symbolic view: Cmds menu

Point

barycenter

Calculates the hypothetical center of mass of a set of points, each with a given weight (a real number). Each point, weight pair is enclosed in square brackets as a vector.

```
barycenter([[point1, weight1], [point2,
weight2],…,[pointn, weightn]])
```

Example:

`barycenter` $\left(\begin{bmatrix} \text{point}(1) & 1 \\ \text{point}(1+i) & 2 \\ \text{point}(1-i) & 1 \end{bmatrix}\right)$ returns point `(1/2, 1/4)`

center

Returns the center of a circle.

```
center(circle)
```

Example: `center(circle(x`^{2}`+y`^{2}`-x-y))` gives `point(1/2,1/2)`

division_point

For two points A and B, and a numerical factor *k*, returns a point C such that C-B=*k**(C-A).

```
division_point(point1, point2, realk)
```

Example: `division_point(0,6+6*i,4)` returns point (8,8)

element

Creates a point on a geometric object whose abscissa is a given value or creates a real value on a given interval.

```
element(object, real) or element(real1..real2)
```

Examples:

`element(plotfunc(x`^{2}`),-2)` creates a point on the graph of $y = x^2$. Initially, this point will appear at (–2,4). You can move the point, but it will always remain on the graph of its function.

`element(0..5)` creates a value of 2.5 initially. Tapping on this value and pressing Enter enables you to press ▶ and ◀ to increase or decrease the value in a manner similar to a slider bar. Press Enter again to close the slider bar. The value you set can be used as a coefficient in a function you subsequently plot.

inter

Returns the intersections of two curves as a vector.

```
inter(curve1, curve2)
```

Example: inter$\left(8-\frac{x^2}{6}, \frac{x}{2}-1\right)$ returns $\begin{bmatrix} 6 & 2 \\ -9 & \frac{-11}{2} \end{bmatrix}$. This indicates that there are two intersections:

- (6,2)
- (–9,–5.5)

isobarycenter

Returns the hypothetical center of mass of a set of points. Works like barycenter but assumes that all points have equal weight.

```
isobarycenter(point1, point2, …,pointn)
```

Example: `isobarycenter(-3,3,3*√3*i)` returns point(3*√3*i/3), which is equivalent to (0,√3).

midpoint

Returns the midpoint of a segment. The argument can be either the name of a segment or two points that define a segment. In the latter case, the segment need not actually be drawn.

```
midpoint(segment) or midpoint(point1, point2)
```

Example: `midpoint(0,6+6i)` returns `point(3,3)`

orthocenter

Returns the orthocenter of a triangle; that is, the intersection of the three altitudes of a triangle. The argument can be either the name of a triangle or three non-collinear points that define a triangle. In the latter case, the triangle does not need to be drawn.

```
orthocenter(triangle) or orthocenter(point1,
point2, point3)
```

Example: `orthocenter(0,4i,4)` returns `(0,0)`

point

Creates a point, given the coordinates of the point. Each coordinate may be a value or an expression involving variables or measurements on other objects in the geometric construction.

```
point(real1, real2) or point(expr1, expr2)
```

Examples:

`point(3,4)` creates a point whose coordinates are (3,4). This point may be selected and moved later.

`point(abscissa(A), ordinate(B))` creates a point whose x-coordinate is the same as that of a point A and whose y-coordinate is the same as that of a point B. This point will change to reflect the movements of point A or point B.

point2d

Randomly re-distributes a set of points such that, for each point, x ∈ [–5,5] and y ∈ [–5,5]. Any further movement of one of the points will randomly re-distribute all of the points with each tap or direction key press.

```
point2d(point1, point2, …, pointn)
```

trace

Begins tracing of a specified point.

```
trace(point)
```

stop trace

Stops tracing of a specified point, but does not erase the current trace. This command is only available in Plot view. In Symbolic view, uncheck the trace object to erase the trace and stop further tracing

erase trace

Erases the trace of a point, but does not stop tracing. Any further movement of the point will be traced. In Symbolic view, uncheck the trace object to erase the trace and stop further tracing.

Line

DrawSlp

Given three real numbers *m*, *a*, *b*, draws a line with slope *m* that passes through the point (*a*, *b*).

```
DrawSlp(a,b,m)
```

Example: `DrawSlp(2,1,3)` draws the line given by y=3x–5

altitude

Given three non-collinear points, draws the altitude of the triangle defined by the three points that passes through the first point. The triangle does not have to be drawn.

```
altitude(point1, point2, point3)
```

Example: `altitude(A, B, C)` draws a line passing through point A that is perpendicular to $\overline{BC}$.

bisector

Given three points, creates the bisector of the angle defined by the three points whose vertex is at the first point. The angle does not have to be drawn in the Plot view.

```
bisector(point1, point2, point3)
```

Examples:

`bisector(A,B,C)` draws the bisector of ∡ BAC.

`bisector(0,-4i,4)` draws the line given by y=–x

exbisector

Given three points that define a triangle, creates the bisector of the exterior angles of the triangle whose common vertex is at the first point. The triangle does not have to be drawn in the Plot view.

```
exbisector(point1, point2, point3)
```

Examples:

`exbisector(A,B,C)` draws the bisector of the exterior angles of ΔABC whose common vertex is at point A.

`exbisector(0,−4i,4)` draws the line given by y=x

half_line

Given 2 points, draws a ray from the first point through the second point.

```
half_line((point1, point2)
```

line

Draws a line. The arguments can be two points, a linear expression of the form a**x*+b**y*+c, or a point and a slope as shown in the examples.

`line(point1, point2)` or `line(a*x+b*y+c)` or
`line(point1, slope=real`*m*`)`

Examples:

`line(2+i, 3+2i)` draws the line whose equation is y=x–1; that is, the line through the points (2,1) and (3,2).

`line(2x−3y−8)` draws the line whose equation is 2x–3y=8

`line(3−2i,slope=1/2)` draws the line whose equation is x–2y=7; that is, the line through (3, –2) with slope m=1/2.

median_line

Given three points that define a triangle, creates the median of the triangle that passes through the first point and contains the midpoint of the segment defined by the other two points.

```
median_line(point1, point2, point3)
```

Example:

`median_line(0, 8i, 4)` draws the line whose equation is y=2x; that is, the line through (0,0) and (2,4), the midpoint of the segment whose endpoints are (0, 8) and (4, 0).

parallel

Draws a line through a given point that is parallel to a given line.

```
parallel(point,line)
```

Examples:

`parallel(A, B)` draws the line through point A that is parallel to line B.

`parallel(3-2i, x+y-5)` draws the line through the point (3, –2) that is parallel to the line whose equation is x+y=5; that is, the line whose equation is y=–x+1.

perpen_bisector

Draws the perpendicular bisector of a segment. The segment is defined either by its name or by its two endpoints.

```
perpen_bisector(segment) or
perpen_bisector(point1, point2)
```

Examples:

`perpen_bisector(GC)` draws the perpendicular bisector of segment C.

`perpen_bisector(GA, GB)` draws the perpendicular bisector of segment AB.

`perpen_bisector(3+2i, i)` draws the perpendicular bisector of a segment whose endpoints have coordinates (3, 2) and (0, 1); that is, the line whose equation is y=x/3+1.

perpendicular

Draws a line through a given point that is perpendicular to a given line. The line may be defined by its name, two points, or an expression in x and y.

```
perpendicular(point, line) or
perpendicular(point1, point2, point3)
```

Examples:

`perpendicular(GA, GD)` draws a line perpendicular to line D through point A.

`perpendicular(3+2i, GB, GC)` draws a line through the point whose coordinates are (3, 2) that is perpendicular to line BC.

`perpendicular(3+2i,line(x-y=1))` draws a line through the point whose coordinates are (3, 2) that is perpendicular to the line whose equation is x – y = 1; that is, the line whose equation is y=–x+5.

segment

Draws a segment defined by its endpoints.

```
segment(point1, point2)
```

Examples:

`segment(1+2i, 4)` draws the segment defined by the points whose coordinates are (1, 2) and (4, 0).

`segment(GA, GB)` draws segment AB.

tangent

Draws the tangent(s) to a given curve through a given point. The point does not have to be a point on the curve.

```
tangent(curve, point)
```

Examples:

`tangent(plotfunc(x^2), GA)` draws the tangent to the graph of y=x^2 through point A.

`tangent(circle(GB, GC-GB), GA)` draws one or more tangent lines through point A to the circle whose center is at point B and whose radius is defined by segment BC.

Polygon

equilateral_triangle

Draws an equilateral triangle defined by one of its sides; that is, by two consecutive vertices. The third point is calculated automatically, but is not defined symbolically. If a lowercase variable is added as a third argument, then the coordinates of the third point are stored in that variable. The orientation of the triangle is counterclockwise from the first point.

```
equilateral_triangle(point1, point2) or
equilateral_triangle(point1, point2, var)
```

Examples:

`equilateral triangle(0,6)` draws an equilateral triangle whose first two vertices are at (0, 0) and (6,0); the third vertex is calculated to be at (3,3*√3).

`equilateral triangle(0,6, v)` draws an equilateral triangle whose first two vertices are at (0, 0) and (6,0); the third vertex is calculated to be at (3,3*√3) and these coordinates are stored in the CAS variable *v*. In CAS view, entering v returns point(3*(√3*i+1)), which is equal to (3,3*√3).

hexagon

Draws a regular hexagon defined by one of its sides; that is, by two consecutive vertices. The remaining points are calculated automatically, but are not defined symbolically. The orientation of the hexagon is counterclockwise from the first point.

```
hexagon(point1, point2) or hexagon(point1,
point2, var1, var2, var3, var4)
```

Examples:

`hexagon(0,6)` draws a regular hexagon whose first two vertices are at (0, 0) and (6, 0).

`hexagon(0,6, a, b, c, d)` draws a regular hexagon whose first two vertices are at (0, 0) and (6, 0) and stores the other four points into the CAS variables *a*, *b*, *c*, and *d*. You do not have to define variables for all four remaining points, but the coordinates are stored in order. For example, `hexagon(0,6, a)` stores just the third point into the CAS variable *a*.

isosceles_triangle

Draws an isosceles triangle defined by two of its vertices and an angle. The vertices define one of the two sides equal in length and the angle defines the angle between the two sides of equal length. Like `equilateral_triangle`, you have the option of storing the coordinates of the third point into a CAS variable.

```
isosceles_triangle(point1, point2, angle)
```

Example:

`isosceles_triangle(GA, GB, angle(GC, GA, GB)` defines an isosceles triangle such that one of the two sides of equal length is AB, and the angle between the two sides of equal length has a measure equal to that of ∡ ACB.

isopolygon

Draws a regular polygon given the first two vertices and the number of sides, where the number of sides is greater than 1. If the number of sides is 2, then the segment is drawn. You can provide CAS variable names for storing the coordinates of the calculated points in the order they were created. The orientation of the polygon is counterclockwise.

```
isopolygon(point1, point2, realn), where realn
is an integer greater than 1.
```

Example

`isopolygon(GA, GB, 6)` draws a regular hexagon whose first two vertices are the points A and B.

parallelogram

Draws a parallelogram given three of its vertices. The fourth point is calculated automatically but is not defined symbolically. As with most of the other polygon commands, you can store the fourth point's coordinates into a CAS variable. The orientation of the parallelogram is counterclockwise from the first point.

```
parallelogram(point1, point2, point3)
```

Example:

`parallelogram(0,6,9+5i)` draws a parallelogram whose vertices are at (0, 0), (6, 0), (9, 5), and (3,5). The coordinates of the last point are calculated automatically.

polygon

Draws a polygon from a set of vertices.

```
polygon(point1, point2, …, pointn)
```

Example:

`polygon(GA, GB, GD)` draws ΔABD

quadrilateral

Draws a quadrilateral from a set of four points.

```
quadrilateral(point1, point2, point3, point4)
```

Example:

`quadrilateral(GA, GB, GC, GD)` draws quadrilateral ABCD.

rectangle

Draws a rectangle given two consecutive vertices and a point on the side opposite the side defined by the first two vertices or a scale factor for the sides perpendicular to the first side. As with many of the other polygon commands, you can specify optional CAS variable names for storing the coordinates of the other two vertices as points.

```
rectangle(point1, point2, point3) or
rectangle(point1, point2, realk)
```

Examples:

`rectangle(GA, GB, GE)` draws a rectangle whose first two vertices are points A and B (one side is segment AB). Point E is on the line that contains the side of the rectangle opposite segment AB.

`rectangle(GA, GB, 3, p, q)` draws a rectangle whose first two vertices are points A and B (one side is segment AB). The sides perpendicular to segment AB have length 3*AB. The third and fourth points are stored into the CAS variables *p* and *q*, respectively.

rhombus

Draws a rhombus, given two points and an angle. As with many of the other polygon commands, you can specify optional CAS variable names for storing the coordinates of the other two vertices as points.

```
rhombus(point1, point2, angle)
```

Example

`rhombus(GA, GB, angle(GC, GD, GE))` draws a rhombus on segment AB such that the angle at vertex A has the same measure as ∡ DCE.

right_triangle

Draws a right triangle given two points and a scale factor. One leg of the right triangle is defined by the two points, the vertex of the right angle is at the first point, and the scale factor multiplies the length of the first leg to determine the length of the second leg.

```
right_triangle(point1, point2, realk)
```

Example:

`right_triangle(GA, GB, 1)` draws an isosceles right triangles with its right angle at point A, and with both legs equal in length to segment AB.

square

Draws a square, given two consecutive vertices as points.

```
square(point1, point2)
```

Example:

Example: square(0, 3+2i, *p*, *q*) draws a square with vertices at (0, 0), (3, 2), (1, 5), and (-2, 3). The last two vertices are computed automatically and are saved into the CAS variables *p* and *q*.

triangle

Draws a triangle, given its three vertices.

```
triangle(point1, point2, point3)
```

Example:

`triangle(GA, GB, GC)` draws ΔABC.

Curve

function

Draws the plot of a function, given an expression in the independent variable x. Note the use of lowercase x.

```
plotfunc(Expr)
```

Example:

Example: plotfunc(3*sin(*x*)) draws the graph of *y*=3*sin(*x*).

circle

Draws a circle, given the endpoints of the diameter, or a center and radius, or an equation in x and y.

circle(point1, point2) or circle(point1, point 2-point1) or circle(equation)

Examples:

`circle(GA, GB)` draws the circle with diameter AB.

`circle(GA, GB-GA)` draws the circle with center at point A and radius AB.

`circle(x^2+y^2=1)` draws the unit circle.

This command can also be used to draw an arc.

`circle(GA, GB, 0, π/2)` draws a quarter-circle with diameter AB.

circumcircle

Draws the circumcircle of a triangle; that is, the circle circumscribed about a triangle.

```
circumcircle(point1, point2, point3)
```

Example:

`circumcircle(GA, GB, GC)` draws the circle circumscribed about ΔABC

conic

Plots the graph of a conic section defined by an expression in x and y.

```
conic(expr)
```

Example:

`conic(x^2+y^2-81)` draws a circle with center at (0,0) and radius of 9

ellipse

Draws an ellipse, given the foci and either a point on the ellipse or a scalar that is one half the constant sum of the distances from a point on the ellipse to each of the foci.

```
ellipse(point1, point2, point3) or
ellipse(point1, point2, realk)
```

Examples:

`ellipse(GA, GB, GC)` draws the ellipse whose foci are points A and B and which passes through point C.

`ellipse(GA, GB, 3)` draws an ellipse whose foci are points A and B. For any point P on the ellipse, AP+BP=6.

excircle

Draws one of the excircles of a triangle, a circle tangent to one side of the triangle and also tangent to the extensions of the other two sides.

```
excircle(point1, point2, point3)
```

Example:

`excircle(GA, GB, GC)` draws the circle tangent to BC and to the rays AB and AC.

hyperbola

Draws a hyperbola, given the foci and either a point on the hyperbola or a scalar that is one half the constant difference of the distances from a point on the hyperbola to each of the foci.

```
hyperbola(point1, point2, point3) or
hyperbola(point1, point2, realk)
```

Examples:

`hyperbola(GA, GB, GC)` draws the hyperbola whose foci are points A and B and which passes through point C.

`hyperbola(GA, GB, 3)` draws a hyperbola whose foci are points A and B. For any point P on the hyperbola, |AP-BP|=6.

incircle

Draws the incircle of a triangle, the circle tangent to all three sides of the triangle.

```
incircle(point1, point2, point3)
```

Example:

`incircle(GA, GB, GC)` draws the incircle of ΔABC.

locus

Given a first point and a second point that is an element of (a point on) a geometric object, draws the locus of the first point as the second point traverses its object.

```
locus(point,element)
```

parabola

Draws a parabola, given a focus point and a directrix line, or the vertex of the parabola and a real number that represents the focal length.

`parabola(point,line)` or `parabola(vertex,real)`

Examples:

`parabola(GA, GB)` draws a parabola whose focus is point A and whose directrix is line B.

`parabola(GA, 1)` draws a parabola whose vertex is point A and whose focal length is 1.

Transform

dilation

Dilates a geometric object, with respect to a center point, by a scale factor.

```
homothety(point, realk, object)
```

Example:

`homothety(GA, 2, GB)` creates a dilation centered at point A that has a scale factor of 2. Each point P on geometric object B has its image P′ on ray AP such that AP′=2AP.

inversion

Draws the inversion of a point, with respect to another point, by a scale factor.

```
inversion(point1, realk, point2)
```

Example:

`inversion(GA, 3, GB)` draws point C on line AB such that AB*AC=3. In this case, point A is the center of the inversion and the scale factor is 3. Point B is the point whose inversion is created.

In general, the inversion of point A through center C, with scale factor k, maps A onto A′, such that A′ is on line CA and CA*CA′=k, where CA and CA′ denote the lengths of the corresponding segments. If k=1, then the lengths CA and CA′ are reciprocals.

projection

Draws the orthogonal projection of a point onto a curve.

```
projection(curve, point)
```

reflection

Reflects a geometric object over a line or through a point. The latter is sometimes referred to as a half-turn.

```
reflection(line, object) or reflection(point,
object)
```

Examples:

`reflection(line(x=3),point(1,1))` reflects the point at (1, 1) over the vertical line x=3 to create a point at (5,1).

`reflection(1+i, 3-2i)` reflects the point at (3,–2) through the point at (1, 1) to create a point at (–1, 4).

rotation

Rotates a geometric object, about a given center point, through a given angle.

```
rotate(point, angle, object)
```

Example:

`rotate(GA, angle(GB, GC, GD),GK)` rotates the geometric object labeled K, about point A, through an angle equal to ∡ CBD.

similarity

Dilates and rotates a geometric object about the same center point.

similarity(point, real*k*, angle, object)

Example:

`similarity(0, 3, angle(0,1,i),point(2,0))` dilates the point at (2,0) by a scale factor of 3 (a point at (6,0)), then rotates the result 90° counterclockwise to create a point at (0, 6).

translation

Translates a geometric object along a given vector. The vector is given as the difference of two points (head-tail).

```
translation(vector, object)
```

Examples:

`translation(0-i, GA)` translates object A down one unit.

`translation(GB-GA, GC)` translates object C along the vector AB.

Measure Plot

angleat

Used in Symbolic view. Given the three points of an angle and a fourth point as a location, displays the measure of the angle defined by the first three points. The measure is displayed, with a label, at the location in the Plot view given by the fourth point. The first point is the vertex of the angle.

```
angleat(point1, point2, point3, point4)
```

Example:

In degree mode, `angleat(point(0, 0), point(2√3, 0), point(2√3, 3), point(-6, 6))` displays “`appoint(0,0)=30.0`” at point (–6,6)

angleatraw

Works the same as angleat, but without the label.

areaat

Used in Symbolic view. Displays the algebraic area of a polygon or circle. The measure is displayed, with a label, at the given point in Plot view.

```
areaat(polygon, point) or areaat(circle,
point)
```

Example:

`areaat(circle(x^2+y^2=1), point(-4,4))` displays “`acircle(x^2+y^2=1)= π`” at point (-4, 4))

areaatraw

Works the same as areaat, but without the label.

distanceat

Used in Symbolic view. Displays the distance between 2 geometrical objects. The measure is displayed, with a label, at the given point in Plot view.

```
distanceat(object1, object2, point)
```

Example:

`distanceat(1+i, 3+3*i, 4+4*i)` returns “`1+i 3+3*i=2√2`” at point (4,4)

distanceatraw

Works the same as distanceat, but without the label.

perimeterat

Used in Symbolic view. Displays the perimeter of a polygon or circle. The measure is displayed, with a label, at the given point in Plot view.

`perimeterat(polygon, point)` or
`perimeterat(circle, point)`

Example:

`perimeterat(circle(x^2+y^2=1), point(-4,4))` displays "`pcircle(x^2+y^2=1)= 2*π`" at point (-4, 4)

perimeteratraw

Works the same as perimeterat, but without the label.

slopeat

Used in Symbolic view. Displays the slope of a straight object (segment, line, etc.). The measure is displayed, with a label, at the given point in Plot view.

`slopeat(object, point)`

Example:

`slopeat(line(point(0,0), point(2,3)), point(-8,8))` displays "`sline(point(0,0), point(2,3))=3/2`" at point (–8, 8)

slopeatraw

Works the same as `slopeat`, but without the label.

Numeric view: Cmds menu

Measure

abscissa

Returns the x coordinate of a point or the x length of a vector.

`abscissa(point)` or `abscissa(vector)`

Example:

`abscissa(GA)` returns the x-coordinate of the point A.

affix

Returns the coordinates of a point or both the *x*- and *y*-lengths of a vector as a complex number.

```
   affix(point) or affix(vector)
```

Example:

if GA is a point at (1, –2), then `affix(GA)` returns 1–2i.

angle

Returns the measure of a directed angle. The first point is taken as the vertex of the angle as the next two points in order give the measure and sign.

```
   angle(vertex, point2, point3)
```

Example:

`angle(GA, GB, GC)` returns the measure of ∡ BAC.

arcLen

Returns the length of the arc of a curve between two points on the curve. The curve is an expression, the independent variable is declared, and the two points are defined by values of the independent variable.

This command can also accept a parametric definition of a curve. In this case, the expression is a list of 2 expressions (the first for *x* and the second for *y*) in terms of a third independent variable.

```
   arcLen(expr, real1, real2)
```

Examples:

`arcLen(x^2, x, –2, 2)` returns 9.29….

`arcLen({sin(t), cos(t)}, t, 0, π/2)` returns 1.57…

area

Returns the area of a circle or polygon.

```
   area(circle) or area(polygon)
```

This command can also return the area under a curve between two points.

```
   area(expr, x=value1..value2)
```

Examples:

If GA is defined to be the unit circle, then `area(GA)` returns π.

`area(4-x^2/4, x=-4..4)` returns 14.666…

coordinates

Given a vector of points, returns a matrix containing the x- and y-coordinates of those points. Each row of the matrix defines one point; the first column gives the x-coordinates and the second column contains the y-coordinates.

```
coordinates([point1, point2, …, pointn]))
```

distance

Returns the distance between two points or between a point and a curve.

`distance(point1, point2)` or `distance(point, curve)`

Examples:

`distance(1+i, 3+3i)` returns 2.828… or 2√2.

if GA is the point at (0, 0) and GB is defined as plotfunc(4–x^2/4), then distance (GA, GB) returns 3.464… or 2√3.

distance2

Returns the square of the distance between two points or between a point and a curve.

`distance2(point1, point2)` or `distance2(point, curve)`

Examples:

`distance2(1+i, 3+3i)` returns 8.

If GA is the point at (0, 0) and GB is defined as plotfunc(4-x^2/4), then `distance2(GA, GB)` returns 12.

equation

Returns the Cartesian equation of a curve in x and y, or the Cartesian coordinates of a point.

```
equation(curve) or equation(point)
```

Example:

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as circle(GA, GB-GA), then `equation(GC)` returns $x^2 + y^2 = 1$.

extract_measure

Returns the definition of a geometric object. For a point, that definition consists of the coordinates of the point. For other objects, the definition mirrors their definition in Symbolic view, with the coordinates of their defining points supplied.

```
extract_measure(Var)
```

ordinate

Returns the y coordinate of a point or the y length of a vector.

```
ordinate(point) or ordinate(vector)
```

Example:

Example: `ordinate(GA)` returns the *y*-coordinate of the point A.

parameq

Works like the **equation** command, but returns parametric results in complex form.

```
parameq(GeoObj )
```

perimeter

Returns the perimeter of a polygon or the circumference of a circle.

`perimeter(polygon)` or `perimeter(circle)`

Examples:

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as circle(GA, GB-GA), then `perimeter(GC)` returns 2π.

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as square(GA, GB-GA), then `perimeter(GC)` returns 4.

radius

Returns the radius of a circle.

```
radius(circle)
```

Example:

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as circle(GA, GB-GA), then `radius(GC)` returns 1.

Test

is_collinear

Takes a set of points as argument and tests whether or not they are collinear. Returns 1 if the points are collinear and 0 otherwise.

```
is_collinear(point1, point2, …, pointn)
```

Example:

`is_collinear(point(0,0), point(5,0), point(6,1))` returns 0

is_concyclic

Takes a set of points as argument and tests if they are all on the same circle. Returns 1 if the points are all on the same circle and 0 otherwise.

```
is_concyclic(point1, point2, …, pointn)
```

Example:

`is_concyclic(point(-4,-2), point(-4,2), point(4,-2), point(4,2))` returns 1

is_conjugate

Tests whether or not two points or two lines are conjugates for the given circle. Returns 1 if they are and 0 otherwise.

```
is_conjugate(circle, point1, point2) or
is_conjugate(circle, line1, line2)
```

is_element

Tests if a point is on a geometric object. Returns 1 if it is and 0 otherwise

```
is_element(point, object)
```

Example:

`is_element(point(`$\frac{\sqrt{2}}{2}$`,`$\frac{\sqrt{2}}{2}$`), circle(0,1))` returns 1.

is_equilateral

Takes three points and tests whether or not they are vertices of a single equilateral triangle. Returns 1 if they are and 0 otherwise.

```
is_equilateral(point1, point2, point3)
```

Example:

`is_equilateral(point(0,0), point(4,0), point(2,4))` returns 0.

is_isoceles

Takes three points and tests whether or not they are vertices of a single isosceles triangle. Returns 0 if they are not. If they are, returns the number order of the common point of the two sides of equal length (1, 2, or 3). Returns 4 if the three points form an equilateral triangle.

```
is_isosceles(point1, point2, point3)
```

Example:

`is_isoscelesl(point(0,0), point(4,0), point(2,4))` returns 3.

is_orthogonal

Tests whether or not two lines or two circles are orthogonal (perpendicular). In the case of two circles, tests whether or not the tangent lines at a point of intersection are orthogonal. Returns 1 if they are and 0 otherwise.

`is_orthogonal(line1, line2)` or
`is_orthogonal(circle1, circle2)`

Example:

`is_orthogonal(line(y=x),line(y=-x))` returns 1.

is_parallel

Tests whether or not two lines are parallel. Returns 1 if they are and 0 otherwise.

```
is_parallel(line1, line2)
```

Example:

`is_parallel(line(2x+3y=7),line(2x+3y=9)` returns 1.

is_parallelogram

Tests whether or not a set of four points are vertices of a parallelogram. Returns 0 if they are not. If they are, then returns 1 if they form only a parallelogram, 2 if they form a rhombus, 3 if they form a rectangle, and 4 if they form a square.

```
is_parallelogram(point1, point2, point3,
point4)
```

Example:

`is_parallelogram(point(0,0), point(2,4), point(0,8), point(-2,4))` returns 2.

is_perpendicular

Similar to **is_orthogonal**. Tests whether or not two lines are perpendicular.

```
is_perpendicular(line1, line2)
```

is_rectangle

Tests whether or not a set of four points are vertices of a rectangle. Returns 0 if they are not, 1 if they are, and 2 if they are vertices of a square.

```
is_rectangle(point1, point2, point3, point4)
```

Examples:

`is_rectangle(point(0,0), point(4,2), point(2,6), point(-2,4))` returns 2.

With a set of only three points as argument, tests whether or not they are vertices of a right triangle. Returns 0 if they are not. If they are, returns the number order of the common point of the two perpendicular sides (1, 2, or 3).

`is_rectangle(point(0,0), point(4,2), point(2,6))` returns 2.

is_square

Tests whether or not a set of four points are vertices of a square. Returns 1 if they are and 0 otherwise.

```
is_square(point1, point2, point3, point4)
```

Example:

`is_square(point(0,0), point(4,2), point(2,6), point(-2,4))` returns 1.

Other Geometry functions

The following functions are not available from a menu in the Geometry app, but are available from the Catlg menu.

convexhull

Returns a vector containing the points that serve as the convex hull for a given set of points.

```
convexhull(point1, point2, …, pointn)
```

harmonic_conjugate

Returns the harmonic conjugate of 3 points. Specifically, returns the harmonic conjugate of point3 with respect to point1 and point2. Also accepts three parallel or concurrent lines; in this case, it returns the equation of the harmonic conjugate line.

`harmonic_conjugate(point1, point2, point3)` or
`harmonic_conjugate(line1, line2, line3)`

Example:

`harmonic_conjugate(point(0, 0), point(3, 0), point(4, 0))` returns `point(12/5, 0)`

harmonic_division

Returns the harmonic conjugate of 3 points. Specifically, returns the harmonic conjugate of point3 with respect to point1 and point2 and stores the result in the variable `var`. Also accepts three parallel or concurrent lines; in this case, it returns the equation of the harmonic conjugate line.

`harmonic_division(point1, point2, point3, var)`
or `harmonic_division(line1, line2, line3, var)`

Example:

`harmonic_division(point(0, 0), point(3, 0), point(4, 0), p)` returns `point(12/5, 0)` and stores it in the variable `p`

is_harmonic

Tests whether or not 4 points are in a harmonic division or range. Returns 1 if they are or 0 otherwise.

is_harmonic(point1, point2, point3, point4)

```
is_harmonic(point1, point2, point3, point4)
```

Example:

`is_harmonic(point(0, 0), point(3, 0), point(4, 0), point(12/5, 0))` returns `1`

is_harmonic_circle_bundle

Returns 1 if the circles build a beam, 2 if they have the same center, 3 if they are the same circle and 0 otherwise.

```
is_harmonic_circle_bundle({circle1, circle2,
…, circlen})
```

is_harmonic_line_bundle

Returns 1 if the lines are concurrent, 2 if they are all parallel, 3 if they are the same line and 0 otherwise.

```
is_harmonic_line_bundle({line1, line2, …,
linen}))
```

is_rhombus

Tests whether or not a set of four points are vertices of a rhombus. Returns 0 if they are not, 1 if they are, and 2 if they are vertices of a square.

```
is_rhombus(point1, point2, point3, point4)
```

Example:

`is_rhombus(point(0,0), point(-2,2), point(0,4), point(2,2))` returns `2`

LineHorz

Draws the horizontal line y=a.

```
LineHorz(a)
```

Example:

`LineHorz(-2)` draws the horizontal line whose equation is y = –2

LineVert

Draws the vertical line x=a.

```
LineVert(a)
```

Example:

`LineVert(–3)` draws the vertical line whose equation is x = –3

open_polygon

Connects a set of points with line segments, in the given order, to produce a polygon. If the last point is the same as the first point, then the polygon is closed; otherwise, it is open.

`open_polygon(point1, point2, …, point1)` or
`open_polygon(point1, point2, …, pointn)`

polar

Returns the polar line of the given point as pole with respect to the given circle.

```
polar(circle, point)
```

Example:

`polar(circle(x^2+y^2=1),point(1/3,0))` returns `x=3`

polar_coordinates

Returns a vector containing the polar coordinates of a point or a complex number.

`polar_coordinates(point)` or
`polar_coordinates(complex)`

Example:

`polar_coordinates(√2, √2)` returns `[2, π/4])`

pole

Returns the pole of the given line with respect to the given circle.

```
pole(circle, line)
```

Example:

`pole(circle(x^2+y^2=1), line(x=3))` returns `point(1/3, 0)`

powerpc

Given a circle and a point, returns the difference between the square of the distance from the point to the circle''s center and the square of the circle's radius.

```
powerpc(circle, point)
```

Example

`powerpc(circle(point(0,0), point(1,1)-point(0,0)), point(3,1))` returns `8`

radical_axis

Returns the line whose points all have the same powerpc values for the two given circles.

```
radical_axis(circle1, circle2)
```

Example:

`radical_axis(circle(((x+2)²+y²) = 8),circle(((x-2)²+y²) = 8))` returns `line(x=0)`

reciprocation

Given a circle, returns the poles (points) of given polar lines or the polar lines of given poles (points).

`reciprocation(circle, point)` or
`reciprocation(circle, line)` or
`reciprocation(circle, list)`

Example:

`reciprocation(circle(x^2+y^2=1),{point(1/3,0), line(x=2)})` returns `[line(x=3), point(1/2, 0)]`

single_inter

Returns the intersection of `curve1` and `curve2` that is closest to `point`.

```
single_inter(curve1, curve2, point)
```

Example:

`single_inter(line(y=x),circle(x^2+y^2=1), point(1,1))` returns `point(((1+i)* √2)/2)`

vector

Creates a vector from point1 to point2. With one point as argument, the origin is used as the tail of the vector.

```
vector(point1, point2) or vector(point)
```

Example:

`vector(point(1,1), point(3,0))` creates a vector from (1, 1) to (3, 0).

vertices

Returns a list of the vertices of a polygon.

```
vertices(polygon)
```

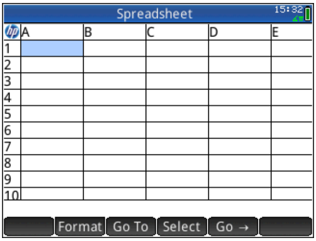
vertices_abca

Returns the closed list of the vertices of a polygon.

```
vertices_abca(polygon)
```

9

Spreadsheet



	A	B	C	D	E
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

The Spreadsheet app provides a grid of cells for you to enter content (such as numbers, text, expressions, and so on) and to perform certain operations on what you enter.

To open the Spreadsheet app, press Apps Info and select **Spreadsheet**.

You can create any number of customized spreadsheets, each with its own name (see “Creating an app” on page 107). You open a customized spreadsheet in the same way: by pressing Apps Info and selecting the particular spreadsheet.

The maximum size of any one spreadsheet is 10,000 rows by 676 columns.

The app opens in Numeric view. There is no Plot or Symbolic view. There is a Symbolic Setup view (Shift Symb Setup) that enables you to override certain system-wide settings. (See “Common operations in Symbolic Setup view” on page 87.)

Getting started with the Spreadsheet app

Suppose you have a stall at a weekend market. You sell furniture on consignment for their owners, taking a 10% commission for yourself. You have to pay the landowner $100 a day to set up your stall and you will keep the stall open until you have made $250 for yourself.

1. Open the Spreadsheet app: Press

   Press Apps Info and select `Spreadsheet`.

2. Select column `A`. Either tap on `A` or use the cursor keys to highlight the `A` cell (that is, the heading of the `A` column).

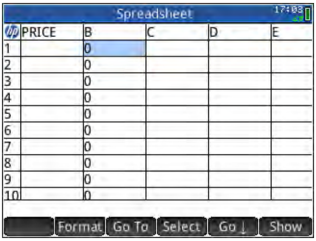
3. Enter PRICE and tap Name. You have named the entire first column PRICE.

4. Select column B. Either tap on B or use the cursor keys to highlight the B cell.

5. Enter a formula for your commission (being 10% of the price of each item sold):

   Shift = PRICE × 0.1 Enter

   Because you entered the formula in the heading of a column, it is automatically copied to every cell in that column. At the moment only 0 is shown, since there are no values in the PRICE column yet.



	PRICE	B	C	D	E
1		0			
2		0			
3		0			
4		0			
5		0			
6		0			
7		0			
8		0			
9		0			
10		0			

6. Once again select the header of column B.

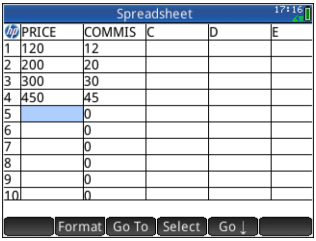
7. Tap Format and select Name.

8. Type COMMIS and tap OK.

   Note that the heading of column B is now COMMIS.

9. It is always a good idea to check your formulas by entering some dummy values and noting if the result is as expected. Select cell A1 and make sure that Go ↓ and not Go → is showing in the menu. (If not, tap the button.) This option means that your cursor automatically selects the cell immediately *below* the one you have just entered content into.

10. Add some values in the PRICE column and note the result in the COMMIS column. If the results do not look right, you can tap the COMMIS heading, tap Edit and fix the formula.



	PRICE	COMMIS	C	D	E
1	120	12			
2	200	20			
3	300	30			
4	450	45			
5		0			
6		0			
7		0			
8		0			
9		0			
10		0			

11. To delete the dummy values, select cell A1, tap Select, press ▼ until all the dummy values are selected, and then press Del.

12. Select cell C1.

13. Enter a label for your takings:

    Shift ≐ ALPHA alpha 0 Notes " " TAKINGS Enter ≈

    Notice that text strings, but not names, need to be enclosed within quotation marks.

14. Select cell D1.

15. Enter a formula to add up your takings:

    Shift ≐ SUM ( ) PRICE Enter ≈

    You could have specified a range—such as A1:A100—but by specifying the name of the column, you can be sure that the sum will include all the entries in the column.

16. Select cell C3.

17. Enter a label for your total commission:

    Shift ≐ ALPHA alpha 0 Notes " " TOTAL COMMIS Enter ≈

    Note that the column is not wide enough for you to see the entire label in C3. We need to widen column C.

18. Select the heading cell for column C, tap Format and select **Column ↔**.

    An input form appears for you to specify the required width of the column.

19. Enter 100 and tap OK.

    You may have to experiment until you get the column width exactly as you want it. The value you enter will be the width of the column in pixels.

20. Select cell D3.

21. Enter a formula to add up your commission:

    Shift ≐ SUM ( ) COMMIS Enter ≈

    Note that instead of entering SUM by hand, you could have chosen it from the Apps menu (one of the Toolbox menus).

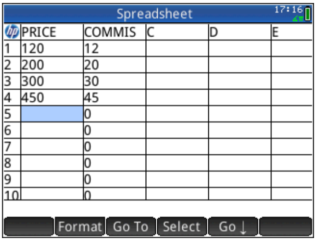
22. Select cell C5.

23. Enter a label for your fixed costs:

    Shift ÷ ALPHA 0 COSTS Enter

24. In cell D5, enter 100. This is what you have to pay the landowner for renting the space for your stall.

25. Enter the label PROFIT in cell C7.



	PRICE	COMMIS	C	D	E
1	120	12			
2	200	20			
3	300	30			
4	450	45			
5		0			
6		0			
7		0			
8		0			
9		0			
10		0			

26. In cell D7, enter a formula to calculate your profit:

    Shift ÷ D3 − D5 Enter

    You could also have named D3 and D5—say, TOTCOM and COSTS respectively. Then the formula in D7 could have been =TOTCOM–COSTS.

27. Enter the label GOAL in cell E1.

    You can swipe the screen with a finger, or repeatedly press the cursor keys, to bring E1 into view.

28. Enter 250 in cell F1.

    This is the minimum profit you want to make on the day.

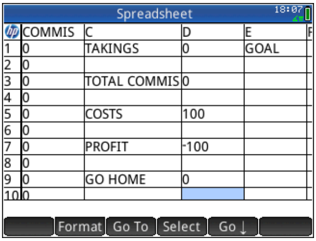
29. In cell C9, enter the label GO HOME.

30. In cell D9, enter:

    Shift ÷ D7 ≥ F1 Enter

    You can select ≥ from the relations palette (Shift 6).

    What this formula does is place 0 in D9 if you have not reached your goal profit, and 1 if you have. It provides a quick way for you to see when you have made enough profit and can go home.



	COMMIS	C	D	E	F
1	0	TAKINGS	0	GOAL	
2	0				
3	0	TOTAL COMMIS	0		
4	0				
5	0	COSTS	100		
6	0				
7	0	PROFIT	-100		
8	0				
9	0	GO HOME	0		
10	0				

31. Select C9 and D9.

    You can select both cells with a finger drag, or by highlighting C9, selecting Select and pressing ▶.

32. Tap Format and select `Color`.

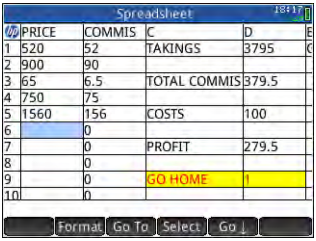
33. Choose a color for the contents of the selected cells.

34. Tap Format and select `Fill`.

35. Choose a color for the background of the selected cells.

    The most important cells in the spreadsheet will now stand out from the rest.

The spreadsheet is complete, but you may want to check all the formulas by adding some dummy data to the `PRICE` column. When the profit reaches 250, you should see the value in `D9` change from 0 to 1.



	PRICE	COMMIS	C	D	E
1	520	52	TAKINGS	3795	(
2	900	90			
3	65	6.5	TOTAL COMMIS	379.5	
4	750	75			
5	1560	156	COSTS	100	
6		0			
7		0	PROFIT	279.5	
8		0			
9		0	GO HOME	1	
10		0			

Basic operations

Navigation, selection and gestures

You can move about a spreadsheet by using the cursor keys, by swiping, or by tapping Go To and specifying the cell you want to move to.

You select a cell simply by moving to it. You can also select an entire column—by tapping the column letter—and select an entire row (by tapping the row number). You can also select the entire spreadsheet: just tap on the unnumbered cell at the top-left corner of the spreadsheet. (It has the HP logo in it.)

A block of cells can be selected by pressing down on a cell that will be a corner cell of the selection and, after a second, dragging your finger to the diagonally opposite cell. You can also select a block of cells by moving to a corner cell, tapping Select and using the cursor keys to move to the diagonally opposite cell. Tapping on Sel• or another cell deselects the selection.

Cell references

You can refer to the value of a cell in formulas as if it were a variable. A cell is referenced by its column and row coordinates, and references can be absolute or relative. An absolute reference is written as $C$R (where *C* is the column number and *R* the row number). Thus $B$7 is an absolute reference. In a formula it will always refer to the data in cell B7 wherever that formula, or a copy of it, is placed. On the other hand, B7 is a relative reference. It is based on the *relative position* of cells. Thus a formula in, say, B8 that references B7 will reference C7 instead of B7 if it is copied to C8.

Ranges of cells can also be specified, as in C6:E12, as can entire columns (E:E) or entire rows ($3:$5). Note that the alphabetic component of column names can be uppercase or lowercase except for columns g, l, m, and z. These must be in lowercase *if not preceded by $*. Thus cell B1 can be referred to as B1,b1,$B$1 or $b$1 whereas M1 can only be referred to as m1, $m$1, or $M$1. (G, L, M, and Z are names reserved for graphic objects, lists, matrices, and complex numbers.)

Cell naming

Cells, rows, and columns can be named. The name can then be used in a formula. A named cell is given a blue border.

Method 1

To name an *empty* cell, row, or column, go the cell, row header, or column header, enter a name and tap Name.

Method 2

To name a cell, row, or column—whether it is empty or not:

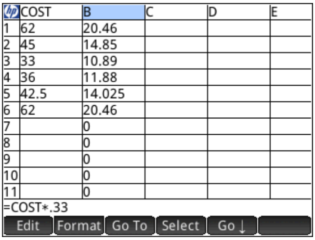
1. Select the cell, row, or column.
2. Tap Format and select Name.
3. Enter a name and tap OK.

Using names in calculations

The name you give a cell, row, or column can be used in a formula. For example, if you name a cell TOTAL, you could enter in another cell the formula =TOTAL*1.1.

The following is a more complex example involving the naming of an entire column.

1. Select cell A (that is the header cell for column A).
2. Enter COST and tap Name.
3. Select cell B (that is the header cell for column B).
4. Enter Shift = COST*0.33 and tap OK.
5. Enter some values in column A and observe the calculated results in column B.



	COST	B	C	D	E
1	62	20.46			
2	45	14.85			
3	33	10.89			
4	36	11.88			
5	42.5	14.025			
6	62	20.46			
7		0			
8		0			
9		0			
10		0			
11		0			

=COST*.33

Entering content

You can enter content directly in the spreadsheet or import data from a statistics app.

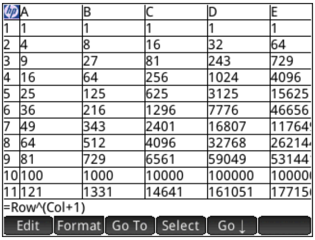
Direct entry

A cell can contain any valid calculator object: a real number (3.14), a complex number ($a + ib$), an integer (#1Ah), a list ({1, 2}), a matrix or vector([1, 2]), a string ("text"), a unit (2_m) or an expression (that is, a formula). Move to the cell you want to add content to and start entering the content as you would in Home view. Press Enter when you have finished. You can also enter content into a number of cells with a single entry. Just select the cells, enter the content—for example, =Row*3—and press Enter.

What you enter on the entry line is evaluated as soon as you press Enter, with the result placed in the cell or cells. However, if you want to retain the underlying formula, precede it with Shift =. For example, suppose that want to add cell A1 (which contains 7) to cell B2 (which contains 12). Entering A1 + B2 Enter in, say, A4 yields19, as does entering Shift = A1 + B2 in A5. However, if the value in A1 (or B2) changes, the value in A5 changes but not the value in A4. This is because the expression (or formula) was retained in A5. To see if a cell contains just the value shown in it or also an underlying formula that generates the value, move your cursor to the cell. The entry line shows a formula if there is one.

A single formula can add content to every cell in a column or row. For example, move to `C` (the heading cell for column C), enter Shift ≐ `SIN(Row)` and press Enter. Each cell in the column is populated with the sine of the cell's row number. A similar process enables you to populate every cell in a row with the same formula. You can also add a formula once and have it apply to *every* cell in the spreadsheet. You do this by placing the formula in the cell at the top left (the cell with the HP logo in it). To see how this works, suppose you want to generate a table of powers (squares, cubes, and so on) starting with the squares:

1. Tap on the cell with the HP logo in it (at the top left corner). Alternatively, you can use the cursor keys to move to that cell (just as you can to select a column or row heading).



	A	B	C	D	E
1	1	1	1	1	1
2	4	8	16	32	64
3	9	27	81	243	729
4	16	64	256	1024	4096
5	25	125	625	3125	15625
6	36	216	1296	7776	46656
7	49	343	2401	16807	11764
8	64	512	4096	32768	26214
9	81	729	6561	59049	53144
10	100	1000	10000	100000	10000
11	121	1331	14641	161051	17715

=Row^(Col+1)

2. On the entry line type Shift ≐ Row x^y Col + 1

   Note that `Row` and `Col` are built-in variables. They are placeholders for the row number and column number of the cell that has a formula containing them.

3. Tap OK or Press Enter.

   Note that each column gives the *n*th power of the row number starting with the squares. Thus 9^5 is 59,049.

Import data

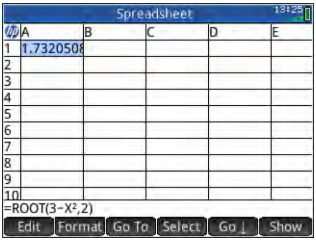
You can import data from the Statistics 1Var and Statistics 2Var apps (and from any app customized from a statistics app). In the procedure immediately below, dataset `D1` from the Statistics 1Var app is being imported.

1. Select a cell.
2. Enter `Statistics_1Var.D1`.
3. Press Enter.

The column is filled with the data from the statistics app, starting with the cell selected at step 1. Any data in that column will be overwritten by the data being imported.

You can also export data from the Spreadsheet app to a statistics app. See “Entering and editing statistical data” on page 215 for the general procedure. It can be used in both the Statistics 1Var and Statistics 2Var apps.

External functions



	A	B	C	D	E
1	1.7320508				
2					
3					
4					
5					
6					
7					
8					
9					
10					

=ROOT(3−X²,2)

You can use in a formula any function available on the Math, CAS, App, User or Catlg menus (see chapter 21, “Functions and commands” on page 307). For example, to find the root of 3 – x^2 closest to x = 2, you could enter in a cell Shift = ALPHA ALPHA ROOT ALPHA ( ) 3 − ALPHA × x^2 , 2 Enter. The answer displayed is 1.732…

You could also have selected a function from a menu. For example:

1. Press Shift =.
2. Press Mem and tap CAS.
3. Select `Polynomial` > `Find Roots`.

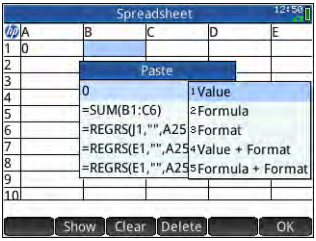
   Your entry line will now look like this: `=CAS.proot()`.
4. Enter the coefficients of the polynomial, in descending order, separating each with a comma:

   +/− 1 , 0 , 3
5. Press Enter to see the result. Select the cell and tap Show to see a vector containing both roots: [1.732… –1.732…].
6. Tap OK to return to the spreadsheet.

Note that the CAS prefix added to your function is to remind you that the calculation will be carried out by the CAS (and thus a symbolic result will be returned, if possible). You can also force a calculation to be handled by the CAS by tapping CAS in the spreadsheet.

There are additional spreadsheet functions that you can use (mostly related to finance and statistics calculations). See "Spreadsheet app functions" on page 349.

Copy and paste



0

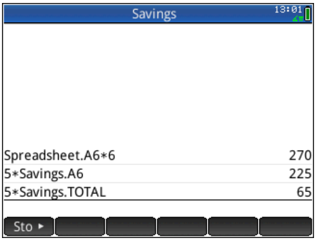
0
=SUM(B1:C6)
=REGRS(J1,"",A25
=REGRS(E1,"",A25
=REGRS(E1,"",A25

To copy one or more cells, select them and press Shift View Copy (Copy).

Move to the desired location and press Shift Menu Paste (Paste).

You can choose to paste either the value, formula, format, both value and format, or both formula and format.

External references



```
Spreadsheet.A6*6          270
5*Savings.A6              225
5*Savings.TOTAL            65
```

You can refer to data in a spreadsheet from outside the Spreadsheet app by using the reference `SpreadsheetName.CR`. For example, in Home view you can refer to cell A6 in the built-in spreadsheet by entering `Spreadsheet.A6`. Thus the formula `6*Spreadsheet.A6` would multiply whatever value is currently in cell A6 in the built-in app by 6.

If you have created a customized spreadsheet called, say, **Savings**, you simply refer to it by its name, as in `5*Savings.A6`.

An external reference can also be to a named cell, as in `5*Savings.TOTAL`.

In the same way, you can also enter references to spreadsheet cells in the CAS.

If you are working outside a spreadsheet, you cannot refer to a cell by its absolute reference. Thus `Spreadsheet.$A$6` produces an error message.

Note that a reference to a spreadsheet name is case-sensitive.

Referencing variables

Any variable can be inserted in a cell. This includes Home variables, App variables, CAS variables and user variables.

Variables can be referenced or entered. For example, if you have assigned 10 to P in Home view, you could enter =P*5 in a spreadsheet cell, press Enter and get 50. If you subsequently changed the value of P, the value in that cell automatically changes to reflect the new value. This is an example of a *referenced* variable.

If you just wanted the current value of P and not have the value change if P changes, just enter P and press Enter. This is an example of an *entered* variable.

Variables given values in other apps can also be referenced in a spreadsheet. In chapter 13 we see how the Solve app can be used to solve equations. An example used is $V^2 = U^2 + 2AD$. You could have four cells in a spreadsheet with =V, =U, =A, and =D as formulas. As you experiment with different values for these variables in the Solve app, the entered and the calculated values are copied to the spreadsheet (where further manipulation could be done).

The variables from other apps includes the results of certain calculations. For example, if you have plotted a function in the Function app and calculated the signed area between two *x*-values, you can reference that value in a spreadsheet by pressing Vars, tapping App, and then selecting Function > Results > SignedArea.

Numerous system variables are also available. For example, you could enter Shift + Enter to get the last answer calculated in Home view. You could also enter Shift . Shift + Enter to get the last answer calculated in Home view and have the value automatically updated as new calculations are made in Home view. (Note that this works only with the Ans from Home view, not the Ans from CAS view.)

All the variables available to you are listed on the variables menus, displayed by pressing Vars. A comprehensive list of these variables is provided in chapter 22, “Variables”, beginning on page 423.

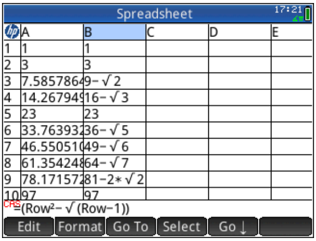
Using the CAS in spreadsheet calculations

You can force a spreadsheet calculation to be performed by the CAS, thereby ensuring that results are symbolic (and thus exact). For example, the formula =√Row in row 5 gives 2.2360679775 if not calculated by the CAS, and √5 if it is.

You choose the calculation engine when you are entering the formula. As soon as you begin entering a formula, the Format key changes to CAS or CAS• (depending on the last selection). This is a toggle key. Tap on it to change it from one to the other.

When CAS is showing, the calculation will be numeric (with the number of significant digits limited by the precsion of the calculator). When CAS• is showing, the calculation will be performed by CAS and be exact.

In the example at the right, the formula in cell A is exaclty the same as the formula in cell B: = Row^{2}−√(Row−1). The only difference is that CAS• was showing (or selected) while the formula was being entered in B, thereby forcing the calculation to be performed by the CAS. Note that CAS appears in red on the entry line if the cell selected contains a formula that is being calculated by the CAS.



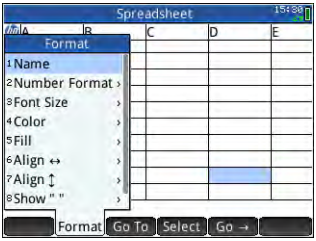
	A	B	C	D	E
1	1	1			
2	3	3			
3	7.5857864	9−√2			
4	14.267949	16−√3			
5	23	23			
6	33.763932	36−√5			
7	46.550510	49−√6			
8	61.354248	64−√7			
9	78.171572	81−2*√2			
10	97	97			

CAS =(Row^{2}−√(Row−1))

Buttons and keys

Button or key	Purpose
Edit	Activates the entry line for you to edit the object in the selected cell. (Only visible if the selected cell has content.)
Name	Converts the text you have entered on the entry line to a name. (Only visible when the entry line is active.)
CAS / CAS•	A toggle button that is only visible when the entry line is active. Both options force the expression to be handled by the CAS, but only CAS evaluates it.
$	Tap to enter the $ symbol. A shortcut when entering absolute references. (Only visible when the entry line is active.)
Format	Displays formatting options for the selected cell, block, column, row, or the entire spreadsheet. See "Formatting options" on page 208.
Go To	Displays an input form for you to specify the cell you want to jump to.
Select	Sets the calculator to *select* mode so that you can easily select a block of cells using the cursor keys. It changes to Sel• to enable you to deselect cells. (You can also press, hold and drag to select a block of cells.)
Go → or Go ↓	A toggle button that sets the direction the cursor moves after content has been entered in a cell.
Show	Displays the result in the selected cell in full-screen mode, with horizontal and vertical scrolling enabled. (Only visible if the selected cell has content.)
Sort	Enables you to select a column to sort by, and to sort it in ascending or descending order. (Only visible if cells are selected.)
Cancel	Cancel the input and clear the entry line.
OK	Accept and evaluate the input.
Shift Esc Clear	Clears the spreadsheet.

Formatting options



The formatting options appear when you tap Format. They apply to whatever is currently selected: a cell, block, column, row, or the entire spreadsheet.

The options are:

- **Name**: displays an input form for you to give a name to whatever is selected
- **Number Format**: Auto, Standard, Fixed, Scientific, or Engineering. See "Home settings" on page 30 for more details.
- **Font Size**: Auto or from 10 to 22 point
- **Color**: color for the content (text, number, etc.) in the selected cells; the gray-dotted option represents Auto
- **Fill**: background color that fills the selected cells; the gray-dotted option represents Auto
- **Align ↔**: horizontal alignment—Auto, Left, Center, Right
- **Align ↕**: vertical alignment—Auto, Top, Center, Bottom
- **Column ↔**: displays an input form for you to specify the required width of the selected columns; only available if you have selected the entire spreadsheet or one or more entire columns.

  You can also change the width of a selected column with an open or closed horizontal pinch gesture.
- **Row ↕**: displays an input form for you to specify the required height of the selected rows; only available if you have selected the entire spreadsheet or one or more entire rows.

  You can also change the height of a selected row with an open or closed vertical pinch gesture.
- **show "**: show quote marks around strings in the body of the spreadsheet—Auto, Yes, No
- **Textbook**: display formulas in textbook format—Auto, Yes, No
- **Caching**: turn this option on to speed up calculations in spreadsheets with many formulas; only available if you have selected the entire spreadsheet

Format Parameters

Each format attribute is represented by a parameter that can be referenced in a formula. For example, `=D1(1)` returns the formula in cell D1 (or nothing if D1 has no formula). The attributes that can be retrieved in a formulas by referencing its associated parameter are listed below.

Parameter	Attribute	Result
0	content	contents (or empty)
1	formula	formula
2	name	name (or empty)

3	number format	Standard = 0
		Fixed = 1
		Scientific = 2
		Engineering = 3

4	number of decimal places	1 to 11, or unspecified = –1
5	font	0 to 6, unspecified = –1 (with 0 = 10 pt and 6 = 22pt).
6	background color	cell fill color, or 32786 if unspecified
7	foreground color	cell contents color, or 32786 if unspecified
8	horizontal alignment	Left = 0, Center = 1, Right = 2, unspecified = –1
9	vertical alignment	Top = 0, Center = 1, Bottom = 2, unspecified = –1
10	show strings in quotes	Yes = 0, No = 1, unspecified = –1
11	textbook mode (as opposed to algebraic mode)	Yes = 0, No = 1, unspecified = –1

As well as retrieving format attributes, you can set a format attribute (or cell content) by specifying it in a formula in the relevant cell. For example, wherever it is placed `g5(1):=6543` enters `6543` in cell g5. Any previous content in g5 is replaced. Similarly, `B3(5):=2` forces the contents of B3 to be displayed in medium font size.

Spreadsheet functions

As well as the functions on the **Math**, **CAS** and **Catlg** menus, you can use special spreadsheet functions. These can be found on the **App** menu, one of the Toolbox menus. Press Mem B, tap App and select `Spreadsheet`. The functions are described on "Spreadsheet app functions" on page 349.

Remember to precede a function by an equals sign (Shift =) if you want the result to automatically update as the values it is dependent on change. Without an equals sign you will be entering just the current value.

10

Statistics 1Var app

The Statistics 1Var app can store up to ten data sets at one time. It can perform one-variable statistical analysis of one or more sets of data.

The Statistics 1Var app 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 in Home and recall the values of specific statistics variables.

The values computed in the Statistics 1Var app are saved in variables, and can be re-used in Home view and in other apps.

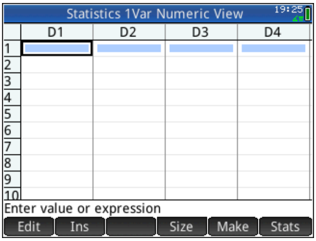
Getting started with the Statistics 1Var app

Suppose that you are measuring the heights of students in a classroom to find the mean height. The first five students have the following measurements: 160 cm, 165 cm, 170 cm, 175 cm and180 cm.

1. Open the Statistics 1Var app:

   Apps Info Select

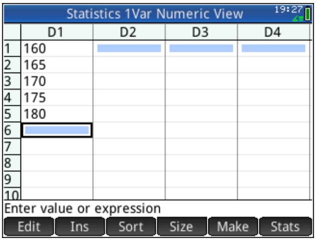
   `Statistics 1Var`



Enter value or expression

2. Enter the measurement data in column D1:

   160 Enter
   165 Enter
   170 Enter
   175 Enter
   180 Enter



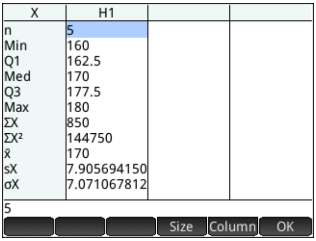
Statistics 1Var Numeric View 19:27

	D1	D2	D3	D4
1	160			
2	165			
3	170			
4	175			
5	180			
6				
7				
8				
9				
10				

Enter value or expression

3. Find the mean of the sample.

   Tap Stats to see the statistics calculated from the sample data in `D1`. The mean ($\bar{x}$) is 170. There are more statistics than can be displayed on one screen. Thus you may need to scroll to see the statistic you are after.



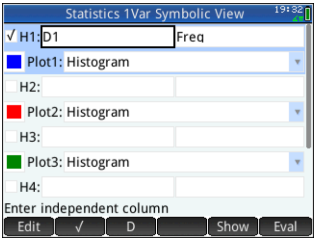
X	H1		
n	5		
Min	160		
Q1	162.5		
Med	170		
Q3	177.5		
Max	180		
ΣX	850		
ΣX²	144750		
x̄	170		
sX	7.905694150		
σX	7.071067812		

5

   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 `D1`, `H1` is automatically set to use `D1` for data, and the frequency of each data point is set to 1. You can select other columns of data from the Symbolic view of the app.

4. Tap OK to close the statistics window.

5. Press Symb Setup to see the data-set definitions.



Statistics 1Var Symbolic View 19:32

√ H1: D1 Freq

Plot1: Histogram

H2:

Plot2: Histogram

H3:

Plot3: Histogram

H4:

Enter independent column

   The first field in each set of definitions is where you specify the column of data that is to be analyzed, the second field is where you specify the column that has the frequencies of each data point, and the third field (**Plotn**) is where you choose the type of plot that will represent the data in Plot view: Histogram, Box and Whisker, Normal Probability, Line, Bar, or Pareto.

Symbolic view: menu items

The menu items you can tap on in Symbolic view are:

Menu item	Purpose
Edit	Copies the column variable (or variable expression) to the entry line for editing. Tap OK when done.
√	Selects (or deselects) a statistical analysis (H1–H5) for exploration.
D	Enters `D` directly (to save you having to press two keys).
Show	Displays the current expression in textbook format in full-screen view. Tap OK when done.
Eval	Evaluates the highlighted expression, resolving any references to other definitions.

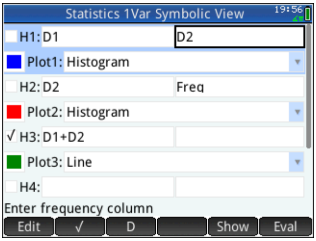
To continue our example, suppose that the heights of the rest of the students in the class are measured and that each one is rounded to the nearest of the five values first recorded. Instead of entering all the new data in `D1`, we simply add another column, `D2`, that holds the frequencies of our five data points in `D1`.

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

6. Tap on **Freq** to the right of `H1` (or press ▶ to highlight the second `H1` field).

7. Enter the name of the column that you will contain the frequencies (in this example, `D2`):

   D 2 OK



Statistics 1Var Symbolic View

□	H1: D1	D2
🟦	Plot1: Histogram	
□	H2: D2	Freq
🟥	Plot2: Histogram	
√	H3: D1+D2	
🟩	Plot3: Line	
□	H4:	

Enter frequency column

8. If you want to choose a color for the graph of the data in Plot view, see “Choose a color for plots” on page 85.

9. If you have more than one analysis defined in Symbolic view, deselect any analysis you are not currently interested in.

10. Return to Numeric view:

    Num Setup

11. In column D2, enter the frequency data shown in the table above:

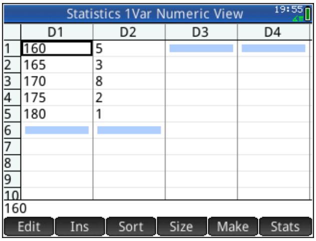
    ▶ 5 Enter

    3 Enter

    8 Enter

    2 Enter

    1 Enter



Statistics 1Var Numeric View

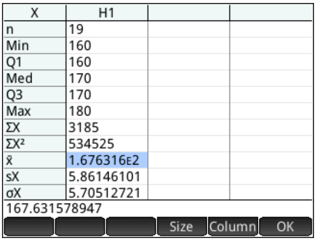
	D1	D2	D3	D4
1	160	5		
2	165	3		
3	170	8		
4	175	2		
5	180	1		
6				
7				
8				
9				
10				

160

12. Recalculate the statistics:

    Stats

    The mean height now is approximately 167.631 cm.



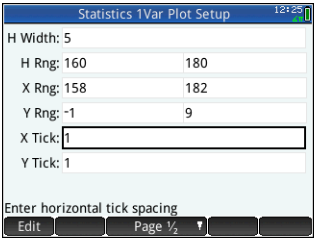
X	H1		
n	19		
Min	160		
Q1	160		
Med	170		
Q3	170		
Max	180		
ΣX	3185		
ΣX²	534525		
x̄	1.676316E2		
sX	5.86146101		
σX	5.70512721		

167.631578947

13. Configure a histogram plot for the data.

OK Shift Plot ↳Setup ((Setup)

Enter parameters appropriate to your data. Those shown at the right will ensure that all the data in this particular example are displayed in Plot view.



Statistics 1Var Plot Setup

H Width: 5

H Rng: 160 180

X Rng: 158 182

Y Rng: -1 9

X Tick: 1

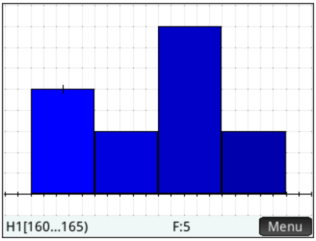
Y Tick: 1

Enter horizontal tick spacing

14. Plot a histogram of the data.

Plot ↳Setup

Press ▶ and ◀ to move the tracer and see the interval and frequency of each bin. You can also tap to select a bin. Tap and drag to scroll the Plot view. You can also zoom in or out on the cursor by pressing + Ans and − Base respectively.



H1[160...165) F:5

Entering and editing statistical data

Each column in Numeric view is a dataset and is represented by a variable named D0 to D9. There are three ways to get data into a column:

- Go to Numeric view and enter the data directly. See “Getting started with the Statistics 1Var app” on page 211 for an example.
- Go to Home view and copy the data from a list. For example, if you enter L1 Sto ▸ D1 in Home view, the items in list L1 are copied into column D1 in the Statistics 1Var app.
- Go to Home view and copy the data from the Spreadsheet app. For example, suppose the data of interest is in A1:A10 in the Spreadsheet app and you want to copy it into column D7. With the Statistics

1Var app open, return to Home view and enter `Spreadsheet.A1:A10` Sto ▸ `D7` Enter.

Whichever method you use, the data you enter is automatically saved. You can leave this app and come back to it later. You will find that the data you last entered is still available.

After entering the data, you must define data sets—and the way they are to be plotted—in Symbolic view.

Numeric view: menu items

The menu items you can tap on in Numeric view are:

Item	Purpose
Edit	Copies the highlighted item into the entry line.
Ins	Inserts a zero value above the highlighted cell.
Sort	Sorts the data in various ways. See "Sort data values" on page 217.
Size	Displays a menu from which you can choose small, medium, or large font.
Make	Displays an input form for you to enter a formula that will generate a list of values for a specified column. See "Generating data" on page 217.
Stats	Calculates statistics for each data set selected in Symbolic view. See "Computed statistics" on page 218.

Edit a data set

In Numeric view, highlight the data to change, type a new value, and press Enter. You can also highlight the data, tap Edit to copy it to the entry line, make your change, and press Enter.

Delete data

- To delete a 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 Esc Clear (Clear). Select the column and tap OK.
- To delete all data in every column, press Shift Esc Clear (Clear), select `All columns`, and tap OK.

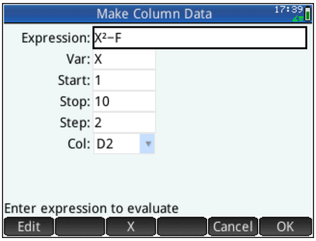
Insert data

1. Highlight the cell below where you want to insert a value.
2. Tap Ins and enter the value.

If you just want to add more data to the data set and it is not important where it goes, select the last cell in the data set and start entering the new data.

Generating data

You can enter a formula to generate a list of data points for a specified column. In the example at the right, 5 data-points will be placed in column D2. They will be generated by the expression *X*^{2}– *F* where *X* comes from the set {1, 3, 5, 7, 9}. These are the values between 1 and 10 that differ by 2. *F* is whatever value has been assigned to it elsewhere (such as in Home view). If *F* happened to be 5, column D2 is populated with {–4, 4, 20, 44, 76}.


Make Column Data

Expression: X²–F
Var: X
Start: 1
Stop: 10
Step: 2
Col: D2

Enter expression to evaluate

Sort data values

You can sort up to three columns of data at a time, based on a selected independent column.

1. In Numeric view, place the highlight in the column you want to sort, and tap Sort.
2. Specify the sort order: `Ascending` or `Descending`.
3. Specify the independent and dependent data columns. Sorting is by the independent column. For instance, if ages are in `C1` and incomes in `C2` and

you want to sort by income, then you make C2 the independent column and C1 the dependent column.

4. Specify any frequency data column.
5. Tap OK.

   The independent column is sorted as specified and any other columns are sorted to match the independent column. To sort just one column, choose None for the Dependent and Frequency columns.

Computed statistics

Tapping Stats displays the following results for each dataset selected in Symbolic view.

Statistic	Definition
n	Number of data points
Min	Minimum value
Q1	First quartile: median of values to left of median
Med	Median value
Q3	Third quartile: median of values to right of median
Max	Maximum value
ΣX	Sum of data values (with their frequencies)
ΣX^2	Sum of the squares of the data values
$\bar{x}$	Mean
sX	Sample standard deviation
σX	Population standard deviation
serrX	Standard error

When the data set contains an odd number of values, the median value is not used when calculating Q1 and Q3. For example, for the 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.

Plotting

You can plot:

- Histograms
- Box-and-Whisker plots
- Normal Probability plots
- Line plots
- Bar graphs
- Pareto charts

Once you have entered your data and defined your data set, you can plot your data. You can plot up to five box-and-whisker plots at a time; however, with the other types, you can only plot one at a time.

To plot statistical data

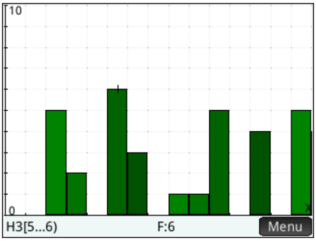
1. In the Symbolic view, select the data sets you want to plot.
2. From the **Plotn** menu, select the plot type.
3. For any plot, but especially for a histogram, adjust the plotting scale and range in the Plot Setup view. If you find histogram bars too fat or too thin, you can adjust them by changing the `HWIDTH` setting. (See “Setting up the plot (Plot Setup view)” on page 221.)
4. Press Plot Setup. If the scaling is not to your liking, press View Copy and select `Autoscale`.

   `Autoscale` can be relied upon to give a good starting scale which can then be adjusted, either directly in the Plot view or in the Plot Setup view.

Plot types

Histogram

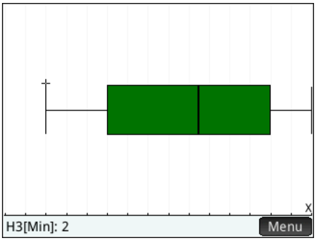
The first set of numbers below the plot indicate where the cursor is. In the example at the right, the cursor is in the bin for data between 5 and 6 (but not including 6), and the frequency for



that bin is 6. The data set is defined by H3 in Symbolic view. You can see information about other bins by pressing ▶ or ◀.

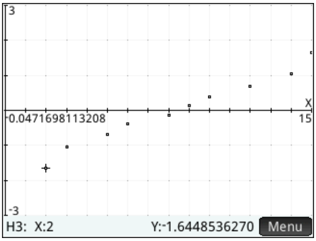
Box-and-Whisker plot

The left whisker marks the minimum data value. The box marks the first quartile, the median, and the third quartile. The right whisker marks the maximum data value. The numbers below the plot give the statistic at the cursor. You can see other statistics by pressing ▶or ◀.



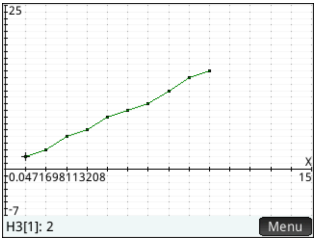
Normal probability plot

The normal probability plot is used to determine whether or not sample data is more or less normally distributed. The more linear the data appear, the more likely that the data are normally distributed.



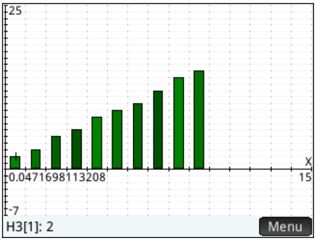
Line plot

The line plot connects points of the form (*x*, *y*), where *x* is the row number of the data point and *y* is its value.



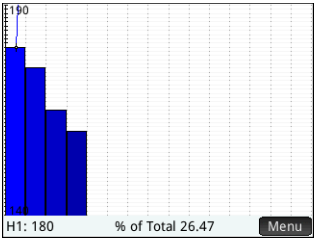
Bar graph

The bar graph shows the value of a data point as a vertical bar placed along the *x*-axis at the row number of the data point.



Pareto chart

A pareto chart places the data in descending order and displays each with its percentage of the whole.



H1: 180 % of Total 26.47

Setting up the plot (Plot Setup view)

The Plot Setup view (Shift Plot Setup) enables you to specify many of the same plotting parameters as other apps (such as **X Rng** and **Y Rng**). There are two settings unique to the Statistics 1Var app:

Histogram width

H Width enables you to specify the width of a histogram bin. This determines how many bins will fit in the display, as well as how the data is distributed (that is, how many data points each bin contains).

Histogram range

H Rng enables you to specify the range of values for a set of histogram bins. The range runs from the left edge of the leftmost bin to the right edge of the rightmost bin.

Exploring the graph

The Plot view (Plot Setup) has zooming and tracing options, as well as coordinate display. The `Autoscale` option is available from the View menu (View Copy) as well as the Zoom menu.The View menu also enables you to view graphs in split-screen mode (as explained on page 91).

For all plot types, you can tap and drag to scroll the Plot view. You can also zoom in or out on the cursor by pressing + and − respectively.

Plot view: menu items

The menu items you can tap on in Plot view are:

Button	Purpose
Zoom	Displays the Zoom menu.
Trace•	Turns trace mode on or off. See “Zoom” on page 100.)
Defn	Displays the definition of the current statistical plot.
Menu	Shows or hides the menu.

11

Statistics 2Var app

The Statistics 2Var app can store up to ten data sets at one time. It can perform two-variable statistical analysis of one or more sets of data.

The Statistics 2Var app 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 in Home and in the Spreadsheet app.

The values computed in the Statistics 2Var app are saved in variables. These can be referenced in Home view and in other apps.

Getting started with the Statistics 2Var app

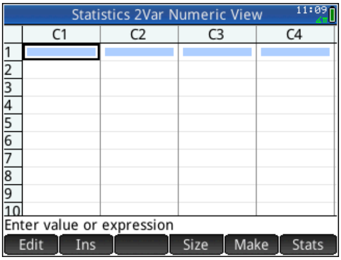
The following example uses the advertising and sales data in the table below. In the example, you will enter the data, compute summary statistics, fit a curve to the data, and predict the effect of more advertising on sales.

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

Open the Statistics 2Var app

1. Open the Statistics 2Var app:

   Apps Info Select `Statistics 2Var`.



Statistics 2Var Numeric View 11:09

	C1	C2	C3	C4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Enter value or expression

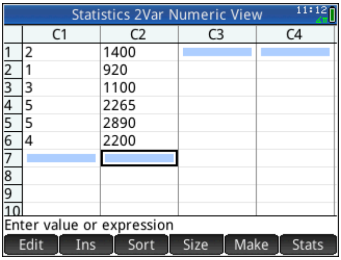
Enter data

2. Enter the advertising minutes data in column C1:

   2 Enter 1 Enter 3 Enter 5 Enter 5 Enter 4 Enter

3. Enter the resulting sales data in column C2:

   1400 Enter
   920 Enter
   1100 Enter
   2265 Enter
   2890 Enter
   2200 Enter



Statistics 2Var Numeric View 11:12

	C1	C2	C3	C4
1	2	1400		
2	1	920		
3	3	1100		
4	5	2265		
5	5	2890		
6	4	2200		
7				
8				
9				
10				

Enter value or expression

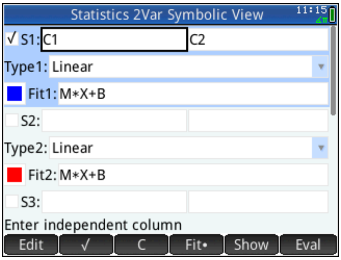
Choose data columns and fit

In Symbolic view, you can define up to five analyses of two-variable data, named `S1` to `S5`. In this example, we will define just one: `S1`. The process involves choosing data sets and a fit type.

4. Specify the columns that contain the data you want to analyze:

   Symb Setup

   In this case, C1 and C2 appear by default. But you could have entered your data into columns other than C1 and C2.



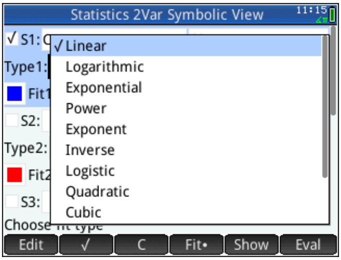
Statistics 2Var Symbolic View 11:15

✓ S1: C1 C2
Type1: Linear
Fit1: M*X+B
S2:
Type2: Linear
Fit2: M*X+B
S3:

Enter independent column

5. Select a fit:

   From the **Type 1** field select a fit. In this example, select `Linear`.



6. If you want to choose a color for the graph of the data in Plot view, see “Choose a color for plots” on page 85.

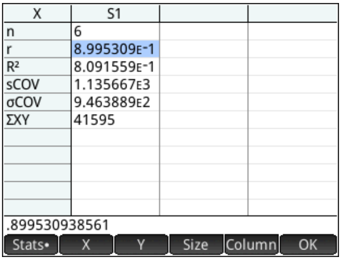
7. If you have more than one analysis defined in Symbolic view, deselect any analysis you are not currently interested in.

Explore statistics

8. Find the correlation, *r*, between advertising time and sales:

   Num Setup Stats

   The correlation is r=0.8995…



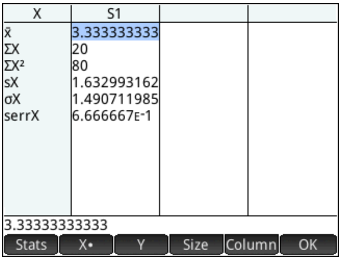
X	S1
n	6
r	8.995309E-1
R²	8.091559E-1
sCOV	1.135667E3
σCOV	9.463889E2
ΣXY	41595

.899530938561

9. Find the mean advertising time ($\bar{x}$).

   X

   The mean advertising time, $\bar{x}$, is 3.33333… minutes.



X	S1
x̄	3.333333333
ΣX	20
ΣX²	80
sX	1.632993162
σX	1.490711985
serrX	6.666667E-1

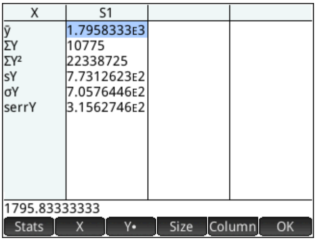
3.33333333333

10. Find the mean sales ($\bar{y}$).

Y

The mean sales, $\bar{y}$, is approximately $1,796.

Press OK to return to Numeric view.



X	S1		
ȳ	1.7958333E3		
ΣY	10775		
ΣY²	22338725		
sY	7.7312623E2		
σY	7.0576446E2		
serrY	3.1562746E2		

1795.83333333

Setup plot

11. Change the plotting range to ensure that all the data points are plotted (and to select a different data-point indicator, if you wish).

Shift Plot (Setup)

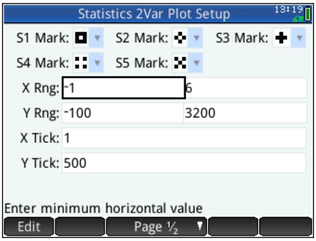
+/− 1 Enter 6

Enter +/− 100

Enter 3200

Enter ▼ 500

Enter



Statistics 2Var Plot Setup

S1 Mark: ■ S2 Mark: ✥ S3 Mark: ✚

S4 Mark: ⁘ S5 Mark: ⁙

X Rng: -1 6

Y Rng: -100 3200

X Tick: 1

Y Tick: 500

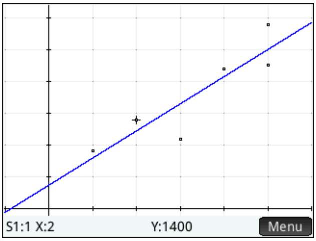
Enter minimum horizontal value

Plot the graph

12. Plot the graph.

Plot

Notice that the regression curve (that is, a curve to best fit the data points) is plotted by default.

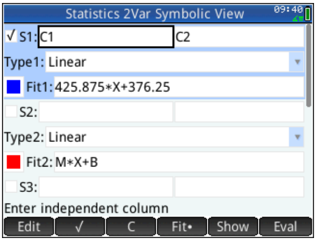


Display the equation

13. Return to the Symbolic view.

    Symb Setup

    Note the expression in the **Fit1** field. It shows that the slope (*m*) of the regression line is 425.875 and the *y*-intercept (*b*) is 376.25.



Statistics 2Var Symbolic View 09:40

√ S1: C1 C2

Type1: Linear

🟦 Fit1: 425.875*X+376.25

□ S2:

Type2: Linear

🟥 Fit2: M*X+B

□ S3:

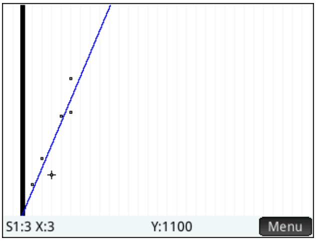
Enter independent column

Predict values

Let's now predict the sales figure if advertising were to go up to 6 minutes.

14. Return to the Plot view:

    Plot Setup

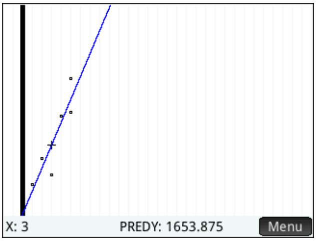


S1:3 X:3 Y:1100

The trace option is active by default. This option will move the cursor from data point to data point as you press ▶ or ◀. As you move from data point to data point, the corresponding *x*- and *y*-values appear at the bottom of the screen. In this example, the *x*-axis represents minutes of advertising and the *y*-axis represents sales.

However, there is no data point for 6 minutes. Thus we cannot move the cursor to *x* = 6. Instead, we need to *predict* what *y* will be when *x* = 6, based on the data we do have. To do that, we need to trace the regression curve, not the data points we have.

15. Press ▼ or ▲ to set the cursor to trace the regression line rather than the data points.



X: 3 PREDY: 1653.875

The cursor jumps from whatever data point it was on to the regression curve.

16. Tap on the regression line near *x* = 6 (near the right edge of the display). Then press ▶ until *x* = 6. If the *x*-value is not shown at the bottom left of the screen, tap Menu. When you reach *x* = 6, you will see that the **PREDY** value (also displayed at the bottom of the screen) reads 2931.5. Thus the model predicts that sales would rise to $2,931.50 if advertising were increased to 6 minutes.

Tip You could use the same tracing technique to predict—although roughly—how many minutes of advertising you would need to gain sales of a specified amount. However, a more accurate method is available: return to Home view and enter `Predx(s)` where *s* is the sales figure. `Predy` and `Predx` are app functions. They are discussed in detail in "Statistics 2Var app functions" on page 365.

Entering and editing statistical data

Each column in Numeric view is a dataset and is represented by a variable named `C0` to `C9`. There are three ways to get data into a column:

- Go to Numeric view and enter the data directly. See "Getting started with the Statistics 2Var app" on page 223 for an example.
- Go to Home view and copy the data from a list. For example, if you enter `L1` Sto ▸ `C1` in Home view, the items in list `L1` are copied into column `C1` in the Statistics 1Var app.
- Go to Home view and copy the data from a the Spreadsheet app. For example, suppose the data of interest is in A1:A10 in the Spreadsheet app and you want to copy it into column `C7`. With the Statistics 2Var app open, return to Home view and enter `Spreadsheet.A1:A10` Sto ▸ `C7` Enter.

Note A data column must have at least four data points to provide valid two-variable statistics.

Whichever method you use, the data you enter is automatically saved. You can leave this app and come back to it later. You will find that the data you last entered is still available.

After entering the data, you must define data sets—and the way they are to be plotted—in Symbolic view.

Numeric view menu items

The buttons you can tap on in Numeric view are:

Button	**Purpose**
Edit	Copies the highlighted item to the entry line.
Ins	Inserts a new cell above the highlighted cell (and gives it a value of 0).
Sort	Opens an input form for you to choose to sort the data in various ways.
Size	Displays a menu for you to choose the small, medium, or large font.
Make	Opens an input form for you to create a sequence based on an expression, and to store the result in a specified data column. See "Generating data" on page 217.
Stats	Calculates statistics for each data set selected in Symbolic view. See "Computed statistics" on page 233.

Edit a data set

In Numeric view, highlight the data to change, type a new value, and press Enter ≈. You can also highlight the data, tap Edit, make your change, and tap OK.

Delete data

- To delete a 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 Esc Clear (Clear). Select the column and tap OK.
- To delete all data in every column, press Shift Esc Clear (Clear), select `All columns`, and tap OK.

Insert data

Highlight the cell below where you want to insert a value. Tap Ins and enter the value.

If you just want to add more data to the data set and it is not important where it goes, select the last cell in the data set and start entering the new data.

Sort data values

You can sort up to three columns of data at a time, based on a selected independent column.

1. In Numeric view, place the highlight in the column you want to sort, and tap Sort.
2. Specify the Sort Order: `Ascending` or `Descending`.
3. Specify the independent and dependent data columns. Sorting is by the independent column. For instance, if ages are in `C1` and incomes in `C2` and you want to sort by Income, then you make `C2` the independent column and `C1` the dependent column.
4. Specify any Frequency data column.
5. Tap OK.

   The independent column is sorted as specified and any other columns are sorted to match the independent column. To sort just one column, choose `None` for the `Dependent` and `Frequency` columns.

Defining a regression model

You define a regression model in Symbolic view. There are three ways to do so:

- Accept the default option to fit the data to a straight line.
- Choose a pre-defined fit type (logarithmic, exponential, and so on).
- Enter your own mathematical expression. The expression will be plotted so that you can see how closely it fits the data points.

Choose a fit

1. Press Symb ↳Setup to display the Symbolic view.
2. For the analysis you are interested in (S1 through S5), select the **Type** field.
3. Tap the field again to see the menu of fit types.
4. Select your preferred fit type from the menu. (See "Fit types" on page 231.)

Fit types

Twelve fit types are available:

Fit type	Meaning
`Linear`	(Default.) Fits the data to a straight line: $y = mx+b$. Uses a least-squares fit.
`Logarithmic`	Fits the data to a logarithmic curve: $y = m \ln x + b$.
`Exponential`	Fits the data to the natural exponential curve: $y = b \cdot e^{mx}$.
`Power`	Fits the data to a power curve: $.y = b \cdot x^m$.
`Exponent`	Fits the data to an exponential curve: $y = b \cdot m^x$.
`Inverse`	Fits the data to an inverse variation: $y = \frac{m}{x} + b$

Fit type	Meaning (Continued)
`Logistic`	Fits the data 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.
`Quadratic`	Fits the data to a quadratic curve: $y = ax^2+bx+c$. Needs at least three points.
`Cubic`	Fits the data to a cubic polynomial: $y = ax^3 + b^2x + cx + d$
`Quartic`	Fits to a quartic polynomial, $y = ax^4 + bx^3 + cx^2 + dx + e$
`Trigonometric`	Fits the data to a trigonometric curve: $y = a \cdot \sin(bx + c) + d$. Needs at least three points.
`User Defined`	Define your own fit (see below).

To define your own fit

1. Press Symb ↳Setup to display the Symbolic view.
2. For the analysis you are interested in (S1 through S5), select the **Type** field.
3. Tap the field again to see a menu of fit types.
4. Select `User Defined` from the menu.
5. Select the corresponding **Fit**$_n$ field.
6. Enter an expression and press Enter ≈. The independent variable must be *X*, and the expression must not contain any unknown variables. Example: $1.5 \cdot \cos(x) + 0.3 \cdot \sin(x)$. Note that in this app, variables must be entered in uppercase.

Computed statistics

When you tap Stats, three sets of statistics become available. By default, the statistics involving both the independent and dependent columns are shown. Tap X to see the statistics involving just the independent column or Y to display the statistics derived from the dependent column. Tap Stats to return to the default view. The tables below describe the statistics displayed in each view.

The statistics computed when you tap Stats are:

Statistic	Definition
n	The number of data points.
r	Correlation coefficient of the independent and dependent data columns, based only on the linear fit (regardless of the fit type chosen). Returns a value between –1 and 1, where 1 and –1 indicate best fits.
R^2	The coefficient of determination, that is, the square of the correlation coefficient. The value of this statistics is dependent on the Fit type chosen. A measure of 1 indicates a perfect fit.
sCOV	Sample covariance of independent and dependent data columns.
σ COV	Population covariance of independent and dependent data columns.
ΣXY	Sum of all the individual products of of x and y.

The statistics displayed when you tap X are:

Statistic	Definition
$\bar{x}$	Mean of x- (independent) values.
ΣX	Sum of x-values.
ΣX^2	Sum of x^2-values.
sX	The sample standard deviation of the independent column.
σX	The population standard deviation of the independent column.
serrX	the standard error of the independent column

The statistics displayed when you tap Y are:

Statistic	Definition
$\bar{y}$	Mean of y- (dependent) values.
ΣY	Sum of y-values.
ΣY^2	Sum of y^2-values.
sY	The sample standard deviation of the dependent column.
σY	The population standard deviation of the dependent column.
serrY	The standard error of the dependent column.

Plotting statistical data

Once you have entered your data, selected the data set to analyze and specified your fit model, you can plot your data. You can plot up to five scatter plots at a time.

1. In Symbolic view, select the data sets you want to plot.
2. Make sure that the full range of your data will be plotted. You do this by reviewing (and adjusting, if

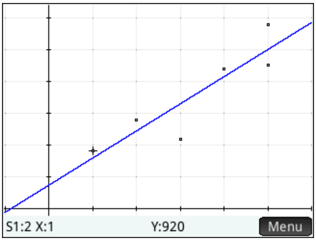
necessary), the **X Rng** and **Y Rng** fields in Plot Setup view. (Shift Plot Setup).

3. Press Plot Setup.

   If the data set and regression line are not ideally positioned, Press View Copy and select `Autoscale`. Autoscale can be relied upon to give a good starting scale which can then be adjusted later in the Plot Setup view.

Tracing a scatter plot

The figures below the plot indicate that the cursor is at the second data point of `S1`, at ((1, 920). Press ▶ to move to the next data point and display information about it.

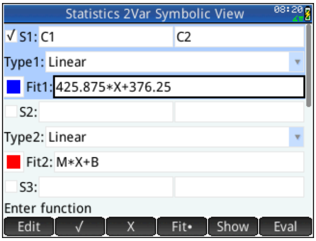


Tracing a curve

If the regression line is not showing, tap Fit. The coordinates of the tracer cursor are shown at the bottom of the screen. (If they are not visible, tap Menu.)

Press Symb Setup to see the equation of the regression line in Symbolic view.

If the equation is too wide for the screen, select it and press Show.


Statistics 2Var Symbolic View 08:20

√ S1: C1 C2

Type1: Linear

🟦 Fit1: 425.875*X+376.25

S2:

Type2: Linear

🟥 Fit2: M*X+B

S3:

Enter function

The example above shows that the slope of the regression line (m) is 425.875 and the *y*-intercept (b) is 376.25.

Tracing order

While ▶ and ◀ move the cursor along a fit or from point to point in a scatter plot, use ▲ and ▼ to choose the scatter plot or fit you wish to trace. For each active analysis (S1–S5), the tracing order is the scatter plot first and the fit second. So if both S1 and S2 are active, the tracer is by default on the S1 scatter plot when you press Plot Setup . Press ▼ to trace the S1 fit. At this point, press ▲ to return to the S1 scatter plot or ▼ again to trace the S2 scatter plot. Press ▼ a third time to trace the S2 fit. If you press ▼ a fourth time, you will return to the S1 scatter plot. If you are confused as to what you are tracing, just tap Defn to see the definition of the object (scatter plot or fit) currently being traced.

Plot view: menu items

The menu items in Plot view are:

Button	**Purpose**
Zoom	Displays the Zoom menu.
Trace•	Turns trace mode on or off.
Fit•	Shows or hides a curve that best fits the data points according to the selected regression model.
Go To	Enables you to specify a value on the regression line to jump to (or a data point to jump to if your cursor is on a data point rather than on the regression line). You might need to press ▲ or ▼ to move the cursor to the object of interest: the regression line or the data points.
Menu	Shows or hides the menu buttons.

Plot setup

As with all the apps that provide a plotting feature, he Plot Setup view—Shift Plot (Setup)—enables you to set the range and appearance of Plot view. The common settings available are discussed in "Common operations in Plot Setup view" on page 96. The Plot Setup view in the Statistics 2Var app has two additional settings:

Plotting mark

Page 1 of the Plot Setup view has fields named`S1MARK` through `S5MARK`. These fields enable you to specify one of five symbols to use to represent the data points in each data set. This will help you distinguish data sets in Plot view if you have chosen to plot more than one.

Connect

Page 2 of the Plot Setup view has a **Connect** field. If you choose this option, straight lines join the data points in Plot view.

Predicting values

PredX is a function that predicts a value for X given a value for Y. Likewise, PredY is a function that predicts a value for Y given a value for X. In both cases, the prediction is based on the equation that best fits the data according to the specified fit type.

You can predict values in the Plot view of the Statistics 2Var app and also in Home view.

In Plot view

1. In the Plot view, tap Fit to display the regression curve for the data set (if it is not already displayed).
2. Make sure the trace cursor is on the regression curve. (Press ▲ or ▼ if it is not.)
3. Press ▶ or ◀. The cursor moves along the regression curve and the corresponding X and Y values are displayed across the bottom of the screen. (If these values are not visible, tap Menu.)

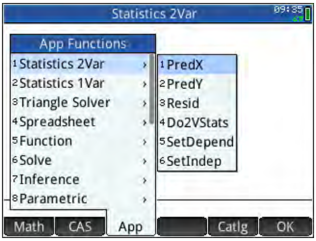
You can force the cursor to a specific X value by tapping Go To, entering the value and tapping OK. The cursor jumps to the specified point on the curve.

In Home view

If the Statistics 2Var app is the active app, you can also predict X and Y values in the Home view.

- Enter PredX(*Y*) Enter to predict the X value for the specified Y value.
- Enter PredY(*X*) Enter to predict the Y value for the specified X value.

You can type PredX and PredY directly on the entry line, or select them from the App functions menu (under the Statistics 2Var category). The App functions menu is one of the Toolbox menus (Mem).



Tip In cases where more than one fit curve is displayed, the `PredX` and `PredY` functions use the first active fit defined in Symbolic view.

Troubleshooting a plot

If you have problems plotting, check the following:

- The fit (that is, regression model) that you intended to select is the one selected.
- Only those data sets you want to analyze or plot are selected in Symbolic view.
- The plotting range is suitable. Try pressing View Copy and selecting `Autoscale`, *or* adjust the plotting parameters in Plot Setup view.
- Ensure that both paired columns contain data, and are of the same length.

12

Inference app

The Inference app enables you to calculate confidence intervals and undertake hypothesis tests based on the Normal Z-distribution or Student's t-distribution. In addition to the Inference app, the Math menu has a full set of probability functions based on various distributions (Chi-Square, F, Binomial, Poisson, etc.).

Based on 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

Sample data

The Inference app comes with sample data (which you can always restore by resetting the app). This sample data is useful in helping you gain an understanding of the app.

Getting started with the Inference app

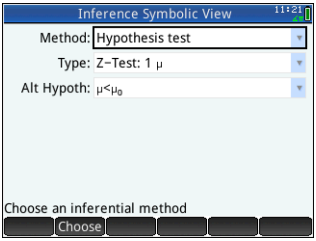
Let's conduct a Z-Test on one mean using the sample data.

Open the Inference app

1. Open the Inference app:

   Apps Info Select `Inference`

   The Inference app opens in Symbolic view.



Inference Symbolic View

Method: Hypothesis test

Type: Z–Test: 1 μ

Alt Hypoth: $\mu<\mu_0$

Choose an inferential method

Symbolic view options

The table below summarizes the options available in Symbolic view for the two inference methods: hypothesis test and confidence interval.

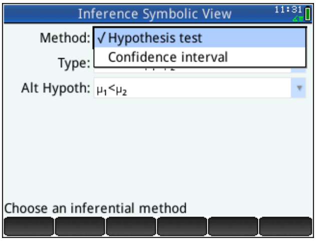
Hypothesis Test	Confidence Interval
Z-Test: 1 μ, the Z-Test on one mean	Z-Int: 1 μ, the confidence interval for one mean, based on the Normal distribution
Z-Test: $\mu_1 - \mu_2$, the Z-Test on the difference between two means	Z-Int: $\mu_1 - \mu_2$, the confidence interval for the difference between two means, based on the Normal distribution
Z-Test: 1 π, the Z-Test on one proportion	Z-Int: 1 π, the confidence interval for one proportion, based on the Normal distribution
Z-Test: $\pi_1 - \pi_2$, the Z-Test on the difference between two proportions	Z-Int: $\pi_1 - \pi_2$, the confidence interval for the difference between two proportions, based on the Normal distribution
T-Test: 1 μ, the T-Test on one mean	T-Int: 1 μ, the confidence interval for one mean, based on the Student's t-distribution
T-Test: $\mu_1 - \mu_2$, the T-Test on the difference between two means	T-Int: $\mu_1 - \mu_2$, the confidence interval for the difference between two means, based on the Student's t-distribution

If you choose one of the hypothesis tests, you can choose an 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 ≠.

In this section, we will conduct a Z-Test on one mean on the example data to illustrate how the app works.

Select the inference method

2. `Hypothesis Test` is the default inference method. If it is not selected, tap on the Method field and select it.



Inference Symbolic View 11:31

Method: √ Hypothesis test

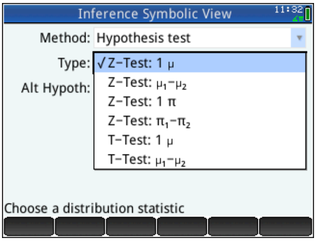
Confidence interval

Type:

Alt Hypoth: $\mu_1<\mu_2$

Choose an inferential method

3. Choose the type of test. In this case, select `Z-Test: 1` μ from the **Type** menu.



Inference Symbolic View 11:32

Method: Hypothesis test

Type: √ Z-Test: 1 μ

Z-Test: $\mu_1-\mu_2$

Z-Test: 1 π

Z-Test: $\pi_1-\pi_2$

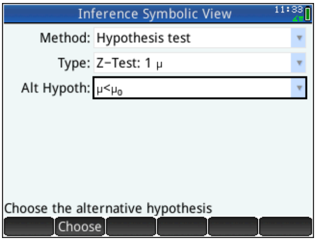
T-Test: 1 μ

T-Test: $\mu_1-\mu_2$

Alt Hypoth:

Choose a distribution statistic

4. Select an alternative hypothesis. In this case, select $\mu< \mu_0$ from the **Alt Hypoth** menu.



Inference Symbolic View 11:33

Method: Hypothesis test

Type: Z-Test: 1 μ

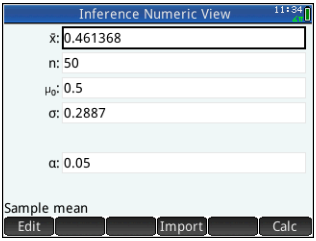
Alt Hypoth: $\mu<\mu_0$

Choose the alternative hypothesis

Enter data

5. Go to Numeric view to see the sample data.

Num ↳Setup



Inference Numeric View 11:34

$\bar{x}$: 0.461368

n: 50

μ_0: 0.5

σ: 0.2887

α: 0.05

Sample mean

The table below describes the fields in this view for the sample data.

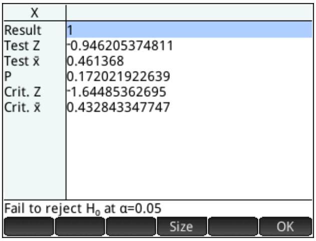
Field name	Definition
$\bar{x}$	Sample mean
n	Sample size
μ_0	Assumed population mean
σ	Population standard deviation
α	Alpha level for the test

The Numeric view is where you enter the sample statistics and population parameters for the situation you are examining. The sample data supplied here belong to the case in which a student has generated 50 pseudo-random numbers on his graphing calculator. If the algorithm is working properly, the mean would be near 0.5 and the population standard deviation is known to be approximately 0.2887. The student is concerned that the sample mean (0.461368) seems a bit low and it testing the less than alternative hypothesis against the null hypothesis.

Display the test results

6. Display the test results:

   Calc



```
X
Result     1
Test Z     -0.946205374811
Test x̄     0.461368
P          0.172021922639
Crit. Z    -1.64485362695
Crit. x̄    0.432843347747

Fail to reject H0 at α=0.05
                          Size          OK
```

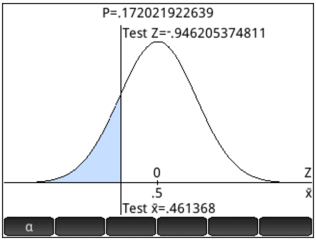
   The test distribution value and its associated probability are displayed, along with the critical value(s) of the test and the associated critical value(s) of the statistic. In this case, the test indicates that one should not reject the null hypothesis.

   Tap OK to return to Numeric view.

Plot the test results

7. Display a graphical view of the test results:

   Plot Setup



   The graph of the distribution is displayed, with the test Z-value marked. The corresponding X-value is also shown.

   Tap α to see the critical Z-value. With the alpha level showing, you can press ▼ or ▲ to decrease or increase the α-level.

Importing statistics

The Inference app can calculate confidence intervals and test hypotheses based on data in the Statistics 1Var and Statistics 2Var apps. The following example illustrates the process.

A series of six experiments gives the following values as the boiling point of a liquid:

82.5, 83.1, 82.6, 83.7, 82.4, and 83.0

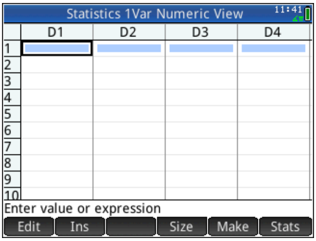
Based on this sample, we want to estimate the true boiling point at the 90% confidence level.

Open the Statistics 1Var app

1. Open the Statistics 1Var app:

   Apps Info Select

   `Statistics 1Var`



Statistics 1Var Numeric View 11:41

	D1	D2	D3	D4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Enter value or expression

Clear unwanted data

2. If there is unwanted data in the app, clear it:

   Shift Esc Clear All columns

Enter data

3. In column D1, enter the boiling points found during the experiments.

   82 . 5 Enter ≈

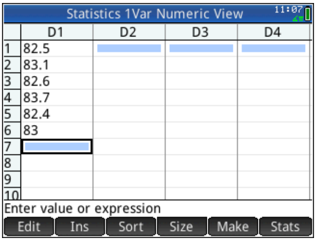
   83 . 1 Enter ≈

   82 . 6 Enter ≈

   83 . 7 Enter ≈

   82 . 4 Enter ≈

   83 Enter ≈



Statistics 1Var Numeric View 11:07

	D1	D2	D3	D4
1	82.5			
2	83.1			
3	82.6			
4	83.7			
5	82.4			
6	83			
7				
8				
9				
10				

Enter value or expression

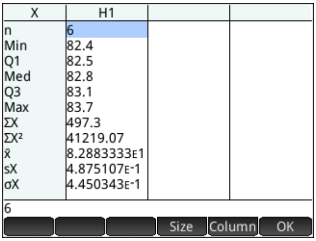
Calculate statistics

4. Calculate statistics:

   Stats

   The statistics calculated will now be imported into the Inference app.

5. Tap OK to close the statistics window.



X	H1
n	6
Min	82.4
Q1	82.5
Med	82.8
Q3	83.1
Max	83.7
ΣX	497.3
ΣX²	41219.07
x̄	8.2883333E1
sX	4.875107E-1
σX	4.450343E-1

6

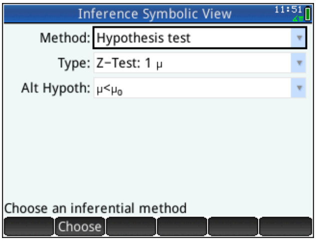
Open the Inference app

6. Open the Inference app and clear the current settings.

   Apps Info Select

   `Inference`

   Shift Esc Clear



Inference Symbolic View

Method: Hypothesis test

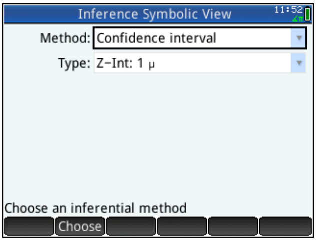
Type: Z-Test: 1 μ

Alt Hypoth: $\mu < \mu_0$

Choose an inferential method

Select inference method and type

7. Tap on the **Method** field and select `Confidence Interval`.



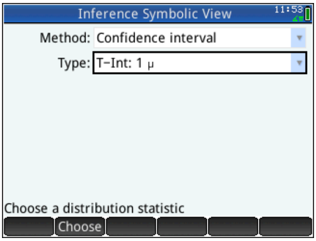
Inference Symbolic View

Method: Confidence interval

Type: Z-Int: 1 μ

Choose an inferential method

8. Tap on **Type** and select `T-Int: 1 μ`



Inference Symbolic View

Method: Confidence interval

Type: T-Int: 1 μ

Choose a distribution statistic

Import the data

9. Open Numeric view:

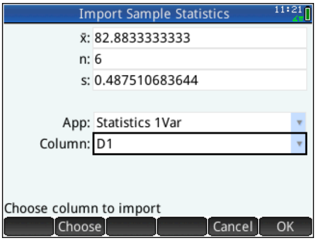
   Num Setup

10. Specify the data you want to import:

    Tap Import.

11. From the **App** field select the statistics app that has the data you want to import.

12. In the **Column** field specify the column in that app where the data is stored. (D1 is the default.)



Import Sample Statistics

$\bar{x}$: 82.8833333333

n: 6

s: 0.487510683644

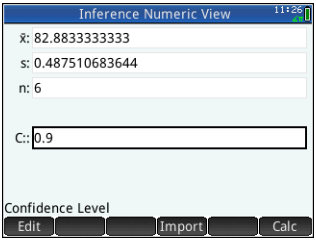
App: Statistics 1Var

Column: D1

Choose column to import

13. Tap OK.

14. Specify a 90% confidence interval in the **C** field.



Inference Numeric View

$\bar{x}$: 82.8833333333

s: 0.487510683644

n: 6

C:: 0.9

Confidence Level

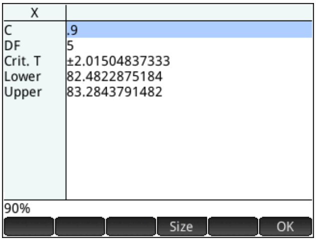
Display results numerically

15. Display the confidence interval in Numeric view:

Calc

16. Return to Numeric view:

OK



X	
C	.9
DF	5
Crit. T	±2.01504837333
Lower	82.4822875184
Upper	83.2843791482

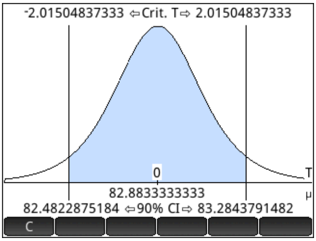
90%

Display results graphically

17. Display the confidence interval in Plot view.

Plot Setup

The 90% confidence interval is [82.48…, 83.28…].



-2.01504837333 ⇦Crit. T⇨ 2.01504837333
0
T
82.8833333333
μ
82.4822875184 ⇦90% CI⇨ 83.2843791482
C

Hypothesis tests

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

The HP Prime hypothesis tests use the Normal Z-distribution or the Student's t-distribution to calculate probabilities. If you wish to use other distributions, please use the Home view and the distributions found within the Probability category of the Math menu.

One-Sample Z-Test

Menu name

Z-Test: 1 μ

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 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:

$$H_0\colon \mu < \mu_0$$
$$H_0\colon \mu > \mu_0$$
$$H_0\colon \mu \neq \mu_0$$

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
Test $\bar{x}$	Value of $\bar{x}$ associated with the test Z-value
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\bar{x}$	Boundary value(s) of $\bar{x}$ 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 means of the two populations are equal, H_0: $\mu_1 = \mu_2$.

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

H_0: $\mu_1 < \mu_2$
H_0: $\mu_1 > \mu_2$
H_0: $\mu_1 \neq \mu_2$

Inputs

The inputs are:

Field name	Definition
$\bar{x}_1$	Sample 1 mean
$\bar{x}_2$	Sample 2 mean
n_1	Sample 1 size
n_2	Sample 2 size
σ_1	Population 1 standard deviation
σ_2	Population 2 standard deviation
α	Significance level

Results

The results are:

Result	Description
Test Z	Z-Test statistic
Test $\Delta\ \bar{x}$	Difference in the means associated with the test Z-value
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\Delta\ \bar{x}$	Difference in the means associated with the α level you supplied

One-Proportion Z-Test

Menu name

Z-Test: $1\ \pi$

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 is an assumed value, $H_0: \pi = \pi_0$.

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

$$H_0\text{: } \pi < \pi_0$$
$$H_0\text{: } \pi > \pi_0$$
$$H_0\text{: } \pi \neq \pi_0$$

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 Z	Z-Test statistic
Test $\hat{p}$	Proportion of successes in the sample
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\hat{p}$	Proportion of successes 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, this test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the proportions of successes in the two populations are equal, H_0: $\pi_1 = \pi_2$.

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

$$H_0: \pi_1 < \pi_2$$
$$H_0: \pi_1 > \pi_2$$
$$H_0: \pi_1 \neq \pi_2$$

Inputs

The inputs are:

Field name	Definition
x_1	Sample 1 success count
x_2	Sample 2 success count
n_1	Sample 1 size
n_2	Sample 2 size
α	Significance level

Results

The results are:

Result	Description
Test Z	Z-Test statistic
Test $\Delta \hat{p}$	Difference between the proportions of successes in the two samples that is associated with the test Z-value
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\Delta \hat{p}$	Difference in the proportion of successes in the two samples associated with the α level you supplied

One-Sample T-Test

Menu name

T-Test: 1 μ

This 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:

$$H_0\colon \mu < \mu_0$$
$$H_0\colon \mu > \mu_0$$
$$H_0\colon \mu \neq \mu_0$$

Inputs

The inputs are:

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

Results

The results are:

Result	Description
Test T	T-Test statistic
Test $\bar{x}$	Value of $\bar{x}$ associated with the test t-value
P	Probability associated with the T-Test statistic
DF	Degrees of freedom
Critical T	Boundary value(s) of T associated with the α level that you supplied
Critical $\bar{x}$	Boundary value(s) of $\bar{x}$ required by the α value that you supplied

Two-Sample T-Test

Menu name

T-Test: $\mu_1 - \mu_2$

This 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:

$$H_0: \mu_1 < \mu_2$$
$$H_0: \mu_1 > \mu_2$$
$$H_0: \mu_1 \neq \mu_2$$

Inputs

The inputs are:

Field name	Definition
$\bar{x}_1$	Sample 1 mean
$\bar{x}_2$	Sample 2 mean
s_1	Sample 1 standard deviation
s_2	Sample 2 standard deviation
n_1	Sample 1 size
n_2	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
Test $\Delta \bar{x}$	Difference in the means associated with the test t-value
P	Probability associated with the T-Test statistic
DF	Degrees of freedom
Critical T	Boundary values of T associated with the α level that you supplied
Critical $\Delta \bar{x}$	Difference in the means associated with the α level you supplied

Confidence intervals

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

One-Sample Z-Interval

Menu name

Z-Int: $1\ \mu$

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

Inputs

The inputs are:

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

Results

The results are:

Result	**Description**
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for μ
Upper	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
n_1	Sample 1 size
n_2	Sample 2 size
σ_1	Population 1 standard deviation
σ_2	Population 2 standard deviation
C	Confidence level

Results

The results are:

Result	Description
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for $\Delta\mu$
Upper	Upper bound for $\Delta\mu$

One-Proportion Z-Interval

Menu name

Z-Int: 1π

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
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for π
Upper	Upper bound for π

Two-Proportion Z-Interval

Menu name

Z-Int: $\pi_1 - \pi_2$

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
n_1	Sample 1 size
n_2	Sample 2 size
C	Confidence level

Results

The results are:

Result	Description
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for $\Delta\pi$
Upper	Upper bound for $\Delta\pi$

One-Sample T-Interval

Menu name

T-Int: 1 μ

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

Inputs

The inputs are:

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

Results

The results are:

Result	Description
C	Confidence level
DF	Degrees of freedom
Critical T	Critical values for T
Lower	Lower bound for μ
Upper	Upper bound for μ

Two-Sample T-Interval

Menu name

T-Int: $\mu_1 - \mu_2$

This option uses the Student's t-distribution to calculate a confidence interval for the difference between the means of two populations, $\mu_1 - \mu_2$, when the population standard deviations, $\sigma_1$and σ_2, are unknown.

Inputs

The inputs are:

Result	Definition
$\bar{x}_1$	Sample 1 mean
$\bar{x}_2$	Sample 2 mean
s_1	Sample 1 standard deviation
s_2	Sample 2 standard deviation
n_1	Sample 1 size
n_2	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
C	Confidence level
DF	Degrees of freedom
Critical T	Critical values for T
Lower	Lower bound for $\Delta\mu$
Upper	Upper bound for $\Delta\mu$

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Solve app

The Solve app enables you to define up to ten equations or expressions each with as many variables as you like. You can solve a single equation or expression for one of its variables, based on a seed value. You can also solve a system of equations (linear or non-linear), again using seed values.

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 of the equation 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.

For brevity, the term *equation* in this chapter will cover both equations and expressions.

Solve works only with real numbers.

Getting started with the Solve app

The Solve app uses the customary app views: Symbolic, Plot and Numeric described in chapter 5, though the Numeric view is significantly different from the other apps as it is dedicated to numerical solving rather than to displaying a table of values.

For a description of the menu buttons common to the other apps that are also available in this app, see:

- “Symbolic view: Summary of menu buttons” on page 86
- “Plot view: Summary of menu buttons” on page 96

One equation

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

The equation to solve is:

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

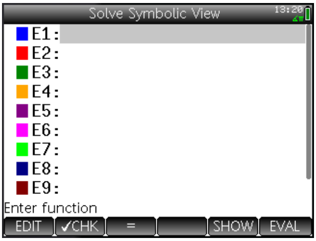
where V = final speed, U = initial speed, A = acceleration needed, and D = distance.

Open the Solve app

1. Open the Solve app.

   Apps Info Select `Solve`

   The Solve app starts in Symbolic view, where you specify the equation to solve.



E1:
E2:
E3:
E4:
E5:
E6:
E7:
E8:
E9:
Enter function

Note In addition to the built-in variables, you can use one or more variables you created yourself (either in Home view or in the CAS). For example, if you've created a variable called ME, you could include it in an equation such as this: $Y^2 = G^2 + ME$.

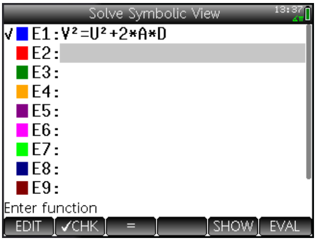
Functions defined in other apps can also be referenced in the Solve app. For example, if you have defined F1(X) to be $X^2 + 10$ in the Function app, you can enter `F1(X)=50` in the Solve app to solve the equation $X^2 + 10 = 50$.

Clear the app and define the equation

2. If you have no need for any equations or expressions already defined, press Shift Esc Clear (Clear). Tap OK to confirm your intention to clear the app.

3. Define the equation.

   ALPHA alpha V x^2 Shift = ALPHA alpha U x^2 + Ans 2 ALPHA alpha A ALPHA alpha D Enter ≈



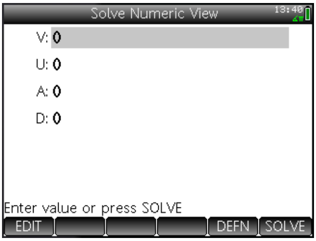
√ E1:V²=U²+2*A*D
E2:
E3:
E4:
E5:
E6:
E7:
E8:
E9:
Enter function

Enter known variables

4. Display the Numeric view.

   Num Setup

   Here you specify the values of the known variables, highlight the variable that you want to solve for, and tap Solve.



V: 0
U: 0
A: 0
D: 0

Enter value or press SOLVE

5. Enter the values for the known variables.

   2 7 . 7 8 Enter 1 6 . 6 7 Enter ▼ 1 0 0 Enter

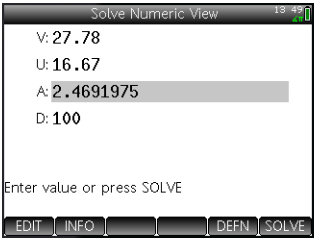
Note Some variables may already have values against them when you display the Numeric view. This occurs if the variables have been assigned values elsewhere. For example, in Home view you might have assigned 10 to variable U: 10 Sto ► U. Then when you open the Numeric view to solve an equation with U as a variable, 10 will be the default value for U. This also occurs if a variable has been given a value in some previous calculation (in an app or program).

To reset all pre-populated variables to zero, press Shift Esc Clear.

Solve the unknown variable

6. Solve for the unknown variable (*A*).

   Move the cursor to the A field and tap Solve.



V: 27.78
U: 16.67
A: 2.4691975
D: 100

Enter value or press SOLVE

   Therefore, the acceleration needed to increase the speed of a car from 16.67 m/s (60 kph) to 27.78 m/s (100 kph) over a distance of 100 m is approximately 2.4692 m/s^2.

   The equation is linear with respect to the variable A. Hence we can conclude that there are no further solutions for A. We can also see this if we plot the equation.

Plot the equation

The Plot view shows one graph for each side of the solved equation. You can choose any of the variables to be the independent variable by selecting it in Numeric view. So in this example make sure that A is highlighted.

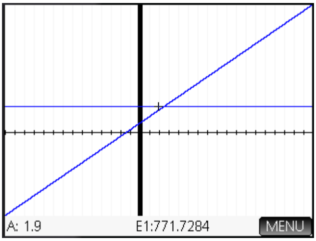
The current equation is $V^2 = U^2 + 2AD$. The plot view will plot two equations, one for each side of the equation. One of these is $Y = V^2$, with $V = 27.78$, making $Y = 771.7284$. This graph will be a horizontal line. The other graph will be $Y = U^2 + 2AD$ with $U =16.67$and $D = 100$, making, $Y = 200A + 277.8889$. This graph is also a line. The desired solution is the value of A where these two lines intersect.

7. Plot the equation for variable `A`.

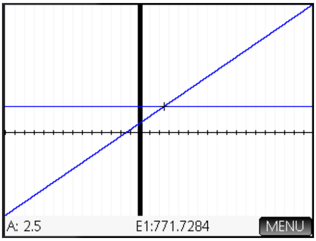
   View Copy

   Select `Auto Scale`.

   Select `Both sides of En` (where `n` is the number of the selected equation)



8. By default, the tracer is active. Using the cursor keys, move the trace cursor along either graph until it nears the intersection.Note that the value of `A` displayed near the bottom left corner of the screen closely matches the value of A you calculated above.



The Plot view provides a convenient way to find an approximation to a solution when you suspect that there are a number of solutions. Move the trace cursor close to the solution (that is, the intersection) of interest to you and then open Numeric view. The solution given in Numeric view will be will be for the solution nearest the trace cursor.

Note By dragging a finger horizontally or vertically across the screen, you can quickly see parts of the plot that are initially outside the x and y ranges you set.

Several equations

You can define up to ten equations and expressions in Symbolic view and select those you want to solve together as a system. For example, suppose you want to solve the system of equations consisting of:

- $X^2 + Y^2 = 16$ and
- $X - Y = -1$

Open the Solve app

1. Open the Solve app.

   Apps Info Select `Solve`

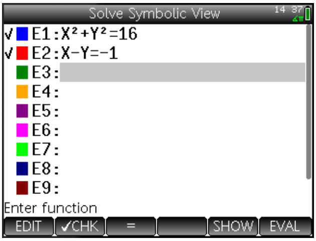
2. If you have no need for any equations or expressions already defined, press Shift Esc Clear (Clear). Tap OK to confirm your intention to clear the app.

Define the equations

3. Define the equations.

   ALPHA X x² + ALPHA Y x² Shift = 16 Enter

   ALPHA X − ALPHA Y Shift = +/− 1 Enter



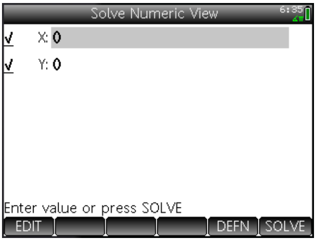
√ 🟦 E1:X²+Y²=16
√ 🟥 E2:X−Y=−1
🟩 E3:
🟧 E4:
🟪 E5:
E6:
🟩 E7:
🟦 E8:
🟥 E9:
Enter function

   Make sure that both equations are selected, as we are looking for values of *X* and *Y* that satisfy both equations.

Enter a seed value

4. Display Numeric view.

   Num Setup



√ X: 0
√ Y: 0
Enter value or press SOLVE

   Unlike the example above, in this example we have no values for any variable. You can either enter a seed value for one of the variables, or let the calculator provide a solution. (Typically a seed value is a value that directs the calculator to provide, if possible, a solution that is closest to it rather than some other value.) In this example, let's look for a solution in the vicinity of *X* = 2.

5. Enter the seed value in the X field:

   2 OK

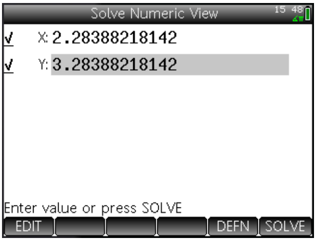
   The calculator will provide one solution (if there is one) and you will not be alerted if there are multiple solutions. Vary the seed values to find other potential solutions.

6. Select the variables you want solutions for. In this example we want to find values for both X and Y, so make sure that both variables are selected.

   Note too that if you have more than two variables, you can enter seed values for more than one of them.

Solve the unknown variables

7. Tap Solve to find a solution near *X* = 2 that satisfies each selected equation. Solutions, if found, are displayed beside each selected variable.



√ X: 2.28388218142

√ Y: 3.28388218142

Enter value or press SOLVE

Limitations

You cannot plot equations if more than one is selected in Symbolic view.

The HP Prime will not alert you to the existence of multiple solutions. If you suspect that another solution exists close to a particular value, repeat the exercise using that value as a seed. (In the example just discussed, you will find another solution if you enter –4 as the seed value for *X*.)

In some situations, the Solve app will use a random number seed in its search for a solution. This means that it is not always predictable which seed will lead to which solution when there are multiple solutions.

Solution information

When you are solving a single equation, the Info button appears on the menu after you tap Solve. Tapping Info displays a message giving you some information about the solutions found (if any). Tap OK to clear the message.

Message	Meaning
`Zero`	The Solve app 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 two sides of the equation have 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. Either the two values are neighbors (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 `Extremum` message indicates that it is highly likely that there is no solution. Use Numeric view to verify this (and note that any values shown are suspect).

Message	Meaning (Continued)
Cannot find solution	No values satisfy the selected equation or expression.
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.

Linear Solver app

The Linear Solver app enables 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 app will attempt to solve for *x* and *y* (and *z* in three-equation sets).

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

Getting started with the Linear Solver app

The following example defines the following set of equations and then solves for the unknown variables:

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

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

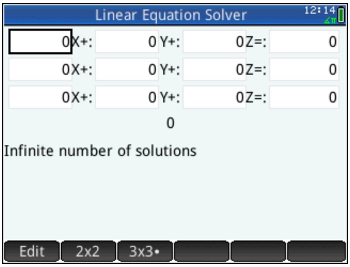
$$6x + 4y = 6$$

Open the Linear Solver app

1. Open the Linear Solver app.

   Apps Info Select `Linear Solver`

   The app opens in Numeric view.



0X+: 0 Y+: 0Z=: 0

0X+: 0 Y+: 0Z=: 0

0X+: 0 Y+: 0Z=: 0

0

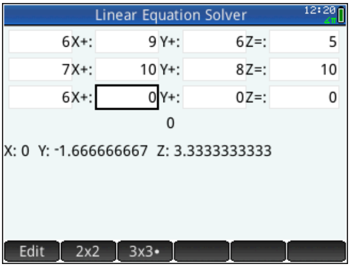
Infinite number of solutions

Note If the last time you used the Linear Solver app you solved for two equations, the two-equation input form is displayed. To solve a three-equation set, tap 3x3; now the input form displays three equations.

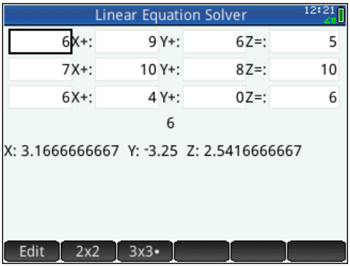
Define and solve the equations

2. You define the equations you want to solve by entering the coefficients of each variable in each equation and the constant term. Notice that the cursor is positioned immediately to the left of *x* in the first equation, ready for you to insert the coefficient of *x* (6). Enter the coefficient and either tap OK or press Enter ≈.
3. The cursor moves to the next coefficient. Enter that coefficient and either tap OK or press Enter ≈. Continue doing likewise until you have defined all the equations.

Once you have entered enough values for the solver to be able to generate solutions, those solutions appear near the bottom of the display. In this example, the solver was able to find solutions for *x*, *y*, and *z* as soon as the first coefficient of the last equation was entered.

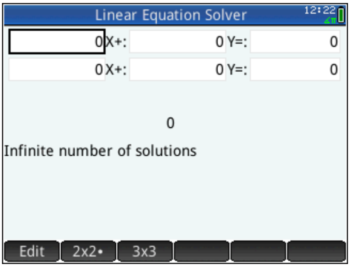

Linear Equation Solver
```
6X+:   9 Y+:   6Z=:   5
7X+:  10 Y+:   8Z=:  10
6X+:   0 Y+:   0Z=:   0
0
X: 0  Y: -1.666666667  Z: 3.3333333333
```

As you enter each of the remaining known values, the solution changes. The graphic at the right shows the final solution once all the coefficients and constants had been entered.


Linear Equation Solver
```
6X+:   9 Y+:   6Z=:   5
7X+:  10 Y+:   8Z=:  10
6X+:   4 Y+:   0Z=:   6
6
X: 3.1666666667  Y: -3.25  Z: 2.5416666667
```

Solve a two-by-two system

If the three-equation input form is displayed and you want to solve a two-equation set, tap 2x2.


Linear Equation Solver

0	X+:	0	Y=:	0	
0	X+:	0	Y=:	0	

0
Infinite number of solutions

Note You can enter any expression that resolves to a numerical result, including variables. Just enter the name of a variable. For more information on assigning values to variables, see "Storing a value in a variable" on page 42.

Menu items

The menu items are:

- Edit: moves the cursor to the entry line where you can add or change a value. You can also highlight a field, enter a value, and press Enter ≈. The cursor automatically moves to the next field, where you can enter the next value and press Enter ≈.
- 2x2: displays the page for solving a system of 2 linear equations in 2 variables; changes to 2x2• when active
- 3x3: displays the page for solving a system of 3 linear equations in 3 variables; changes to 3x3• when active.

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Parametric app

The Parametric app enables 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 app

The Parametric app uses the customary app views: Symbolic, Plot and Numeric described in chapter 5.

For a description of the menu buttons available in this app, see:

- "Symbolic view: Summary of menu buttons" on page 86
- "Plot view: Summary of menu buttons" on page 96, and
- "Numeric view: Summary of menu buttons" on page 104

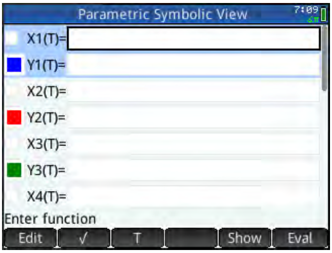
Throughout this chapter, we will explore the parametric equations *x*(*T*) = 8sin(*T*) and *y*(*T*) = 8cos(*T*). These equations produce a circle.

Open the Parametric app

1. Open the Parametric app.

   Apps Info Select `Parametric`

   The Parametric app starts in Symbolic view. This is the *defining view*. It is where you symbolically define (that is, specify) the parametric expressions you want to explore.


Parametric Symbolic View

X1(T)=

🟦 Y1(T)=

X2(T)=

🟥 Y2(T)=

X3(T)=

🟩 Y3(T)=

X4(T)=

Enter function

The graphical and numerical data you see in Plot view and Numeric view are derived from the symbolic functions defined here.

Define the functions

There are 20 fields for defining functions. These are labelled `X1(T)` through `X9(T)` and `X0(T)`, and `Y1(T)` through `Y9(T)` and `Y0(T)`. Each X function is paired with a Y function.

2. Highlight which pair of functions you want to use, either by tapping on, or scrolling to, one of the pair. If you are entering a new function, just start typing. If you are editing an existing function, tap Edit and make your changes. When you have finished defining or changing the function, press Enter.

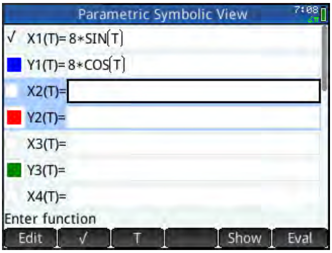
3. Define the two expressions.

8 SIN xtθn

Enter

8 COS xtθn

Enter



Parametric Symbolic View 7:08

✓ X1(T)=8*SIN(T)

🟦 Y1(T)=8*COS(T)

X2(T)=

🟥 Y2(T)=

X3(T)=

🟩 Y3(T)=

X4(T)=

Enter function

Notice how the xtθn key enters whatever variable is relevant to the current app. In the Function app, xtθn enters an X. In the Parametric app it enters a T. In the Polar app, discussed in chapter16, it enters θ.

4. Decide if you want to:

   – give one or more function a custom color when it is plotted

   – evaluate a dependent function

   – deselect a definition that you don’t want to explore

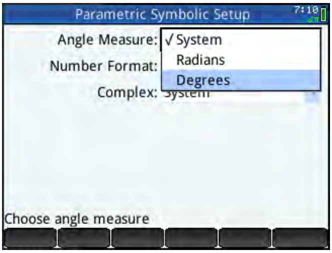
   – incorporate variables, math commands and CAS commands in a definition.

   For the sake of simplicity we can ignore these operations in this example. However, they can be useful and are described in detail in “Common operations in Symbolic view” on page 81.

Set the angle measure

Set the angle measure to degrees:

5. Shift Symb Setup (Settings)



Parametric Symbolic Setup

Angle Measure: √System / Radians / Degrees

Number Format:

Complex: System

Choose angle measure

6. Tap the **Angle Measure** field and select `Degrees`.

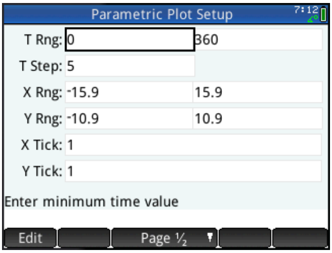
   You could also have set the angle measure on the **Home Settings** screen. However, Home settings are system-wide. By setting the angle measure in an app rather than Home view, you are limiting the setting just to that app.

Set up the plot

7. Open the Plot Setup view:

   Shift Plot Setup (Setup)

8. Set up the plot by specifying appropriate graphing options. In this example, set the **T Rng** and **T Step** fields so that *T* steps from 0° to 360° in 5° steps:



Parametric Plot Setup

T Rng:	0	360
T Step:	5	
X Rng:	-15.9	15.9
Y Rng:	-10.9	10.9
X Tick:	1	
Y Tick:	1	

Enter minimum time value

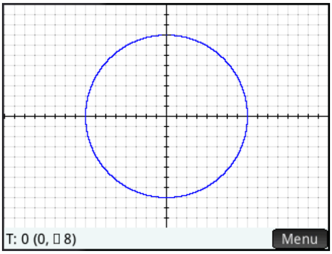
   Select the 2nd **T Rng** field and enter:

   360 OK 5 OK

Plot the functions

9. Plot the functions:

   Plot Setup



Explore the graph

The menu button gives you access to common tools for exploring plots:

Zoom : displays a range of zoom options. (The + and − keys can also be used to zoom in and out.)

TRACE• : when active, enables a tracing cursor to be moved along the contour of the plot (with the coordinates of the cursor displayed at the bottom of the screen).

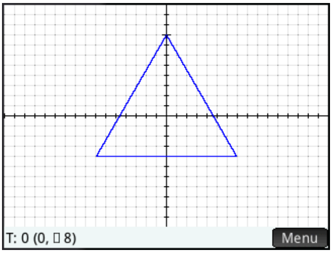
Go To : specify a `T` value and the cursor moves to the corresponding *x* and *y* coordinates.

Defn : display the functions responsible for the plot.

Detailed information about these tools is provided in "Common operations in Plot view" on page 88.

Typically you would modify a plot by changing its definition in Symbolic view. However, you can modify some plots by changing the Plot Setup parameters. For example, you can plot a triangle instead of a circle simply by changing two plot setup parameters. The definitions in Symbolic view remain unchanged. Here is how it is done:

10. Press Shift Plot (Setup).
11. Change **T Step** to 120.
12. Tap Page ½.
13. From the **Method** menu, select `Fixed-Step Segments`.
14. Press Plot.



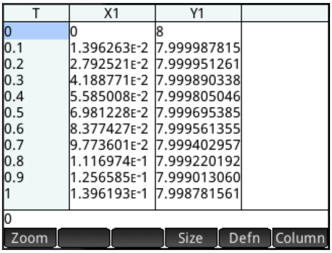
A triangle is displayed instead of a circle. This is because the new value of **T Step** makes the points being plotted 120° apart instead of the nearly continuous 5°. And by selecting `Fixed-Step Segments` the points 120° apart are connected with line segments.

Display the numeric view

15. Display the Numeric view:

    Num Setup

16. With the cursor in the `T` column, type a new value and tap OK. The table scrolls to the value you entered.



T	X1	Y1	
0	0	8	
0.1	1.396263E-2	7.999987815	
0.2	2.792521E-2	7.999951261	
0.3	4.188771E-2	7.999890338	
0.4	5.585008E-2	7.999805046	
0.5	6.981228E-2	7.999695385	
0.6	8.377427E-2	7.999561355	
0.7	9.773601E-2	7.999402957	
0.8	1.116974E-1	7.999220192	
0.9	1.256585E-1	7.999013060	
1	1.396193E-1	7.998781561	

0

You can also zoom in or out on the independent variable (thereby decreasing or increasing the increment between consecutive values). This and other options are explained in “Common operations in Numeric view” on page 100.

You can see the Plot and Numeric views side by side. See “Combining Plot and Numeric Views” on page 106.

16

Polar app

The Polar app enables you to explore polar equations. Polar equations are equations in which *r*—the distance a point is from the origin: (0,0)—is defined in terms of θ, the angle a segment from the point to the origin makes with the polar axis. Such equations take the form $r = f(\theta)$.

Getting started with the Polar app

The Polar app uses the six standard app views described in chapter 5, “An introduction to HP apps”, beginning on page 69. That chapter also describes the menu buttons used in the Polar app.

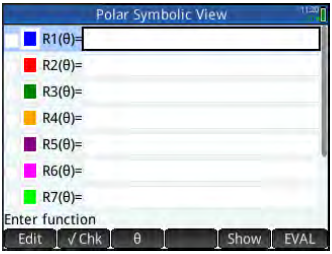
Throughout this chapter, we will explore the expression $5\pi\cos(\theta/2)\cos(\theta)^2$.

Open the Polar app

1. Open the Polar app:

   Apps Info Select `Polar`

   The app opens in Symbolic view.



Polar Symbolic View

R1(θ)=

R2(θ)=

R3(θ)=

R4(θ)=

R5(θ)=

R6(θ)=

R7(θ)=

Enter function

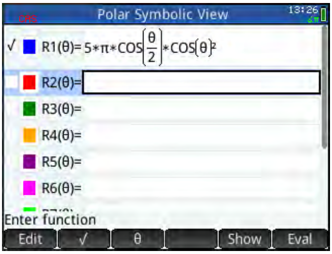
Define the function

There are 10 fields for defining polar functions. These are labelled `R1(θ)` through `R9(θ)` and `R0(θ)`.

2. Highlight the field you want to use, either by tapping on it or scrolling to it. If you are entering a new function, just start typing. If you are editing an existing function, tap Edit and make your changes. When you have finished defining or changing the function, press Enter ≈.

3. Define the expression `5πcos(θ/2)cos(θ)`^{2}.

   5 Shift 3 COS
   xtθn ÷ 2 ▶ ▶
   COS xtθn ▶ x^2
   Enter


Polar Symbolic View
✓ 🟦 R1(θ)=5*π*COS$\left(\frac{\theta}{2}\right)$*COS(θ)^2
🟥 R2(θ)=
🟩 R3(θ)=
🟧 R4(θ)=
🟪 R5(θ)=
🟪 R6(θ)=
Enter function

   Notice how the xtθn key enters whatever variable is relevant to the current app. In this app the relevant variable is θ.

4. If you wish, choose a color for the plot other than its default. You do this by selecting the colored square to the left of the function set, tapping Choose, and selecting a color from the color-picker.

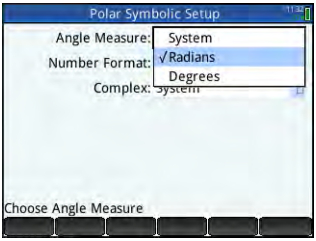
For more information about adding definitions, modifying definitions, and evaluating dependent definitions in Symbolic view, see "Common operations in Symbolic view" on page 81.

Set angle measure

Set the angle measure to radians:

5. Shift Symb (Settings)

6. Tap the **Angle Measure** field and select `Radians`.


Polar Symbolic Setup
Angle Measure: System
Number Format: ✓Radians
Complex: Degrees
Choose Angle Measure

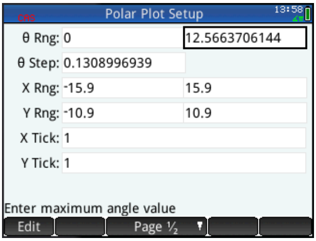
For more information on the Symbolic Setup view, see "Common operations in Symbolic Setup view" on page 87.

Set up the plot

7. Open the Plot Setup view:

   Shift Plot (Setup)

8. Set up the plot by specifying appropriate graphing options. In this example, set the upper limit of the range of the independent variable to 4π:


Polar Plot Setup

θ Rng: 0 12.5663706144

θ Step: 0.1308996939

X Rng: -15.9 15.9

Y Rng: -10.9 10.9

X Tick: 1

Y Tick: 1

Enter maximum angle value

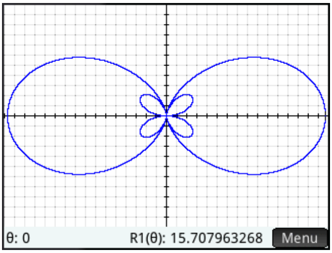
Select the 2nd θ **Rng** field and enter 4 Shift 3 π # (π) OK

There are numerous ways of configuring the appearance of Plot view. For more information, see "Common operations in Plot Setup view" on page 96.

Plot the expression

9. Plot the expression:

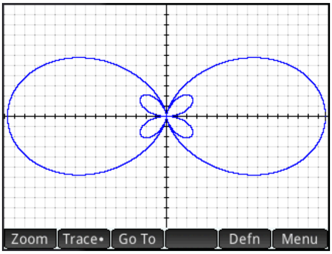
Plot Setup


θ: 0 R1(θ): 15.707963268

Explore the graph

10. Display the Plot view menu.

Menu



A number of options appear to help you explore the graph, such as zooming and tracing. You can also jump directly to a particular θ value by entering that value. The **Go To** screen appears with the number you typed on the entry line. Just tap OK to accept it. (You could also tap the Go To button and spwecify the target value.)

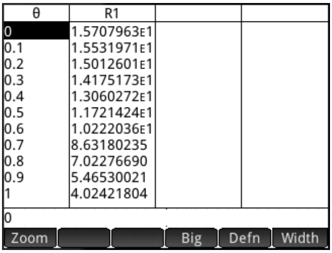
If only one polar equation is plotted, you can see the equation that generated the plot by tapping Defn. If there are several equations plotted, move the tracing cursor to the plot you are interested—by pressing ▲ or ▼—and then tap Defn.

For more information on exploring plots in Plot view, see "Common operations in Plot view" on page 88.

Display the Numeric view

11. Open the Numeric view:

    Num ↳Setup



θ	R1		
0	1.5707963E1		
0.1	1.5531971E1		
0.2	1.5012601E1		
0.3	1.4175173E1		
0.4	1.3060272E1		
0.5	1.1721424E1		
0.6	1.0222036E1		
0.7	8.63180235		
0.8	7.02276690		
0.9	5.46530021		
1	4.02421804		

0

    The Numeric view displays a table of values for θ and R1. If you had specified, and selected, more than one polar function in Symbolic view, a column of evaluations would appear for each one: R2, R3, R4 and so on.

12. With the cursor in the θ column, type a new value and tap OK.The table scrolls to the value you entered.

You can also zoom in or out on the independent variable (thereby decreasing or increasing the increment between consecutive values). This and other options are explained in "Common operations in Numeric view" on page 100.

You can see the Plot and Numeric views side by side. See "Combining Plot and Numeric Views" on page 106.

17

Sequence app

The Sequence app provides you with various ways 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*) or
- in any combination of the above.

You can define a sequence by specifying just the first term and the rule for generating all subsequent terms. However, you will have to enter the second term if the HP Prime 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.

The app enables you to create two types of graphs:

- a **Stairsteps** graph, which plots points of the form (*n*, *Un*)
- a **Cobweb** graph, which plots points of the form (*Un–1*, *Un*).

Getting started with the Sequence app

The following example explores 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.

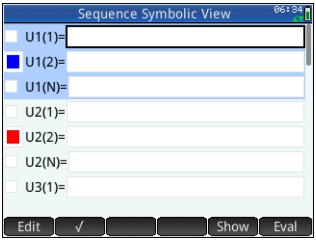
Open the Sequence app

1. Open the Sequence app:

   Apps Info Select

   `Sequence`

   The app opens in Symbolic view.



Define the expression

2. Define the Fibonacci sequence:

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

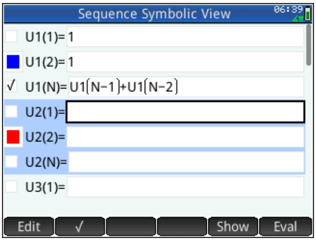
   In the U1(1) field, specify the first term of the sequence:

   1 Enter

   In the U1(2) field, specify the second term of the sequence:

   1 Enter

   In the U1(N) field, specify the formula for finding the nth term of the sequence from the previous two terms (using the buttons at the bottom of the screen to help with some entries):



U1(1)=1

U1(2)=1

√ U1(N)=U1(N−1)+U1(N−2)

   U1 (N−1) + U1 (N−2) Enter

3. Optionally choose a color for your graph (see "Choose a color for plots" on page 85).

Set up the plot

4. Open the Plot Setup view:

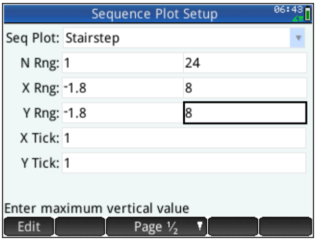
   Shift Plot (Setup)

5. Reset all settings to their default values:

   Shift Esc (Clear)

6. Select `Stairstep` from the **Seq Plot** menu.

7. Set the **X Rng** maximum, and the **Y Rng** maximum, to 8 (as shown at the right).



Sequence Plot Setup

Seq Plot: Stairstep

N Rng: 1 24

X Rng: -1.8 8

Y Rng: -1.8 8

X Tick: 1

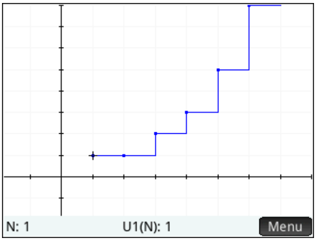
Y Tick: 1

Enter maximum vertical value

Plot the sequence

8. Plot the Fibonacci sequence:

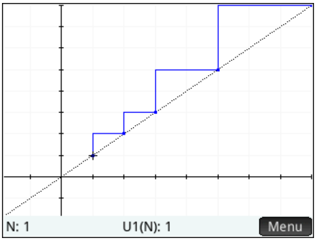
   Plot Setup



9. Return to Plot Setup view (Shift Plot Setup) and select `Cobweb`, from the **Seq Plot** menu.

10. Plot the sequence:

    Plot Setup



Explore the graph

The Menu button gives you access to common plot-exploration tools, such as:

- Zoom : Zoom in or out on the plot
- Trace• : Trace along a graph
- Go To : Go to a specified N value
- Defn : Display the sequence definition

These tools are explained in “Common operations in Plot view” on page 88.

Split screen and autoscaling options are also available by pressing View Copy.

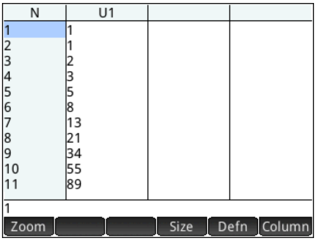
Display Numeric view

11. Display Numeric view:

    Num Setup

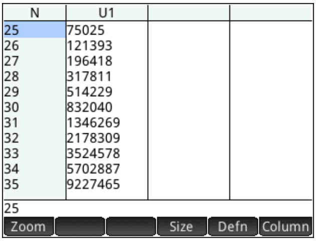
12. With the cursor anywhere in the **N** column, type a new value and tap OK.

    The table of values scrolls to the value you entered. You can then see the corresponding value in the sequence. The example at the right shows that the 25th value in the Fibonacci sequence is 75,025.



N	U1		
1	1		
2	1		
3	2		
4	3		
5	5		
6	8		
7	13		
8	21		
9	34		
10	55		
11	89		

1



N	U1		
25	75025		
26	121393		
27	196418		
28	317811		
29	514229		
30	832040		
31	1346269		
32	2178309		
33	3524578		
34	5702887		
35	9227465		

25

Explore the table of values

The Numeric view gives you access to common table-exploration tools, such as:

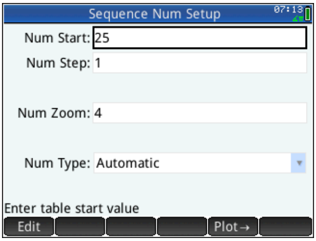
- Zoom: Change the increment between consecutive values
- Size: Change the size of the font
- Defn: Display the sequence definition
- Column: Choose the number of sequences to display

These tools are explained in “Common operations in Numeric view” on page 100.

Split screen and autoscaling options are also available by pressing View Copy.

Set up the table of values

The Numeric Setup view provides options common to most of the graphing apps, although there is no zoom factor as the domain for the sequences is the set of counting numbers. See "Common operations in Numeric Setup view" on page 105 for more information.



Sequence Num Setup 07:13

Num Start: 25

Num Step: 1

Num Zoom: 4

Num Type: Automatic

Enter table start value

Another example: Explicitly-defined sequences

In the following example, we define the nth term of a sequence simply in terms of n itself. In this case, there is no need to enter either of the first two terms numerically.

Define the expression

1. Define $U1(N) = \left(-\frac{2}{3}\right)^N$

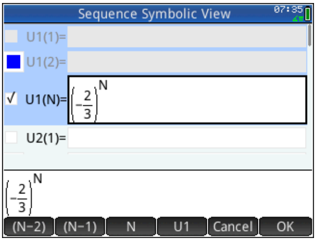
   Select U1(N)

   ( ) +/– ▢,√▢,|▢| and select $\frac{□}{□}$

   2 ▼ 3

   ▶ ▶ x^y N

   Enter



Sequence Symbolic View 07:35

U1(1)=

U1(2)=

✓ U1(N)= $\left(-\frac{2}{3}\right)^N$

U2(1)=

$\left(-\frac{2}{3}\right)^N$

Setup the plot

2. Open the Plot Setup view:

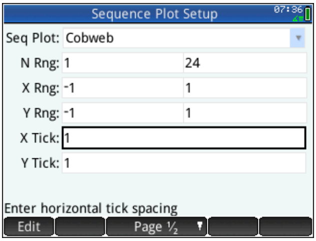
   Shift Plot (Setup)

3. Reset all settings to their default values:

   Shift Esc (Clear)

4. Tap **Seq Plot** and select `Cobweb`.

5. Set both **X Rng** and **Y Rng** to [–1, 1] as shown above.



Sequence Plot Setup 07:36

Seq Plot: Cobweb

N Rng: 1 24

X Rng: -1 1

Y Rng: -1 1

X Tick: 1

Y Tick: 1

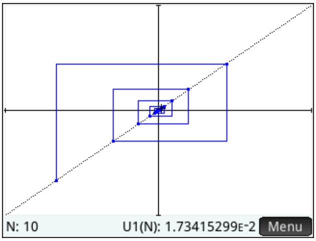
Enter horizontal tick spacing

Plot the sequence

6. Plot the sequence:

   Plot Setup

   Press Enter ≈ to see the dotted lines in the figure to the right. Press it again to hide the dotted lines.

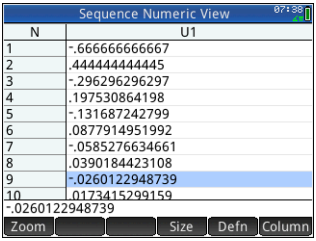


Explore the table of sequence values

7. View the table:

   Num Setup

8. Tap Column and select 1 to see the sequence values.


Sequence Numeric View 07:38

N	U1
1	-.666666666667
2	.444444444445
3	-.296296296297
4	.197530864198
5	-.131687242799
6	.0877914951992
7	-.0585276634661
8	.0390184423108
9	-.0260122948739
10	.0173415299159

-.0260122948739

Zoom | | | Size | Defn | Column

18

Finance app

The Finance app enables you to solve time-value-of-money (TVM) and amortization problems. You can use the app to do compound interest calculations and to create amortization tables.

Compound interest is accumulative interest, that is, interest on interest already earned. The interest earned on a given principal 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.

Getting Started with the Finance app

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. First, what are the required monthly payments? Second, 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.

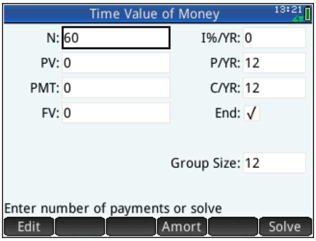
1. Start the Finance app.

   Apps Info Select `Finance`

   The app opens in the Numeric view.

2. In the **N** field, enter 5 × 12 and press Enter ≈.

   Notice that the result of the calculation (60) appears in the field. This is the number of months over a five-year period.



Time Value of Money 13:21

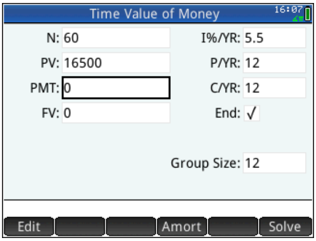
N:	60	I%/YR:	0
PV:	0	P/YR:	12
PMT:	0	C/YR:	12
FV:	0	End:	√
		Group Size:	12

Enter number of payments or solve

3. In the `I%/YR` field, type 5.5—the interest rate—and press Enter.

4. In `PV` field, type 19500 − 3000 and press Enter. This is the present value of the loan, being the purchase price less the deposit.

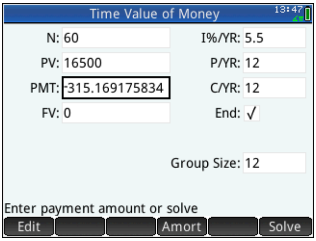
5. Leave `P/YR` and `C/YR` both at `12` (their default values). Leave `End` as the payment option. Also, leave future value, `FV`, as `0` (as your goal is to end up with a future value of the loan of 0).



Time Value of Money 16:07

N: 60 I%/YR: 5.5
PV: 16500 P/YR: 12
PMT: 0 C/YR: 12
FV: 0 End: √
Group Size: 12

6. Move the cursor to the `PMT` field and tap Solve. The PMT value is calculated as –315.17. In other words, your monthly payment will be $315.17.



Time Value of Money 13:47

N: 60 I%/YR: 5.5
PV: 16500 P/YR: 12
PMT: -315.169175834 C/YR: 12
FV: 0 End: √
Group Size: 12

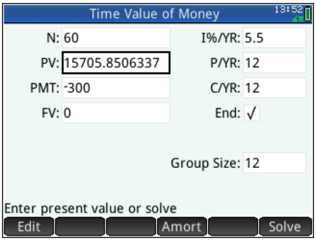
Enter payment amount or solve

The PMT value is negative to indicate that it is money owed by you.

Note that the PMT value is greater than 300, that is, greater than the amount you can afford to pay each month. So you ned to re-run the calculations, this time setting the PMT value to –300 and calculating a new PV value.

7. In the `PMT` field, enter +/− 300 move the cursor to the `PV` field, and tap Solve.

The PV value is calculated as 15,705.85, this being the maximum you can borrow. Thus, with your $3,000 deposit, you can afford a car with a price tag of up to $18,705.85.

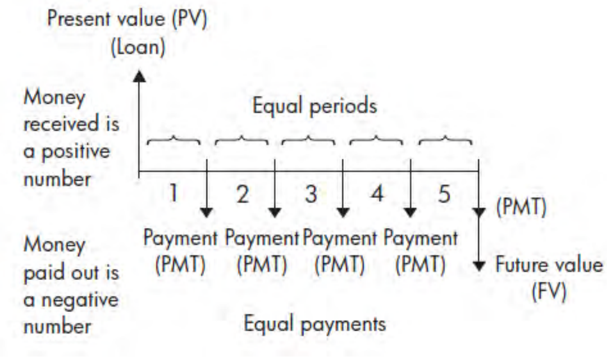

Time Value of Money

N: 60
I%/YR: 5.5
PV: 15705.8506337
P/YR: 12
PMT: -300
C/YR: 12
FV: 0
End: √
Group Size: 12

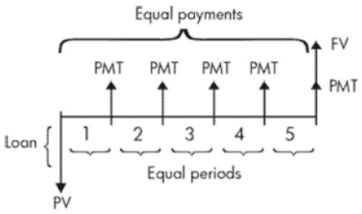
Enter present value or solve

Cash flow diagrams

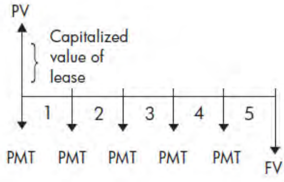
TVM transactions can be represented in *cash flow diagrams*. A cash flow diagram is a time line divided into equal segments representing the compounding periods. Arrows represent the cash flows. These could be positive (upward arrows) or negative (downward arrows), depending on the point of view of the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



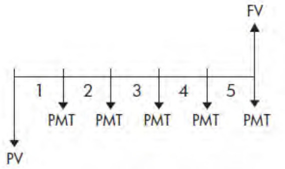
The following cash flow diagram shows a loan from the *lender's* point of view:



Cash flow diagrams also specify *when* payments occur relative to the compounding periods.The diagram to the right shows lease payments at the *beginning* of the period.



This diagram shows deposits (PMT) into an account at the end of each period.



Time value of money (TVM)

Time-value-of-money (TVM) calculations 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.

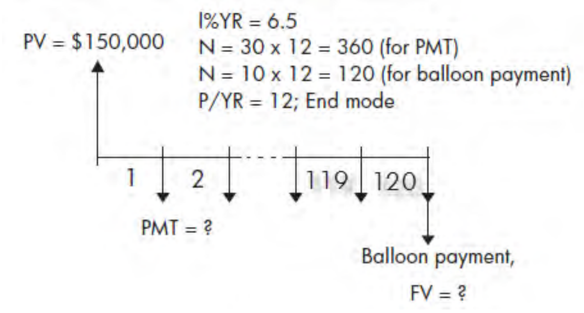
There are seven TVM variables:

Variable	Description
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*. This 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.
P/YR	The number of payments made in a year.
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 un-checking or checking the `End` option.
C/YR	The number of compounding periods in a year.
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 its value at the end of the investment period.

TVM calculations: Another example

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—that is, the value of the mortgage after 10 years of payment.

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



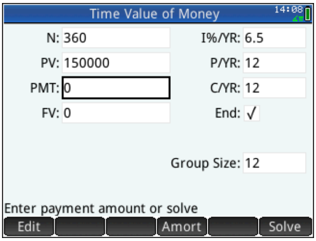
1. Start the Finance app:

   Apps Info Select `Finance`

2. Return all fields to their default values:

   Shift Esc Clear

3. Enter the known TVM variables, as shown in the figure.



Time Value of Money 14:08

N: 360 I%/YR: 6.5
PV: 150000 P/YR: 12
PMT: 0 C/YR: 12
FV: 0 End: ✓

Group Size: 12

Enter payment amount or solve

4. Highlight `PMT` and tap Solve. The `PMT` field shows –984.10. In other words, the monthly payments are $948.10.

5. To determine the balloon payment or future value (FV) for the mortgage after 10 years, enter 120 for `N`, highlight `FV`, and tap Solve.

   The `FV` field shows –127,164.19, indicating that the future value of the loan (that is, how much is still owing) as $127,164.19.

Calculating amortizations

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

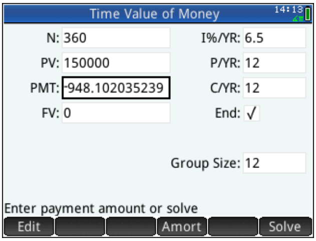
To calculate amortizations:

1. Start the Finance app.
2. Specify the number of payments per year (`P/YR`).
3. Specify whether payments are made at the beginning or end of periods.
4. Enter values for `I%YR`, `PV`, `PMT`, and `FV`.
5. Enter the number of payments per amortization period in the `Group Size` field. By default, the group size is 12 to reflect annual amortization.
6. Tap Amort. The calculator displays an amortization table. For each amortization period, the table shows the amounts applied to interest and principal, as well as the remaining balance of the loan.

Example: Amortization for a home mortgage

Using the data from the previous example of a home mortgage with balloon payment (see page 291), calculate how much has been applied to the principal, how much has been paid in interest, and the balance remaining after the first 10 years (that is, after 12 × 10 = 120 payments).

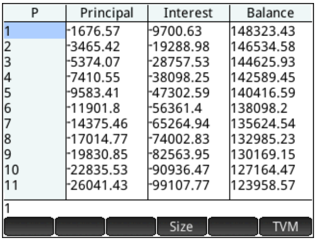
1. Make your data match that shown in the figure to the right.



N: 360
PV: 150000
PMT: -948.102035239
FV: 0
I%/YR: 6.5
P/YR: 12
C/YR: 12
End: √
Group Size: 12

Enter payment amount or solve

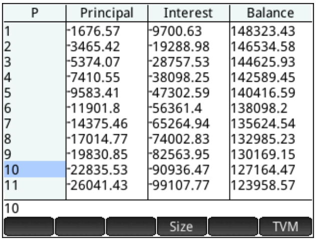
2. Tap Amort.



P	Principal	Interest	Balance
1	-1676.57	-9700.63	148323.43
2	-3465.42	-19288.98	146534.58
3	-5374.07	-28757.53	144625.93
4	-7410.55	-38098.25	142589.45
5	-9583.41	-47302.59	140416.59
6	-11901.8	-56361.4	138098.2
7	-14375.46	-65264.94	135624.54
8	-17014.77	-74002.83	132985.23
9	-19830.85	-82563.95	130169.15
10	-22835.53	-90936.47	127164.47
11	-26041.43	-99107.77	123958.57

1

3. Scroll down the table to payment group 10. Note that after 10 years, $22,835.53 has been paid off the principal and $90,936.47 paid in interest, leaving a balloon payment due of $127,164.47.

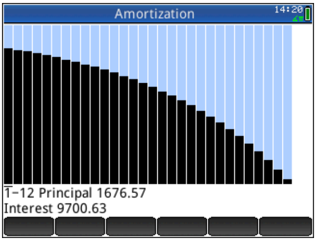


P	Principal	Interest	Balance
1	-1676.57	-9700.63	148323.43
2	-3465.42	-19288.98	146534.58
3	-5374.07	-28757.53	144625.93
4	-7410.55	-38098.25	142589.45
5	-9583.41	-47302.59	140416.59
6	-11901.8	-56361.4	138098.2
7	-14375.46	-65264.94	135624.54
8	-17014.77	-74002.83	132985.23
9	-19830.85	-82563.95	130169.15
10	-22835.53	-90936.47	127164.47
11	-26041.43	-99107.77	123958.57

10

Amortization graph

Press Plot Setup to see the amortization schedule presented graphically. The balance owing at the end of each payment group is indicated by the height of a bar. The amount by which the principal has been reduced, and interest paid, during a payment group is shown at the bottom of the bottom of the screen. The example at the right shows the first payment group selected. This represents the first group of 12 payments (or the state of the loan at the end of the first year). By the end of that year, the principal had been reduced by $1,676.57 and $9,700.63 had been paid in interest.



1–12 Principal 1676.57
Interest 9700.63

Tap ▶ or ◀ to see the amount by which the principal has been reduced, and interest paid, during other payment groups.

19

Triangle Solver app

The Triangle Solver app enables you to calculate the length of a side of a triangle, or the size of an angle in a triangle, from information you supply about the other lengths, angles, or both.

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 app 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 app will calculate the remaining values.

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

If you are determining the lengths and angles of a *right-angled* triangle, a simpler input form is available by tapping ⊿.

Getting started with the Triangle Solver app

The following example calculates 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.

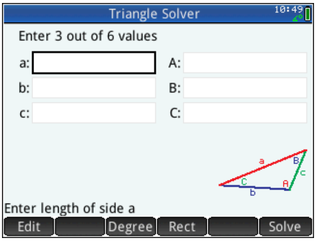
Open the Triangle Solver app

1. Open the Triangle Solver app.

   Apps Info Select

   `Triangle Solver`

   The app opens in Numeric view.



Triangle Solver 10:49

Enter 3 out of 6 values

a: A:

b: B:

c: C:

Enter length of side a

2. If there is unwanted data from a previous calculation, you can clear it all by pressing Shift Esc Clear (Clear).

Set angle measure

Make sure that your angle measure mode is appropriate. By default, the app starts in degree mode. If the angle information you have is in radians and your current angle measure mode is degrees, change the mode to degrees before running the solver. Tap Degree or Radians depending on the mode you want. (The button is a toggle button.)

Note The lengths of the sides are labeled **a**, **b**, and **c**, and the angles are labeled **A**, **B**, and, **C**. 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 **C** (since **C** 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 **A**. The illustration on the screen will help you determine where to enter the known values.

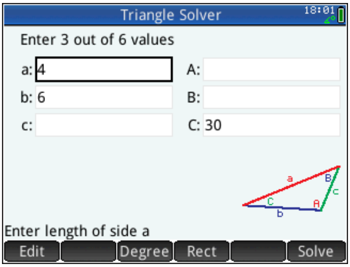
Specify the known values

3. Go to a field whose value you know, enter the value and either tap OK or press Enter ≈. Repeat for each known value.

   (a). In **a** type 4 and press Enter ≈.

   (b). In **b** type 6 and press Enter ≈.

   (c). In **C** type 30 and press Enter ≈.


Triangle Solver

Enter 3 out of 6 values

a: 4 A:

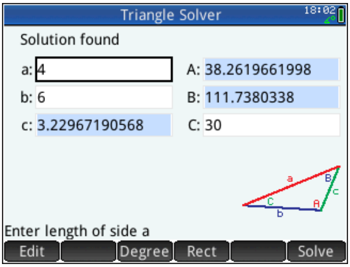
b: 6 B:

c: C: 30

Enter length of side a

Solve for the unknown values

4. Tap Solve. The app displays the values of the unknown variables. As the illustration at the right shows, the length of the unknown side in our example is 3.22967… The other two angles have also been calculated.


Triangle Solver 18:02

Solution found

a: 4 A: 38.2619661998

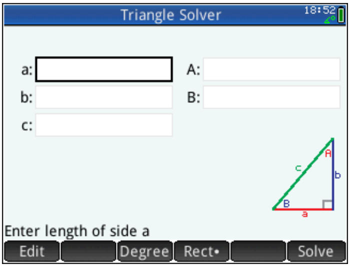
b: 6 B: 111.7380338

c: 3.22967190568 C: 30

Enter length of side a

Choosing triangle types

The Triangle Solver app has two input forms: a general input form and a simpler, specialized form for right-angled triangles. If the general input form is displayed, and you are investigating a right-angled triangle, tap ⊿ to display the simpler input form. To return to the general input form, tap Rect•. 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.


Triangle Solver 18:52

a: A:

b: B:

c:

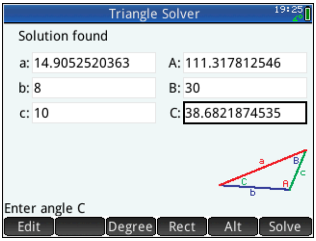
Enter length of side a

Special cases

The indeterminate case

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

In this case, the Alt button is displayed (as in this example). You can tap Alt to display the second solution and tap Alt again to return to the first solution.



Triangle Solver 19:25

Solution found

a: 14.9052520363 A: 111.317812546

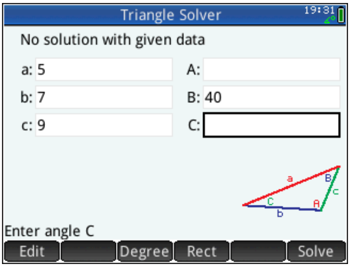
b: 8 B: 30

c: 10 C: 38.6821874535

Enter angle C

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.



Triangle Solver 19:31

No solution with given data

a: 5 A:

b: 7 B: 40

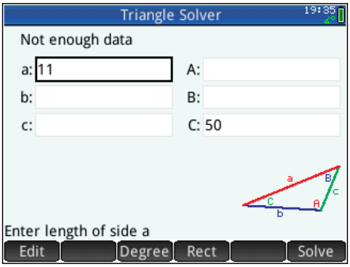
c: 9 C:

Enter angle C

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.



Triangle Solver 19:35

Not enough data

a: 11 A:

b: B:

c: C: 50

Enter length of side a

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

20

The Explorer apps

There are three explorer apps. These are designed for you to explore the relationships between the parameters of a function and the shape of the graph of that function. The explorer apps are:

- Linear Explorer

  For exploring linear functions

- Quadratic Explorer

  For exploring quadratic functions

- Trig Explorer

  For exploring sinusoidal functions

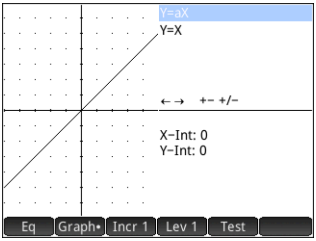
There are two modes of exploration: graph mode and equation mode. In graph mode you manipulate a graph and note the corresponding changes in its equation. In equation mode you manipulate an equation and note the corresponding changes in its graphical representation. Each explorer app has a number of equations and graphs for to explore, and app has a test mode. In test mode, you test you skills at matching equations to graphs.

Linear Explorer app

The Linear Explorer app can be used to explore the behavior of the graphs of $y = ax$ and $y = ax + b$ as the values of *a* and *b* change.

Open the app

Press Apps Info and select `Linear Explorer`.



The left half of the display shows the graph of a linear function. The right half shows the general form of the equation being explored at the top and, below it, the current equation of that form. The keys you can use to manipulate the graph or equation appear below the equation. The x- and y-intercepts are given at the bottom.

There are two types (or levels) of linear equation available for you to explore: y = ax and y = ax + b. You choose between them by tapping Lev 1 or Lev 2.

The keys available to you to manipulate the graph or equation depend on the level you have chosen. For example, the screen for a level 1 equation shows this:

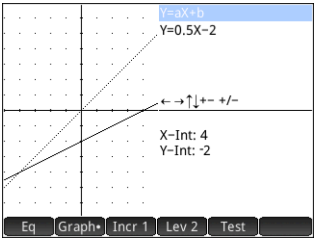
↔ +− +/−

This means that you can press ◀, ▶, +, − and +/−. If you choose a level 2 equation, the screen shows this:

↔↑↓+− +/−

This means that you can press ◀, ▶, ▲, ▼, +, − and +/−.

Graph mode



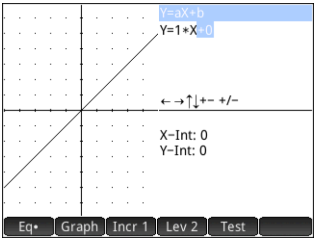
The app opens in graph mode (indicated by the dot on the `Graph` button at the bottom of the screen). In graph mode, the ▲and ▼ keys translate the graph vertically, effectively changing the y-intercept of the line. Tap Incr 1 to change the magnitude of the increment for vertical translations. The ◀ and ▶ keys (as well as − and +) decrease and increase the slope. Press +/− to change the sign of the slope.

The form of the linear function is shown at the top right of the display, with the current equation that matches the graph just below it. As you manipulate the graph, the equation updates to reflect the changes.

Equation mode

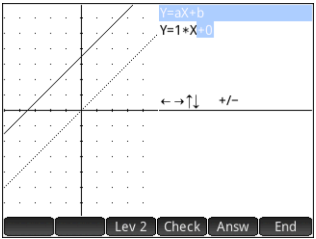
Tap Eq to enter equation mode. A dot will appear on the `Eq` button at the bottom of the screen.

In equation mode, you use the cursor keys to move between parameters in the equation and change their values, observing the effect on the graph displayed. Press ▼ or ▲ to decrease or increase the value of the selected parameter. Press ▶ or ◀ to select another parameter. Press +/- to change the sign of *a*.



Test mode

Tap Test to enter test mode. In Test mode you test your skill at matching an equation to the graph shown. Test mode is like equation mode in that you use the cursor keys to select and change the value of each parameter in the equation. The goal is to try to match the graph that is shown.



The app displays the graph of a randomly chosen linear function of the form dictated by your choice of level. (Tap Lev 1 or Lev 2 to change the level.) Now press the cursor keys to select a parameter and set its value. When you are ready, tap Check to see if you have correctly matched your equation to the given graph.

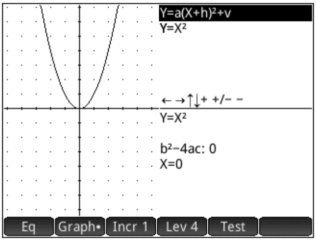
Tap Answ to see the correct answer and tap End to exit Test mode.

Quadratic Explorer app

The Quadratic Explorer app can be used to investigate the behavior of $y = a(x+h)^2+v$ as the values of *a*, *h* and *v* change.

Open the app

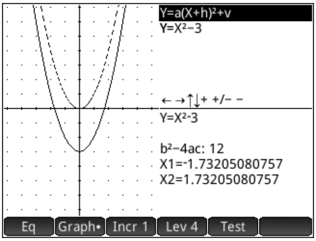
Press Apps Info and select `Quadratic Explorer`.



Y=a(X+h)²+v
Y=X²
←→↑↓+ +/− −
Y=X²
b²−4ac: 0
X=0

The left half of the display shows the graph of a quadratic function. The right half shows the general form of the equation being explored at the top and, below it, the current equation of that form. The keys you can use to manipulate the graph or equation appear below the equation. (These will change depending on the level of equation you choose.) Displayed beneath they keys is the equation, the discriminant (that is, b^2-4ac), and the roots of the quadratic.

Graph mode



Y=a(X+h)²+v
Y=X²−3
←→↑↓+ +/− −
Y=X²-3
b²−4ac: 12
X1=-1.73205080757
X2=1.73205080757

The app opens in graph mode. In graph mode, you manipulate a copy of the graph using whatever keys are available. The original graph—converted to dotted lines—remains in place for you to easily see the result of your manipulations.

Four general forms of quadratic equations are available for you to explore:

$y = ax^2$ [Level 1]

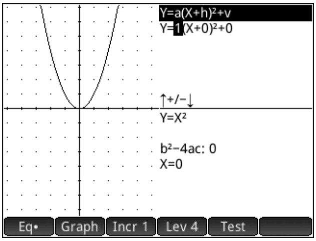
$y = (x+h)^2$ [Level 2]

$y = x^2+v$ [Level 3]

$y = a(x+h)^2+v$ [Level 4]

Choose a general form by tapping the Level button—Lev 1, Lev 2 and so on—until the form you want is displayed. The keys available to you to manipulate the graph vary from level to level.

Equation mode



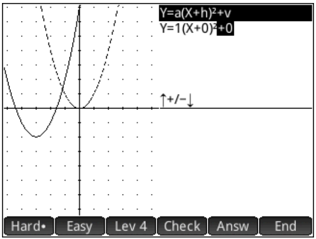
Y=a(X+h)²+v
Y=1(X+0)²+0

↑+/-↓
Y=X²

b²-4ac: 0
X=0

Tap Eq to move to equation mode. In equation mode, you use the cursor keys to move between parameters in the equation and change their values, observing the effect on the graph displayed. Press ▼ or ▲ to decrease or increase the value of the selected parameter. Press ▶ or ◀ to select another parameter. Press +/− to change the sign. You have four forms (or levels) of graph, and the keys available for manipulating the equation depend on the level chosen.

Test mode



Y=a(X+h)²+v
Y=1(X+0)²+0

↑+/-↓

Tap Test to enter test mode. In Test mode you test your skill at matching an equation to the graph shown. Test mode is like equation mode in that you use the cursor keys to select and change the value of each parameter in the equation. The goal is to try to match the graph that is shown.

The app displays the graph of a randomly chosen quadratic function. Tap the Level button to choose between one of four forms of quadratic equation. You can also choose graphs that are relatively easy to match or graphs that are harder match (by tapping Easy or Hard respectively).

Now press the cursor keys to select a parameter and set its value. When you are ready, tap Check to see if you have correctly matched your equation to the given graph.

Tap Answ to see the correct answer and tap End to exit Test mode.

Trig Explorer app

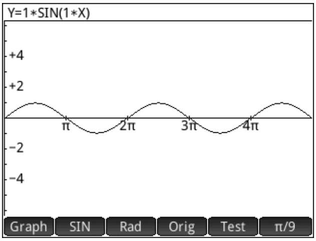
The Trig Explorer app can be used to investigate the behavior of the graphs $y = a \cdot \sin(bx + c) + d$ and $y = a \cdot \cos(bx + c) + d$ as the values of *a*, *b*, *c* and *d* change.

The menu items available in this app are:

- Eq or Graph: toggles between graph mode and equation mode
- SIN or COS: toggles between sine and cosine graphs
- Rad or Deg: toggles between radians and degrees as the angle measure for *x*
- Orig or Extr: toggles between translating the graph (Orig), and changing its frequency or amplitude (Extr). You make these changes using the cursor keys.
- Test: enters test mode
- π/9 or 20°: toggles the increment by which parameter values change: π/9, π/6, π/4, or 20°, 30°, 45° (depending on angle measure setting)

Open the app

Press Apps Info and select `Trig Explorer`.

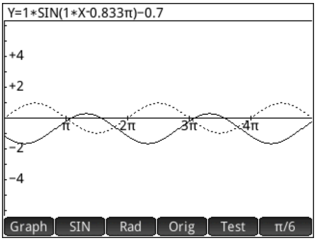


Y=1*SIN(1*X)

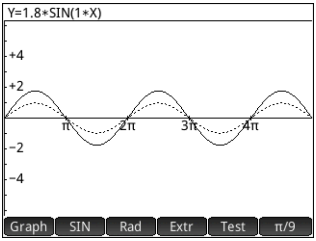
An equation is shown at the top of the display, with its graph shown below it.

Choose the type of function you want to explore by tapping either COS or SIN.

Graph mode


Y=1*SIN(1*X-0.833π)-0.7

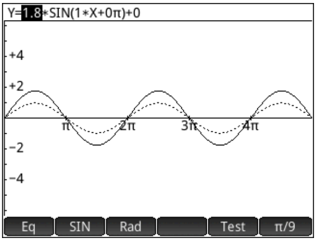
The app opens in graph mode. In graph mode, you manipulate a copy of the graph by pressing the cursor keys. All four keys are available. The original graph—converted to dotted lines—remains in place for you to easily see the result of your manipulations.


Y=1.8*SIN(1*X)

When Orig is chosen, the cursor keys simply translate the graph horizontally and vertically. When Extr is chosen, pressing ▲ or ▼ changes the *amplitude* of the graph (that is, it is stretched or shrunk vertically); and pressing ◀ or ▶ changes the *frequency* of the graph (that is, it is stretched or shrunk horizontally).

The π/9 or 20° button at the far right of the menu determines the increment by which the graph moves with each press of a cursor key. By default, the increment is set at $\pi/9$ or 20°.

Equation mode


Y=1.8*SIN(1*X+0π)+0

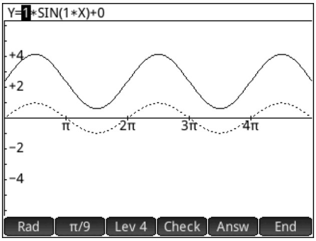
Tap Graph to switch to equation mode. In equation mode, you use the cursor keys to move between parameters in the equation and change their values. You can then observe the effect on the graph displayed. Press ▼ or ▲ to decrease or increase the value of the selected parameter. Press ▶ or ◀ to select another parameter.

You can switch back to graph mode by tapping Eq.

Test mode

Tap Test to enter test mode. In test mode you test your skill at matching an equation to the graph shown. Test mode is like equation mode in that you use the cursor keys to select and change the value of one or more parameters in the equation. The goal is to try to match the graph that is shown.

The app displays the graph of a randomly chosen sinusoidal function. Tap a Level button— Lev 1 , Lev 2 and so on—to choose between one of five types of sinusoidal equations.


Y=1*SIN(1*X)+0

Now press the cursor keys to select each parameter and set its value. When you are ready, tap Check to see if you have correctly matched your equation to the given graph.

Tap Answ to see the correct answer and tap End to exit Test mode.

21

Functions and commands

Many mathematical functions are available from the calculator’s keyboard. These are described in “Keyboard functions” on page 309. Other functions and commands are collected together in the Toolbox menus (Mem B). There are five Toolbox menus:

- **Math**

  A collection of non-symbolic mathematical functions (see “Math menu” on page 313)

- **CAS**

  A collection of symbolic mathematical functions (see “CAS menu” on page 324)

- **App**

  A collection of app functions that can be called from elsewhere in the calculator, such as Home view, CAS view, the Spreadsheet app, and in a program (see “App menu” on page 347)

  Note that the Geometry app functions can be called from elsewhere in the calculator, but they are designed to be used in the Geometry app. For that reason, the Geometry functions are not described in this chapter. They are described in the Geometry chapter.

- **User**

  The functions that you have created (see “Creating your own functions” on page 421) and the programs you have created that contain functions that have been exported.

- **Catlg**

  All the functions and commands:

  – on the **Math** menu

  – on the **CAS** menu

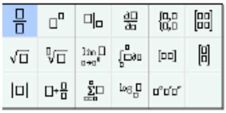
  – used in the Geometry app

- used in programming
- used in the Matrix Editor
- used in the List Editor
- and some additional functions and commands

See "Ctlg menu" on page 378.

Although the **Catlg** menu includes all the programming commands, the Commands menu (Cmds) in the Program Editor contains all the programming commands *grouped by category*. It also contains the Template menu (Tmplt), which contains the common programming structures. See chapter 27, "Programming in HP PPL", beginning on page 497 for complete descriptions of these commands.

Some functions can be chosen from the math template (displayed by pressing Units). See "Math template" on page 24.



You can also create your own functions. See "Creating your own functions" on page 421.

Setting the form of menu items

You can choose to have entries on the Math and CAS menus presented either by their descriptive name or their command name. (The entries on the Catlg menu are always presented by their command name.)

Descriptive name	**Command name**
Factor List	ifactors
Complex Zeros	cZeros
Groebner Basis	gbasis
Factor by Degree	factor_xn
Find Roots	proot

The default menu presentation mode is to provide the descriptive names for the Math and CAS functions. If you prefer the functions to be presented by their command name, deselect the **Menu Display** option on the second page of the **Home Settings** screen (see "Home settings" on page 30).

Abbreviations used in this chapter

In describing the syntax of functions and commands, the following abbreviations and conventions are used:

`Eqn`: an equation

`Expr`: a mathematical expression

`Fnc`: a function

`Frac`: a fraction

`Intgr`: an integer

`Obj`: signifies that objects of more than one type are allowable here

`Poly`: a polynomial

`RatFrac`: a rational fraction

`Val`: a real value

`Var`: a variable

Parameters that are optional are given in square brackets, as in `NORMAL_ICDF([μ,σ,]p)`.

For ease of reading, commas are used to separate parameters, but these are only necessary to separate parameters. Thus a single-parameter command needs no comma after the parameter even if, in the syntax shown below, there is a comma between it and an optional parameter. An example is the syntax `zeros(Expr,[Var])`. The comma is needed only if you are specifying the optional parameter `Var`.

Keyboard functions

The most frequently used functions are available directly from the keyboard. Many of the keyboard functions also accept complex numbers as arguments. Enter the keys and inputs shown below and press Enter to evaluate the expression.

In the examples below, shifted functions are represented by the actual keys to be pressed, with the function name shown in parentheses. For example, Shift SIN (ASIN) means that to make an arc sine calculation (ASIN), you press Shift SIN.

The examples below show the results you would get in Home view. If you are in the CAS, the results are given in simplified symbolic format. For example:

Shift x^2 320 returns 17.88854382 in Home view, and 8*√5 in the CAS.

+ , − , × ÷

Add, subtract, multiply, divide. Also accepts complex numbers, lists, and matrices.

value1 + value2, etc.

LN

Natural logarithm. Also accepts complex numbers.

LN(*value*)

Example:

LN(1) returns 0

Shift LN (e^x)

Natural exponential. Also accepts complex numbers.

e^{value}

Example:

e^5 returns 148.413159103

LOG

Common logarithm. Also accepts complex numbers.

LOG(*value*)

Example:

LOG(100) returns 2

Shift LOG (10^x)

Common exponential (antilogarithm). Also accepts complex numbers.

ALOG(value)

Example:

ALOG(3) returns 1000

SIN COS TAN

Sine, cosine, tangent. Inputs and outputs depend on the current angle format: degrees or radians.

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

Example:

`TAN(45)` returns `1` (degrees mode)

Shift SIN (ASIN)

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

`ASIN`(*value*)

Example:

`ASIN(1)` returns `90` (degrees mode)

Shift COS (ACOS)

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

`ACOS`(*value*)

Example:

`ACOS(1)` returns `0` (degrees mode)

Shift TAN (ATAN)

Arc tangent: $\tan^{-1}x$. Output range is from –90° to 90° or $-\pi/2$ to $\pi/2$. 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 √ x^2 L

Square root. Also accepts complex numbers.

√*value*

Example:

√320 returns `17.88854382`

ⁿ√ x^y F

x raised to the power of *y*. Also accepts complex numbers.

value ^{power}

Example:

`2`^{8} returns `256`

Shift ⁿ√ x^y F

The *n*th root of *x*.

root√*value*

Example:

`3√8` returns `2`

Shift x^{-1} ÷ T

Reciprocal.

value $^{-1}$

Example:

`3` $^{-1}$ returns `.333333333333`

|x| +/– M

Negation. Also accepts complex numbers.

–*value*

Example:

`-(1+2*i)` returns `-1-2*i`

Shift |x| +/– M (|x|)

Absolute value.

|*value*|
|*x*+*y***i*|

|*matrix*|

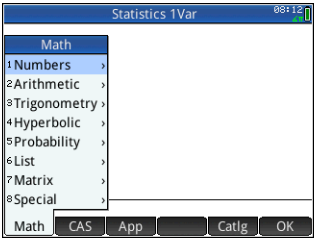
For a complex number, |*x*+*y***i*| returns $\sqrt{x^2+y^2}$. For a matrix, |*matrix*| returns the Frobenius norm of the matrix.

Example:

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

Math menu

Press Mem B to open the Toolbox menus (one of which is the Math menu). The functions and commands available on the Math menu are listed as they are categorized on the menu.



Numbers

Ceiling Smallest integer greater than or equal to *value*.

```
CEILING(value)
```

Examples:

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

Floor Greatest integer less than or equal to *value*.

```
FLOOR(value)
```

Example:

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

IP Integer part.

```
IP(value)
```

Example:

`IP(23.2)` returns `23`

FP Fractional part.

```
FP(value)
```

Example:

`FP (23.2)` returns `.2`

Round Rounds *value* to decimal *places*. Also accepts complex numbers.

```
ROUND(value,places)
```

`ROUND` can also round to a number of significant digits if *places* is a negative integer (as shown in the second example below).

Examples:

```
ROUND(7.8676,2) returns 7.87
ROUND(0.0036757,-3) returns 0.00368
```

Truncate Truncates *value* to decimal *places*. Also accepts complex numbers.

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

`TRUNCATE` can also round to a number of significant digits if *places* is a negative integer (as shown in the second example below).

Examples:

```
TRUNCATE(2.3678,2) returns 2.36
TRUNCATE(0.0036757,–3) returns 0.00367
```

Mantissa Mantissa—that is, the significant digits—of *value*, where value is a floating-point number.

```
MANT(value)
```

Example:

```
MANT(21.2E34) returns 2.12
```

Exponent Exponent of *value*. That is, the integer component of the power of 10 that generates *value*.

```
XPON(value)
```

Example:

`XPON(123456)` returns `5` (since $10^{5.0915...}$ equals 123456)

Arithmetic

Maximum Maximum. The greater of two values.

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

Example:

```
MAX(8/3,11/4) returns 2.75
```

Note that in Home view a non-integer result is given as a decimal fraction. If you want to see the result as a common fraction, press a b/c ≐. This key cycles through decimal, fraction, and mixed number representations. Or, if you prefer, press CAS Settings. This opens the computer algebra system. If you want to return to Home view to make further calculations, press ⌂ Settings.

Minimum Minimum. The lesser of two values.

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

Example:

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

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

```
value1 MOD value2
```

Example:

`74 MOD 5` returns `4`

Find Root Function root-finder (like the Solve app). 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((A*9.8/600)-1,A,1)` returns `61.2244897959.`

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

```
%(x,y)
```

Example:

`%(20,50)` returns `10`

Complex

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

```
ARG(x+y*i)
```

Example:

`ARG(3+3*i)` returns `45` (degrees mode)

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

```
CONJ(x+y*i)
```

Example:

`CONJ(3+4*i)` returns `(3-4*i)`

Real Part Real part x, of a complex number, $(x+y*i)$.

```
RE(x+y*i)
```

Example:

`RE(3+4*i)` returns `3`

Imaginary Part Imaginary part, *y*, of a complex number, $(x+y*i)$.

```
IM(x+y*i)
```

Example:

`IM(3+4*i)` returns `4`

Unit Vector 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(POLYEVAL([1,2,-25,-26,2],-2))` returns `-1`
`SIGN((3,4))` returns `(.6+.8i)`

Exponential

ALOG Antilogarithm (exponential).

```
ALOG(value)
```

EXPM1 Exponential minus 1: $e^x - 1$.

```
EXPM1(value)
```

LNP1 Natural log plus 1: $\ln(x+1)$.

```
LNP1(value)
```

Trigonometry

The trigonometry functions can also take complex numbers as arguments. For SIN, COS, TAN, ASIN, ACOS, and ATAN, see “Keyboard functions” on page 309.

CSC Cosecant: 1/sin*x*.

```
CSC(value)
```

ACSC Arc cosecant.

```
ACSC(value)
```

SEC Secant: 1/cos*x*.

```
SEC(value)
```

ASEC Arc secant.

```
ASEC(value)
```

COT Cotangent: cos*x*/sin*x*.

```
COT(value)
```

ACOT Arc cotangent.

```
ACOT(value)
```

Hyperbolic

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

SINH Hyperbolic sine.

```
SINH(value)
```

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

```
ASINH(value)
```

COSH Hyperbolic cosine

```
COSH(value)
```

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

```
ACOSH(value)
```

TANH Hyperbolic tangent.

```
TANH(value)
```

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

```
ATANH(value)
```

Probability

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

```
value!
```

Example:

`5!` returns `120`

Combination The number of combinations (without regard to order) of *n* things taken *r* at a time.

```
COMB(n,r)
```

Example: Suppose you want to know how many ways five things can be combined two at a time.

`COMB(5,2)`returns `10.`

Permutation Number of permutations (with regard to order) of n things taken r at a time: n!/(n–r)!.

```
PERM (n,r)
```

Example: Suppose you want to know how many permutations there are for five things taken two at a time.

`PERM(5,2)`returns `20.`

Random

Number Random number. With no argument, this function returns a random number between zero and one. With one argument *a*, it returns a random number between 0 and *a*. With two arguments, *a*, and *b*, returns *a* random number between *a* and *b*. With three arguments, *n*, *a*, and *b*, returns *n* random number between *a* and *b*.

```
RANDOM
RANDOM(a)
RANDOM(a,b
RANDOM(n,a,b)
```

Integer Random integer. With no argument, this function returns either 0 or 1 randomly. With one integer argument *a*, it returns a random integer between 0 and *a*. With two arguments, *a*, and *b*, returns *a* random integer between *a* and *b*. With three integer arguments, *n*, *a*, and *b*, returns *n* random integers between *a* and *b*.

```
RANDINT
RANDINT(a)
RANDINT(a,b)
RANDINT(n,a,b)
```

Normal Random real number with normal distribution N(μ,σ).

```
RANDNORM(μ,σ)
```

Seed Sets the seed value on which the random functions operate. By specifying the same seed value on two or more calculators, you ensure that the same random numbers appear on each calculator when the random functions are executed.

```
RANDSEED(value)
```

Density

Normal Normal probability density function. Computes the probability density at value *x*, given the mean, μ, and standard deviation, σ, of a normal distribution. If only one argument is supplied, it is taken as *x*, and the assumption is that $\mu=0$ and $\sigma=1$.

```
NORMALD([μ,σ,]x)
```

Example:

`NORMALD(0.5)` and `NORMALD(0,1,0.5)` both return `0.352065326764.`

T Student’s t probability density function. Computes the probability density of the Student's t-distribution at *x*, given *n* degrees of freedom.

```
STUDENT(n,x)
```

Example:

`STUDENT(3,5.2)` returns `0.00366574413491.`

χ^2 χ^2 probability density function. Computes the probability density of the χ^2 distribution at *x*, given *n* degrees of freedom.

```
CHISQUARE(n,x)
```

Example:

`CHISQUARE(2,3.2)` returns `0.100948258997.`

F Fisher (or Fisher–Snedecor) probability density function. Computes the probability density at the value *x*, given numerator *n* and denominator *d* degrees of freedom.

```
FISHER(n,d,x)
```

Example:

`FISHER(5,5,2)` returns `0.158080231095.`

Binomial Binomial probability density function. Computes the probability of *k* successes out of *n* trials, each with a probability of success of *p*. Returns Comb(n,k) if there is no third argument. Note that *n* and *k* are integers with $k \le n$.

```
BINOMIAL(n,k,p)
```

Example: Suppose you want to know the probability that just 6 heads would appear during 20 tosses of a fair coin.

`BINOMIAL(20,6,0.5)` returns `0.0369644165039.`

Poisson Poisson probability mass function. Computes the probability of *k* occurrences of an event during a future interval given μ, the mean of the occurrences of that event during that interval in the past. For this function, *k* is a non-negative integer and μ is a real number.

```
POISSON(μ,k)
```

Example: Suppose that on average you get 20 emails a day. What is the probability that tomorrow you will get 15?

`POISSON(20,15)` returns `0.0516488535318.`

Cumulative

Normal Cumulative normal distribution function. Returns the lower-tail probability of the normal probability density function for the value *x*, given the mean, μ, and standard deviation, σ, of a normal distribution. If only one argument is supplied, it is taken as *x*, and the assumption is that μ=0 and σ=1.

```
NORMALD_CDF([μ,σ,]x)
```

Example:

`NORMALD_CDF(0,1,2)` returns `0.977249868052.`

T Cumulative Student's t distribution function. Returns the lower-tail probability of the Student's t-probability density function at *x*, given *n* degrees of freedom.

```
STUDENT_CDF(n,x)
```

Example:

`STUDENT_CDF(3,-3.2)` returns `0.0246659214814.`

χ^2 Cumulative χ^2 distribution function. Returns the lower-tail probability of the χ^2 probability density function for the value *x*, given *n* degrees of freedom.

```
CHISQUARE_CDF(n,k)
```

Example:

`CHISQUARE_CDF(2,6.1)` returns `0.952641075609`.

F Cumulative Fisher distribution function. Returns the lower-tail probability of the Fisher probability density function for the value *x*, given numerator *n* and denominator *d* degrees of freedom.

```
FISHER_CDF(n,d,x)
```

Example:

`FISHER_CDF(5,5,2)` returns `0.76748868087`.

Binomial Cumulative binomial distribution function. Returns the probability of *k* or fewer successes out of *n* trials, with a probability of success, *p* for each trial. Note that *n* and *k* are integers with $k \le n$.

```
BINOMIAL_CDF(n,p,k)
```

Example: Suppose you want to know the probability that during 20 tosses of a fair coin you will get either 0, 1, 2, 3, 4, 5, or 6 heads.

`BINOMIAL_CDF(20,0.5,6)` returns `0.05765914917`.

Poisson Cumulative Poisson distribution function. Returns the probability *x* or fewer occurrences of an event in a given time interval, given μ expected occurrences.

```
POISSON_CDF(μ,x)
```

Example:

`POISSON_CDF(4,2)` returns `0.238103305554`.

Inverse

Normal Inverse cumulative normal distribution function. Returns the cumulative normal distribution value associated with the lower-tail probability, *p*, given the mean, μ, and standard deviation, σ, of a normal distribution. If only one argument is supplied, it is taken as *p*, and the assumption is that μ=0 and σ=1.

```
NORMALD_ICDF([μ,σ,]p)
```

Example:

`NORMALD_ICDF(0,1,0.841344746069)` returns `1`.

T Inverse cumulative Student's t distribution function. Returns the value *x* such that the Student's-t lower-tail probability of *x*, with *n* degrees of freedom, is *p*.

```
STUDENT_ICDF(n,p)
```

Example:

`STUDENT_ICDF(3,0.0246659214814)` returns `–3.2.`

χ^2 Inverse cumulative χ^2 distribution function. Returns the value *x* such that the χ^2 lower-tail probability of *x*, with *n* degrees of freedom, is *p*.

```
CHISQUARE_ICDF(n,p)
```

Example:

`CHISQUARE_ICDF(2,0.957147873133)` returns `6.3.`

F Inverse cumulative Fisher distribution function. Returns the value *x* such that the Fisher lower-tail probability of *x*, with numerator *n* and denominator *d* degrees of freedom, is *p*.

```
FISHER_ICDF(n,d,p)
```

Example:

`FISHER_ICDF(5,5,0.76748868087)` returns `2.`

Binomial Inverse cumulative binomial distribution function. Returns the number of successes, *k,* out of *n* trials, each with a probability of *p,* such that the probability of *k* or fewer successes is *q*.

```
BINOMIAL_ICDF(n,p,q)
```

Example:

`BINOMIAL_ICDF(20,0.5,0.6)` returns `11.`

Poisson Inverse cumulative Poisson distribution function. Returns the value *x* such that the probability of *x* or fewer occurrences of an event, with μ expected (or mean) occurrences of the event in the interval, is *p*.

```
POISSON_ICDF(μ,p)
```

Example:

`POISSON_ICDF(4,0.238103305554)` returns `3.`

List

These functions work on data in a list. They are explained in detail in chapter 24, “Lists”, beginning on page 451.

Matrix

These functions work on matrix data stored in matrix variables. They are explained in detail in chapter 25, “Matrices”, beginning on page 463.

Special

Beta Returns the value of the beta function (B) for two numbers *a* and *b*.

```
Beta(a,b)
```

Gamma Returns the value of the gamma function (Γ) for a number *a*.

```
Gamma(a)
```

Psi Returns the value of the *n*th derivative of the digamma function at *x*=*a*, where the digamma function is the first derivative of ln(Γ(*x*)).

```
Psi(a,n)
```

Zeta Returns the value of the zeta function (Z) for a real *x*.

```
Zeta(x)
```

erf Returns the floating point value of the error function at *x*=*a*.

```
erf(a)
```

erfc Returns the value of the complementary error function at *x*=*a*.

```
erfc(a)
```

Ei Returns the exponential integral of an expression.

```
Ei(Expr)
```

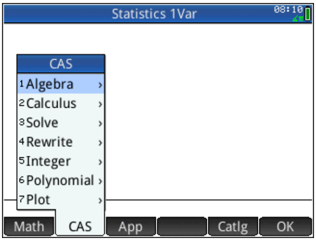
Si Returns the sine integral of an expression.

```
Si(Expr)
```

Ci Returns the cosine integral of an expression.

```
Ci(Expr)
```

CAS menu



Press Mem B to open the Toolbox menus (one of which is the CAS menu). The functions on the CAS menu are those most commonly used. Many more functions are available. See “Ctlg menu”, beginning on page 378.

Note that the Geometry functions appear on the App menu. They are described in “Geometry functions and commands”, beginning on page 165.

The result of a CAS command may vary depending on the CAS settings. The examples in this chapter assume the default CAS settings unless otherwise noted.

Algebra

Simplify Returns an expression simplified.

```
simplify(Expr)
```

Example:

`simplify(4*atan(1/5)-atan(1/239))` yields `(1/4)*pi`

Collect Returns a polynomial or list of polynomials factorized over the field of the coefficients.

```
collect(Poly or LstPoly)
```

Example:

`collect(x^2-4)` gives `(x-2)*(x+2)`

Expand Returns an expression expanded.

```
expand(Expr)
```

Example:

`expand((x+y)*(z+1))` gives `y*z+x*z+y+x`

Factor Returns a polynomial factorized.

```
factor(Poly)
```

Example:

`factor(x^4-1)` gives `(x-1)*(x+1)*(x^2+1)`

Substitute Substitutes a value for a variable in an expression.

```
Syntax: subst(Expr,Var=value)
```

Example:

`subst(x/(4-x^2),x=3)` returns `-3/5`

Partial Fraction Performs partial fraction decomposition on a fraction.

```
partfrac(RatFrac or Opt)
```

Example:

`partfrac(x/(4-x^2))` returns `(-1/2)/(x-2)-(1/2)/((x+2)`

Extract

Numerator Simplified Numerator. For the integers a and b, returns the numerator of the fraction a/b after simplification.

```
numer(a,b)
```

Example:

`numer(10,12)` returns `5`

Denominator Simplified Denominator. For the integers a and b, returns the denominator of the fraction a/b after simplification.

```
denom(a/b)
```

Example:

`denom(10,12)` returns `6`

Left Side Returns the left side of an equation or the left end of an interval.

```
left(Expr1=Expr2) or left(Real1..Real2)
```

Example:

`left(x^2-1=2*x+3)` returns `x^2-1`

Right Side Returns the right side of an equation or the right end of an interval.

`right(Expr1=Expr2)` or `right(Real1..Real2)`

`Example:`

`right(x^2-1=2*x+3)` returns `2*x+3`

Calculus

Differentiate With one expression as argument, returns derivative of the expression with respect to *x*. With one expression and one variable as arguments, returns the derivative or partial derivative of the expression with respect to the variable. With one expression and more than one variable as arguments, returns the derivative of the expression with respect to the variables in the second argument. These arguments can be followed by $*k* (*k* is an integer) to indicate the number of times the expression should be derived with respect to the variable. For example, diff(exp(x*y),x$3,y$2,z) is the same as diff(exp(x*y),x,x,x,y,y,z).

```
diff(Expr,[var])
```

or

```
diff(Expr,var1$k1,var2$k2,...)
```

Example:

`diff(x^3-x)` gives `3*x^2-1`

Integrate Returns the indefinite integral of an expression. With one expression as argument, returns the indefinite integral with respect to *x*. With the optional second, third and fourth arguments you can specify the variable of integration and the bounds of the integrate.

```
int(Expr,[Var(x)],[Real(a)],[Real(b)])
```

Example:

`int(1/x)` gives `ln(abs(x))`

Limit Returns the limit of an expression when the variable approaches a limit point *a* or +/– infinity. With the optional fourth argument you can specify whether it is the limit from below, above or bidirectional (–1 for limit from below, +1 for limit from above, and 0 for bidirectional limit). If the fourth argument is not provided, the limit returned is bidirectional.

```
limit(Expr,Var,Val,[Dir(1, 0, -1)])
```

Example:

`limit((n*tan(x)-tan(n*x))/(sin(n*x)-n*sin(x)),x,0)` gives `2`

Series Returns the series expansion of an expression in the vicinity of a given equality variable. With the optional third and fourth arguments you can specify the order and direction of the series expansion. If no order is specified the series returned is fifth order. If no direction is specified, the series is bidirectional.

```
series(Expr,Equal(var=limit_point),[Orde
r],[Dir(1,0,-1)])
```

Example:

`series((x^4+x+2)/(x^2+1),x=0,5)` gives `2+x-2x^2-x^3+3x^4+x^5+x^6*order_size(x)`

Summation Returns the discrete sum of Expr with respect to the variable Var from Real1 to Real2. You can also use the summation template in the Template menu. With only the first two arguments, returns the discrete antiderivative of the expression with respect to the variable.

```
sum(Expr,Var,Real1, Real2,[Step])
```

Example:

`sum(n^2,n,1,5)` returns `55`

Differential

Curl Returns the rotational curl of a vector field. Curl([A B C], [x y z]) is defined to be [dC/dy-dB/dz dA/dz-dC/dx dB/dx-dA/dy].

```
curl([Expr1, Expr2, …, ExprN], [Var1,
Var2, …, VarN])
```

Example:

`curl([2*x*y,x*z,y*z],[x,y,z])` returns `[z-x,0,z-2*x]`

Divergence Returns the divergence of a vector field, defined by:

divergence([A,B,C],[x,y,z])=dA/dx+dB/dy+dC/dz.

```
divergence([Expr1, Expr2, …, ExprN],
[Var1, Var2, …, VarN])
```

Example:

`divergence([x^2+y,x+z+y,z^3+x^2],[x,y,z])` gives `2*x+3*z^2+1`

Gradient Returns the gradient of an expression. With a list of variables as second argument, returns the vector of partial derivatives.

```
grad(Expr,LstVar)
```

Example:

`grad(2*x^2*y-x*z^3,[x,y,z])` gives `[2*2*x*y-z^3,2*x^2,-x*3*z^2]`

Hessian Returns the Hessian matrix of an expression.

```
hessian(Expr,LstVar)
```

Example:

`hessian(2*x^2*y-x*z,[x,y,z])` gives `[[4*y,4*x,-1],[2*2*x,0,0],[-1,0,0]]`

Integral

By Parts u Performs integration by parts of the expression f(x)=u(x)*v'(x), with f(x) as the first argument and u(x) (or 0) as the second argument. Specifically, returns a vector whose first element is u(x)*v(x) and whose second element is v(x)*u'(x). With the optional third, fourth and fifth arguments you can specify a variable of integration and bounds of the integration. If no variable of integration is provided, it is taken as x.

```
ibpu(f(Var), u(Var), [Var], [Real1],
[Real2])
```

Example:

`ibpu(x*ln(x), x)` returns `[x^2*ln(x) -x*ln(x)-x]`

By Parts v Performs integration by parts of the expression f(x)=u(x)*v'(x), with f(x) as the first argument and v(x) (or 0) as the second argument. Specifically, returns a vector whose first element is u(x)*v(x) and whose second element is v(x)*u'(x). With the optional third, fourth and fifth arguments you can specify a variable of integration and bounds of the integration. If no variable of integration is provided, it is taken as x.

```
ibpdv(f(Var), v(Var), [Var], [Real1],
[Real2])
```

Example:

`ibpdv(ln(x),x)` gives `[x*ln(x),-1]`

F(b)–F(a) Returns F(*b*)–F(*a*).

```
preval(Expr(F(var)),Real(a),Real(b),[Var])
```

Example:

`preval(x^2-2,2,3)` gives `5`

Limits

Riemann Sum Returns in the neighborhood of *n*=+∞ an equivalent of the sum of Xpr(var1,var2) for var2 from var2=1 to var2=var1 when the sum is looked at as a Riemann sum associated with a continuous function defined on [0,1].

```
sum_riemann(Expr(Xpr),Lst(var1,var2))
```

Example:

`sum_riemann(1/(n+k),[n,k])` gives `ln(2)`

Taylor Returns the Taylor series expansion of an expression at a point or at infinity (by default, at x=0 and with relative order=5).

```
taylor(Expr,[Var=Value],[Order])
```

Example:

`taylor(sin(x)/x,x=0)` returns `1-(1/6)*x^2+(1/120)*x^4+x^6*order_size(x)`

Taylor of Quotient Returns the n-degree Taylor polynomial for the quotient of 2 polynomials.

```
divpc(Poly1,Poly2,Integer)
```

Example:

`d divpc(x^4+x+2,x^2+1,5)` returns the 5th-degree polynomial `x^5+3*x^4-x^3-2*x^2+x+2`

Transform

Laplace Returns the Laplace transform of an expression.

```
laplace(Expr,[Var],[LapVar])
```

Example:

`laplace(exp(x)*sin(x))` gives `1/(x^2-2*x+2)`

Inverse Laplace Returns the inverse Laplace transform of an expression.

```
invlaplace(Expr,[Var],[IlapVar])
```

Example:

`ilaplace(1/(x^2+1)^2)` returns `((-x)*cos(x))/2+sin(x)/2`

FFT With one argument (a vector), returns the discrete Fourier transform in R.

```
fft(Vect)
```

With two additional integer arguments a and p, returns the discrete Fourier transform in the field Z/pZ, with a as primitive nth root of 1 (n=size(vector)).

```
fft((Vector, a, p)
```

Example:

`fft([1,2,3,4,0,0,0,0])` gives `[10.0,-0.414213562373-7.24264068712*(i),-2.0+2.0*i,2.41421356237-1.24264068712*i,-2.0,2.41421356237+1.24264068712*i,-2.0-2.0*i]`

Inverse FFT Returns the inverse discrete Fourier transform.

```
ifft(Vector)
```

Example:

`ifft([100.0,-52.2842712475+6*i,-8.0*i,4.28427124746-6*i,4.0,4.28427124746+6*i,8*i,-52.2842712475-6*i])` gives `[0.99999999999,3.99999999999,10.0,20.0,25.0,24.0,16.0,-6.39843733552e-12]`

Solve

Solve Returns a list of the solutions (real and complex) to a polynomial equation or a set of polynomial equations.

```
solve(Eq,[Var]) or solve({Eq1, Eq2,…}, [Var])
```

Examples:

`solve(x^2-3=1)` returns `{-2,2}`

`solve({x^2-3=1, x+2=0},x)` returns `{-2}`

Zeros With an expression as argument, returns the real zeros of the expression; that is, the solutions when the expression is set equal to zero.

With a list of expressions as argument, returns the matrix where the rows are the real solutions of the system formed by setting each expression equal to zero.

```
zeros(Expr,[Var]) or zeros({Expr1,
Expr2,…},[{Var1, Var2,…}])
```

Example:

`zeros(x^2-4)` returns `[-2  2]`

Complex Solve Returns a list of the complex solutions to a polynomial equation or a set of polynomial equations.

```
csolve(Eq,[Var])
```

or

```
csolve({Eq1, Eq2,…}, [Var])
```

Example:

`csolve(x^4-1=0, x)` returns `{1  -1  -i  i}`

Complex Zeros With an expression as argument, returns a vector containing the complex zeros of the expression; that is, the solutions when the expression is set equal to zero.

With a list of expressions as argument, returns the matrix where the rows are the complex solutions of the system formed by setting each expression equal to zero.

```
cZeros(Expr,[Var]
```

or

```
cZeros({Expr1, Expr2,…},[{Var1, Var2,…}])
```

Example:

`cZeros(x^4-1)` returns `[1  -1  -i  i]`

Numerical Solve Returns the numerical solution of an equation or a system of equations.

```
nSolve(Eq,Var) or nSolve(Expr, Var=Guess)
```

Example:

`nSolve(cos(x)=x,x=1.3)` gives `0.739085133215`

Differential Equation

Returns the solution to a differential equation.

```
deSolve(Eq,[TimeVar],Var)
```

Example:

`desolve(y''+y=0,y)` returns `G_0*cos(x)+G_1*sin(x)`

ODE Solve

Ordinary Differential Equation solver. Solves an ordinary differential equation given by Expr, with variables declared in VectrVar and initial conditions for those variables declared in VectrInit. For example, odesolve(f(t,y),[t,y],[t0,y0],t1) returns the approximate solution of y'=f(t,y) for the variables t and y with initial conditions t=t0 and y=y0.

```
odesolve(Expr,VectVar,VectInitCond,Final
Val,[tstep=Val,curve])
```

Example:

`odesolve(sin(t*y),[t,y],[0,1],2)` returns `[1.82241255674]`

Linear System

Given a vector of linear equations and a corresponding vector of variables, returns the solution to the system of linear equations.

```
linsolve([LinEq1, LinEq2,…], [Var1,
Var2,…])
```

Example:

`linsolve([x+y+z=1,x-y=2,2*x-z=3],[x,y,z])` returns `[3/2,-1/2,0]`

Rewrite

lncollect

Rewrites an expression with the logarithms collected. Applies ln(*a*)+*n**ln(*b*) = ln(*a***b*^*n*) for an integer *n*.

```
lncollect(Expr)
```

Example:

`lncollect(ln(x)+2*ln(y))` returns `ln(x*y^2)`

powexpand

Rewrites an expression containing a power that is a sum or product as a product of powers. Applies *a*^(*b*+*c*)=(*a*^*b*)*(*a*^*c*).

```
powexpand(Expr)
```

Example:

`powexpand(2^(x+y))` yields `(2^x)*(2^y)`

texpand Expands a transcendental expression.

```
texpand(Expr)
```

Example:

`texpand(sin(2*x)+exp(x+y))` returns `exp(x)*exp(y)+ 2*cos(x)*sin(x))`

Exp & Ln

e^{y*lnx} → x^y Returns an expression of the form $e^{n*ln(x)}$ rewritten as a power of x. Applies $e^{n*ln(x)}=x^n$.

```
exp2pow(Expr)
```

Example:

`exp2pow(exp(3*ln(x)))` gives `x^3`

x^y → e^{y*lnx} Returns an expression with powers rewritten as an exponential. Essentially the inverse of `exp2pow`.

```
pow2exp(Expr)
```

Example:

`pow2exp(a^b)` gives `exp(b*ln(a))`

exp2trig Returns an expression with complex exponentials rewritten in terms of sine and cosine.

```
exp2trig(Expr)
```

Example:

`exp2trig(exp(i*x))` gives `cos(x)+(i)*sin(x)`

expexpand Returns an expression with exponentials in expanded form.

```
expexpand(Expr)
```

Example:

`expexpand(exp(3*x))` gives `exp(x)^3`

Sine

asinx → acosx Returns an expression with asin(*x*) rewritten as π/2– acos(*x*).

```
asin2acos(Expr)
```

Example:

`asin2acos(acos(x)+asin(x))` returns `π/2`

asinx → atanx Returns an expression with asin(*x*) rewritten as:

$$\operatorname{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

```
asin2atan(Expr)
```

Example:

`asin2atan(2*asin(x))` returns

$$2 \cdot \operatorname{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

sinx → cosx*tanx Returns an expression with sin(*x*) rewritten as cos(*x*)*tan(*x*).

```
sin2costan(Expr)
```

Example:

`sin2costan(sin(x))` gives `tan(x)*cos(x)`

Cosine

acosx → asinx Returns an expression with acos(*x*) rewritten as π/2–asin(*x*).

```
acos2asin(Expr)
```

Example:

`acos2asin(acos(x)+asin(x))` returns `π/2`

acosx → atanx Returns an expression with acos(*x*) rewritten as:

$$\frac{\pi}{2} - \operatorname{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

```
acos2atan(Expr)
```

Example:

`acos2atan(2*acos(x))` gives

$$2 \cdot \left(\frac{\pi}{2} - \operatorname{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)\right)$$

cosx → sinx/tanx Returns an expression with cos(*x*) rewritten as sin(*x*)/tan(*x*).

```
cos2sintan(Expr)
```

Example:

`cos2sintan(cos(x))` gives `sin(x)/tan(x)`

Tangent

atanx → asinx

Returns an expression with atan(*x*) rewritten as:

$$\operatorname{asin}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

```
atan2asin(Expr)
```

Example:

`atan2asin(atan(2*x))` returns

$$\operatorname{asin}\left(\frac{2\cdot x}{\sqrt{1-(2\cdot x)^2}}\right)$$

atanx → acosx

Returns an expression with atan(*x*) rewritten as:

$$\frac{\pi}{2}-\operatorname{acos}\left(\frac{x}{\sqrt{1+x^2}}\right)$$

```
atan2acos(Expr)
```

tanx → sinx/cosx

Returns an expression with tan(*x*) rewritten as sin(*x*)/cos(*x*).

```
tan2sincos(Expr)
```

Example:

`tan2sincos(tan(x))` gives `sin(x)/cos(x)`

halftan

Returns an expression with sin(*x*), cos(*x*) or tan(*x*) rewritten as tan(*x*/2).

```
halftan(Expr)
```

Example:

`halftan(sin(x))` returns $\dfrac{2\cdot\tan\left(\frac{x}{2}\right)}{\tan\left(\frac{x}{2}\right)^2+1}$

Trig

trigx → sinx

Returns an expression simplified using the formulas sin(x)^2+cos(x)^2=1 and tan(x)=sin(x)/cos(x). Sin(x) is given precedence over cos(x) and tan(x) in the result.

```
trigsin(Expr)
```

Example:

`trigsin(cos(x)^4+sin(x)^2)` returns `sin(x)^4-sin(x)^2+1`

trigx → cosx Returns an expression simplified using the formulas sin(x)^2+cos(x)^2=1 and tan(x)=sin(x)/cos(x). Cos(x) is given precedence over sin(x) and tan(x) in the result.

```
trigcos(Expr)
```

Example:

`trigcos(sin(x)^4+sin(x)^2)` returns `cos(x)^4-3*cos(x)^2+2`

trigx → tanx Returns an expression simplified using the formulas sin(x)^2+cos(x)^2=1 and tan(x)=sin(x)/cos(x). Tan(x) is given precedence over sin(x) and cos(x) in the result.

```
trigtan(Expr)
```

Example:

`trigtan(cos(x)^4+sin(x)^2)` returns `(tan(x)^4+tan(x)^2+1)/(tan(x)^4+2*tan(x)^2+1)`

atrig2ln Returns an expression with inverse trigonometric functions rewritten using the natural logarithm function.

```
atrig2ln(Expr)
```

Example:

`atrig2ln(atan(x))` returns $\frac{i}{2} \cdot \ln\frac{(i+x)}{(i-x)}$

tlin Returns a trigonometric expression with the products and integer powers linearized.

```
tlin(ExprTrig)
```

Example:

`tlin(sin(x)^3)` gives $\frac{3}{4} \cdot \sin(x) - \frac{1}{4} \cdot \sin(3 \cdot x)$

tcollect Returns a trigonometric expression linearized and with any sine and cosine terms of the same angle collected together.

```
tcollect(Expr)
```

Example:

`tcollect(sin(x)+cos(x))` returns

$\sqrt{2} \cdot \cos\left(x - \frac{1}{4} \cdot \pi\right)$

trigexpand Returns a trigonometric expression in expanded form.

```
trigexpand(Expr)
```

Example:

`trigexpand(sin(3*x))` gives `(4*cos(x)^2-1)*sin(x)`

trig2exp Returns an expression with trigonometric functions rewritten as complex exponentials (without linearization).

```
trig2exp(Expr)
```

Example:

`trig2exp(sin(x))` returns

$$\frac{-i}{2}\cdot\left(\exp(i\cdot x)-\frac{1}{\exp(i\cdot x)}\right)$$

Integer

Divisors Returns the list of divisors of an integer or a list of integers.

```
idivis(Integer)
```

or

```
idivis({Intgr1, Intgr2,…})
```

Example:

`idivis(12)` returns `[1, 2, 3, 4, 6, 12]`

Factors Returns the prime factor decomposition of an integer.

```
ifactor(Integer)
```

Example:

With the CAS setting `Simplify` set to `None`, `ifactor(150)` returns `2*3*5^2`

Factor List Returns a vector containing the prime factors of an integer or a list of integers, with each factor followed by its multiplicity.

```
ifactors(Integer)
```

or

```
ifactors({Intgr1, Intgr2,…})
```

Example:

`ifactors(150)` returns `[2, 1, 3, 1, 5, 2]`

GCD Returns the greatest common divisor of two or more integers.

```
gcd(Intgr1, Intgr2,…)
```

Example:

`gcd(32,120,636)` returns `4`

LCM Returns the lowest common multiple of two or integers.

```
lcm(Intgr1, Intgr2,…)
```

Example:

`lcm(6,4)` returns `12`

Prime

Test if Prime Tests whether or not a given integer is a prime number.

```
isPrime(Integer)
```

Example:

`isPrime(19999)` returns `false`

Nth Prime Returns the *n*th prime number.

`ithprime(Intg(n))` where `n` is between 1 and 200,000

Example:

`ithprime(5)` returns `11`

Next Prime Returns the next prime or pseudo-prime after an integer.

```
nextprime(Integer)
```

Example:

`nextprime(11)` returns `13`

Previous Prime Returns the prime or pseudo-prime number closest to but smaller than an integer.

```
prevprime(Integer)
```

Example:

`prevprime(11)` returns `7`

Euler Compute’s Euler's totient for an integer.

```
euler(Integer)
```

Example:

`euler(6)` returns `2`

Division

Quotient Returns the integer quotient of the Euclidean division of two integers.

```
iquo(Intgr1, Intgr2)
```

Example:

`iquo(63, 23)` returns `2`

Remainder Returns the integer remainder from the Euclidean division of two integers.

```
irem(Intgr1, Intgr2)
```

Example:

`irem(63, 23)` returns `17`

a^n MOD p For the three integers *a*, *n*, and *p*, returns a^n modulo *p* in [0, *p*–1].

```
powmod(a, n, p,[Expr],[Var])
```

Example:

`powmod(5,2,13)` returns `12`

Chinese Remainder Integer Chinese Remainder Theorem for two equations. Takes two vectors, [a p] and [b q], and returns a vector of two integers, [r n] such that x ≡ r mod n. In this case, x is such that x ≡ a mod p and x ≡ b mod q; also n=p*q.

```
ichinrem(LstIntg(a,p),LstIntg(b,q))
```

Example:

`ichinrem([2, 7], [3, 5])` returns `[-12, 35]`

Polynomial

Find Roots Given a polynomial in x (or a vector containing the coefficients of a polynomial), returns a vector containing its roots.

`proot(Poly)` or `proot(Vector)`

Example:

`proot([1,0,-2])` returns
`[-1.41421356237,1.41421356237]`

Coefficients Given a polynomial in x, returns a vector containing the coefficients. If the polynomial is in a variable other than x, then declare the variable as the second argument. With an integer as the optional third argument, returns the coefficient of the polynomial whose degree matches the integer.

```
coeff(Poly, [Var], [Integer])
```

Examples:

coeff(x^2-2) returns [1 0 -2]

coeff(y^2-2, y, 1) returns 0

Divisors Given a polynomial, returns a vector containing the divisors of the polynomial.

```
divis(Poly) or divis({Poly1, Poly2,…})
```

Example:

divis(x^2-1) returns [1 -1+x 1+x (-1+x)*(1+x)]

Factor List Returns a vector containing the prime factors of a polynomial or a list of polynomials, with each factor followed by its multiplicity.

```
factors(Poly) or factors({Poly1,
Poly2,…})
```

Example:

factors(x^4-1) returns [x-1 1 x+1 1 x^2+1 1]

GCD Returns the greatest common divisor of two or more polynomials.

```
gcd(Poly1,Poly2...)
```

Example:

gcd(x^4-1, x^2-1) returns x^2-1

LCM Returns the least common multiple of two or more polynomials.

```
lcm(Poly1, Poly2,…)
```

Example:

lcm(x^2-2*x+1,x^3-1) gives (x-1)*(x^3-1)

Create

Poly to Coef Given a polynomial, returns a vector containing the coefficients of the polynomial. With a variable as second argument, returns the coefficients of a polynomial with respect to the variable. With a list of variables as the second argument, returns the internal format of the polynomial.

```
symb2poly(Expr,[Var])
```

or

```
symb2poly(Expr, {Var1, Var2,…})
```

Example:

`symb2poly(x*3+2.1)` returns `[3  2.1]`

Coef to Poly With one vector as argument, returns a polynomial in *x* with coefficients (in decreasing order) obtained from the argument vector. With a variable as second argument, returns a similar polynomial in that variable.

```
poly2symb(Vector, [Var]))
```

Example:

`poly2symb([1,2,3],x)` returns `(x+2)*x+3`

Roots to Coef Returns a vector containing the coefficients (in decreasing order) of the univariate polynomial whose roots are specified in the argument vector.

```
pcoef(Vect)
```

Example:

`pcoeff([1,0,0,0,1])` returns `[1,-2,1,0,0,0]`

Roots to Poly Takes as argument a vector. The vector contains each root or pole of a rational function. Each root or pole is followed by its order, with poles having negative order. Returns the rational function in x that has the roots and poles (with their orders) specified in the argument vector.

`fcoeff(Vector)` where `Vector` has the form `[Root1, Oder1, Root2, Order2, …])`

Example:

`fcoeff([1,2,0,1,3,-1])` returns `(x-1)^2*x*(x-3)^-1`

Random Returns a vector of the coefficients of a polynomial of degree `Integer` and where the coefficients are random integers in the range –99 through 99 with uniform distribution or in an interval specified by `Interval`. Use with poly2symbol to create a random polynomial in any variable.

`randpoly(Integer, Interval, [Dist])`, where `Interval` is of the form `Real1..Real2.`

Example:

`randpoly(t, 8, -1..1)` returns a vector of 9 random integers, all of them between –1 and 1.

Minimum With only a matrix as argument, returns the minimal polynomial in *x* of a matrix written as a list of its coefficients. With a matrix and a variable as arguments, returns the minimum polynomial of the matrix written in symbolic form with respect to the variable.

```
pmin(Mtrx,[Var])
```

Example:

`pmin([[1,0],[0,1]],x)` gives `x-1`

Algebra

Quotient Returns a vector containing the coefficients of the Euclidean quotient of two polynomials. The polynomials may be written as a list of coefficients or in symbolic form.

```
quo(List1, List2, [Var])
```

or

```
quo(Poly1, Poly2, [Var])
```

Example:

`quo({1, 2, 3, 4}, {-1, 2})` returns `[-1  -4  -11]`

Remainder Returns a vector containing the coefficients of the remainder of the Euclidean quotient of two polynomials. The polynomials may be written as a list of coefficients or in symbolic form.

```
rem(List1, List2, [Var])
```

or

```
rem(Poly1, Poly2, [Var])
```

Example:

`rem({1, 2, 3, 4}, {-1, 2})` returns `[26]`

Degree

Returns the degree of a polynomial.

```
degree(Poly)
```

Example:

`degree(x^3+x)` gives `3`

Factor by Degree

For a given polynomial in *x* of degree *n*, factors out x^n and returns the resulting product.

```
factor_xn(Poly)
```

Example:

`factor_xn(x^4-1)` gives `x^4*(1-x^-4)`

Coef. GCD

Returns the greatest common divisor (GCD) of the coefficients of a polynomial.

```
content(Poly,[Var])
```

Example:

`content(2*x^2+10*x+6)` gives `2`

Zero Count

If *a* and *b* are real, this returns the number of sign changes in the specified polynomial in the interval [*a*,*b*]. If *a* or *b* are non-real, it returns the number of complex roots in the rectangle bounded by *a* and *b*. If *Var* is omitted, it is assumed to be *x*.

```
sturmab(Poly[,Var],a,b)
```

Examples:

`sturmab(x^2*(x^3+2),-2,0)` returns `1`

`sturmab(n^3-1,n,-2-i,5+3i)` returns `3`

Chinese Remainder

Given a matrix whose 2 rows each contain the coefficients of a polynomial, returns the Chinese remainder of the polynomials, also written as a matrix.

```
chinrem([Lst||Expr,Lst||Expr],[Lst||Expr,

Lst||Expr])
```

Example:

`chinrem` $\left(\begin{bmatrix}1&2&0\\1&0&1\end{bmatrix},\begin{bmatrix}1&1&0\\1&1&1\end{bmatrix}\right)$ returns

```
[[2  2  1] [1  1  2  1  1]]
```

Special

Cyclotomic Returns the list of coefficients of the cyclotomic polynomial of an integer.

```
cyclotomic(Integer)
```

Example:

`cyclotomic(20)` gives [1 0 –1 0 1 0 –1 0 1]

Groebner Basis Given a vector of polynomials and a vector of variables, returns the Groebner basis of the ideal spanned by the set of polynomials.

```
gbasis([Poly1  Poly2…], [Var1  Var2…])
```

Example:

`gbasis([x^2-y^3,x+y^2],[x,y])` returns `[y^4-y^3,x+y^2]`

Groebner Remainder Given a polynomial and both a vector of polynomials and a vector of variables, returns the remainder of the division of the polynomial by the Groebner basis of the vector of polynomials.

```
greduce(Poly1, [Poly2  Poly3 …], [Var1 Var2…])
```

Example:

`greduce(x*y-1,[x^2-y^2,2*x*y-y^2,y^3],[x,y])` returns `1/2*y^2-1`

Hermite Returns the Hermite polynomial of degree *n,* where *n* is an integer less than 1556.

```
hermite(Integer)
```

Example:

`hermite(3)` gives `8*x^3-12*x`

Lagrange Given a vector of abscissas and a vector of ordinates, returns the Lagrange polynomial for the points specified in the two vectors. This function can also take a matrix as argument, with the first row containing the abscissas and the second row containing the ordinates.

```
lagrange([X1 X2…], [Y1  Y2…]))
```

or

$$\texttt{lagrange}\left(\begin{bmatrix} X1 & X2 & \ldots \\ Y1 & Y2 & \ldots \end{bmatrix}\right)$$

Example:

`lagrange([1,3],[0,1])` gives `(x-1)/2`

Laguerre Given an integer *n*, returns the Laguerre polynomial of degree *n.*

```
laguerre(Integer))
```

Example:

`laguerre(4)` returns `1/24*a^4+(-1/6)*a^3*x+5/12*a^3+1/4*a^2*x^2+(-3/2)*a^2*x+35/24*a^2+(-1/6)*a*x^3+7/4*a*x^2+(-13/3)*a*x+25/12*a+1/24*x^4+(-2/3)*x^3+3*x^2-4*x+1`

Legendre Given an integer *n*, returns the Legendre polynomial of degree *n.*

```
legendre(Integer)
```

Example:

`legendre(4)` returns $\frac{35}{8} \cdot x^4 + \frac{15}{4} \cdot x^2 + \frac{3}{8}$

Chebyshev Tn Given an integer *n*, returns the Tchebyshev polynomial (of the first kind) of degree *n.*

```
tchebyshev1(Integer)
```

Example:

`tchebyshev1(3)` gives `4*x^3-3*x`

Chebyshev Un Given an integer *n*, returns the Tchebyshev polynomial (of the second kind) of degree *n.*

```
tchebyshev2(Integer)
```

Example:

`tchebyshev2(3)` gives `8*x^3-4*x`

Plot

Function Used to define a function graph in the Symbolic view of the Geometry app. Plots the graph of an expression written in terms of the independent variable *x*. Note that the variable is lowercase.

```
plotfunc(Expr)
```

Example:

`plotfunc(3*sin(x))` draws the graph of y=3*sin(x)

Implicit Used to define an implicit graph in the Symbolic view of the Geometry app. Plots the graph of an equation written in terms of the independent variable *x* and the dependent variable *y*. Note that the variables are lowercase.

```
plotimplicit(Expr)
```

Example:

`plotimplicit(x^2-2*y^2+3*x*y)` plots a rotated hyperbola

Slopefield Used to define a slopefield graph in the Symbolic view of the Geometry app. Plots the graph of the slopefield for the differential equation *y'*=f(*x*,*y*) over the given *x*-range and *y*-range.

```
plotfield(Expr, x=X1..X2, y=Y1..Y2)
```

Example:

`plotfield(x*sin(y), x=-6..6, y=-6..6)` draws the slopefield for y'=x*sin(y) in the square region defined by the x-interval [–6, 6] and the y-interval [–6, 6].

Contour Used to define a contour graph in the Symbolic view of the Geometry app. Given an expression in *x* and *y*, as well as a list of variables and a list of values, plots the contour graph of the surface *z*=f(*x*,*y*). Specifically, plots the contour lines z1, z2, etc. defined by the list of values.

Example:

`plotcontour(x^2+2*y^2-2, {x, y}, {2, 4, 6})` draws the three contour lines of z=x^2+2*y^2–2 for z=2, z=4, and z=6.

ODE Used in the Symbolic view of the Geometry app. Draws the solution of the differential equation *y*′=f(*x*,*y*) that contains as initial condition the point (x_0, y_0). The first argument is the expression f(*x*,*y*), the second argument is the vector of variables (abscissa must be listed first), and the third argument is the initial condition {x_0, y_0}.

plotode(Expr, {Var1, Var2}, {X_0, Y_0})

Example:

`plotode(x*sin(y), {x,y}, {-2, 2})` draws the graph of the solution to y′=x*sin(y) that passes through the point (–2, 2) as an initial condition.

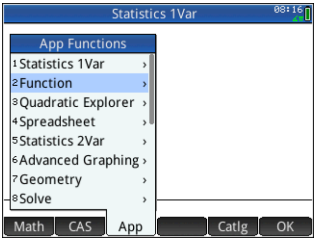
List Used in the Symbolic view of the Geometry app, this command plots a set of points and connects them with segments. Each point is defined by a vector.

`plotlist([X1, Y1], [X2, Y2], …))`

Example:

`plotlist([0, 0], [2,2], [4,0])` connects the points (0, 0), (2, 2), and (4, 0), in order, with straight line segments.

App menu



Press Mem B to open the Toolbox menus (one of which is the App menu). App functions are used in HP apps to perform common calculations. For example, in the Function app, the Plot view **Fcn** menu has a function called `SLOPE` that calculates the slope of a given function at a given point. The `SLOPE` function can also be used from the Home view or a program to give the same results. The app functions described in this section are grouped by app.

Function app functions

The Function app functions provide the same functionality found in the Function app's Plot view under the FCN menu. All these operations work on functions. The functions may be expressions in X or the names of the Function app variables F0 through F9.

AREA

Area under a curve or between curves. Finds the signed area under a function or between two functions. Finds the area under the function Fn or below Fn and above the function Fm, from lower X-value to upper X-value.

```
AREA(Fn,[Fm,]lower,upper)
```

Example:

`AREA(-X,X`^{2}`-2,-2,1)` returns `4.5`

EXTREMUM

Extremum of a function. Finds the extremum (if one exists) of the function Fn that is closest to the X-value guess.

```
EXTREMUM(Fn, guess)
```

Example:

`EXTREMUM(X`^{2}`-X-2,0)` returns `0.5`

ISECT

Intersection of two functions. Finds the intersection (if one exists) of the two functions Fn and Fm that is closest to the X-value guess.

```
ISECT(Fn,Fm,guess)
```

Example:

`ISECT(X,3-X,2)` returns `1.5`

ROOT

Root of a function. Finds the root of the function Fn (if one exists) that is closest to the X-value guess.

```
ROOT(Fn,guess)
```

Example:

`ROOT(3-X`^{2}`,2)` returns `1.732...`

SLOPE

Slope of a function. Returns the slope of the function Fn at the X-value (if the function's derivative exists at that value).

```
SLOPE(Fn,value)
```

Example:

`SLOPE(3-X`^{2}`,2)` returns `-4`

Solve app functions

The Solve app has a single function that solves a given equation or expression for one of its variables. *En* may be an equation or expression, or it may be the name of one of the Solve Symbolic variables E0–E9.

SOLVE

Solve. Solves an equation for one of its variables. Solves the equation *En* for the variable *var*, using the value of *guess* as the initial value for the value of the variable *var*. If *En* is an expression, then the value of the variable *var* that makes the expression equal to zero is returned.

```
SOLVE(En,var,guess)
```

Example:

SOLVE(X^2-X-2,X,3) returns 2

This function also returns an integer that is indicative of the type of solution found, as follows:

0—an exact solution was found

1—an approximate solution was found

2—an extremum was found that is as close to a solution as possible

3—neither a solution, an approximation, nor an extremum was found

See chapter 13, "Solve app", beginning on page 259, for more information about the types of solutions returned by this function.

Spreadsheet app functions

The spreadsheet app functions can be selected from the App Toolbox menu: press Mem B, tap App and select `Spreadsheet`. They can also be selected from the View menu (View Copy) when the Spreadsheet app is open.

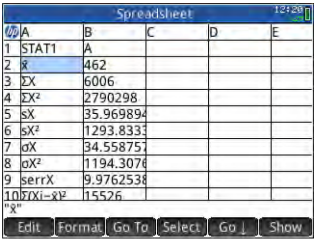
The syntax for many, but not all, the spreadsheet functions follows this pattern:

```
functionName(input,[optional
parameters])
```

`Input` is the input list for the function. This can be a cell range reference, a simple list or anything that results in a list of values.

One useful optional parameter is `Configuration`. This is a string that controls which values are output. Leaving the parameter out produces the default output. The order of the values can also be controlled by the order that they appear in the string.

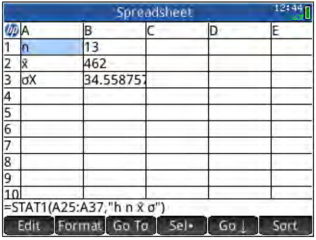
For example: `=STAT1(A25:A37)` produces the following default output, based on the numerical values in cells A25 through A37.



	A	B	C	D	E
1	STAT1	A			
2	$\bar{x}$	462			
3	ΣX	6006			
4	ΣX^2	2790298			
5	sX	35.969894			
6	sX^2	1293.8333			
7	σX	34.558757			
8	σX^2	1194.3076			
9	serrX	9.9762538			
10	$\Sigma(Xi-\bar{x})^2$	15526			

"x̄"

However, if you just wanted to see the number of data-points, the mean, and the standard deviation, you would enter `=STAT1(A25:A37,”h n x̄ σ”)`. What the configuration string is indicating here is that row headings are required (h), but just return the number of data-points (n), the mean ($\bar{x}$), and the standard deviation (σ). See page 352 for details on the configuration string for this command.



	A	B	C	D	E
1	n	13			
2	$\bar{x}$	462			
3	σX	34.558757			
4					
5					
6					
7					
8					
9					
10					

=STAT1(A25:A37,"h n x̄ σ")

SUM

Calculates the sum of a range of numbers.

```
SUM([input])
```

For example, `SUM(B7:B23)` returns the sum of the numbers in the range B7 to B23. You can also specify a block of cells, as in `SUM(B7:C23)`.

An error is returned if a cell in the specified range contains a non-numeric object.

AVERAGE

Calculates the arithmetic mean of a range of numbers.

```
AVERAGE([input])
```

For example, `AVERAGE(B7:B23)` returns the arithmetic mean of the numbers in the range B7 to B23. You can also specify a block of cells, as in `AVERAG(B7:C23)`.

An error is returned if a cell in the specified range contains a non-numeric object.

AMORT

Amortization. Calculates the principal, interest, and balance of a loan over a specified period. Corresponds to pressing Amort in the Finance app.

```
AMORT(Range, NbPmt, IPYR, PV, PMTV[, PPYR=12,
CPYR=PPYR, GSize=PPYR, BEG=0, fix=current],
"configuration"])
```

`Range`: the cell range where the results are to be placed. If only one cell is specified, then the range is automatically calculated starting from that cell.

`Configuration`: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

h – show row headers

H – show column headers

S – show the start of the period

E – show the end of the period

P – show the principal paid this period

B – show the balance at the end of the period

I – show the interest paid this period

All the other input parameters (except `fix`) are Finance app Numeric view variables; see page 440 for details. Note that only the first four are required. `fix` is the number of decimal places to be used in the displayed results.

STAT1

The STAT1 function provides a range of one-variable statistics. It can calculate all or any of $\bar{X}$, Σ, Σ^2, s, s^2, σ, σ^2, serr, $\sum(x_i-\bar{x})^2$, n, min, q1, med, q3, and max.

```
STAT1(Input range, [mode], [outlier
removal Factor], ["configuration"])
```

Input range is the data source (such as A1:D8).

Mode defines how to treat the input. The valid values are:

1 = Single data. Each column is treated as an independent dataset.

2 = Frequency data. Columns are used in pairs and the second column is treated as the frequency of appearance of the first column.

3 = Weight data. Columns are used in pairs and the second column is treated as the weight of the first column.

4 = One–Two data. Columns are used in pairs and the 2 columns are multiplied to generate a data point.

If more than one column is specified, they are each treated as a different input data set. If only one row is selected, it is treated as 1 data set. If two columns are selected, the mode defaults to frequency.

Outlier Removal Factor: This allows for the removal of any datapoint that is more than *n* times the standard deviation (where *n* is the outlier removal factor). By default this factor is set to 2.

Configuration: indicates which values you want to place in which row and if you want row or columns headers. Place the symbol for each value in the order that you want to see the values appear in the spreadsheet. The valid symbols are:

H (Place column headers)			h (Place row headers)		
$\bar{x}$	Σ	Σ^2	s	s^2	σ
σ^2	serr	$\sum(x_i-\bar{x})^2$	n	min	q1
med	q3	max			

For example if you specify "h n Σ x̄", the first column will contain row headers, the first row will be the number of items in the input data, the second the sum of the items and the third the mean of the data. If you do not specify a configuration string, a default string will be used.

Notes:

The STAT1 f function only updates the content of the destination cells when the cell that contains the formula is calculated. This means that if the spreadsheet view contains at the same time results and inputs, but not the cell that contains the call to the STAT1 function, updating the data will not update the results as the cell that contains STAT1 is not recalculated (since it is not visible).

The format of cells that receive headers is changed to have `Show " "` set to false.

The STAT1 function will overwrite the content of destination cells, potentially erasing data.

Examples:

```
STAT1(A25:A37)

STAT1(A25:A37,”h n x̄ σ”).
```

REGRS

Attempts to fit the input data to a specified function (default is linear).

```
REGRS(Input range,[model],
["configuration"])
```

- Input range: specifies the data source; for example A1:D8. It must contain an even number of columns. Each pair will be treated as a distinct set of datapoints.
- model: specifies the model to be used for the regression:

  1 y= sl*x+int

  2 y= sl*ln(x)+int

  3 y= int*exp(sl*x)

  4 y= int*x^sl

  5 y= int*sl^x

  6 y= sl/x+int

7 y= L/(1 + a*exp(b**x*))

8 y= a*sin(b**x*+c)+d

9 y= c*x*^2+b*x*+a

10 y= d*x*^3+c*x*^2+b*x*+a

11 y= e*x*^4+d*x*^3+c*x*^2+b*x*+a

- Configuration: a string which indicates which values you want to place in which row and if you want row and columns headers. Place each parameter in the order that you want to see them appear in the spreadsheet. (If you do not provide a configuration string, a default one will be provided.) The valid parameters are:
  - H (Place column headers)
  - h (Place row headers)
  - sl (slope, only valid for models 1–6)
  - int (intercept, only valid for models 1–6)
  - cor (correlation, only valid for models 1–6)
  - cd (Coefficient of determination, only valid for models 1–6, 8–10)
  - sCov (Sample covariance, only valid for models 1–6)
  - pCov (Population covariance, only valid for models 1–6)
  - L (L parameter for model 7)
  - a (a parameter for models 7-–11)
  - b (b parameter for models 7-–11)
  - c (c parameter for models 8–11)
  - d (d parameter for models 8, 10–11)
  - e (e parameter for model 11)
  - py (place 2 cells, one for user input and the other to display the predicted y for the input)
  - px (place 2 cells, one for user input and the other to display the predicted x for the input)

Example: `REGRS(A25:B37,2)`

PredY

Returns the predicted Y for a given x.

```
PredY(mode, x, parameters)
```

- `Mode` governs the regression model used:

  1 y= sl*x+int

  2 y= sl*ln(x)+int

  3 y= int*exp(sl*x)

  4 y= int*x^sl

  5 y= int*sl^x

  6 y= sl/x+int

  7 y= L/(1 + a*exp(b*x))

  8 y= a*sin(b*x+c)+d

  9 y= cx^2+bx+a

  10 y= dx^3+cx^2+bx+a

  11 y= ex^4+dx^3+cx^2+bx+a
- `Parameters` is either one argument (a list of the coefficients of the regression line), or the n coefficients one after another.

PredX

Returns the predicted x for a given y.

```
PredX(mode, y, parameters)
```

- `Mode` governs the regression model used:

  1 y= sl*x+int

  2 y= sl*ln(x)+int

  3 y= int*exp(sl*x)

  4 y= int*x^sl

  5 y= int*sl^x

  6 y= sl/x+int

  7 y= L/(1 + a*exp(b*x))

  8 y= a*sin(b*x+c)+d

  9 y= cx^2+bx+a

  10 y= dx^3+cx^2+bx+a

  11 y= ex^4+dx^3+cx^2+bx+a
- `Parameters` is either one argument (a list of the coefficients of the regression line), or the n coefficients one after another.

HypZ1mean

The one-sample Z-test for a mean.

```
HypZ1mean(x̄, n, μ0, σ, α, mode, ["configuration"])
```

The input parameters can be a range reference, a list of cell references, or a simple list of values.

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tZ: the test Z-value
- tM: the input $\bar{x}$ value
- prob: the lower-tail probability
- cZ: the critical Z-value associated with the input a-level
- cx1: the lower critical value of the mean associated with the critical Z-value
- cx2: the upper critical value of the mean associated with the critical Z-value
- std: the standard deviation

Example:

```
HypZ1mean(0.461368, 50, 0.5, 0.2887, 0.05, 1,
"")
```

HYPZ2mean

The two-sample Z-test for the difference of two means.

```
HypZ2mean(x̄1, x̄2, n1, n2, σ1, σ2, α, mode,
["configuration"])
```

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$
- Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.
- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tZ: Test Z
- tM: the input $\Delta\bar{x}$ value
- prob: the lower-tail probability
- cZ: the critical Z-value associated with the input a-level
- cx1: the lower critical value of $\Delta\bar{x}$ associated with the critical Z-value
- cx2: the upper critical value of $\Delta\bar{x}$ associated with the critical Z-value
- std: the standard deviation

Example:

```
HypZ2mean(0.461368, 0.522851, 50, 50, 0.2887,
0.2887, 0.05, 1, "")
```

HypZ1prop

The one-sample Z-test for a proportion.

`HypZ1prop(x,n,π0,α,mode,` `[”configuration”])` where *x* is the success count of the sample

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi < \pi_0$
- 2: $\pi > \pi_0$
- 3: $\pi \neq \pi_0$

- Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.
- h: header cells will be created
- acc:0 or 1 to reject or fail to reject the null hypothesis
- tZ: the test Z-value
- tP: the test proportion of successes
- prob: the lower-tail probability
- cZ: The critical Z-value associated with the input a-level
- cp1: the lower critical proportion of successes associated with the critical Z-value
- cp2: the upper critical proportion of successes associated with the critical Z-value
- std: the standard deviation

Example:

```
HypZ1prop(21, 50, 0.5, 0.05,1, "")
```

HypZ2prop

The two-sample Z-test for comparing two proportions.

`HypZ2prop(x1,x2,n1,n2,α,mode,` `[”configuration”])` where x_1 and x_2 are the success counts of the two samples)

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi_1 < \pi_2$
- 2: $\pi_1 > \pi_2$
- 3: $\pi_1 \neq \pi_2$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: 0 or 1 to reject or fail to reject the null hypothesis
- tZ: the test Z-value
- tP: the test $\Delta\pi$ value

- prob: the lower-tail probability
- cZ: The critical Z-value associated with the input a-level
- cp1: The lower critical value of $\Delta\pi$ associated with the critical Z-value
- cp2: The upper critical value of $\Delta\pi$ associated with the critical Z-value

Example:

```
HypZ2prop(21, 26, 50, 50, 0.05, 1, "")
```

HypT1mean

The one-sample t-test for a mean.

```
HypT1mean(x̄,s,n,μ0,α,mode,[”configuration”])
```

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tT: the test T-value
- tM: the input $\bar{x}$ value
- prob: the lower-tail probability
- df: the degrees of freedom
- cT: the critical T-value associated with the input a-level
- cx1: the lower critical value of the mean associated with the critical T-value
- cx2: the upper critical value of the mean associated with the critical T-value

Example:

```
HypT1mean(0.461368, 0.2776, 50, 0.5, 0.05, 1, 
"")
```

HypT2mean

The two-sample T-test for the difference of two means.

```
HypT2mean((x1,x2,s1,s2,n1,n2,α,pooled,mode,
["configuration”])
```

Pooled: Specifies whether or not the samples are pooled

- 0: not pooled
- 1: pooled

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tT: the test T-value
- tM: the input $\Delta\bar{x}$ value
- prob: the lower-tail probability
- cT: the critical T-value associated with the input a-level
- cx1: the lower critical value of $\Delta\bar{x}$ associated with the critical T-value
- cx2: the upper critical value of $\Delta\bar{x}$ associated with the critical T-value

Example:

```
HypT2mean(0.461368, 0.522851, 0.2776,
0.2943,50, 50, 0, 0.05, 1, "")
```

ConfZ1mean

The one-sample Normal confidence interval for a mean.

```
ConfZ1mean(x̄,n,s,C,[”configuration”])
```

Configuration is a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval
- zXh: the upper bound of the confidence interval
- std: the standard deviation

Example:

```
ConfZ1mean(0.461368, 50, 0.2887, 0.95, "")
```

ConfZ2mean

The two-sample Normal confidence interval for the difference of two means.

ConfZ2mean($\bar{x}_1$, $\bar{x}_2$, n_1, n_2, s_1, s_2, C,
[”configuration”])

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval
- zXh: the upper bound of the confidence interval
- zXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfZ2mean(0.461368, 0.522851, 50, 50, 0.2887,
0.2887, 0.95, "")
```

ConfZ1prop

The one-sample Normal confidence interval for a proportion.

```
ConfZ1prop(x,n,C,[”configuration”])
```

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval

- zXh: the upper bound of the confidence interval
- zXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfZ1prop(21, 50, 0.95, "")
```

ConfZ2prop The two-sample Normal confidence interval for the difference of two proportions.

```
ConfZ2prop(x1,x2,n1,n2,C,[”configuration”])
```

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval
- zXh: the upper bound of the confidence interval
- zXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfZ2prop(21, 26, 50, 50, 0.95, "")
```

ConfT1mean The one-sample Student’s T confidence interval for a mean.

```
ConfT1mean(x̄,s,n,C,[”configuration”])
```

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- DF: the degrees of freedom
- T: the critical T-value
- tXl: the lower bound of the confidence interval
- tXh: the upper bound of the confidence interval
- std: the standard deviation

Example:

```
ConfT1mean(0.461368, 0.2776, 50, 0.95,
"")
```

ConfT2mean The two-sample Student's T confidence interval for the difference of two means.

ConfT2mean($\bar{x}_1$, $\bar{x}_2$, s_1, s_2, n_1, n_2, C, pooled, [”configuration”])

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- DF: the degrees of freedom
- T: the critical T-value
- tXl: the lower bound of the confidence interval
- tXh: the upper bound of the confidence interval
- tXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfT2mean(0.461368, 0.522851, 0.2776, 0.2943,
50, 50, 0, 0.95, "")
```

Statistics 1Var app functions

The Statistics 1Var app has three functions designed to work together to calculate summary statistics based on one of the statistical analyses (H1–H5) defined in the Symbolic view of the Statistics 1Var app.

Do1VStats

Do1-variable statistics. Performs the same calculations as tapping Stats in the Numeric view of the Statistics 1Var app and stores the results in the appropriate Statistics 1Var app results variables. *Hn* must be one of the Statistics 1Var app Symbolic view variables `H1-H5`.

```
Do1VStats(Hn)
```

Example:

`Do1VStats(H1)` executes summary statistics for the currently defined `H1` analysis.

SetFreq

Set frequency. Sets the frequency for one of the statistical analyses (`H1-H5`) defined in the Symbolic view of the Statistics 1Var app. The frequency can be either one of the columns `D0-D9`, or any positive integer. *Hn* must be one of the Statistics 1Var app Symbolic view variables `H1-H5`. If used, *Dn* must be one of the column variables `D0-D9`; otherwise, *value* must be a positive integer.

```
SetFreq(Hn,Dn)
```

or

```
SetFreq(Hn,value)
```

Example:

`SetFreq(H2,D3)` sets the **Frequency** field for the `H2` analysis to use the list `D3`.

SetSample

Set sample data. Sets the sample data for one of the statistical analyses (`H1-H5`) defined in the Symbolic view of the Statistics 1Var app. Sets the data column to one of the column variables `D0-D9` for one of the statistical analyses `H1-H5`.

```
SetSample(Hn,Dn)
```

Example:

`SetSample(H2,D2)` sets the **Independent Column** field for the `H2` analysis to use the data in the list `D2`.

Statistics 2Var app functions

The Statistics 2Var app has a number of functions. Some are designed to calculate summary statistics based on one of the statistical analyses (`S1-S5`) defined in the Symbolic view of the Statistics 2Var app. Others predict X- and Y-values based on the fit specified in one of the analyses.

PredX

Predict X. Uses the fit from the first active analysis (`S1-S5`) found to predict an x-value given the y-value.

```
PredX(value)
```

PredY

Predict Y. Uses the fit from the first active analysis (`S1-S5`) found to predict a y-value given the x-value.

```
PredY(value)
```

Resid

Residuals. Returns the list of residuals for the given analysis (`S1-S5`), based on the data and a fit defined in the Symbolic view for that analysis.

```
Resid(Sn) or Resid()
```

Resid() looks for the first defined analysis in the Symbolic view (S1-S5).

Do2VStats

Do 2-variable statistics. Performs the same calculations as tapping Stats in the Numeric view of the Statistics 2Var app and stores the results in the appropriate Statistics 2Var app results variables. `Sn` must be one of the Statistics 2Var app Symbolic view variables `S1-S5`.

```
Do2VStats(Sn)
```

Example:

`Do1VStats(S1)` executes summary statistics for the currently defined `S1` analysis.

SetDepend

Set dependent column. Sets the dependent column for one of the statistical analyses `S1-S5` to one of the column variables `C0-C9`.

```
SetDepend(Sn,Cn)
```

Example:

`SetDepend(S1,C3)` sets the **Dependent Column** field for the `S1` analysis to use the data in list `C3`.

SetIndep

Set independent column. Sets the independent column for one of the statistical analyses S1–S5 to one of the column variables C0–C9.

```
SetIndep(Sn,Cn)
```

Example:

`SetIndep(S1, C2)` sets the **Independent Column** field for the S1 analysis to use the data in list C2.

Inference app functions

The Inference app has a single function that returns the same results as tapping Calc in the Numeric view of the Inference app. The results depend on the contents of the Inference app variables Method, Type, and AltHyp.

DoInference

Calculate confidence interval or test hypothesis. Uses the current settings in the Symbolic and Numeric views to calculate a confidence interval or test an hypothesis. Performs the same calculations as tapping Calc in the Numeric view of the Inference app and stores the results in the appropriate Inference app results variables.

```
DoInference()
```

HypZ1mean

The one-sample Z-test for a mean. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The input $\bar{x}$ value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of the statistic associated with the critical Z-value

HypZ1mean($\bar{x}$,n,μ_0,σ,α,mode)

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Example:

HypZ1mean(0.461368, 50, 0.5, 0.2887, 0.05, 1) returns {1, -.9462…, 0.4614, 0.8277…, 1.6448…, 0.5671…}

HYPZ2mean

The two-sample Z-test for means. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The test $\Delta\bar{x}$ value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of $\Delta\bar{x}$ associated with the critical Z-value

HypZ2mean($\bar{x}_1$, $\bar{x}_2$, n_1, n_2, σ_1, σ_2, α, mode)

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$

Example:

HypZ2mean(0.461368, 0.522851, 50, 50, 0.2887, 0.2887, 0.05, 1) returns {1, -1.0648…, -0.0614…, 0.8565…, 1.6448…, 0.0334…}

HypZ1prop

The one-proportion Z-test. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The test π value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of π associated with the critical Z-value

HypZ1prop(x, n, π_0, α, mode)

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi < \pi_0$
- 2: $\pi > \pi_0$
- 3: $\pi \neq \pi_0$

Example:

`HypZ1prop(21, 50, 0.5, 0.05,1)` returns `{1, -1.1313…, 0.42, 0.8710…, 1.6448…, 0.6148…}`

HypZ2prop

The two-sample Z-test for proportions. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The test Δπ value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of Δπ associated with the critical Z-value

`HypZ2prop(`x_1`,`x_2`,`n_1`,`n_2`,`α`,mode)`

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi_1 < \pi_2$
- 2: $\pi_1 > \pi_2$
- 3: $\pi_1 \neq \pi_2$

Example:

`HypZ2prop(21, 26, 50, 50, 0.05, 1)` returns `{1, -1.0018…, -0.1, 0.8417…, 1.6448…, 0.0633…}`

HypT1mean

The one-sample t-test for a mean. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test T-value
- The input $\bar{x}$ value
- The upper-tail probability
- The degrees of freedom
- The upper critical T-value associated with the input a-level
- The critical value of the statistic associated with the critical t-value

`HypT1mean(`$\bar{x}$`,s,n,`μ_0`,`α`,mode)`

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Example:

`HypT1mean(0.461368, 0.2776, 50, 0.5, 0.05, 1)` returns `{1, -.9462…, 0.4614, 0.8277…, 1.6448…, 0.5671…}`

HypT2mean

The two-sample T-test for means. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test T-value
- The test $\Delta\bar{x}$ value
- The upper-tail probability
- The degrees of freedom
- The upper critical T-value associated with the input a-level
- The critical value of $\Delta\bar{x}$ associated with the critical T-value

`HypT2mean((`$x_1, x_2, s_1, s_2, n_1, n_2, \alpha$`,pooled,mode)`

Pooled: Specifies whether or not the samples are pooled

- 0: not pooled
- 1: pooled

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$

Example:

`HypT2mean(0.461368, 0.522851, 0.2776, 0.2943,50, 50, 0.05, 0, 1)` returns `{1, -1.0746…, -0.0614…, 0.8574…, 97.6674…, 1.6606…, 0.0335…}`

ConfZ1mean

The one-sample Normal confidence interval for a mean. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

```
ConfZ1mean(x̄,n,σ,C)
```

Example:

`ConfZ1mean(0.461368, 50, 0.2887, 0.95)` returns `{-1.9599…, 0.3813…, 0.5413…}`

ConfZ2mean

The two-sample Normal confidence interval for the difference of two means. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfZ2mean($\bar{x}_1$, $\bar{x}_2$, n_1, n_2, σ_1, σ_2, C)

Example:

`ConfZ2mean(0.461368, 0.522851, 50, 50, 0.2887, 0.2887, 0.95)` returns `{-1.9599…, -0.1746…, 0.0516…)}`

ConfZ1prop

The one-sample Normal confidence interval for a proportion. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

```
ConfZ1prop(x,n,C)
```

Example:

`ConfZ1prop(21, 50, 0.95)` returns `{-1.9599…, 0.2831…, 0.5568…}`

ConfZ2prop

The two-sample Normal confidence interval for the difference of two proportions. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfZ2prop(x_1,x_2,n_1,n_2,C)

Example:

`ConfZ2prop(21, 26, 50, 50, 0.95)` returns `{-1.9599…, -0.2946…, 0.0946…)}`

ConfT1mean

The one-sample Student’s T confidence interval for a mean. Returns a list containing (in order):

- The degrees of freedom
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfT1mean($\bar{x}$,s,n,C)

Example:

`ConfT1mean(0.461368, 0.2776, 50, 0.95)` returns `{49, -.2009…, 0.5402…}`

ConfT2mean

The two-sample Student’s T confidence interval for the difference of two means. Returns a list containing (in order):

- The degrees of freedom
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfT2mean($\bar{x}_1$, $\bar{x}_2$, s_1,s_2,n_1, n_2,pooled,C)

Example:

`ConfT2mean(0.461368, 0.522851, 0.2887, 0.2887, 50, 50, 0.95,0)` returns `{98.0000…, -1.9844, -0.1760…, 0.0531…)}`

Finance app functions

The Finance app uses a set of functions that all reference the same set of Finance app variables. These correspond to the fields in the Finance app Numeric view. There are 5 main TVM variables, 4 of which are mandatory for each of these functions, as they each solve for and return the value of the fifth variable to two decimal places. `DoFinance` is the sole exception to this syntax rule. Note that money paid to you is entered as a positive number and money you pay to others as part of a cash flow is entered as a negative number. There are 3 other variables that are optional and have default values. These variables occur as arguments to the Finance app functions in the following set order:

- `NbPmt`—the number of payments
- `IPYR`—the annual interest rate
- `PV`—the present value of the investment or loan
- `PMTV`—the payment value
- `FV`—the future value of the investment or loan
- `PPYR`—the number of payments per year (12 by default)
- `CPYR`—the number of compounding periods per year (12 by default)
- `BEG`—payments made at the beginning or end of the period; the default is BEG=0, meaning that payments are made at the end of each period

The arguments `PPYR`, `CPYR`, and `BEG` are optional; if not supplied, `PPYR`=12, `CPYR=PPYR`, and `BEG`=0.

CalcFV

Solves for the future value of an investment or loan.

```
CalcFV(NbPmt,IPYR,PV,PMTV[,PPYR,CPYR,BEG]
```

Example:

`CalcFV(360, 6.5, 150000, -948.10)` returns `-2.25`

CalcIPYR

Solves for the interest rate per year of an investment or loan.

```
CalcIPYR(NbPmt,PV,PMTV,FV[,PPYR,CPYR,
BEG])
```

Example:

`CalcIPYR(360, 150000, -948.10, -2.25)` returns `6.50`

CalcNbPmt

Solves for the number of payments in an investment or loan.

```
CalcNbPmt(IPYR,PV,PMTV,FV[,PPYR,CPYR,BEG])
```

Example:

`CalcNbPmt(6.5, 150000, -948.10, -2.25)` returns `360.00`

CalcPMT

Solves for the value of a payment for an investment or loan.

```
CalcPMT(NbPmt,IPYR,PV,FV[,PPYR,CPYR,BEG])
```

Example:

`CalcPMT(360, 6.5, 150000, -2.25)` returns `-948.10`

CalcPV

Solves for the present value of an investment or loan.

```
CalcPV(NbPmt,IPYR,PMTV,FV[,PPYR,CPYR,BEG])
```

Example:

`CalcPV(360, 6.5, -948.10, -2.25)` returns `150000.00`

DoFinance

Calculate TVM results. Solves a TVM problem for the variable *TVMVar*. The variable must be one of the Finance app's Numeric view variables. Performs the same calculation as tapping Solve in the Numeric view of the Finance app with *TVMVar* highlighted.

```
DoFinance(TVMVar)
```

Example:

`DoFinance(FV)` returns the future value of an investment in the same way as tapping Solve in the Numeric view of the Finance app with `FV` highlighted.

Linear Solver app functions

The Linear Solver app has 3 functions that offer the user flexibility in solving 2x2 or 3x3 linear systems of equations.

Solve2x2

Solves a 2x2 linear system of equations.

`Solve2x2`(*a, b, c, d, e, f*)

Solves the linear system represented by:

ax+by=c

dx+ey=f

Solve3x3

Solves a 3x3 linear system of equations.

`Solve3x3`(*a, b, c, d, e, f, g, h, i, j, k, l*)

Solves the linear system represented by:

ax+by+cz=d

ex+fy+gz=h

ix+jy+kz=l

LinSolve

Solve linear system. Solves the 2x2 or 3x3 linear system represented by matrix.

`LinSolve(`*matrix*)

Example:

`LinSolve`([[`A, B, C`], [`D, E,F`]]) solves the linear system:

ax+by=c

dx+ey=f

Triangle Solver app functions

The Triangle Solver app has a group of functions which allow you to solve a complete triangle from the input of three consecutive parts of the triangle (one of which must be a side length). The names of these commands use A to signify an angle and S to signify a side length. To use these commands, enter three inputs in the specified order given by the command name. These commands all return a list of the three unknown values (lengths of sides and/or measures of angles).

AAS

Angle-Angle-Side. Takes as arguments the measures of two angles and the length of the side opposite the first angle and returns a list containing the length of the side opposite the second angle, the length of the third side, and the measure of the third angle (in that order).

```
AAS(angle,angle,side)
```

Example:

`AAS(30, 60, 1)` in degree mode returns `{1.732…, 2, 90}`

ASA

Angle-Side-Angle. Takes as arguments the measure of two angles and the length of the included side and returns a list containing the length of the side opposite the first angle, the length of the side opposite the second angle, and the measure of the third angle (in that order).

```
ASA(angle,side,angle)
```

Example:

`ASA(30, 2, 60)` in degree mode returns `{1, 1.732…, 90}`

SAS

Side-Angle-Side. Takes as arguments the length of two sides and the measure of the included angle and returns a list containing the length of the third side, the measure of the angle opposite the third side and the measure of the angle opposite the second side.

```
SAS(side,angle,side)
```

Example:

`SAS(2, 60, 1)` in degree mode returns `{1.732…, 30, 90}`

SSA

Side-Side-Angle. Takes as arguments the lengths of two sides and the measure of a non-included angle and returns a list containing the length of the third side, the measure of the angle opposite the second side, and the measure of the angle opposite the third side. Note: In an ambiguous case, this command will only give you one of the two possible solutions.

```
SSA(side,side,angle)
```

Example:

`SSA(1, 2, 30)` returns `{1.732…, 90, 60}`

SSS

Side-Side-Side Takes as arguments the lengths of the three sides of a triangle and returns the measures of the angles opposite them, in order.

```
SSS(side,side,side)
```

Example:

`SSS(3, 4, 5)` in degree mode returns `{36.8…, 53.1…, 90}`

DoSolve

Solves the current problem in the Triangle Solver app. The Triangle Solver app must have enough data entered to ensure a successful solution; that is, there must be at least three values entered, one of which must be a side length. Returns a list containing the unknown values in the Numeric view, in their order of appearance in that view (left to right and top to bottom).

```
DoSolve()
```

Linear Explorer functions

SolveForSlope

Solve for slope. Takes as input the coordinates of two points (x_1, y_1) and (x_2, y_2) and returns the slope of the line containing those two points.

`SolveForSlope(`x_1, x_2, y_1, y_2`)`

Example:

`SolveForSlope(3,2,4,2)` returns `2`

SolveForYIntercept

Solve for y-intercept. Takes as input the coordinates of a point (*x*, *y*), and a slope *m*, and returns the *y*-intercept of the line with the given slope that contains the given point.

```
SolveForYIntercept(x, y, m)
```

Example:

`SolveForYIntercept(2,3,-1)` returns `5`

Quadratic Explorer functions

SOLVE

Solve quadratic. Given the coefficients of a quadratic equation $ax^2+bx+c=0$, returns the real solutions.

```
SOLVE(a, b, c)
```

Example:

`SOLVE(1,0,-4)` returns `{-2, 2}`

DELTA

Discriminant. Given the coefficients of a quadratic equation $ax^2+bx+c=0$, returns the value of the discriminant in the Quadratic Formula.

```
DELTA(a, b, c)
```

Example:

`DELTA(1,0,-4)` returns `16`

Common app functions

In addition to the app functions specific to each app, there are three functions common to the following apps. These use as an argument an integer from 0 to 9, which corresponds to one of the Symbolic view variables for that app.

- Function (F0–F9)
- Solve (E0–E9)
- Statistics 1Var (H1–H5)
- Statistics 2Var (S1–S5)
- Parametric (X0/Y0–X9/Y9)
- Polar (R0–R9)
- Sequence (U0–U9)
- Advanced Graphing (V0–V9)

CHECK

Check. Checks—that is, *selects*—the Symbolic view variable corresponding to `Digit`. Used primarily in programming to activate Symbolic view definitions in apps.

```
CHECK(Digit)
```

Example:

With the Function app as the current app, `CHECK(1)` checks the Function app Symbolic view variable F1. The result is that `F1(X)` is drawn in the Plot view and has a column of function values in the Numeric view of the Function app. With another app as the current app, you would have to enter `Function.CHECK(1).`

UNCHECK

Un-Check. Un-checks—that is, deselects—the Symbolic view variable corresponding to `Digit`. Used primarily in programming to de-activate symbolic view definitions in apps.

```
UNCHECK(Digit)
```

Example:

With the Sequence app as the current app, `UNCHECK(2)` un-checks the Sequence app Symbolic view variable `U2`. The result is that `U2(N)` is no longer drawn in Plot view and has no column of values in the Numeric view of the Sequence app. With another app as the current app, you would have to enter `Sequence.UNCHECK(2)`.

ISCHECK

Test for check. Tests whether a Symbolic view variable is checked. Returns 1 if the variable is checked and 0 if it is not checked.

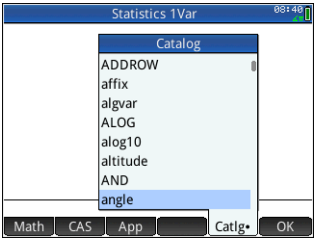
```
ISCHECK(Digit)
```

Example:

With the Function app as the current app, `ISCHECK(3)` checks to see if `F3(X)` is checked in the Symbolic view of the Function app.

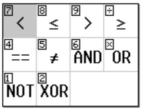
Ctlg menu

The Catlg menu brings together all the functions and commands available on the HP Prime. However, this section describes the functions and commands that can only be found on the Catlg menu. The functions and commands that are also on the Math menu are



described in “Keyboard functions” on page 309. Those that are also on the CAS menu are described in “CAS menu” on page 324. The functions and commands specific to the Geometry app are described in “Geometry functions and commands” on page 165, and those specific to programming are described in “Program commands” on page 527. The matrix functions are described in “Matrix functions” on page 475and the list functions are described in “List functions” on page 457.

Some of the options on the Catlg menu can also be chosen from the relations palette (Shift 9)



7 <	8 ≤	9 >	÷ ≥
4 ==	5 ≠	6 AND	× OR
1 NOT	2 XOR		

! Factorial. Returns the factorial of a positive integer. For non-integers, ! = Γ(x + 1). This calculates the Gamma function.

```
value!
```

Example:

`6!` returns `720`

% *x* percent of *y*. Returns (x/100)*y.

```
%(x, y)
```

Example:

`%(20,50)` returns `10`

%CHANGE Percent change from x to y. Returns 100*(y-x)/x.

```
%CHANGE(x, y)
```

Example:

`%CHANGE(20,50)` returns `150`

%TOTAL Percent total; the percentage of x that is y. Returns 100*y/x.

```
%TOTAL(x, y)
```

Example:

`%TOTAL(20,50)` returns `250`

(Inserts opening parenthesis.

***** Multiplication symbol. Returns the product of two numbers or the scalar product of two vectors.

+ Addition symbol. Returns the sum of two numbers, the term-by-term sum of two lists or two matrices, or adds two strings together.

– Subtraction symbol. Returns the difference of two numbers, or the term-by-term subtraction of two lists or two matrices.

.* List or matrix multiplication symbol. Returns the term-by-term multiplication of two lists or two matrices.

`List1.*List2` or `Matrix1.*Matrix2`

Example:

`[[1,2],[3,4]].*[[3,4],[5,6]]` gives
`[[3,8],[15,24]]`

./ List or matrix division symbol. Returns the term-by-term division of two lists or two matrices.

.^ Returns the list or matrix where each term is the corresponding term of the list or matrix given as argument, raised to the power *n*.

`List.^Integer` or `Matrix.^Integer`

/ Division symbol. Returns the quotient of two numbers, or the term by term quotient of two lists. For division of a matrix by a square matrix, returns the left-multiplication by the inverse of the square matrix.

:= Stores the evaluated expression in the variable. Note that `:=` cannot be used with the graphics variables G0–G9. See the command `BLIT`.

`var:=expression`

Example:

`A:=3` stores the value 3 in the variable A

< Strict less-than-inequality test. Returns 1 if the left side of the inequality is less than the right side, and 0 otherwise. Note that more than two objects can be compared. Thus 6 < 8 < 11 returns 1 (because it is true) whereas 6 < 8 < 3 returns 0 (as it is false).

<= Less than or equal inequality test. Returns 1 if the left side of the inequality is less than the right side or if the two sides are equal, and 0 otherwise. Note that more than two objects can be compared. See comment above regarding <.

<> Inequality test. Returns 1 if the inequality is true, and 0 if the inequality is false.

= Equality symbol. Connects two members of an equation.

== Equality test. Returns 1 if the left side and right side are equal, and 0 otherwise.

> Strict greater than inequality test. Returns 1 if the left side of the inequality is greater than the right side, and 0 otherwise. Note that more than two objects can be compared. See comment above regarding <.

>= Greater than or equal inequality test. Returns 1 if the left side of the inequality is greater than the right side or if the two sides are equal, and 0 otherwise. Note that more than two objects can be compared. See comment above regarding <.

^ Power symbol. Raises a number to a power or a matrix to an integer power.

a2q Given a symmetric matrix and a vector of variables, returns the quadratic form of the matrix using the variables in the vector.

```
a2q(Matrix, [Var1, Var2….])
```

Example:

`a2q([[1,2],[4,4]],[x,y])` returns `x^2+6*x*y+4*y^2`

abcuv Given three polynomials A, B, and C, returns U and V such that A*U+B*V=C. With a variable as the final argument, U and V are expressed in terms of that variable (if needed); otherwise, x is used.

```
abcuv(PolyA, PolyB, PolyC, [Var])
```

Example:

`abcuv(x^2+2*x+1,x^2-1,x+1)` returns `[1/2  -1/2]`

additionally Used in programming with `assume` to state an additional assumption about a variable.

Example:

```
assume(n,integer);

additionally(n>5);
```

algvar Returns the matrix of the symbolic variable names used in an expression. The list is ordered by the algebraic extensions required to build the original expression.

```
algvar(Expr)
```

Example:

`algvar(sqrt(x)+y)` gives $\begin{bmatrix} y \\ x \end{bmatrix}$

AND Logical And. Returns 1 if the left and right sides both evaluate to true and returns 0 otherwise.

```
Expr1 AND Expr2
```

Example:

`3 +1==4 AND 4 < 5` returns `1`

append Appends an element to a list or vector.

```
append((List, Element)
```

or

```
append(Vector, Element)
```

Example:

```
append([1,2,3],4) gives [1,2,3,4]
```

apply Returns a vector containing the results of applying a function to the elements in a list.

```
apply(Var→f(Var), List)
```

Example:

`apply(x→x^3,[1,2,3])` gives `[1,8,27]`

assume Used in programming to state an assumption about a variable.

```
assume(Var,Expr)
```

Example:

```
assume(n, integer)
```

basis Given a matrix, returns the basis of the linear subspace defined by the set of vectors in the matrix.

```
basis(Matrix))
```

Example:

`basis([[1,2,3],[4,5,6],[7,8,9],[10,11,12]])` gives `[[-3,0,3],[0,-3,-6]]`

black Used in the Symbolic view of the Geometry app. In the definition of a geometric object, including the statement “display=black” specifies that the object defined will be drawn in black.

blue Used in the Symbolic view of the Geometry app. In the definition of a geometric object, including the statement “display=blue” specifies that the object defined will be drawn in dark blue.

bounded_function Returns the argument returned by a limit function thereby indicating that the function is bounded.

breakpoint Used in programming to insert an intentional stopping or pausing point.

canonical_form Returns a second degree trinomial in canonical form.

```
canonical_form(QuadraticExpr,[Var])
```

Example:

`canonical_form(2*x^2-12*x+1)` gives `2*(x-3)^2-17`

cat Evaluates the objects in a sequence, then returns them concatenated as a string.

```
cat(Object1, Object2,…)
```

Example:

`cat("aaa",c,12*3)` gives `"aaac36"`

cFactor Returns an expression factorized over the complex field (on Gaussian integers if there are more than two).

```
cfactor(Expr)
```

Example:

`cFactor(x^2*y+y)` gives `(x+i)*(x-i)*y`

charpoly Returns the coefficients of the characteristic polynomial of a matrix. With only one argument, the variable used in the polynomial is *x*. With a variable as second argument, the polynomial returned is in terms of that variable.

```
charpoly(Mtrx,[Var])
```

Example:

`charpoly` $\left(\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}, z\right)$ returns $z^2-5\cdot z-2$

chrem Returns a vector containing the Chinese remainders for two sets of integers, contained in either two vectors or two lists.

```
chrem(List1, List2) or chrem(Vector1, Vector2)
```

Example:

`chrem([2,3],[7,5])` returns `[-12,35]`

col Given a matrix and integer *n*, returns the column of index *n* of the matrix.

```
col(Matrix, Integer)
```

Example:

`col`$\left(\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\\ 7 & 8 & 9\end{bmatrix}, 2\right)$ returns `[2,5,8]`

colDim Returns the number of columns of a matrix.

```
colDim(Mtrx)
```

Example:

`colDim`$\left(\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\end{bmatrix}\right)$ returns `3`

comDenom Rewrites a sum of rational fractions as a one rational fraction. The denominator of the one rational fraction is the common denominator of the rational fractions in the original expression. With a variable as second argument, the numerator and denominator are developed according to it.

```
comDenom(Expr,[Var])
```

Example:

`comDenom(1/x+1/y^2+1)` gives `(x*y^2+x+y^2)/(x*y^2)`

companion Returns the companion matrix of a polynomial.

```
companion(Poly,Var)
```

Example:

`companion(x^2+5x-7,x)` returns $\left(\begin{bmatrix} 0 & 7 \\ 1 & -5 \end{bmatrix}\right)$

compare Compares objects, and returns 1 if type(arg1)<type(arg2) or if type(arg1)=type(arg2) and arg1<arg2, and returns 0 otherwise.

```
compare(Object1,Object2)
```

Example:

`compare(1,2)` gives `1`

complexroot With a polynomial and a real as its two arguments, returns a matrix. Each row of the matrix contains either a complex root of the polynomial with its multiplicity or an interval containing such a root and its multiplicity. The interval defines a (possibly) rectangular region in the complex plane where a complex root lies.

With two additional complex numbers as third and fourth arguments, returns a matrix as described for two arguments, but only for those roots lying in the rectangular region defined by the diagonal created by the two complex numbers

```
complexroot(Poly, Real, [Complex1], [Complex2])
```

Example:

`complexroot(x^3+8, 0.01)` returns

$$\begin{bmatrix} -2 & 1 \\ \begin{bmatrix} \frac{1017-1782\cdot i}{1024} & \frac{1026-1773\cdot i}{1024} \end{bmatrix} & 1 \\ \begin{bmatrix} \frac{1395+378\cdot i}{512-512\cdot i} & \frac{-189+702\cdot i}{256+256\cdot i} \end{bmatrix} & 1 \end{bmatrix}$$

This matrix indicates there is 1 complex root at *x*=–2, with another root between the two values in the second row vector and a third root between the two values in the third row vector.

contains Given a list or vector and an element, returns the index of the first occurrence of the element in the list or vector; if the element does not appear in the list or vector, returns 0.

`contains((List, Element)` or `contains(Vector, Element)`

Example:

`contains({0,1,2,3},2)` returns `3`

CopyVar Copies the first variable into the second variable without evaluation.

`CopyVar(Var1,Var2)`

correlation Returns the correlation of the elements of a list or matrix.

`correlation(List)` or `correlation(Matrix)`

Example:

`correlation` $\begin{bmatrix} 1 & 2 \\ 1 & 1 \\ 4 & 7 \end{bmatrix}$ returns $\frac{33}{6 \cdot \sqrt{31}}$

count Applies a function to the elements in a list or matrix and returns their sum.

`count(Function, List)` or `count(Function, Matrix)`

Example:

`count((x→x,[2,12,45,3,7,78])` returns `147`

covariance Returns the covariance of the elements in a list or matrix.

`covariance(List)` or `covariance(Matrix)`

Example:

`covariance` $\left(\begin{bmatrix} 1 & 2 \\ 1 & 1 \\ 4 & 7 \end{bmatrix}\right)$ returns $\frac{11}{3}$

covariance_ correlation Returns a vector containing both the covariance and the correlation of the elements of a list or matrix.

`covariance_correlation(List)` or
`covariance_correlation(Matrix)`

Example:

`covariance_correlation` $\left(\begin{bmatrix} 1 & 2 \\ 1 & 1 \\ 4 & 7 \end{bmatrix}\right)$ returns $\begin{bmatrix} \frac{11}{3} & \frac{33}{6 \cdot \sqrt{31}} \end{bmatrix}$

cpartfrac Returns the result of partial fraction decomposition of a rational fraction in the complex field.

`cpartfrac(RatFrac)`

Example:

`cpartfrac`$\left(\frac{x}{4-x^2}\right)$ returns $-\frac{\frac{1}{2}}{x-2}-\frac{\frac{1}{2}}{x+2}$

crationalroot Returns the list of complex rational roots of a polynomial without indicating the multiplicity.

`crationalroot(Poly)`

Example:

`crationalroot(2*x^3+(-5-7*i)*x^2+`

`(-4+14*i)*x+8-4*i)` returns $\begin{bmatrix} \frac{3+i}{2} & 2 \cdot i & 1+i \end{bmatrix}$

cumSum Accepts as argument either a list or a vector and returns a list or vector whose elements are the cumulative sum of the original argument.

`cumSum(List)` or `cumSum(Vector)`

Example:

`cumSum([0,1,2,3,4])` returns `[0,1,3,6,10]`

cyan Used in the Symbolic view of the Geometry app. In the definition of a geometric object, including the statement “display=cyan” specifies that the object defined will be drawn in light blue.

delcols Given a matrix and an integer *n*, deletes the *n*th column from the matrix and returns the result. If an interval of two integers is used instead of a single integer, deletes all columns in the interval and returns the result.

`delcols(Matrix, Integer)` or `delcols(Matrix, Intg1..Intg2)`

Example:

$$\texttt{delcols}\left(\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\\ 7 & 8 & 9\end{bmatrix}, 2\right) \text{ returns } \begin{bmatrix}1 & 3\\ 4 & 6\\ 7 & 9\end{bmatrix}$$

delrows Given a matrix and an integer n, deletes the nth row from the matrix and returns the result. If an interval of two integers is used instead of a single integer, deletes all rows in the interval and returns the result.

`delrows(Matrix, Integer)` or `delrows(Matrix, Intg1..Intg2)`

Example:

$$\texttt{delrows}\left(\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\\ 7 & 8 & 9\end{bmatrix}, 2..3\right) \text{ returns } \begin{bmatrix}1 & 2 & 3\end{bmatrix}$$

deltalist Returns the list of the differences between consecutive terms in the original list.

`deltalist(Lst)`

Example:

`deltalist([1,4,8,9])` gives `[3,4,1]`

Dirac Returns the value of the Dirac delta function for a real number.

`Dirac(Real)`

Example:

`Dirac(1)` gives `0`

e Enters the mathematical constant e (Euler's number).

egcd Given two polynomials, A and B, returns three polynomials U, V and D such that:

`U(x)*A(x)+V(x)*B(x)=D(x),`

where `D(x)=GCD(A(x),B(x))`, the greatest common divisor of polynomials A and B.

The polynomials can be provided in symbolic form or as lists of coefficients in descending order.

Without a third argument, it is assumed that the polynomials are expressions of *x*. With a variable as third argument, the polynomials are expressions of it.

`egcd((PolyA, PolyB, [Var])` or `egcd(ListA, ListB, [Var])`

Example:

`egcd((x-1)^2,x^3-1)` gives `[-x-2,1,3*x-3]`

eigenvals Returns the sequence of eigenvalues of a matrix.

`eigenvals(Matrix)`

Example:

$$\texttt{eigenvals}\left(\begin{bmatrix}-2 & -2 & 1\\ -2 & 1 & -2\\ 1 & -2 & -2\end{bmatrix}\right) \text{ returns } [3\ \ -3\ \ -3]$$

eigenvects Returns the eigenvectors of a diagonalizable matrix.

`eigenvects(Matrix)`

Example:

$$\texttt{eigenvects}\left(\begin{bmatrix}-2 & -2 & 1\\ -2 & 1 & -2\\ 1 & -2 & -2\end{bmatrix}\right) \text{ returns } \begin{bmatrix}1 & -3 & -3\\ -2 & 0 & -3\\ 1 & 3 & -3\end{bmatrix}$$

eigVl Returns the Jordan matrix associated with a matrix when the eigenvalues are calculable.

`eigVl(Matrix)`

EVAL Evaluates an expression.

`eval(Expr)`

Example:

`eval(2+3)` returns `5`

evalc Returns a complex expression written in the form `real+i*imag`.

```
evalc(Expr)
```

Example:

$\texttt{evalc}\left(\frac{1}{x+y\cdot i}\right)$ returns $\frac{x}{x^2+y^2}-\frac{i\cdot y}{x^2+y^2}$

evalf Given an expression and a number of significant digits, returns the numerical evaluation of the expression to the given number of significant digits. With just an expression, returns the numerical evaluation based on the CAS settings.

```
evalf(Expr,[Integer])
```

Example:

`evalf(2/3)` gives `0.666666666667`

even Tests whether or not an integer is even. Returns 1 if it is and 0 if it is not.

Example:

`even(1251)` returns `0`

exact Converts a decimal expression to a rational or real expression.

```
exact(Expr)
```

Example:

`exact(1.4141)` gives `14141/10000`

EXP Returns the solution to the mathematical constant e to the power of an expression.

```
exp(Expr)
```

Example:

`exp(0)` gives `1`

exponential_ regression Given a set of points, returns a vector containing the coefficients *a* and *b* of `y=b*a^x`, the exponential which best fits the set of points. The points may be the elements in two lists or the rows of a matrix.

`exponential_regression(Matrix)` or
`exponential_regression(List1, List2)`

Example:

`exponential_regression` $\left(\begin{bmatrix}1.0 & 2.0\\ 0.0 & 1.0\\ 4.0 & 7.0\end{bmatrix}\right)$ returns

`1.60092225473,1.10008339351`

EXPR Parses the string *String* into a number or expression.

`expr (`*`String`*`)`

Examples:

`expr("2+3")` returns `5`

`expr("X+10")` returns `100`, if the variable *X* has the value 90

ezgcd Uses the EZ GCD algorithm to return the greatest common divisor of two polynomials with at least two variables.

`ezgcd(Poly1,Poly2)`

Example:

`ezgcd(x^2-2*xy+y^2-1,x-y)` returns `1`

f2nd Returns a vector consisting of the numerator and denominator of an irreducible form of a rational fraction.

`f2nd(RatFrac)`

Example:

`f2nd` $\left(\frac{x}{x\cdot\sqrt{x}}\right)$ returns $\left[1\ \sqrt{x}\right]$

factorial Returns the factorial of an integer or the solution to the gamma function for a non-integer.

`factorial(Integer)` or `factorial(Real)`

Example:

`factorial(4)` gives `24`

fMax Given an expression in *x*, returns the value of *x* for which the expression has its maximum value. Given an expression and a variable, returns the value of that variable for which the expression has its maximum value.

```
fMax(Expr,[Var])
```

Example:

`fMax(-x^2+2*x+1,x)` gives `1`

fMin Given an expression in *x*, returns the value of *x* for which the expression has its minimum value. Given an expression and a variable, returns the value of that variable for which the expression has its minimum value.

```
fMin(Expr,[Var])
```

Example:

`fMin(x^2-2*x+1,x)` gives `1`

format Returns a real number as a string with the indicated format (f=float, s=scientific, e=engineering).

```
format(Real, String)
```

Example:

`format(9.3456,"s3")` returns `9.35`

fracmod For a given integer *n* (representing a fraction) and an integer *p* (the modulus), returns the fraction *a/b* such that *n=a/b*(mod *p*).

```
fracmod(Integern, Integerp)
```

Example:

`fracmod(41,121)` gives `2/3`

froot Returns a vector containing the roots and poles of a rational polynomial. Each root or pole is followed by its multiplicity.

```
froot(RatPoly)
```

Example:

$\texttt{froot}\left(\frac{x^5 - 2 \cdot x^4 + x^3}{x - 3}\right)$ returns `[0,3,1,2,3,-1]`

fsolve Returns the numerical solution of an equation or a system of equations. With the optional third argument you can specify a guess for the solution or an interval within which it is expected that the solution will occur. With the optional fourth argument you can name the iterative algorithm to be used by the solver.

```
fsolve(Expr,Var,[Guess or Interval],[Method])
```

Example:

`fsolve(cos(x)=x,x,-1..1,bisection_solver)` gives `[0.739085133215]`

function_diff Returns the derivative function of a function (as a mapping).

```
function_diff(Fnc)
```

Example:

`function_diff(sin)` gives `(_x)→cos(_x)`

gauss Given an expression followed by a vector of variables, uses the Gauss algorithm to return the quadratic form of the expression written as a sum or difference of squares of the variables given in the vector.

```
gauss(Expr,VectVar)
```

Example:

`gauss(x^2+2*a*x*y,[x,y])` gives `(a*y+x)^2+(-y^2)*a^2`

GF Creates a Galois Field of characteristic *p* with *p*^*n* elements.

```
GF(Integerp, Integern)
```

Example:

`GF(5,9)` gives `GF(5,k^9-k^8+2*k^7+2*k^5-k^2+2*k-2,[k,K,g],undef)`

gramschmidt Given a basis of a vector subspace, and a function that defines a scalar product on this vector subspace, returns an orthonormal basis for that function.

```
gramschmidt(Vector, Function)
```

Example:

$$\texttt{gramschmidt}\left(\begin{bmatrix}1 & 1+x\end{bmatrix}, (p,q) \rightarrow \int_{-1}^{1} p \cdot q\,dx\right) \text{ returns}$$

$$\begin{bmatrix}\frac{1}{\sqrt{2}} & \frac{1+x-1}{\frac{\sqrt{6}}{3}}\end{bmatrix}$$

green Used in the Symbolic view of the Geometry app. In the definition of a geometric object, including the statement "`display=green`" specifies that the object defined will be drawn in green.

halftan2hypexp Returns an expression with sine, cosine, and tangent rewritten in terms of half-tangent, and sinh, cosh, and tanh rewritten in terms of the natural exponential.

```
halftan_hyp2exp(ExprTrig)
```

Example:

`halftan_hyp2exp(sin(x)+sinh(x))` returns

$$\frac{2 \cdot \tan\left(\frac{x}{2}\right)}{\tan\left(\frac{x}{2}\right)^2 + 1} + \frac{\exp(x) - \frac{1}{\exp(x)}}{2}$$

halt Used in programming to go into step-by-step debugging mode.

hamdist Returns the Hamming distance between two integers.

```
hamdist(Integer1, Integer2)
```

Example:

`hamdist(0x12,0x38)` gives `3`

has Returns 1 if a variable is in an expression, and returns 0 otherwise.

```
has(Expr,Var)
```

Example:

`has(x+y,x)` gives `1`

head Returns the first element of a given vector, sequence or string.

`head(Vector)` or `head(String)` or
`head(Obj1, Obj2,…)`

Example:

`head(1,2,3)` gives `1`

Heaviside Returns the value of the Heaviside function for a given real number (i.e. 1 if *x*>=0, and 0 if *x*<0).

```
Heaviside(Real)
```

Example:

`Heaviside(1)` gives `1`

hyp2exp Returns an expression with hyperbolic terms rewritten as exponentials.

```
hyp2exp(Expr)
```

Example:

`hyp2exp(cosh(x))` returns $\frac{\exp(x)+\frac{1}{\exp(x)}}{2}$

iabcuv Returns [u,v] such as au+bv=c for three integers a,b, and c. Note that c must be a multiple of the greatest common divisor of a and b for there to be a solution.

```
iabcuv(Intgra, Intgrb, Intgrc)
```

Example:

`iabcuv(21,28,7)` gives `[-1,1]`

ibasis Given two matrices, interprets them as two vector spaces and returns the vector basis of their intersection.

```
ibasis(Matrix1, Matrix2)
```

Example:

$\texttt{ibasis}\left(\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\end{bmatrix},\begin{bmatrix}1 & 1 & 1\\0 & 0 & 1\end{bmatrix}\right)$ returns `[-1,-1,0]`

icontent Returns the greatest common divisor of the integer coefficients of a polynomial.

```
icontent(Poly,[Var])
```

Example:

`icontent(24x^3+6x^2-12x+18)` gives `6`

id Returns a vector containing the solution to the identity function for the argument(s).

```
id(Object1, [Object2,…])
```

Example:

`id([1  2], 3, 4)` returns `[[1  2]  3  4]`

identity Given an integer *n*, returns the identity matrix of dimension *n*.

```
identity(Integer)
```

Example:

`identity(3)` returns $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

iegcd Returns the extended greatest common divisor of two integers.

```
iegcd(Integer1, Integer2)
```

Example:

`iegcd(14, 21)` returns `[-1, 1, 7]`

igcd Returns the greatest common divisor of two integers or two rational numbers or two polynomials of several variables.

`igcd((Integer1, Integer2)` or
`igcd(Ratnl1, Ratnl2)` or
`igcd(Poly1, Poly2)`

Examples:

`igcd(24, 36)` returns `12`

`igcd(2/3,3/4)` returns `1/12`

interval2center Returns the center of an interval.

```
interval2center(Interval)
```

Example:

`interval2center(2..5)` returns `7/2`

inv Returns the inverse of an expression or matrix.

`inv(Expr)` or `inv(Matrix)`

Example:

`inv(9/5)` returns `5/9`

iPart Returns a real number without its fractional part or a list of real numbers each without its fractional part.

`iPart(Real)` or `iPart(List)`

Example:

`iPart(4.3)` returns `4`

iquorem Returns the Euclidean quotient and remainder of two integers.

`iquorem(Integer1, Integer2)`

Example:

`iquorem(63, 23)` returns `[2, 17]`

jacobi_symbol Returns the Jacobi symbol of the given integers.

`jacobi_symbol(Integer1, Integer2)`

Example:

`jacobi_symbol(132,5)` gives `-1`

laplacian Returns the Laplacian of an expression with respect to a vector of variables

`laplacian(Expr, Vector)`

Example:

`laplacian(exp(z)*cos(x*y),[x,y,z])` returns
`-x^2*cos(x*y)*exp(z)-`
`y^2*cos(x*y)*exp(z)+cos(x*y)*exp(z)`

lcoeff Returns the coefficient of the term of highest degree of a polynomial. The polynomial can be expressed in symbolic form or as a list.

`lcoeff(Poly)` or `lcoeff(List)` or `lcoeff(Vector)`

Example:

`lcoeff(-2*x^3+x^2+7*x)` returns `-2`

legendre_symbol With a single integer *n*, returns the Legendre polynomial of degree *n*. With two integers, returns the Legendre symbol of the second integer, using the Legendre polynomial whose degree is the first integer.

`legendre_symbol(Integer1, [Integer2])`

Example:

`legendre(4)` gives `35*x^4/8+-15*x^2/4+3/8` while
`legendre(4,2)` returns `443/8` after simplificatio`n`

length Returns the length of a list, string or set of objects.

length(List) or length(String) or
length(Object1, Object2,…)

Example:

length([1,2,3]) gives 3

lgcd Returns the greatest common divisor of a set of integers or polynomials, contained in a list, a vector, or just entered directly as arguments.

lgcd(List) or lgcd(Vector) or lgcd(Integer1,
Integer2, …) or lgcd(Poly1, Poly2, …)

Example:

lgcd([45,75,20,15]) gives 5

lin Returns an expression with the exponentials linearized.

lin(Expr)

Example:

lin((exp(x)^3+exp(x))^2) gives
exp(6*x)+2*exp(4*x)+exp(2*x)

linear_interpolate Takes a regular sample from a polygonal line defined by a matrix of two rows.

linear_interpolate(Matrix,Xmin,Xmax,Xstep)

Example:

linear_interpolate([[1,2,6,9],[3,4,6,7]],1,9,
1) returns
[[1.0,2.0,3.0,4.0,5.0,6.0,7.0,8.0,9.0],
[3.0,4.0,4.5,5.0,5.5,6.0,6.33333333333,6.6666
6666667,7.0]

linear_regression Given a set of points, returns a vector containing the coefficients *a* and *b* of y=a*x+b, the linear which best fits the set of points. The points may be the elements in two lists or the rows of a matrix.

linear_regression(Matrix) or
linear_regression(List1, List2)

Example:

$$\texttt{linear\_regression}\left(\begin{bmatrix}1.0 & 2.0\\0.0 & 1.0\\4.0 & 7.0\end{bmatrix}\right) \text{ returns } [1.53\ldots, 0.769\ldots]$$

list2mat Returns a matrix of *n* columns made by splitting a list into rows, each containing *n* terms. If the number of elements in the list is not divisible by *n*, then the matrix is completed with zeros.

```
list2mat(List, Integer)
```

Example:

`list2mat({1,8,4,9},1)` returns $\begin{bmatrix}1\\8\\4\\9\end{bmatrix}$

lname Returns a list of the variables in an expression.

```
lname(Expr)
```

Example:

`lname(exp(x)*2*sin(y))` gives `[x,y]`

lnexpand Returns the expanded form of a logarithmic expression.

```
lnexpand(Expr)
```

Example:

`lnexpand(ln(3*x))` gives `ln(3)+ln(x)`

logarithmic_regression Given a set of points, returns a vector containing the coefficients a and b of y=a*ln(x)+b, the natural logarithmic function which best fits the set of points. The points may be the elements in two lists or the rows of a matrix.

`logarithmic_regression(Matrix)` or
`logarithmic_regression(List1, List2)`

Example:

`logarithmic_regression` $\begin{bmatrix}1.0 & 1.0\\2.0 & 4.0\\3.0 & 9.0\\4.0 & 9.0\end{bmatrix}$ returns

`[6.3299…, 0.7207…]`

logb Returns the logarithm of base *b* of *a*.

```
logb(a,b)
```

Example:

`logb(5,2)` gives `ln(5)/ln(2)` which is approximately 2.32192809489

logistic_regression Returns y, y', C, y'max, xmax, and R, where y is a logistic function (the solution of y'/y=a*y+b), such that y(x0)=y0 and where [y'(x0),y'(x0+1)...] is the best approximation of the line formed by the elements in the list L.

```
logistic_regression(Lst(L),Real(x0),Real(y0))
```

Example:

`logistic_regression([0.0,1.0,2.0,3.0,4.0],0.0,1.0)` gives `[-17.77/(1+exp(-0.496893925384*x+2.82232341488+3.14159265359*i)),-2.48542227469/(1+cosh(-0.496893925384*x+2.82232341488+3.14159265359*i))]`

lvar Returns a list of variables used in an expression.

```
lvar(Expr)
```

Example:

`lvar(exp(x)*2*sin(y))` gives `[exp(x),sin(y)]`

magenta Used in the Symbolic view of the Geometry app. In the definition of a geometric object, including the statement "`display=magenta`" specifies that the object defined will be drawn in magenta.

map Applies a function to the elements of the list.

```
map(List, Function)
```

Example:

`map([1,2,3],x→x^3)` gives `[1,8,27]`

mat2list Returns a list containing the elements of a matrix.

```
mat2list(Matrix)
```

Example:

`mat2list([[1,8],[4,9]])` gives `[1,8,4,9]`

matpow Given a matrix and an integer n, returns the nth power of the matrix by jordanization.

```
matpow(Matrix, Integer)
```

Example:

`matpow([[1,2],[3,4]],n)` gives `[[(sqrt(33)-3)*((sqrt(33)+5)/2)^n*-6/(-12*sqrt(33))+(-(sqrt(33))-3)*((-(sqrt(33))+5)/2)^n*6/(-12*sqrt(33)),(sqrt(33)-3)*((sqrt(33)+5)/2)^n*(-(sqrt(33))-3)/(-12*sqrt(33))+(-(sqrt(33))-3)*((-(sqrt(33))+5)/2)^n*(-(sqrt(33))+3)/(-12*sqrt(33))],[6*((sqrt(33)+5)/2)^n*-6/(-12*sqrt(33))+6*((-(sqrt(33))+5)/2)^n*6/(-12*sqrt(33)),6*((sqrt(33)+5)/2)^n*(-(sqrt(33))-3)/(-12*sqrt(33))+6*((-(sqrt(33))+5)/2)^n*(-(sqrt(33))+3)/(-12*sqrt(33))]]`

MAXREAL Returns the maximum real number that the HP Prime is capable of representing: $1.79769313486 * 10^{308}$.

mean Returns the arithmetic mean of a list (with an optional list as a list of weights). With a matrix as argument, returns the mean of the columns.

`mean(List1, [List2])` or `mean(Matrix)`

Example:

`mean([1,2,3],[1,2,3])` gives `7/3`

median Returns the median of a list (with an optional list as a list of weights). With a matrix as argument, returns the median of the columns.

`median(List1, [List2]) or median(Matrix)`

Example:

`median([1,2,3,5,10,4])` gives `3.0`

member Given a list or vector and an element, returns the index of the first occurrence of the element in the list or vector; if the element does not appear in the list or vector, returns 0. Similar to `contains`, except that the element comes first in the argument order.

`member(( Element, List)` or `contains(Element, Vector)`

Example:

`member(2, {0,1,2,3})` returns `3`

MINREAL Returns the minimum real number that the HP Prime is capable of representing: $2.22507385851 * 10^{-308}$.

modgcd Uses the modular algorithm to return the greatest common divisor of two polynomials.

```
modgcd(Poly1,Poly2)
```

Example:

`modgcd(x^4-1,(x-1)^2)` gives `x-1`

mRow Given an expression, a matrix, and an integer *n*, multiplies row *n* of the matrix by the expression.

```
mRow(Expr, Matrix, Integer)
```

Example:

$\mathtt{mRow}\left(12, \begin{bmatrix}1 & 2\\ 3 & 4\\ 5 & 6\end{bmatrix}, 1\right)$ returns $\begin{bmatrix}12 & 24\\ 3 & 4\\ 5 & 6\end{bmatrix}$

mult_c_conjugate If the given complex expression has a complex denominator, returns the expression after both the numerator and the denominator have been multiplied by the complex conjugate of the denominator. If the given complex expression does not have a complex denominator, returns the expression after both the numerator and the denominator have been multiplied by the complex conjugate of the numerator.

```
mult_c_conjugate(Expr)
```

Example:

$\mathtt{mult\_c\_conjugate}\left(\frac{1}{3+2\cdot i}\right)$ returns $\frac{1\cdot(3+2\cdot -i)}{(3+2\cdot i)\cdot(3+2\cdot -i)}$

mult_conjugate Takes an expression in which the numerator or the denominator contains a square root. If the denominator contains a square root, returns the expression after both the numerator and the denominator have been multiplied by the complex conjugate of the denominator. If the denominator does not contain a square root, returns the expression after both the numerator and the denominator have been multiplied by the complex conjugate of the numerator.

```
mult_conjugate(Expr)
```

Example:

$\mathtt{mult\_conjugate}(\sqrt{3}-\sqrt{2})$ returns $\frac{(\sqrt{3}-\sqrt{2})\cdot(\sqrt{3}+\sqrt{2})}{\sqrt{3}+\sqrt{2}}$

nDeriv Given an expression, a variable of differentiation, and a real number *h*, returns an approximate value of the derivative of the expression, using `f'(x)=(f(x+h)-f(x+h))/(2*h).`

Without a third argument, the value of *h* is set to 0.001; with a real as third argument, it is the value of h. With a variable as the third argument, returns the expression above with that variable in place of *h*.

`nDeriv(Expr,Var, Real)` or
`nDeriv(Expr, Var1, Var2)`

Example:

`nDeriv(f(x),x,h)` returns `(f(x+h)-(f(x-h)))*0.5/h`

NEG Unary minus. Enters the negative sign.

normal Returns the expanded irreducible form of an expression.

`normal(Expr)`

Example:

`normal(2*x*2)` gives `4*x`

normalize Given a vector, returns it divided by its l_2 norm (where the l_2 norm is the square root of the sum of the squares of the vector's coordinates).

Given a complex number, returns it divided by its modulus.

`normalize(Vector)` or `normalize(Complex)`

Example:

`normalize(3+4*i)` gives `(3+4*i)/5`

NOT Returns the logical inverse of a Boolean expression.

`not(Expr)`

odd Returns 1 if a given integer is odd, and returns 0 otherwise.

`odd(Integer)`

Example:

`odd(6)` gives `0`

OR Logical Or. Returns 1 if either or both sides evaluates to true and 0 otherwise.

`Expr1 OR Expr2`

Example:

`3 +1==4 OR 8 < 5` returns `1`

order_size Returns the remainder (O term) of a series expansion: limit(x^a*order_size(x),x=0)=0 if a>0.

```
order_size(Expr)
```

pa2b2 Takes a prime integer n congruent to 1 modulo 4 and returns [a,b] such that a^2+b^2=n.

```
pa2b2(Integer)
```

Example:

`pa2b2(17)` gives `[4 1]`

pade Returns the Pade approximation of an expression, i.e. a rational fraction P/Q such that P/Q=Expr mod x^(n+1) or mod N with degree(P)<p.

```
pade(Expr, Var, Integern, Integerp)
```

Example:

`pade(exp(x), x, 5, 3)` returns $\frac{-3 \cdot x^2 - 24 \cdot x - 60}{x^3 - 9 \cdot x^2 + 36 \cdot x - 60}$

PI Inserts π.

PIECEWISE Used to define a piecewise-defined function. Takes as arguments pairs consisting of a condition and an expression. Each of these pairs defines a sub-function of the piecewise function and the domain over which it is active.

$$\text{PIECEWISE}\begin{cases} \text{Case1} & \textit{if } \text{Test1} \\ \text{Case2} & \textit{if } \text{Test2} \\ \quad\ldots \end{cases}$$

Example:

$$\text{PIECEWISE}\begin{cases} -x \ \textit{if}\ x < 0 \\ x^2 \ \textit{if}\ x \geq 0 \end{cases}$$

Note that the syntax varies if the Entry setting is not set to Textbook:

```
PIECEWISE(Case1, Test1, ...[ Casen, Testn])
```

plotinequation

Shows the graph of the solution of inequations with 2 variables.

```
plotinequation(Expr,[x=xrange,y=yrange],[xste
p],[ystep])
```

plotparam Used in the Geometry app Symbolic view. Takes a complex expression in one variable and an interval for that variable as arguments. Interprets the complex expression `f(t)+i*g(t)` as `x=f(t)` and `y=g(t)` and plots the parametric equation over the interval specified in the second argument.

```
plotparam(f(Var)+i*g(Var), Var= Interval)
```

Example:

`plotparam(cos(t)+i*sin(t), t=0..2*π)` plots the unit circle

plotpolar Used in the Geometry app Symbolic view. Takes an expression in one variable f(x), and an interval for that variable as arguments. Draws the polar plot `r=f(x)` for *x* in the interval specified.

```
plotpolar(Expr,Var=Interval)
```

Example:

`plotpolar((π/2)`^{x}`, x=−π..π)` plots a partial spiral

plotseq Used in the Geometry app Symbolic view. Given an expression in *x* and a vector containing three values, draws the line y=x, the plot of the function defined by the expression over the domain defined by the interval between the last two values, and draws the cobweb plot for the first n terms of the sequence defined recursively by the expression (starting at the first value).

```
plotseq(f(Var), Var=[Start, Xmin, Xmax],
Integern)
```

Example:

`plotseq(1-x/2, x=[3  -1  6], 5)` plots y=x, y=1–x/2 (from x=–1 to x=6), then draws the first 5 terms of the cobweb plot for u(n)=1-(u(n–1)/2, starting at u(0)=3

polar_point Given the radius and angle of a point in polar form, returns the point with rectangular coordinates in complex form.

```
polar_point(Radius, Angle)
```

Example:

`polar_point(2, π/3)` returns $\texttt{point}\left(2\cdot\left(\frac{1}{2}+\frac{i\cdot\sqrt{3}}{2}\right)\right)$

pole Given a circle and a line, returns the point for which the line is polar with respect to the circle.

```
pole(Crcle,Line)
```

Example:

`pole(circle(0, 1), line(1+i, 2))` returns `point(1/2,1/2)`

POLYCOEF Returns the coefficients of a polynomial with roots given in the vector or list argument.

`POLYCOEF(Vector)` or `POLYCOEF(List)`

Example:

`POLYCOEF({-1, 1})` returns `{1, 0, -1}`

POLYEVAL Given a vector or list of coefficients and a value, evaluates the polynomial given by those coefficients at the given value.

`POLYEVAL(Vector, Value)` or `POLYEVAL(List, Value)`

Example:

`POLYEVAL({1,0,-1},3)` returns `8`

polygon Draws the polygon whose vertices are elements in a list.

```
polygon(Point1, Point2, …, Pointn)
```

Example:

```
polygon(GA,GB,GD) draws ΔABD
```

polygonplot Used in the Geometry app Symbolic view. Given an *n* × *m* matrix, draws and connects the points (*xk*, *yk*), where *xk* is the element in row *k* and column 1, and *yk* is the element in row k and column *j* (with *j* fixed for *k*=1 to *n* rows). Thus, each column pairing generates its own figure, resulting in *m*–1 figures.

```
polygonplot(Matrix)
```

Example:

`polygonplot` $\left(\begin{bmatrix} 1 & 2 & 3 \\ 2 & 0 & 1 \\ -1 & 2 & 3 \end{bmatrix}\right)$ draws two figures, each with three points connected by segments.

polygonscatterplot Used in the Geometry app Symbolic view. Given an *n* × *m* matrix, draws and connects the points (*xk, yk)*, where *xk* is the element in row *k* and column 1, and *yk* is the element in row k and column *j* (with *j* fixed for *k*=1 to *n* rows). Thus, each column pairing generates its own figure, resulting in *m*– figures.

`polygonscatterplot(Matrix)`

Example:

`polygonscatterplot`$\left(\begin{bmatrix}1 & 2 & 3\\ 2 & 0 & 1\\ -1 & 2 & 3\end{bmatrix}\right)$ draws two figures, each with three points connected by segments.

polynomial_ regression Given a set of points defined by two lists, and a positive integer *n*, returns a vector containing the coefficients (a_n, a_{n-1} ... a_0) of y = a_n*x^n + $a_{n-1}x^{n-1}$+ ... a_1*x + a_0), the *n*th order polynomial which best approximates the given points.

`polynomial_regression(List1, List2, Integer)`

Example:

`polynomial_regression({1, 2, 3, 4}, {1, 4, 9, 16},3)` returns `[0  1  0  0]`

POLYROOT Returns the zeros of the polynomial given as argument (either as a symbolic expression or as a vector of coefficients).

`POLYROOT(Poly)` or `POLYROOT(Vector)`

Example:

`POLYROOT([1  0  -1])` returns `[-1  1]`

potential Returns a function whose gradient is the vector field defined by a vector and a vector of variables.

`potential(Vector1, Vector2)`

Example:

`potential([2*x*y+3,x^2-4*z,-4*y],[x,y,z])` returns x^2`*y+3*x-4*y*z`

power_regression Given a set of points defined by two lists, returns a vector containing the coefficients *m* and *b* of *y=b*x^m*, the monomial which best approximates the given points.

```
power_regression(List1, List2)
```

Example:

`power_regression({1, 2, 3, 4}, {1, 4, 9, 16})` returns `[2  1]`

powerpc Given a circle and a point, returns the real number $d^2 – r^2$, where *d* is the distance between the point and the center of the circle, and *r* is the radius of the circle.

```
powerpc(Circle, Point)
```

Example:

`powerpc(circle(0,1+i),3+i)` gives `8`

prepend Adds an element to the beginning of a list or vector.

`prepend(List, Element)` or
`prepend(Vector, Element)`

Example:

`prepend([1,2],3)` gives `[3,1,2]`

primpart Returns a polynomial divided by the greatest common divisor of its coefficients.

```
primpart(Poly,[Var])
```

Example:

`primpart(2x^2+10x+6)` gives `x^2+5*x+3`

product With an expression as the first argument, returns the product of solutions when the variable in the expression goes from a minimum value to a maximum value by a given step. If no step is provided, it is taken as 1.

With a list as the first argument, returns the product of the values in the list.

With a matrix as the first argument, returns the element-by-element product of the matrix.

`product(Expr, Var, Min, Max, Step)` or
`product(List) or product(Matrix)`

Example:

`product(n,n,1,10,2)` gives `945`

propfrac Returns a fraction or rational fraction A/B simplified to Q+r/B, where R<B or the degree of R is less than the degree of B.

`propfrac(Fraction)` or `propfrac(RatFrac)`

Example:

`propfrac(28/12)` gives `2+1/3`

ptayl Given a polynomial P and a value *a*, returns the Taylor polynomial Q such that P(*x*)=Q(*x* – *a*).

`ptayl(Poly, Value, [Var])`

Example:

`ptayl(x^2+2*x+1,1)` gives `x^2+4*x+4`

purge Unassigns a variable name.

`purge(Var)`

q2a Given a quadratic form and a vector of variables, returns the matrix of the quadratic form with respect to the given variables.

`q2a(Expr, Vector)`

Example:

`q2a(x^2+2*x*y+2*y^2,[x,y])` returns $\begin{bmatrix}1 & 1\\ 1 & 2\end{bmatrix}$

quantile Given a list or vector, and a quantile value between 0 and 1, returns the corresponding quantile of the elements of the list or vector.

`quantile(List, Value)` or
`quantile(Vector, Value)`

Example:

`quantile([0,1,3,4,2,5,6],0.25)` returns `1`

quartile1 Given a list or vector, returns the first quartile of the elements of the list or vector. Given a matrix, returns the first quartile of the columns of the matrix.

`quartile1(List)` or `quartile1(Vector)` or
`quartile1(Matrix)`

Example:

`quartile1([1,2,3,5,10,4])` gives `2`

quartile3 Given a list or vector, returns the third quartile of the elements of the list or vector. Given a matrix, returns the third quartile of the columns of the matrix.

`quartile3(List)` or `quartile3(Vector)` or `quartile3(Matrix)`

Example:

`quartile3([1,2,3,5,10,4])` returns `5`

quartiles Returns a matrix containing the minimum, first quartile, median, third quartile, and maximum of the elements of a list or vector. With a matrix as argument, returns the 5-number summary of the columns of the matrix.

`quartiles(List)` or `quartiles(Vector)` or `quartiles(Matrix)`

Example:

`quartiles([1,2,3,5,10,4])` returns $\begin{bmatrix} 1 \\ 2 \\ 3 \\ 5 \\ 10 \end{bmatrix}$

quorem Returns the quotient and remainder of the Euclidean division (by decreasing power) of two polynomials. The polynomials can be expressed as vectors of their coefficients or in symbolic form.

`quorem(Poly,[Var])` or `quorem(Vector, [Var])`

Example:

`quorem([1,2,3,4],[-1,2])` returns `[[-1  -4  11] [26]]`

QUOTE Returns an expression unevaluated.

`quote(Expr)`

randexp Given a positive real number, returns a random real according to the exponential distribution.

`randexp(Real)`

Example:

`randexp(1)` gives `1.17118631006`

randperm Given a positive integer, returns a random permutation of [0,1,2,…,n–1].

```
randperm(Intg(n))
```

Example:

`randperm(4)` returns a random permutation of the elements of the vector `[0  1  2  3]`

ratnormal Rewrites an expression as an irreducible rational fraction.

```
ratnormal(Expr)
```

Example:

`ratnormal`$\left(\frac{x^2-1}{x^3-1}\right)$ returns $\frac{x+1}{x^2+x+1}$

reciprocation Given a circle and a vector containing points and lines, returns a vector containing the polar line of each point and the pole of each line, with respect to the circle.

```
reciprocation(Crcle,Lst(Pnt,Line))
```

Example:

`reciprocation(circle(0,1), [line(1+i, 2), point(1+i*2)])` returns $\left[\text{point}\left(\frac{1}{2},\frac{1}{2}\right)\ \text{line}\left(y=-\frac{1}{2}\cdot x+\frac{1}{2}\right)\right]$

rectangular_ coordinate Given a vector containing the polar coordinates of a point, returns a vector containing the rectangular coordinates of the point.

```
rectangular_coordinates(Vector)
```

Example:

`rectangular_coordinates([1, π/4])` returns $\left[\frac{\sqrt{2}}{2}\ \frac{\sqrt{2}}{2}\right]$

red Used in the Symbolic view of the Geometry app. In the definition of a geometric object, including the statement "`display=red`" specifies that the object defined will be drawn in red.

reduced_conic Takes a conic expression and returns a vector with the following items:

- The origin of the conic
- The matrix of a basis in which the conic is reduced
- 0 or 1 (0 if the conic is degenerate)
- The reduced equation of the conic
- A vector of the conic's parametric equations

```
reduced_conic(Expr, [Vector])
```

Example:

`reduced_conic(x^2+2*x-2*y+1)` returns

$$[[-1\ \ 0]]\begin{bmatrix}0 & 1\\ -1 & 0\end{bmatrix}1\,y^2+2\cdot x\left[-1+-i\cdot\left(-\frac{1}{2}\cdot x\cdot x+i\cdot x\right)\ x-4\ 4\ 0.1\,x^2+2\cdot x-2\cdot y+1-1+(-i)\cdot\left(\frac{-1}{2}\cdot x\cdot x+(i)\cdot x\right)\ \ \right]$$

ref Returns the solution to a system of linear equations written in matrix form.

```
ref(Matrix)
```

Example:

`ref` $\begin{bmatrix}3 & 1 & -2\\ 3 & 2 & 2\end{bmatrix}$ returns $\begin{bmatrix}1 & \frac{1}{3} & \frac{-2}{3}\\ 0 & 1 & 2\end{bmatrix}$

remove Given an element and a list or vector, removes any occurrence of that element in the list or vector and returns the result.

`remove(Element, Vector)` or
`remove(Element, List)`

Example:

`remove(6,[1  2  6  7])` returns `[1  2  7]`

reorder Given an expression and a vector of variables, reorders the variables in the expression according to the order given in the vector.

```
reorder(Expr, Vector)
```

Example:

`reorder(`x^2`+2*x+`y^2`,[y,x])` gives y^2+x^2+2*x

residue Returns the residue of an expression at *a* value.

```
residue(Expr, Var, Value)
```

Example:

`residue(1/z,z,0)` returns `1`

restart Purges all the variables.

```
restart(NULL)
```

resultant Returns the resultant (i.e. the determinant of the Sylvester matrix) of two polynomials.

```
resultant(Poly1, Poly2, Var)
```

Example:

`resultant(x^3+x+1, x^2-x-2,x)` returns `-11`

revlist Reverses the order of the elements in a list or vector.

`revlist(List)` or `revlist(Vector)`

Example:

`revlist([1,2,3])` returns `[3,2,1]`

romberg Uses Romberg's method to return the approximate value of a definite integral.

```
romberg(Expr, Var, Val1, Val2)
```

Example:

`romberg(exp(x^2),x,0,1)` gives `1.46265174591`

row Given a matrix and an integer *n*, returns the row *n* of the matrix. Given a matrix and an interval, returns a vector containing the rows of the matrix indicated by the interval.

`row(Matrix, Integer)` or `row(Matrix, Interval)`

Example:

$\mathrm{row}\left(\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\\ 7 & 8 & 9\end{bmatrix}, 2\right)$ returns `[4,5,6]`

rowAdd Given a matrix and two integers, returns the matrix obtained from the given matrix after the row indicated by the second integer is replaced by the sum of the rows indicated by the two integers.

```
rowAdd(Matrix, Integer1, Integer2)
```

Example:

$$\texttt{rowAdd}\left(\begin{bmatrix}1 & 2\\3 & 4\\5 & 6\end{bmatrix}, 1, 2\right) \text{ returns } \begin{bmatrix}1 & 2\\4 & 6\\5 & 6\end{bmatrix}$$

rowDim Returns the number of rows of a matrix.

```
rowDim(Matrix)
```

Example:

$$\texttt{rowDim}\left(\begin{bmatrix}1 & 2 & 3\\4 & 5 & 6\end{bmatrix}\right) \text{ gives } \texttt{2}$$

rowSwap Given a matrix and two integers, returns the matrix obtained from the given matrix after swapping the two rows indicated by the two integers.

```
rowSwap(Matrix,Integer1,Integer2)
```

Example:

$$\texttt{rowSwap}\left(\begin{bmatrix}1 & 2\\3 & 4\\5 & 6\end{bmatrix}, 1, 2\right) \text{ returns } \begin{bmatrix}3 & 4\\1 & 2\\5 & 6\end{bmatrix}$$

rsolve Given an expression defining a recurrence relation, a variable, and an initial condition, returns the closed form solution (if possible) of the recurrent sequence. Given three lists, each containing multiple items of the above nature, solves the system of recurrent sequences.

```
rsolve(Expr, Var, Condition) or rsolve(List1, List2, List3)
```

Example:

`rsolve(u(n+1)=2*u(n)+n,u(n),u(0)=1)` returns `[-n+2*2`^{n}`-1]`

select Given a Boolean expression in a single variable and a list or vector, tests each element in the list or vector and returns a list or vector containing the elements that satisfy the Boolean.

select(Expr, List) or select(Expr, Vector)

Example:

select(x→x>=5,[1,2,6,7]) gives [6,7]

seq Given an expression, a variable defined over an interval, and a step value, returns a vector containing the sequence obtained when the expression is evaluated within the given interval using the given step. If no step is provided, the step used is 1.

seq(Expr, Var=Interval, [Step])

Example:

seq(2^k,k=0..8) gives [1,2,4,8,16,32,64,128,256]

seqsolve Similar to rsolve. Given an expression defining a recurrence relation in terms of *n* and/or the previous term (*x*), followed by a vector of variables and an initial condition for *x* (the 0th term), returns the closed form solution (if possible) for the recurrent sequence. Given three lists, each containing multiple items of the above nature, solves the system of recurrent sequences.

seqsolve(Expr, Vector, Condition) or
rsolve(List1, List2, List3)

Example:

seqsolve(2x+n,[x,n],1) gives -n-1+2*2^n

shift_phase Returns the result of applying a phase shift of pi/2 to a trigonometric expression.

shift_phase(Expr)

Example:

shift_phase(sin(x)) gives -cos((pi+2*x)/2)

signature Returns the signature of a permutation.

signature(Vector)

Example:

signature([2 1 4 5]) returns -1

simult Returns the solution to a system of linear equations or several systems of linear equations presented in matrix form. In the case of one system of linear equations, takes a matrix of coefficients and a column matrix of constants, and returns the column matrix of the solution.

```
simult(Matrix1, Matrix2)
```

Example:

`simult` $\left(\begin{bmatrix}3 & 1\\3 & 2\end{bmatrix},\begin{bmatrix}-2\\2\end{bmatrix}\right)$ returns $\begin{bmatrix}-2\\4\end{bmatrix}$

sincos Returns an expression with the complex exponentials rewritten in terms of sin and cos.

```
sincos(Expr)
```

Example:

`sincos(exp(i*x))` gives `cos(x)+(i)*sin(x)`

spline Given two lists or vectors (one for the *x*-values and one for the *y*-values), as well as a variable and an integer degree, returns the natural spline through the points given by the two lists. The polynomials in the spline are in terms of the given variable and are of the given degree.

`spline(ListX, ListY, Var, Integer)` or
`spline(VectorX, VectorY, Var, Integer)`

Example:

`spline({0,1,2},{1,3,0},x,3)` returns

$$\left[\frac{-5}{4}\cdot x^3+\frac{13}{4}\cdot x+1 \quad \frac{5}{4}\cdot(x-1)^3+\frac{-15}{4}\cdot(x-1)^2-\frac{1}{2}\cdot(x-1)+3\right]$$

sqrt Returns the square root of an expression.

```
sqrt(Expr)
```

Example:

`sqrt(50)` gives `5*sqrt(2)`

stddev Returns the standard deviation of the elements of a list or a list of the standard deviations of the columns of a matrix. The optional second list is a list of weights.

`stddev(List1, [List2])` or
`stddev(Vector1, [Vector2])` or `stddev(Matrix.`

Example:

`stddev({1,2,3})` returns $\frac{\sqrt{6}}{3}$

stddevp Returns the population standard deviation of the elements of a list or a list of the population standard deviations of the columns of a matrix. The optional second list is a list of weights.

`stddevp(List1, [List2])` or
`stddevp(Vector1, [Vector2])` or
`stddevp(Matrix)`

Example:

`stddevp({1,2,3})` gives `1`

sto Stores a real or string in a variable.

```
sto((Real or Str),Var)
```

sturmseq Returns the Sturm sequence for a polynomial or a rational fraction.

```
sturmseq(Poly,[Var])
```

Example:

`sturmseq(x^3-1,x)` gives `[1 [[1 0 0 -1] [3 0 0] 9] 1]`

subMat Extracts from a matrix a sub matrix whose diagonal is defined by four integers. The first two integers define the row and column of the first element and the last two integers define the row and column of the last element of the sub matrix.

```
subMat(Matrix, Int1, Int2, Int3, Int4)
```

Example:

$$\texttt{subMat}\left(\begin{bmatrix}1 & 2\\ 3 & 4\\ 5 & 6\end{bmatrix}, 2, 1, 3, 2\right) \text{ returns } \begin{bmatrix}3 & 4\\ 5 & 6\end{bmatrix}$$

suppress Given a list and an element, deletes the first occurrence of the element in the list (if there is one) and returns the result.

```
suppress(List, Element)
```

Example:

`suppress([0 1 2 3 2],2)` returns `[0 1 3 2]`

surd Given an expression and an integer *n*, returns the expression raised to the power 1/*n*.

```
surd(Expr, Integer)
```

Example:

`surd(8,3)` gives $8^{\frac{1}{3}}$

sylvester Returns the Sylvester matrix of two polynomials.

```
sylvester(Poly1, Poly2, Var)
```

Example:

`sylvester(x`^{2}`-1,x`^{3}`-1,x)` gives $\begin{bmatrix} 1 & 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 \\ 0 & 0 & 1 & 0 & -1 \\ 1 & 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 & -1 \end{bmatrix}$

table Defines an array where the indexes are strings or real numbers.

```
table(SeqEqual(index_name=element_value))
```

tail Given a list, string, or sequence of objects, returns a vector with the first element deleted.

`tail(List)` or `tail(Vector)` or `tail(String)` or `tail(Obj1, Obj2,…)`

Example:

```
tail([3 2 4 1 0]) gives [2 4 1 0]
```

tan2cossin2 Returns an expression with tan(x) rewritten as (1–cos(2*x))/sin(2*x).

```
tan2cossin2(Expr)
```

Example:

`tan2cossin2(tan(x))` gives `(1-cos(2*x))/sin(2*x)`

tan2sincos2 Returns an expression with tan(x) rewritten as sin(2*x)/(1+cos(2*x)).

```
tan2sincos2(Expr)
```

Example:

`tan2sincos2(tan(x))` gives `sin(2*x)/(1+cos(2*x)`

transpose Returns a matrix transposed (without conjugation).

```
transpose(Matrix)
```

Example:

`transpose`$\left(\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}\right)$ returns $\begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix}$

trunc Given a value or list of values, as well as an integer *n*, returns the value or list truncated to *n* decimal places. If *n* is not provided, it is taken as 0. Accepts complex numbers.

`trunc(Real, Integer)` or `trunc(List, Integer)`

Example:

`trunc(4.3)` gives `4`

tsimplify Returns an expression with transcendentals rewritten as complex exponentials.

`tsimplify(Expr)`

Example:

`tsimplify(exp(2*x)+exp(x))` gives
`exp(x)^2+exp(x)`

type Returns the type of an expression (e.g. list, string).

`type(Expr)`

Example:

`type("abc")` gives `DOM_STRING`

unapply Returns the function defined by an expression and a variable.

`unapply(Expr,Var)`

Example:

`unapply(2*x^2,x)` gives `(x)→2*x^2`

valuation Returns the valuation (degree of the term of lowest degree) of a polynomial. With only a polynomial as argument, the valuation returned is for *x*. With a variable as second argument, the valuation is performed for it.

`valuation(Poly,[Var])`

Example:

`valuation(x^4+x^3)` gives `3`

variance Returns the variance of a list or the list of variances of the columns of a matrix. The optional second list is a list of weights.

`variance(List1, [List2])` or `variance(Matrix)`

Example:

`variance({3, 4, 2})` returns `2/3`

vpotential Given a vector V and a vector of variables, returns the vector U such that curl(U)=V.

```
vpotential(Vector1, Vector2)
```

Example:

vpotential([2*x*y+3,x^2-4*z,-2*y*z],[x,y,z])

returns $\begin{bmatrix}0 & -2\cdot x\cdot y\cdot z & 4\cdot x\cdot z-\frac{1}{3}\cdot x^{3}+3\cdot y\end{bmatrix}$

when Used to introduce a conditional statement.

XOR Exclusive or. Returns 1 if the first expression is true and the second expression is false or if the first expression is false and the second expression is true. Returns 0 otherwise.

```
Expr1 XOR Expr2
```

Example:

```
0 XOR 1 returns 1
```

yellow Used in the Symbolic view of the Geometry app. In the definition of a geometric object, including the statement "`display=yellow`" specifies that the object defined will be drawn in yellow.

zip Applies a bivariate function to the elements of two lists or vectors and returns the results in a vector. Without the default value the length of the vector is the minimum of the lengths of the two lists; with the default value, the shorter list is padded with the default value.

`zip('function'List1, List2, Default)` or
`zip('function', Vector1, Vector2, Default)`

Example:

`zip('+',[a,b,c,d], [1,2,3,4])` returns `[a+1 b+2 c+3 d+4]`

| Inserts a template for substituting a value for a variable in an expression.

```
Expr|Var1=Val1, [Var2=Val2, …]
```

^{2} Returns the square of an expression.

(Expr)^2

π Inserts pi.

∂ Inserts a template for a partial derivative expression.

Σ Inserts a template for a summation expression.

– Inserts a minus sign.

√ Inserts a square root sign.

∫ Inserts a template for an antiderivative expression.

≠ Inequality test. Returns 1 if the left and right sides are not equal and 0 if they are equal.

≤ Less than or equal inequality test. Returns 1 if the left side of the inequality is less than the right side or if the two sides are equal, and 0 otherwise.

≥ Greater than or equal inequality test. Returns 1 if the left side of the inequality is greater than the right side or if the two sides are equal, and 0 otherwise.

▶ Evaluates the expression then stores the result in variable var. Note that ▶ cannot be used with the graphics G0–G9. See the command `BLIT`.

```
expression ▶ var
```

i Inserts the imaginary number *i*.

$^{-1}$ Returns the inverse of an expression.

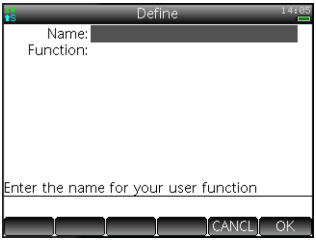
```
(Expr)⁻¹
```

Creating your own functions

You can create your own function by writing a program (see chapter 27) or by using the simpler `DEFINE` functionality. Functions you create yourself appear on the User menu (one of the Toolbox menus).

Suppose you wanted to create the function SINCOS(A,B)=SIN(A)+COS(B)+C.

1. Press Shift xtθn (Define).
2. In the **Name** field, enter a name for the function—for example, SINCOS—and tap OK.

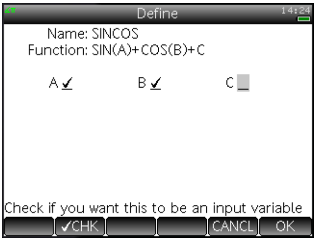


Enter the name for your user function

3. In the **Function** field, enter the function.

   SIN ALPHA A ▶ + COS ALPHA B ▶ ALPHA C OK

   New fields appear below your function, one for each variable used in defining it. You need to decide which ones are to be input arguments for your functions and which ones are global variables whose values are not input within the function. In this example, we'll make A and B input variables, so our new function takes two arguments. The value of C will be provided by global variable C (which by default is zero).



Name: SINCOS
Function: SIN(A)+COS(B)+C
A ✓ B ✓ C □
Check if you want this to be an input variable

4. Make sure that `A` and `B` are selected and `C` is not.
5. Tap OK.

   You can run your function by entering it on the entry line in Home view, or be selecting it from the USER menu. You enter the value for each variable you chose to be a parameter. In this example. we chose A and B to be parameters. Thus you might enter SINCOS(0.5, 0.75). With C=0 and in radians mode, this would return 1.211…

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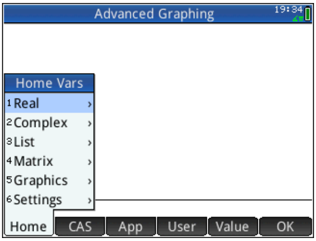
Variables

Variables are objects that have names and contain data. They are used to store data, either for later use or to control settings in the Prime system. There are four types of variables, all of which can be found in the **Vars** menu by pressing Vars:

- Home variables
- CAS variables
- App variables
- User variables



The Home and app variables all have names reserved for them. They are also typed; that is, they can contain only certain *types* of objects. For example, the Home variable `A` can only contain a real number. You use Home variables to store data that is important to you, such as matrices, lists, real numbers, etc. You use app variables to store data in apps or to change app settings. You can accomplish these same tasks via the user interface of an app, but app variables give you a quick way of doing these tasks, either from Home or within a program. For example, you can store the expression "`SIN(X)`" in the Function app variable `F1` in Home View, or you could open the Function app, navigate to `F1(X)`, and enter `SIN(X)` in that field.

CAS and user variables can be created by the user and they have no particular type. Their names may be of any length as well. Thus, `diff(t2,t)` returns `2*t` and `diff((bt)2, bt)` returns `2*bt` for the CAS variables `t` and `bt`. Further evaluation of `2*bt` will only return `2*bt`, unless an object has been stored in `bt`. For example, if you enter `bt:={1,2,3}` and then enter `diff((bt)2, bt)`, the CAS will still return `2*bt`. But if you evaluate that result (using the `EVAL` command), the CAS will now return `{2,4,6}`.

User variables are explicitly created by the user. You create user variables either in a program or by assignment in Home view. User variables created in a program are either declared as local or exported as global. User variables created by assignment or exported from a program will show up in the **Vars** User menu. Local variables exist only within their own program.

The following sections describe the various processes associated with variables, such as creating them, storing objects in them, and retrieving their contents. The rest of the chapter contains tables that list all the Home and app variable names.

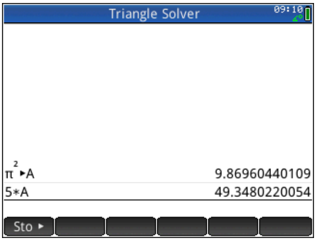
Working with Home variables

Example 1: Assign π^2 to the Home variable *A* and then calculate 5**A*.

1. Press ⌂ Settings to display Home view.
2. Assign π^2 to A:

   Shift 3 x^2 Sto ▸ ALPHA Vars Enter

   The result is written to history.



```
π²▸A                 9.86960440109
5*A                  49.3480220054
```

3. Multiply A by 5:

   5 ×

   ALPHA Vars Enter

This example illustrates the process for storing and using any Home variable, not just the Real Home variables A–Z. It is important to match the object you want to store to the correct type of Home variable. See “Home variables” on page 428 for details.

Working with user variables

Example 2: Create a variable called ME and assign π^2 to it.

1. Press Settings to display Home view.
2. Assign π^2 to ME:

   Shift 3 x^2 Sto ▸ ALPHA +/– ALPHA a b/c Enter

3. A message appears asking if you want to create a variable called ME. Tap OK or press Enter to confirm your intention.

   You can now use that variable in subsequent calculations: ME*3 will yield 29.6…, for example.

Example 3: You can also store objects in variables using the assignment operator: Name:=Object. In this example, we'll store {1,2,3} in the user variable YOU.

1. Assign the list to the variable using the assignment operator:=.

   ALPHA ALPHA 1 , 4 – ALPHA Shift :=

   Shift 8 1 , 2 , 3 Enter

2. A message appears asking if you want to create a variable called YOU. Tap OK or press Enter to confirm your intention.

   The variable YOU is created and contains the list {1,2,3}. You can now use that variable in subsequent calculations: For example, YOU+60 will return {61,62,63}.

Working with app variables

Just as you can assign values to Home and user variables, you can assign values to app variables. You can modify Home settings on the **Home Settings** screen (Shift Settings). But you can also modify a Home setting from Home view by assigning a value to the variable that represents that setting. For example, entering Base:=0 Enter in Home view forces the Home settings field **Integer** (for the integer base) to binary. A value of 1 would force it to octal, 2 to decimal, and 3 to hex. Another example: you can change the angle measure setting from radians to degrees by entering HAngle :=1 Enter in Home view.

Entering `HAngle:=0` Enter forces the setting to return to radians.

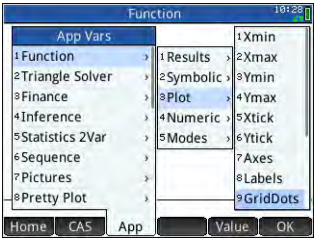
You can see what value has been assigned to a variable—whether Home, app, or user—by entering its name in Home view and pressing Enter. You can enter the name letter by letter, or choose the variable from the Variables menu by pressing Vars.

More about the Vars menu

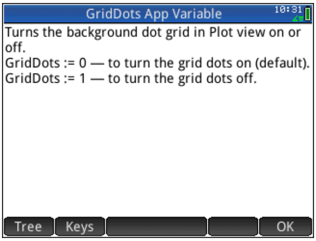
Besides the four variable menus, the **Vars** menu contains a toggle. If you want the value of a variable instead of its name when you choose it from the **Vars** menu, tap Value. A white dot will appear next to the menu button label to indicate that it is active and that variable values rather than names will be returned upon selection.

For the Home and app variables, use the **Vars** menu to get help on the purpose of any of these variables. Select the variable of interest and press Help. Suppose, for example, that you wanted to get help on the Function app variable `GridDots`:

1. Press Vars to open the **Vars** menu.
2. Tap App to open the app variables menu. (If you were interested in a Home variable instead, you would tap Home instead.)



3. Use the cursor keys to navigate to the variable of interest.
4. Press Help to see the help about that variable.
5. Tap OK to exit or Esc to return to the current **Vars** submenu.


GridDots App Variable

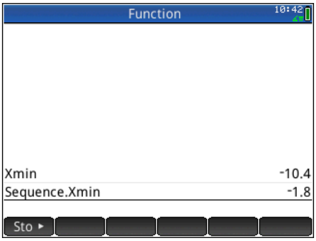
Turns the background dot grid in Plot view on or off.

GridDots := 0 — to turn the grid dots on (default).
GridDots := 1 — to turn the grid dots off.

Qualifying variables

Some app variable names are shared by multiple apps. For example, the Function app has a variable named `Xmin`, but so too does the Polar app, the Parametric app, the Sequence app, and the Solve app. Although named identically, these variables usually hold different values. If you attempt to retrieve the contents of a variable that is used in more than one app by entering just its name in Home view, you will get the contents of that version of the variable in the current app. For example, if the Function app is active and you enter `Xmin` in Home view, you will get the value of `Xmin` from the Function app. If you want the value of `Xmin` from, say, the Sequence app, you must qualify the variable name. Enter `Sequence.Xmin` to retrieve the value of `Xmin` from the Sequence app.

In the figure to the right, the value of `Xmin` from the Function app was retrieved first (–10.4...). The qualified variable name entered second retrieved the value of `Xmin` from the Sequence app (–1.8).



```
Xmin                 -10.4
Sequence.Xmin         -1.8
```

Note the syntax required: `app_name.variable_name`.

The app can be any of the 18 HP apps, or one you have created based on a built-in app. The name of the app variable must match a name listed in the app variables tables below. Spaces are not allowed in an app name and must be represented by the underscore character: Shift ␣ _ .

Tip Non-standard characters in variables name—such as Σ and σ—can be entered by selecting them from the special symbols palette (Shift 9 !,∞,→ S) or from the characters menu (Shift Vars Chars A).

Home variables

The Home variables are accessed by pressing Vars and tapping Home.

Category	Names
Real	A to Z and θ For example, 7.45 Sto ▸ A
Complex	Z0 to Z9 For example, 2+3×*i* Sto ▸ Z1 or (2,3) Sto ▸ Z1 (depending on your Complex number settings)
List	L0 to L9 For example, {1,2,3} Sto ▸ L1.
Matrix	M0 to M9 Store matrices and vectors in these variables. For example, [[1,2],[3,4]] Sto ▸ M1.
Graphics	G0 to G9
Settings	HAngle HFormat HDigits HComplex Date Time Language Entry Integer Base Bits Signed

App variables

The app variables are accessed by pressing Vars and tapping App. They are grouped below by app. (You can find then grouped by view—Symbolic, Numeric, Plot, —in "Variables and Programs" on page 556.)

Note that if you have customized a built-in app, your app will appear on the App variables menu under the name you gave it. You access the variables in a customized app in the same way that you access the variables in built-in apps.

Function app variables

Category	**Names**	
Results [explained below]	SignedArea Extremum Isect	Root Slope

Symbolic	`F1`
	`F2`
	`F3`
	`F4`
	`F5`
		`F6`
		`F7`
		`F8`
		`F9`
		`F0`

Plot	`Axes`
	`Cursor`
	`GridDots`
	`GridLines`
	`Labels`
	`Method`
	`Recenter`
	`Xmax`
		`Xmin`
		`Xtick`
		`Xzoom`
		`Ymax`
		`Ymin`
		`Ytick`
		`Yzoom`

Numeric	`NumStart`
	`NumStep`
	`NumIndep`
		`NumType`
		`NumZoom`

Modes	`AAngle` `AComplex`	`ADigits` `AFormat`

Results variables

Extremum

Contains the value from the last use of the `Extremum` function from the Fcn menu in the Plot view of the Function app. The app function `EXTREMUM` does not store results to this variable.

Isect

Contains the value from the last use of the `Isect` function from the Fcn menu in the Plot view of the Function app. The app function `ISECT` does not store results to this variable.

Root

Contains the value from the last use of the `Root` function from the Fcn menu in the Plot view of the Function app. The app function `ROOT` does not store results to this variable.

SignedArea

Contains the value from the last use of the `Signed Area` function from the Fcn menu in the Plot view of the Function app. The app function `AREA` does not store results to this variable.

Slope

Contains the value from the last use of the `Slope` function from the Fcn menu in the Plot view of the Function app. The app function `SLOPE` does not store results to this variable.

Geometry app variables

Category	Names	
Numeric	`Xmin` Ymin	`Xmax` `Ymax`
Modes	`AAngle` `AComplex`	`ADigits` `AFormat`

Spreadsheet app variables

Category	Names	
Numeric	ColWidth	RowHeight
	Row	Col
	Cell	
Modes	AAngle	ADigits
	AComplex	AFormat

Solve app variables

Category	Names	
Symbolic	E1	E6
	E2	E7
	E3	E8
	E4	E9
	E5	E0
Plot	Axes	Xmin
	Cursor	Xtick
	GridDots	Xzoom
	GridLines	Ymax
	Labels	Ymin
	Method	Ytick
	Recenter	Yzoom
	Xmax	
Modes	AAngle	ADigits
	AComplex	AFormat

Advanced Graphing app variables

Category	Names	
Symbolic	V1	V6
	V2	V7
	V3	V8
	V4	V9
	V5	V0
Plot	Axes	Xmin
	Cursor	Xtick
	GridDots	Xzoom
	GridLines	Ymax
	Labels	Ymin
	Recenter	Ytick
	Xmax	Yzoom
Numeric	NumXStart	NumIndep
	NumYStart	NumType
	NumXStep	NumXZoom
	NumYStep	NumYZoom
Modes	AAngle	ADigits
	AComplex	AFormat

Statistics 1Var app variables

Category	Names	
Results [explained below]	NbItem	ΣX
	MinVal	ΣX2
	Q1	MeanX
	MedVal	sX
	Q3	σX
	MaxVal	serrX
Symbolic	H1	H1Type
	H2	H2Type
	H3	H3Type
	H4	H4Type
	H5	H5Type
Plot	Axes	Xmax
	Cursor	Xmin
	GridDots	Xtick
	GridLines	Xzoom
	Hmin	Ymax
	Hmax	Ymin
	Hwidth	Ytick
	Labels	Yzoom
	Recenter	
Numeric	D1	D6
	D2	D7
	D3	D8
	D4	D9
	D5	D0
Modes	AAngle	ADigits
	AComplex	AFormat

Results

NbItem Contains the number of data points in the current 1-variable analysis (H1−H5).

MinVal Contains the minimum value of the data set in the current 1-variable analysis (H1−H5).

Q1 Contains the value of the first quartile in the current 1-variable analysis (H1−H5).

MedVal Contains the median in the current 1-variable analysis (H1−H5).

Q3 Contains the value of the third quartile in the current 1-variable analysis (H1−H5).

MaxVal Contains the maximum value in the current 1-variable analysis (H1−H5).

Σ**X** Contains the sum of the data set in the current 1-variable analysis (H1−H5).

Σ**X2** Contains the sum of the squares of the data set in the current 1-variable analysis (H1−H5).

MeanX Contains the mean of the data set in the current 1-variable analysis (H1−H5).

sX Contains the sample standard deviation of the data set in the current 1-variable analysis (H1−H5).

σ**X** Contains the population standard deviation of the data set in the current 1-variable analysis (H1−H5).

serrX Contains the standard error of the data set in the current 1-variable analysis (H1−H5).

Statistics 2Var app variables

Category	Names	
Results [explained below]	NbItem	sX
	Corr	σX
	CoefDet	serrX
	sCov	MeanY
	σCov	ΣY
	ΣXY	ΣY2
	MeanX	sY
	ΣX	σY
	ΣX2	serrY
Symbolic	S1	S1Type
	S2	S2Type
	S3	S3Type
	S4	S4Type
	S5	S5Type
Plot	Axes	Xmin
	Cursor	Xtick
	GridDots	Xzoom
	GridLines	Ymax
	Labels	Ymin
	Method	Ytick
	Recenter	Yzoom
	Xmax	
Numeric	C1	C6
	C2	C7
	C3	C8
	C4	C9
	C5	C0
Modes	AAngle	ADigits
	AComplex	AFormat

Results

NbItem
Contains the number of data points in the current 2-variable analysis (S1–S5).

Corr
Contains the correlation coefficient from the latest calculation of summary statistics. This value is based on the linear fit only, regardless of the fit type chosen.

CoefDet
Contains the coefficient of determination from the latest calculation of summary statistics. This value is based on the fit type chosen.

sCov
Contains the sample covariance of the current 2-variable statistical analysis (S1–S5).

σCov
Contains the population covariance of the current 2-variable statistical analysis (S1–S5).

ΣXY
Contains the sum of the X·Y products for the current 2-variable statistical analysis (S1–S5).

MeanX
Contains the mean of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

ΣX
Contains the sum of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

ΣX2
Contains the sum of the squares of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

sX
Contains the sample standard deviation of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

σX
Contains the population standard deviation of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

serrX
Contains the standard error of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

MeanY
Contains the mean of the dependent values (Y) of the current 2-variable statistical analysis (S1–S5).

ΣY Contains the sum of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

ΣY2 Contains the sum of the squares of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

sY Contains the sample standard deviation of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

σY Contains the population standard deviation of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

serrY Contains the standard error of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

Inference app variables

Category	Names	
Results	Result	CritScore
[explained below]	TestScore	CritVal1
	TestValue	CritVal2
	Prob	DF
Symbolic	AltHyp	Type
	Method	
Numeric	Alpha	Pooled
	Conf	s1
	Mean1	s2
	Mean2	σ1
	n1	σ2
	n2	x1
	μ0	x2
	π0	
Modes	`AAngle`	`ADigits`
	`AComplex`	`AFormat`

Results

CritScore Contains the value of the Z- or t-distribution associated with the input α-value

CritVal1 Contains the lower critical value of the experimental variable associated with the negative `TestScore` value which was calculated from the input α-level.

CritVal2 Contains the upper critical value of the experimental variable associated with the positive `TestScore` value which was calculated from the input α-level.

DF Contains the degrees of freedom for the t-tests.

Prob Contains the probability associated with the `TestScore` value.

Result For hypothesis tests, contains 0 or 1 to indicate rejection or failure to reject the null hypothesis.

TestScore Contains the Z- or t-distribution value calculated from the hypothesis test or confidence interval inputs.

TestValue Contains the value of the experimental variable associated with the `TestScore`.

Parametric app variables

Category	Names	
Symbolic	X1	X6
	Y1	Y6
	X2	X7
	Y2	Y7
	X3	X8
	Y3	Y8
	X4	X9
	Y4	Y9
	X5	X0
	Y5	Y0
Plot	Axes	Tstep
	Cursor	Xmax
	GridDots	Xmin
	GridLines	Xtick
	Labels	Xzoom
	Method	Ymax
	Recenter	Ymin
	Tmin	Ytick
	Tmax	Yzoom
Numeric	NumStart	NumType
	NumStep	NumZoom
Modes	AAngle	ADigits
	AComplex	AFormat

Polar app variables

Category	Names	
Symbolic	R1	R6
	R2	R7
	R3	R8
	R4	R9
	R5	R0
Plot	θmin	Recenter
	θmax	Xmax
	θstep	Xmin
	Axes	Xtick
	Cursor	Xzoom
	GridDots	Ymax
	GridLines	Ymin
	Labels	Ytick
	Method	Yzoom
Numeric	NumIndep	NumType
	NumStart	NumZoom
	NumStep	
Modes	AAngle	ADigits
	AComplex	AFormat

Finance app variables

Category	Names	
Numeric	CPYR	NbPmt
	BEG	PMTV
	FV	PPYR
	IPYR	PV
	GSize	
Modes	AAngle	ADigits
	AComplex	AFormat

Linear Solver app variables

Category	Names	
Numeric	LSystem	LSolution[a]
Modes	AAngle AComplex	ADigits AFormat

[a] Contains a vector with the last solution found by the Linear Solver app.

Triangle Solver app variables

Category	Names	
Numeric	SideA SideB SideC Rect	AngleA AngleB AngleC
Modes	AAngle AComplex	ADigits AFormat

Linear Explorer app variables

Category	Names	
Modes	AAngle AComplex	ADigits AFormat

Quadratic Explorer app variables

Category	Names	
Modes	AAngle AComplex	ADigits AFormat

Trig Explorer app variables

Category	Names	
Modes	AAngle AComplex	ADigits AFormat

Sequence app variables

Category	Names	
Symbolic	U1 U2 U3 U4 U5	U6 U7 U8 U9 U0
Plot	Axes Cursor GridDots GridLines Labels Nmin Nmax Recenter	Xmax Xmin Xtick Xzoom Ymax Ymin Ytick Yzoom
Numeric	NumIndep NumStart NumStep	NumType NumZoom
Modes	AAngle AComplex	ADigits AFormat

23

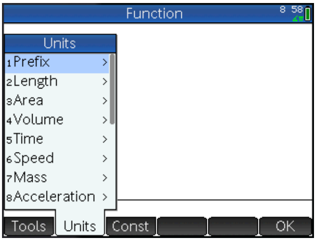
Units and constants

Units

A unit of measurement—such as inch, ohm, or Becquerel—enables you to give a precise magnitude to a physical quantity.

You can attach a unit of measurement to any number or numerical result. A numerical value with units attached is referred to as a *measurement*. You can operate on measurements just as you do on numbers without attached units. The units are kept with the numbers in subsequent operations.

The units are on the **Units** menu. Press Shift (Units) and, if necessary, tap Units.



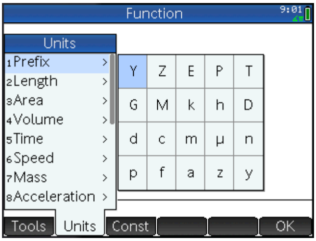
The menu is organized by *category*. Each category is listed at the left, with the units in the selected category listed at the right.

Unit categories

- length
- area
- volume
- time
- speed
- mass
- acceleration
- force
- energy
- power
- pressure
- temperature
- electricity
- light
- angle
- viscosity
- radiation

Prefixes

The **Units** menu includes an entry that is not a unit category, namely, `Prefix`. Selecting this option displays a palette of prefixes.



Y: yotta	Z: zetta	E: exa	P: peta	T: tera
G: giga	M: mega	k: kilo	h: hecto	D: deca
d: deci	c: centi	m: milli	μ: micro	n: nano
p: pico	f: femto	a: atto	z: zepto	y: octo

Unit prefixes provide a handy way of entering large or small numbers. For example, the speed of light is approximately 300,000 m/s. If you wanted to use that in a calculation, you could enter it as 300_km/s, with the prefix *k* selected from the prefix palette.

Select the prefix you want *before* selecting the unit.

Unit calculations

A number plus a unit is a measurement. You can perform calculations with multiple measurements providing that the units of each measurement are from the same category. For example, you can add two measurements of length (even lengths of different units, as illustrated in the following example). But you cannot add, say, a length measurement to a volume measurement.

Example

Suppose you want to add 20 centimeters and 5 inches and have the result displayed in centimeters.

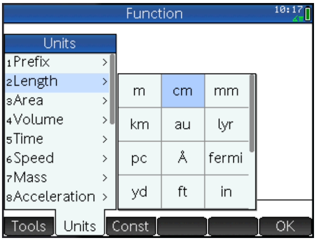
1. If you want the result in cm, enter the centimeter measurement first.

   20 Shift Units (Units)

   Units

   Select `Length`

   Select `cm`



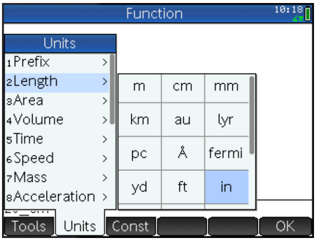
2. Now add 5 inches.

   + 5 Shift Units

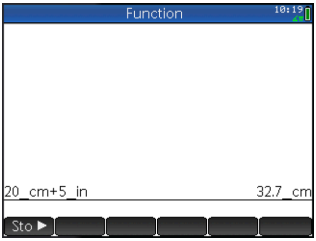
   Select `Length`

   Select `in`

   Enter



   The result is shown as 32.7 cm. If you had wanted the result in inches, then you would have entered the 5 inches first.



```
20_cm+5_in                    32.7_cm
```

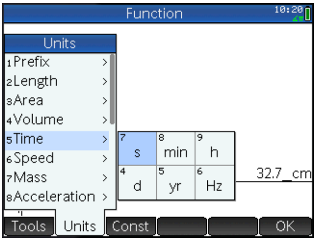
3. To continue the example, let’s divide the result by 4 seconds.

   ÷ 4 Shift Units

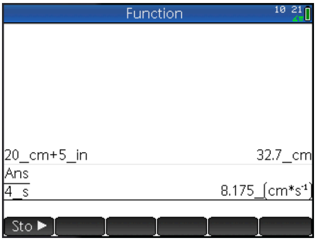
   Select `Time`

   Select `s`

   Enter



   The result is shown as 8.175 cm*s^{-1}.



```
20_cm+5_in                    32.7_cm
Ans
4_s                     8.175_(cm*s⁻¹)
```

4. Now convert the result to kilometers per hour.

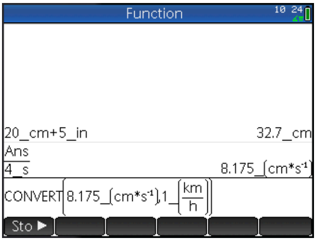
   Sto ▸

   Shift Units

   Select `Speed`

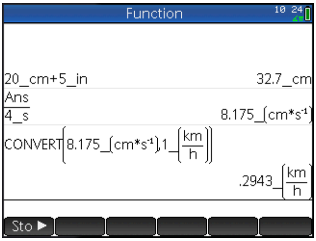
   Select `km/h`

   Enter



```
Function
20_cm+5_in                    32.7_cm
Ans
4_s                    8.175_(cm*s^-1)
CONVERT(8.175_(cm*s^-1),1_(km/h))
Sto ▶
```

   The result is shown as 0.2943 kilometers per hour.



```
Function
20_cm+5_in                    32.7_cm
Ans
4_s                    8.175_(cm*s^-1)
CONVERT(8.175_(cm*s^-1),1_(km/h))
                          .2943_(km/h)
Sto ▶
```

Unit tools

There are a number of tools for managing and operating on units. These are available by pressing Shift Units and tapping Tools.

CONVERT

Converts one unit to another unit of the same category.

`CONVERT(5_m,1_ft)` returns `16.4041994751_ft`

You can also use the last answer as the first argument in a new conversion calculation. Pressing Shift Ans places the last answer on the entry line. You can also select a value from history and tap Copy to copy it to the entry line. Sto ▸ with a measurement calls the convert command as well and converts to whatever unit follows the Store symbol.

MKSA

Meters, kilograms, seconds, amperes. Converts a complex unit into the base components of the MKSA system.

`MKSA(8.175_cm/s)` returns `.08175_m*s−1`

UFACTOR

Unit factor conversion. Converts a measurement using a compound unit into a measurement expressed in constituent units. For example, a Coulomb—a measure of electric charge—is a compound unit derived from the SI base units of Ampere and second: 1 C = 1 A * 1 s. Thus:

`UFACTOR(100_C,1_A))` returns `100_A*s`

USIMPLIFY

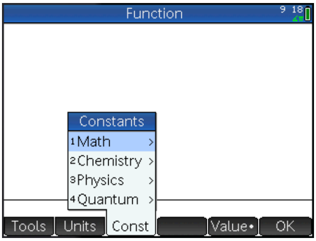
Unit simplification. For example, a Joule is defined as one kg*m^2/s^2. Thus:

`USIMPLIFY(5_kg*m^2/s^2)` returns `5_J`

Physical constants

The values of 34 math and physical constants can be selected (by name or value) and used in calculations. These constants are grouped into four categories: math, chemistry, physics and quantum mechanics. A list of all these constants is given in “List of constants” on page 449.

To display the constants, press Shift Units and then tap Const.



Example

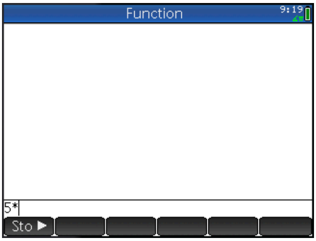
Suppose you want to know the potential energy of a mass of 5 units according to the equation $E = mc^2$.

1. Enter the mass and the multiplication operator:

   5 ×

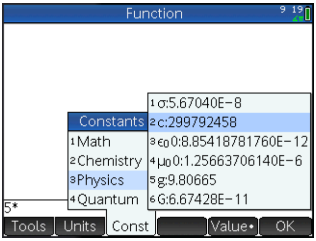
2. Open the constants menu.

   Shift Units Const



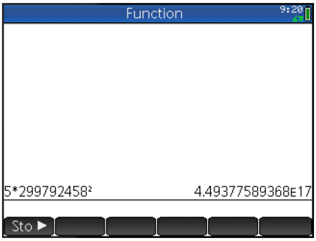
3. Select `Physics`.

4. Select `c: 299792458`.



5. Square the speed of light and evaluate the expression.

   x^2 Enter

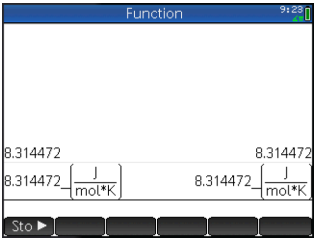


```
5*299792458²                    4.49377589368E17
```

Value or measurement?

You can enter just the value of a constant or the constant and its units (if it has units). If Value• is showing on the screen, the value is inserted at the cursor point. If Value is showing on the screen, the value and its units are inserted at the cursor point.

In the example at the right, the first entry shows the Universal Gas Constant after it was chosen with Value• showing. The second entry shows the same constant, but chosen when Value was showing.



```
8.314472                                8.314472
8.314472_(J/(mol*K))        8.314472_(J/(mol*K))
```

Tapping Value displays Value•, and vice versa.

List of constants

Category	Name and symbol
Math	e MAXREAL MINREAL π i
Chemistry	Avogadro, NA Boltmann, k molar volume, Vm universal gas, R standard temperature, StdT standard pressure, StdP
Phyics	Stefan-Boltzmann, σ speed of light, c permittivity, ε_0 permeability, μ_0 acceleration of gravity, g gravitation, G
Quantum	Planck, h Dirac, $\hbar$ electronic charge, q electron mass, me q/me ratio, qme proton mass, mp mp/me ratio, mpme fine structure, α magnetic flux, Φ Faraday, F Rydberg, R_∞ Bohr radius, a_0 Bohr magneton, μ_B nuclear magneton, μ_N photon wavelength, λ_0 photon frequency, f_0 Compton wavelength, λ_c

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Lists

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}`. Lists represent a convenient way to group related objects.

You can do list operations in Home and in programs.

There are ten list variables available, named `L0` to `L9`, or you can create your own list variable names. You can use them in calculations or expressions in Home or in a program. Retrieve a list name from the Vars menu (Vars), or just type its name from the keyboard.

You can create, edit, delete, send, and receive named lists in the List Catalog: Shift 7 (List). You can also create and store lists—named or unnnamed—in Home view.

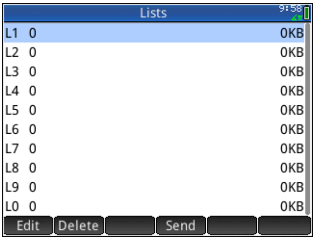
List variables are identical in behavior to the columns `C1`–`C0` in the Statistics 2Var app and the columns `D1`–`D0` in the Statistics 1Var app. You can store a statistics column as a list (or vice versa) and use any of the list functions on the statistics columns, or the statistics functions on the list variables.

Create a list in the List Catalog

1. Open the List Catalog.

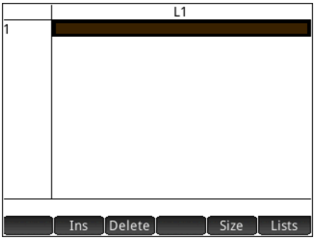
   Shift 7 (List)

   The number of elements in a list is shown beside the list name.



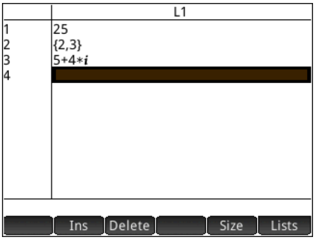
L1	0	0KB
L2	0	0KB
L3	0	0KB
L4	0	0KB
L5	0	0KB
L6	0	0KB
L7	0	0KB
L8	0	0KB
L9	0	0KB
L0	0	0KB

2. Tap on the name you want to assign to the new list (`L1`, `L2`, etc.). The list editor appears.

   If you're creating a new list rather than changing, make sure you choose a list with out any elements in it.

3. Enter the values you want in the list, pressing Enter after each one.

   1 25
   2 {2,3}
   3 5+4*i
   4

   Values can be real or complex numbers (or an expression). If you enter a expression, it is evaluated and the result is inserted in the list.

4. When done, press Shift 7 (List) to return to the List catalog, or press Settings to go to Home view.

List Catalog: Buttons and keys

The buttons and keys in the List Catalog are:

Button or Key	Purpose
Edit	Opens the highlighted list for editing. You can also just tap on a list name.
Delete or Del	Deletes the contents of the selected list.
Send	Transmits the highlighted list to another HP Prime.
Shift Esc (Clear)	Clears all lists.
Shift ▲ or ▼	Moves to the top or bottom of the catalog, respectively.

The List Editor

The List Editor is a special environment for entering data into lists. There are two ways to open the List Editor once the List Catalog is open:

- Highlight the list and tap Edit or
- Tap the name of the list.

List Editor: Buttons and keys

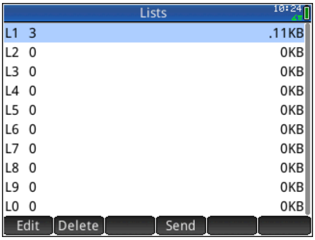
When you open a list, the following buttons and keys are available to you:

Button or Key	Purpose
Edit	Copies the highlighted list item into the entry line.
Ins	Inserts a new value—with default zero—before the highlighted item.
Delete or ⌫ Del	Deletes the highlighted item.
Size	Displays a menu for you to choose the small font, medium font, or large font
Lists	Displays a menu for you to choose how many lists to display at one time: one, two, three, or four. For example, if you have only `L4` displayed and you choose `3` from the **Lists** menu, lists `L5` and `L6` will be displayed in addition to `L4.`
Shift Esc Clear (Clear)	Clears all items from the list.
Shift ▲ or ▼	Moves the cursor to the start or the end of the list.

To edit a list

1. Open the List Catalog.

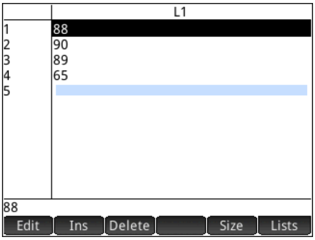
   Shift 7 (List)



Lists 10:24

L1	3	.11KB
L2	0	0KB
L3	0	0KB
L4	0	0KB
L5	0	0KB
L6	0	0KB
L7	0	0KB
L8	0	0KB
L9	0	0KB
L0	0	0KB

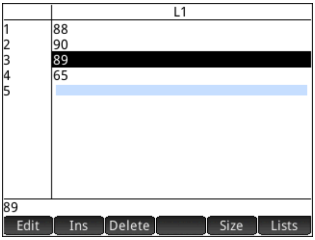
2. Tap on the name of the list (`L1`, `L1`,etc.). The List Editor appears.



	L1
1	88
2	90
3	89
4	65
5	

88

3. Tap on the element you want to edit. (Alternatively, press ▲ or ▼ until the element you want to edit is highlighted.) In this example, edit the third element so that it has a value of 5.



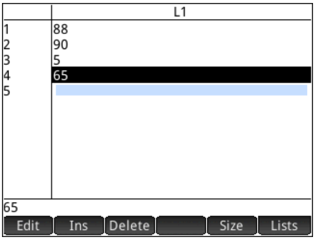
	L1
1	88
2	90
3	89
4	65
5	

89

   5 OK

To insert an element in a list

Suppose you want to insert a new value, 9, in L1(2) in the list L1 shown to the right.

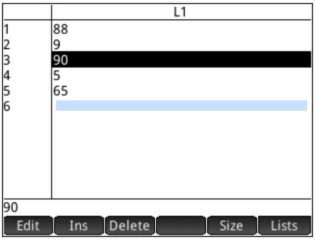


	L1
1	88
2	90
3	5
4	65
5	

65

Select L1(2), that is, the second element in the list.

Ins 9 OK



	L1
1	88
2	9
3	90
4	5
5	65
6	

90

Deleting lists

To delete a list

In the List Catalog, use the cursor keys to highlight the list and press Del. You are prompted to confirm your decision. Tap OK or press Enter.

If the list is one of the reserved lists L0-L9, then only the contents of the list are deleted. The list is simply stripped of its contents. If the list is one you have named (other than L0-L9), then it is deleted entirely.

To delete all lists

In the List Catalog, press Shift Esc Clear (Clear).

The contents of the lists L0-L9 are deleted and any other named lists are deleted entirely.

Lists in Home view

You can enter and operate on lists directly in Home view. The lists can be named or unnamed.

To createa list

1. Press Shift 8 ({}).

   A pair of braces appears on the entry line. All lists must be enclosed in braces.

2. Enter the first element in the list followed by a comma:

   [element] ,

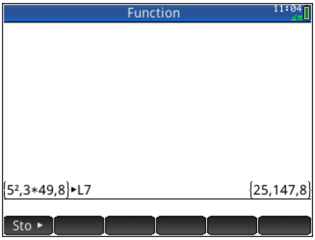
3. Continue adding elements, separating each with a comma.

4. When you have finished entering the elements, press Enter. The list is added to History (with any expressions among the elements evaluated).

To store a list

You can store a list in a variable. You can do this before the list is added to History, or you can copy it from History. When you've entered a list in the entry line or copied it from History to the entry line, tap Sto ►, enter a name for the list and press Enter. The reserved list variable names available to you are `L0` through `L9`; however, you can create a list variable name of your own as well.

For example, to store the list {25,147,8} in `L7`:



```
{5²,3*49,8}▸L7                {25,147,8}
```

1. Create the list on the entry line.
2. Press ▶ to move the cursor outside the list.
3. Tap Sto ►.
4. Enter the name:

   ALPHA alpha x^2 7

5. Complete the operation: Enter.

To display a list

To display a list in Home view, type its name and press Enter.

If the list is empty, a pair of empty braces is returned.

To display one element

To display one element of a list in Home view, enter *listname* (*element#*). For example, if L6 is {3,4,5,6}, then `L6(2)` Enter returns `4`.

To store one element

To store a value in one element of a list in Home view, enter *value* Sto ► *listname* (*element#*). For example, to store 148 as the second element in L2, type `148` Sto ► `L2(2)` Enter.

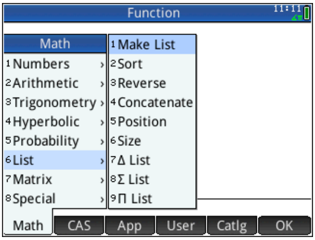
To send a list

You can send lists to another calculator or a PC just as you can apps, programs, matrices, and notes. See “Sharing data” on page 44 for instructions.

List functions

List functions are found on the Math menu. You can use them in Home and 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 Mem B 6 to select the *List* category in the left column of the Math menu. (*List* is the sixth category on the Math menu, which is why pressing 6 will take you straight to the List category.) Tap a function to select it, or use the direction keys to highlight it and either tap OK or press Enter.

List functions are enclosed in parentheses. They have arguments that are separated by commas, as in `CONCAT(L1,L2)`. An argument can be either a list variable name or the actual list; for example, `REVERSE(L1)` or `REVERSE({1,2,3})`.

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 operates on 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.

Menu format

By default, a List function is presented on the Math menu using its descriptive name, not its common command name. Thus the shorthand name `CONCAT` is presented as **Concatenate** and `POS` is presented as **Position**.

If you prefer the Math menu to show command names instead, deselect the **Menu Display** option on page 2 of the **Home Settings** screen (see page 26).

Make List

Calculates a sequence of elements for a new list using the syntax:

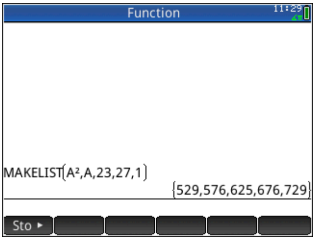
`MAKELIST(`*expression, variable, begin, end, increment*`)`

Evaluates *expression* with respect to *variable,* as *variable* takes on values from *begin* to *end* values, taken at *increment* steps.

Example:

In Home, generate a series of squares from 23 to 27:

Mem B
Select `List`
Select `Make List`
(or `MAKELIST`)
ALPHA Vars x² ,
ALPHA Vars ,
23 ,
27 , 1 Enter



MAKELIST(A²,A,23,27,1)

{529,576,625,676,729}

Sort

Sorts the elements in a list in ascending order.

`SORT(`*list*`)`

Example:

`SORT({2,5,3})` returns `{2,3,5}`

Reverse

Creates a list by reversing the order of the elements in a list.

`REVERSE(`*list*`)`

Example:

`REVERSE({1,2,3})` returns `{3,2,1}`

Concatenate

Concatenates two lists into a new list.

`CONCAT(`*list1, list2*`)`

Example:

`CONCAT({1,2,3},{4})` returns `{1,2,3,4}.`

Position

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`

Size

Returns the number of elements in a list.

`SIZE(`*list*`)`

Example:

`SIZE({1,2,3})` returns `3`

ΔLIST

Creates a new list composed of the first differences of a list; that is, the differences between consecutive elements in the list. The new list has one less element than the original list. The differences for $\{x_1, x_2, x_3, \ldots x_{n-1}, x_n\}$ are $\{x_2 - x_1, x_3 - x_2, \ldots x_n - x_{n-1}\}$.

`ΔLIST(`*list1*`)`

Example:

In Home view, store {3,5,8,12,17,23} in L5 and find the first differences for the list.

Shift 8

3,5,8,12,17,23

▶ Sto ▸

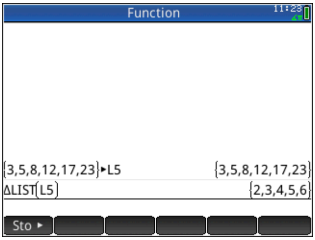
ALPHA x² 5 Enter

Mem

Select `List`

Select `ΔList`

ALPHA x² 5 Enter



```
{3,5,8,12,17,23}▸L5             {3,5,8,12,17,23}
ΔLIST(L5)                              {2,3,4,5,6}
```

ΣLIST

Calculates the sum of all elements in a list.

`ΣLIST(`*list*`)`

Example:

`ΣLIST({2,3,4})` returns `9`.

ΠLIST

Calculates the product of all elements in list.

`ΠLIST(`*list*`)`

Example:

`ΠLIST({2,3,4})` returns `24`.

Finding statistical values for lists

To find statistical values—such as the mean, median, maximum, and minimum of a list—you create a list, store it in a data set and then use the Statistics 1Var app.

Example

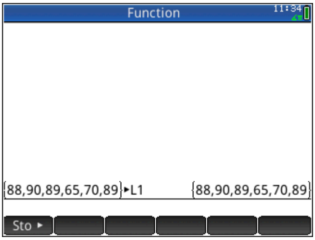
In this example, use the Statistics 1Var app to find the mean, median, maximum, and minimum values of the elements in the list L1, being 88, 90, 89, 65, 70, and 89.

1. In Home view, create L1.

   Shift 8

   88, 90, 89, 65, 70,89 ▶ Sto ▸

   ALPHA x^2 1 Enter

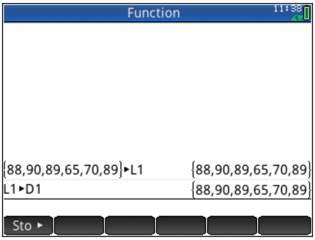


```
{88,90,89,65,70,89}▸L1          {88,90,89,65,70,89}
```

2. In Home view, store L1 in D1.

   ALPHA x^2 1 Sto ▸

   ALPHA $x\,t\,\theta\,n$ 1 Enter



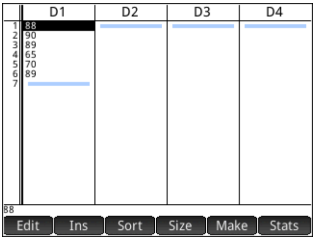
```
{88,90,89,65,70,89}▸L1          {88,90,89,65,70,89}
L1▸D1                           {88,90,89,65,70,89}
```

   You will now be able to see the list data in the Numeric view of the Statistics 1Var app.

3. Start the Statistics 1Var app.

   Apps Select `Statistics 1Var`

   Notice that your list elements are in data set D1.

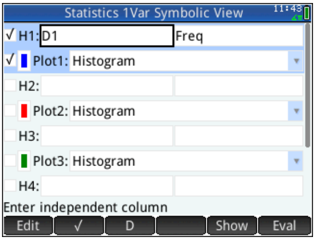


	D1	D2	D3	D4
1	88			
2	90			
3	89			
4	65			
5	70			
6	89			
7				

88

4. In the Symbolic view, specify the data set whose statistics you want to find.

   Symb ↪Setup



Statistics 1Var Symbolic View

√ H1: D1 Freq

√ Plot1: Histogram

H2:

Plot2: Histogram

H3:

Plot3: Histogram

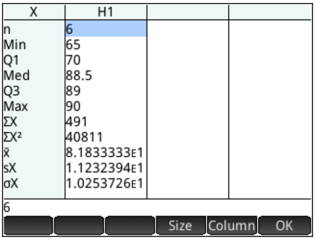
H4:

Enter independent column

   By default, H1 will use the data in D1, so nothing further needs to be done in Symbolic view. However, if the data of interest were in D2, or any column other than D1, you would have to specify the desired data column here.

5. Calculate the statistics.

   Num ↪Setup Stats



X	H1
n	6
Min	65
Q1	70
Med	88.5
Q3	89
Max	90
ΣX	491
ΣX²	40811
x̄	8.1833333E1
sX	1.1232394E1
σX	1.0253726E1

6

6. Tap OK when you are done.

   See the chapter 10, “Statistics 1Var app”, beginning on page 211, for the meaning of each statistic.

25

Matrices

You can create, edit, and operate on matrices and vectors in the Home view, CAS, or in programs. You can enter matrices directly in Home or CAS, or use the Matrix Editor.

Vectors

Vectors are one-dimensional arrays. They are composed of just one row. A vector is represented by single brackets; for example, [1 2 3]. A vector can be a real number vector, or a complex number vector such as [1+2**i* 7+3**i*].

Matrices

Matrices are two-dimensional arrays. They are composed of at least two rows and at least one column. Matrices may contain any combination of or real and complex numbers, such as:

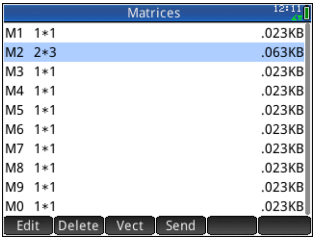
$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} \text{ or } \begin{bmatrix} 1+2i \\ 3-4i \\ 7 \end{bmatrix}.$$

Matrix variables

There are ten reserved matrix variables available, named `M0` to `M9`; however, you can save a matrix in a variable name you define. You can then use them in calculations in Home or CAS views or in a program. You can retrieve matrix names from the Vars menu, or just type their names from the keyboard.

Creating and storing matrices

The Matrix Catalog contains the reserved matrix variables `M0–M9`, as well as any matrix variables you have created in Home or CAS views (or from a program if they are global).



```
Matrices                         12:11
M1  1*1                        .023KB
M2  2*3                        .063KB
M3  1*1                        .023KB
M4  1*1                        .023KB
M5  1*1                        .023KB
M6  1*1                        .023KB
M7  1*1                        .023KB
M8  1*1                        .023KB
M9  1*1                        .023KB
M0  1*1                        .023KB
Edit  Delete  Vect  Send
```

Once you select a matrix name, you can create, edit, and delete matrices in the Matrix Editor. You can also send a matrix to another HP Prime.

To open the Matrix Catalog, press Shift 4 (Matrix).

In the Matrix Catalog, the size of a matrix is shown beside the matrix name. (An empty matrix is shown as `1*1`.) The number of elements in it is shown beside a vector.

You can also create and store matrices—named or unnamed—in Home view. For example, the command:

```
POLYROOT([1,0,-1,0])▶M1
```

stores the roots of the complex vector of length 3 into the variable M1. M1 will thus contain the three roots of $x^3 - x = 0$: 0, 1 and –1.

Matrix Catalog: buttons and keys

The buttons and keys available in the Matrix Catalog are:

Button or Key	Purpose
Edit	Opens the highlighted matrix for editing.
Delete or Del	Deletes the content sof the selected matrix.
Vect	Changes the selected matrix into a one-dimensional vector.
Send	Transmits the highlighted matrix to another HP Prime.
Shift Esc Clear (Clear)	Clears the contents of the reserved matrix variables `M0–M9` and deletes any user-named matrices.

Working with matrices

To open the Matrix Editor

To create or edit a matrix, go to the Matrix Catalog, and tap on a matrix. (You could also use the cursor keys to highlight the matrix and then press Edit.) The Matrix Editor opens.

Matrix Editor: Buttons and keys

The buttons and keys available in the Matrix Editor are.:

Button or Key	Purpose
Edit	Copies the highlighted element to the entry 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.
Size	Displays a menu for you to choose the small font, medium font, or large font.
Go	A three-way toggle that controls how the cursor will move after an element has been entered. Go → moves the cursor to the right, Go ↓ moves it downward, and Go does not move it at all.
Column	Displays a menu for you to choose 1, 2, 3, or 4 columns to be displayed at a time.
Shift Esc Clear (Clear)	Deletes the highlighted row, or column, or the entire matrix. (You are prompted to make a choice.)
Shift ▲ ▼ ◀ ▶	Moves the cursor to the first row, last row, first column, or last column respectively.

To create a matrix in the Matrix Editor

1. Open the Matrix Catalog:

   Shift 4 (Matrix)

2. If you want to create a vector, press ▲ or ▼ until the matrix you want to use is highlighted, tap Vect, and then press Enter. Continue from step 4 below.

3. If you want to create a matrix, either tap on the name of the matrix (M0–M9), or press ▲ or ▼ until the matrix you want to use is highlighted and then press Enter.

   Note that an empty matrix will be shown with a size of `1*1` beside its name.

4. For each element in the matrix, type a number or an expression, and then tap OK or press Enter.

   You can enter **complex numbers** in complex form, that is, (*a*, *b*), where *a* is the real part and *b* is the imaginary part. You can also enter them in the form *a*+*bi*.

5. By default, on entering an element the cursor moves to the next column in the same row. You can use the cursor keys to move to a different row or column. You can also change the direction the cursor automatically moves by tapping Go. The Go button toggles between the following options:

   – Go →: the cursor moves to the cell to the right of the current cell when you press Enter.

   – Go ↓: the cursor moves to the cell below the current cell when you press Enter.

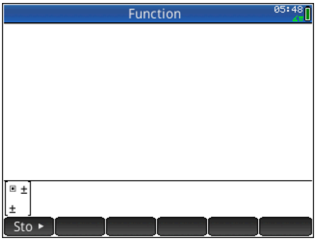
   – Go: the cursor stays in the current cell when you press Enter.

6. When done, press Shift 4 (Matrix) to return to the Matrix Catalog, or press ⌂ Settings to return to Home view. The matrix entries are automatically saved.

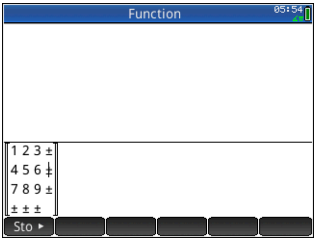
Matrices in Home view

You can enter and operate on matrices directly in Home view. The matrices can be named or unnamed.

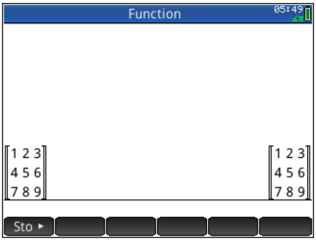
Enter a vector or matrix in Home or CAS views directly in the entry line.



1. Press Shift 5 ([]) to start a vector or matrix. The matrix template will appear, as shown in the figure to the right.
2. Enter a value in the square. Then press ▶ to enter a second value in the same row, or press ▼ to move to the second row. The matrix will grow with you as you enter values, adding rows and columns as needed.



3. You can increase your matrix at any time, adding columns and rows as you please. You can also delete an entire row or column. Just place the cursor on the ± symbol at the end of a row or column. Then press + to insert a new row or column, or − to delete the row or column. You can also press Del to delete a row or column. In the figure above, pressing Del would delete the second row of the matrix.



4. When you are finished, press Enter and the matrix will be displayed in the History. You can then use or name your matrix.

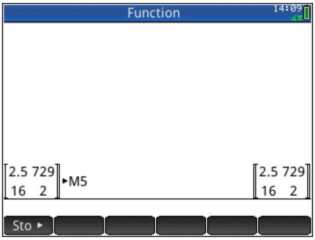
To store a matrix

You can store a vector or matrix in a variable. You can do this before it is added to History, or you can copy it from History. When you've entered a vector or matrix in the entry line or copied it from History to the entry line, tap Sto ▸, enter a name for it and press Enter. The variable names reserved for vectors and matrices are M0 through M9. You can always use a variable name you devise to store a vector or matrix. The new variable will appear in the Vars menu under User.

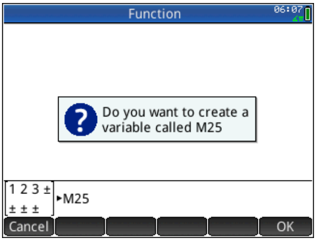
The screen at the right shows the matrix

$$\begin{bmatrix} 2.5 & 729 \\ 16 & 2 \end{bmatrix}$$

being stored in M5. Note that you can enter an expression (like 5/2) for an element of the matrix, and it will be evaluated upon entry

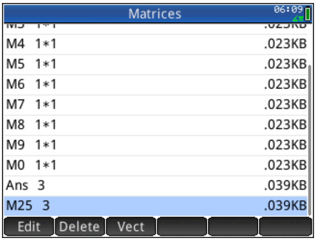


The figure to the right shows the vector [1 2 3] being stored in the user variable M25. You will be prompted to confirm that you want to create your own variable. Tap OK to proceed or Cancel to cancel.



Do you want to create a variable called M25

Once you tap OK, your new matrix will be stored under the name M25. This variable will show up in the User section of the Vars menu. You will also see your new matrix in the Matrix Catalog.



M4	1*1	.023KB
M5	1*1	.023KB
M6	1*1	.023KB
M7	1*1	.023KB
M8	1*1	.023KB
M9	1*1	.023KB
M0	1*1	.023KB
Ans	3	.039KB
M25	3	.039KB

To display a matrix

In Home view, enter the name of the vector or matrix and press Enter. If the vector or matrix is empty, zero is returned inside double square brackets.

To display one element

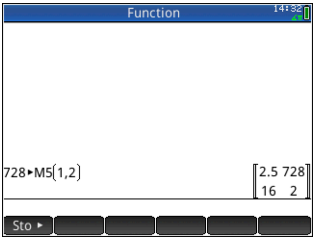
In Home view, enter *matrixname*(*row,column*). For example, if `M2` is `[[3,4],[5,6]]`, then `M2(1,2)` Enter returns `4`.

To store one element

In Home view, enter *value*, tap Sto ▸, and then enter *matrixname*(*row, column*).

For example, to change the element in the first row and second column of M5 to 728 and then display the resulting matrix:

728
Sto ▸ ALPHA +/– 5
( ) 1 , 2
Enter



```
728▸M5(1,2)                [2.5 728]
                           [16    2]
```

An attempt to store an element to a row or column beyond the size of the matrix results in re-sizing the matrix to allow the storage. Any intermediate cells will be filled with zeroes.

To send a matrix

You can send matrices between calculators just as you can send apps, programs, lists, and notes. See "Sharing data" on page 44 for instructions.

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]] in M1 and [[5,6],[7,8]] in M2.

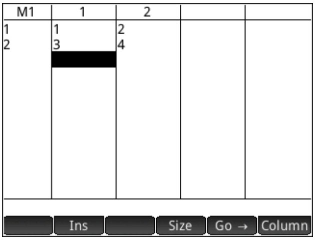
Example

1. Select the first matrix:

   Shift 4 (Matrix)
   Tap M1 or highlight it and press Enter.

2. Enter the matrix elements:

   Go → 1 Enter 2
   Enter 3 Enter
   4 Enter



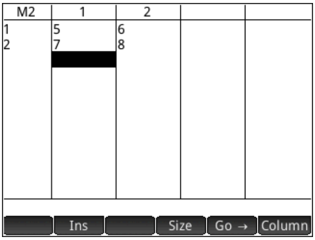
M1	1	2
1	1	2
2	3	4

3. Select the second matrix:

   Shift 4 (Matrix)
   Tap M2 or highlight it and press Enter.

4. Enter the matrix elements:

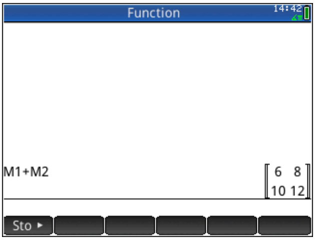
   5 Enter 6
   Enter 7 Enter
   8 Enter



M2	1	2
1	5	6
2	7	8

5. In Home view, add the two matrices you have just created.

   Settings ALPHA +/– 1 +
   ALPHA +/– 2 Enter



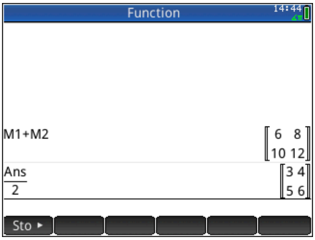
M1+M2 $\begin{bmatrix}6 & 8\\10 & 12\end{bmatrix}$

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



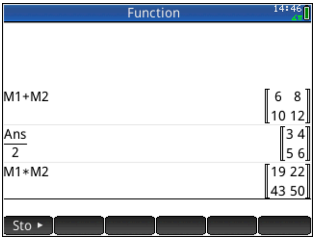
M1+M2 $\begin{bmatrix}6 & 8\\10 & 12\end{bmatrix}$

$\frac{\text{Ans}}{2}$ $\begin{bmatrix}3 & 4\\5 & 6\end{bmatrix}$

To multiply two matrices

To multiply the two matrices that you created for the previous example, press the following keys:

ALPHA +/− 1 × ALPHA +/− 2 Enter



Function 14:46

M1+M2 $\begin{bmatrix} 6 & 8 \\ 10 & 12 \end{bmatrix}$

$\frac{Ans}{2}$ $\begin{bmatrix} 3 & 4 \\ 5 & 6 \end{bmatrix}$

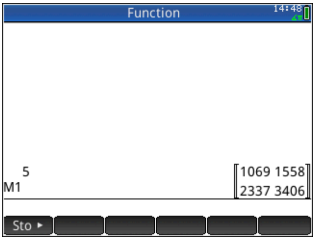
M1*M2 $\begin{bmatrix} 19 & 22 \\ 43 & 50 \end{bmatrix}$

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 +/− 1 x^y 5 Enter



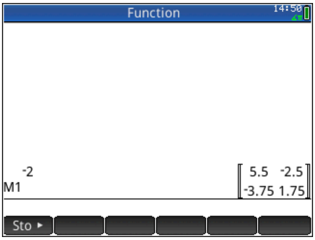
Function 14:48

$M1^{5}$ $\begin{bmatrix} 1069 & 1558 \\ 2337 & 3406 \end{bmatrix}$

You can also raise a matrix to a power without first storing it as a variable.

Matrices can also 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 +/− 1 x^y +/− 2 Enter



Function 14:50

$M1^{-2}$ $\begin{bmatrix} 5.5 & -2.5 \\ -3.75 & 1.75 \end{bmatrix}$

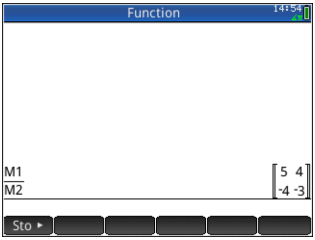
To divide by a square matrix

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 you created for the previous example, press the following keys:

ALPHA +/− 1 ÷
ALPHA +/− 2



$\frac{M1}{M2}$ $\begin{bmatrix} 5 & 4 \\ -4 & -3 \end{bmatrix}$

To invert a matrix

You can invert a *square matrix* in Home view by typing the matrix (or its variable name) and pressing Shift ÷ Enter. You can also use the `INVERSE` command in the Matrix category of the Math menu.

To negate each element

You can change the sign of each element in a matrix by pressing +/−, entering the matrix name, and pressing Enter.

Solving systems of linear equations

You can use matrices to solve systems of linear equations, such as the following:

$$2x+3y+4z=5$$
$$x+y-z=7$$
$$4x-y+2z=1$$

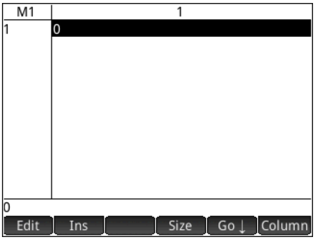
In this example we will use matrices M1 and M2, but you could use any available matrix variable name.

1. Open the Matrix Catalog, clear M1, choose to create a vector, and open the Matrix Editor:

   Shift 4 (Matrix)

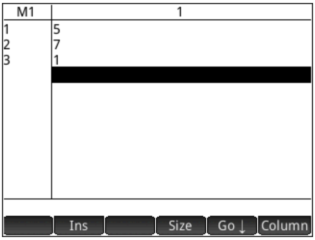
   [press ▲ or ▼ to select M1]

   Del OK Vect Enter



2. Create the vector of the three constants in the linear system.

   5 Enter 7 Enter 1 Enter

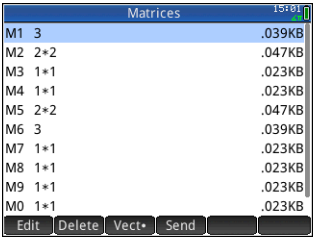


M1	1
1	5
2	7
3	1

3. Return to the Matrix Catalog.

   Shift 4 Matrix U

   The size of M1 should be showing as 3.

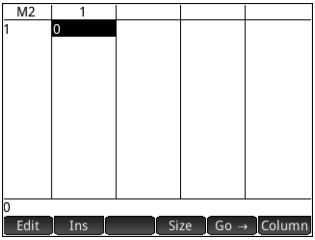


Matrices

M1	3	.039KB
M2	2∗2	.047KB
M3	1∗1	.023KB
M4	1∗1	.023KB
M5	2∗2	.047KB
M6	3	.039KB
M7	1∗1	.023KB
M8	1∗1	.023KB
M9	1∗1	.023KB
M0	1∗1	.023KB

4. Select and clear M2, and re-open the Matrix Editor:

   [Press ▼ or ▲ to select M2] Del OK Enter

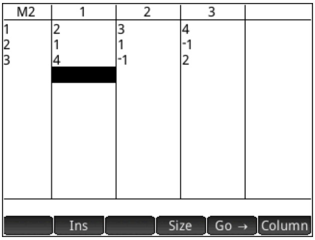


M2	1
1	0

0

5. Enter the equation coefficients.

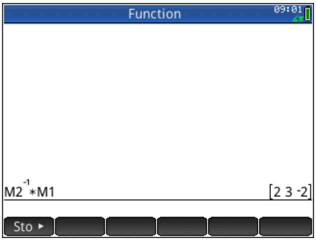
   2 Enter 3 Enter
   [Tap in cell R1, C3.]
   4 Enter
   1 Enter 1 Enter
   +/– 1 Enter
   4 Enter +/– 1
   Enter 2 Enter



M2	1	2	3
1	2	3	4
2	1	1	-1
3	4	-1	2

6. Return to Home view and left-multiply the constants vector by the inverse of the coefficients matrix:

   ⌂ Settings ALPHA +/– 2
   Shift ÷ ×
   ALPHA +/– 1 Enter



```
M2^-1*M1                                   [2 3 -2]
```

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 page 476).

Matrix functions and commands

Functions

Functions can be used in any app or in Home view. They are listed on the Math menu under the Matrix category. They can be used in mathematical expressions—primarily in Home view—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])`.

Menu format

By default, a Matrix function is presented on the Math menu using its descriptive name, not its common command name. Thus the shorthand name `TRN` is presented as **Transpose** and `DET` is presented as **Determinant**.

If you prefer the Math menu to show command names instead, deselect the **Menu Display** option on page 2 of the **Home Settings** screen (see page 26).

Commands

Matrix commands differ from matrix functions in that they do not return a result. For this reason, these functions can be used in an expression and matrix commands cannot.

The matrix commands are designed to support programs that use matrices.

The matrix commands are listed in the Matrix category of the Commands menu in the Program Editor. They are also listed in the Catalog menu, one of the Toolbox menus. Press Mem B and tap Catlg to display the commands catalog. The matrix functions are described in the following sections of this chapter; the matrix commands are described in the chapter Programming (see page 544).

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

The matrix functions are available in the Matrix category on the Math menu: Mem B Select `Matrix` Select a function.

Transpose

Transposes *matrix*. For a complex matrix, TRN finds the conjugate transpose.

`TRN`(*matrix*)

Example:

$$\mathtt{TRN}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right) \text{ returns } \begin{bmatrix}1 & 3\\2 & 4\end{bmatrix}$$

Determinant

Determinant of a square *matrix*.

`DET`(*matrix*)

Example:

$$\mathtt{DET}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right) \text{ returns } -2$$

RREF Reduced Row-Echelon Form. Changes a rectangular *matrix* to its reduced row-echelon form.

RREF(*matrix*)

Example:

$$\mathrm{RREF}\left(\begin{bmatrix}1 & -2 & 1\\3 & 4 & -1\end{bmatrix}\right) \text{ returns } \begin{bmatrix}1 & 0 & 0.2\\0 & 1 & -0.4\end{bmatrix}$$

Create

Make 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. You can also create a vector by the number of elements (e) instead of the number of rows and columns.

MAKEMAT(*expression, rows, columns*)

MAKEMAT(*expression, elements*)

Examples:

MAKEMAT(0,3,3) returns a 3 × 3 zero matrix, [[0,0,0],[0,0,0],[0,0,0]].

MAKEMAT(√2,2,3) returns the 2 × 3 matrix [[√2,√2,√2],[√2,√2,√2]].

MAKEMAT(I+J–1,2,3) returns the 2 × 3 matrix

[[1,2,3],[2,3,4]]

Note in the example above that each element is the sum of the row number and column number minus 1.

MAKEMAT(√2,2) returns the 2-element vector [√2,√2].

Identity Identity matrix. Creates a square matrix of dimension *size* × *size* whose diagonal elements are 1 and off-diagonal elements are zero.

IDENMAT(*size*)

Random Given two integers, *n* and *m*, and a matrix name, creates an *n x m* matrix that contains random integers in the range −99 through 99 with a uniform distribution and stores it in the matrix name.

`randMat`(*MatrixName,n,m*)

Example:

`RANDMAT(M1,2,2)` returns a 2x2 matrix with random integer elements, and stores it in M1.

Jordan Returns a square *nxn* matrix with *expr* on the diagonal, 1 above and 0 everywhere else.

`JordanBlock`(*Expr,n*)

Example:

`JordanBlock(7,3)` returns $\begin{bmatrix} 7 & 1 & 0 \\ 0 & 7 & 1 \\ 0 & 0 & 7 \end{bmatrix}$

Hilbert Given a positive integer, n, returns the n^{th} order Hilbert matrix. Each element of the matrix is given by the formula 1/(j+k-1) where *j* is the row number and *k* is the column number.

`hilbert(n)`

Example:

In CAS view, `hilbert(4)` returns $\begin{bmatrix} 1 & \frac{1}{2} & \frac{1}{3} & \frac{1}{4} \\ \frac{1}{2} & \frac{1}{3} & \frac{1}{4} & \frac{1}{5} \\ \frac{1}{3} & \frac{1}{4} & \frac{1}{5} & \frac{1}{6} \\ \frac{1}{4} & \frac{1}{5} & \frac{1}{6} & \frac{1}{7} \end{bmatrix}$

Isometric Matrix of an isometry given by its proper elements.

`mkisom`(*vector*, *sign(1 or -1)*)

Example:

In CAS view, `mkisom([1,2],1)` returns

$$\begin{bmatrix} \cos(1) & -\sin(1) \\ \sin(1) & \cos(1) \end{bmatrix}$$

Vandermonde Returns the Vandermonde matrix. Given a vector [*n1, n2 … nj*], returns a matrix whose first row is $[(n1)^0, (n1)^1, (n1)^2, \ldots, (n1)^{j-1}]$. The second row is $[(n2)^0, (n2)^1, (n2)^2, \ldots, (n2)^{j-1}]$, etc.

`vandermonde(`*vector*`)`

Example:

`vandermonde([1 3 5])` returns $\begin{bmatrix} 1 & 1 & 1 \\ 1 & 3 & 9 \\ 1 & 5 & 25 \end{bmatrix}$

Basic

Norm Returns the Frobenius norm of a matrix.

`|matrix|`

Example:

$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ returns `5.47722557505`

Row Norm Row Norm. Finds the maximum value (over all rows) for the sums of the absolute values of all elements in a row.

`ROWNORM(`*matrix*`)`

Example:

$\mathrm{ROWNORM}\left(\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}\right)$ returns `7`

Column Norm Column Norm. Finds the maximum value (over all columns) of the sums of the absolute values of all elements in a column.

`COLNORM(`*matrix*`)`

Example:

$\mathrm{COLNORM}\left(\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}\right)$ returns `6`

Spectral Norm

Spectral Norm of a square *matrix*.

SPECNORM(*matrix*)

Example:

SPECNORM$\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns 5.46498570422

Spectral Radius

Spectral Radius of a square *matrix*.

SPECRAD(*matrix*)

Example:

SPECRAD$\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns 5.37228132327

Condition

Condition Number. Finds the 1-norm (column norm) of a square *matrix*.

COND(*matrix*)

Example:

COND$\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns 21

Rank

Rank of a rectangular *matrix*.

RANK(*matrix*)

Example:

RANK$\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns 2

Pivot

Given a matrix, a row number n, and a column number, m, uses Gaussian elimination to return a matrix with zeroes in column *m*, except that the element in column *m* and row *n* is kept as a pivot.

pivot(*matrix,n,m*)

Example:

pivot$\left(\begin{bmatrix}1 & 2\\3 & 4\\5 & 6\end{bmatrix}, 1, 1\right)$ returns $\begin{bmatrix}1 & 2\\0 & -2\\0 & -4\end{bmatrix}$

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*)

Example:

$\mathtt{TRACE}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns `5`

Advanced

Eigenvalues Displays the eigenvalues in vector form for *matrix*.

`EIGENVAL`(*matrix*)

Example:

$\mathtt{EIGENVAL}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns:

$\begin{bmatrix}5.37228\ldots & -0.37228\ldots\end{bmatrix}$.

Eigenvectors 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*)

Example:

$\mathtt{EIGENVV}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns the following matrices:

$$\left\{\begin{bmatrix}0.4159\ldots & -0.8369\ldots\\0.9093\ldots & 0.5742\ldots\end{bmatrix}, \begin{bmatrix}5.3722\ldots & 0\\0 & -0.3722\ldots\end{bmatrix}\right\}$$

Jordan Returns the list made by the matrix of passage and the Jordan form of a matrix.

`jordan`(*matrix*)

Example:

$\mathtt{jordan}\left(\begin{bmatrix}0 & 2\\1 & 0\end{bmatrix}\right)$ returns $\left[\begin{bmatrix}\sqrt{2} & -\sqrt{2}\\1 & 1\end{bmatrix}, \begin{bmatrix}\sqrt{2} & 0\\0 & -\sqrt{2}\end{bmatrix}\right]$

Diagonal Given a list, returns a matrix with the list elements along its diagonal and zeroes elsewhere. Given a matrix, returns a vector of the elements along its diagonal.

`diag`(list) `or diag`(matrix)

Example:

$$\texttt{diag}\left(\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}\right) \text{ returns } \begin{bmatrix} 1 & 4 \end{bmatrix}$$

Cholesky For a numerical symmetric matrix A, returns the matrix L such that A=L*tran(L).

`cholesky`(*matrix*)

Example:

In CAS view, $\texttt{cholesky}\left(\begin{bmatrix} 3 & 1 \\ 1 & 4 \end{bmatrix}\right)$ returns

$$\left(\begin{bmatrix} \sqrt{3} & 0 \\ \frac{\sqrt{3}}{3} & \frac{\sqrt{33}}{3} \end{bmatrix}\right) \text{ after simplification}$$

Hermite Hermite normal form of a matrix with coefficients in Z: returns U,B such that U is invertible in Z, B is upper triangular and B=U*A.

`ihermite(Mtrx(A))`

Example:

$$\texttt{ihermite}\left(\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}\right) \text{ returns } \left[\begin{bmatrix} -3 & 1 & 0 \\ 4 & -1 & 0 \\ -1 & 2 & -1 \end{bmatrix}, \begin{bmatrix} 1 & -1 & -3 \\ 0 & 3 & 6 \\ 0 & 0 & 0 \end{bmatrix}\right]$$

Hessenberg Matrix reduction to Hessenberg form. Returns [P,B] such that B=inv(P)*A*P.

```
hessenberg(Mtrx(A))
```

Example:

In CAS view, $\texttt{hessenberg}\left(\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}\right)$

returns $\begin{bmatrix} \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} & \begin{bmatrix} 0 & \frac{4}{7} & 1 \end{bmatrix} & \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} \\ \begin{bmatrix} 1 & \frac{29}{7} & 2 \end{bmatrix} & \begin{bmatrix} 7 & \frac{39}{7} & 8 \end{bmatrix} & \begin{bmatrix} 0 & \frac{278}{49} & \frac{3}{7} \end{bmatrix} \end{bmatrix}$

Smith Smith normal form of a matrix with coefficients in Z: returns U,B,V such that U and V invertible in Z, B is diagonal, B[i,i] divides B[i+1,i+1], and B=U*A*V.

```
ismith(Mtrx(A))
```

Example:

$\texttt{ismith}\left(\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}\right)$ returns

$$\begin{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 4 & -1 & 0 \\ -1 & 2 & -1 \end{bmatrix} & \begin{bmatrix} 1 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 0 \end{bmatrix} & \begin{bmatrix} 1 & -2 & 1 \\ 0 & 1 & -2 \\ 0 & 0 & 1 \end{bmatrix} \end{bmatrix}$$

Factorize

LQ LQ Factorization. Factorizes a *m* × *n matrix* into three matrices L, Q, and P, where {[L[*m* × *n lowertrapezoidal*]],[Q[*n* × *n orthogonal*]], [P[*m* × *m permutation*]]}and P*A=L*Q.

`LQ(matrix)`

Example:

$$\mathtt{LQ}\left(\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}\right) \text{ returns}$$

$$\left\{\begin{bmatrix}2.2360... & 0\\ 4.9193... & 0.8944...\end{bmatrix},\begin{bmatrix}0.4472... & 0.8944...\\ 0.8944... & -0.4472...\end{bmatrix},\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\right\}$$

LSQ Least Squares. Displays the minimum norm least squares matrix (or vector) corresponding to the system *matrix1**X=*matrix2*.

`LSQ`(*matrix1, matrix2*)

Example:

$$\mathtt{LSQ}\left(\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix},\begin{bmatrix}5\\ 11\end{bmatrix}\right) \text{ returns } \begin{bmatrix}1\\ 2\end{bmatrix}$$

LU LU Decomposition. Factorizes a square *matrix* into three matrices L, U, and P, where {[L[*lowertriangular*]],[U[*uppertriangular*]],[P[*permutation*]] }}
and P*A=L*U.

`LU`(*matrix*)

Example:

$$\mathtt{LU}\left(\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}\right) \text{ returns}$$

$$\left\{\begin{bmatrix}1 & 0\\ 0.3333... & 1\end{bmatrix},\begin{bmatrix}3 & 4\\ 0 & 0.6666...\end{bmatrix},\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}\right\}$$

QR QR Factorization. Factorizes an *m*×*n* matrix A numerically as Q*R, where Q is an orthogonal matrix and R is an upper triangular matrix, and returns R. R is stored in var2 and Q=A*inv(R) is stored in var1.

`QR`(*matrix A,var1,var2*)

Example:

$$\texttt{QR}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right) \text{ returns}$$

$$\left\{\begin{bmatrix}0.3612... & 0.9486...\\0.9486... & -0.3162...\end{bmatrix},\begin{bmatrix}3.1622... & 4.4271...\\0 & 0.6324...\end{bmatrix},\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}\right\}$$

SCHUR Schur Decomposition. Factorizes 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*)

Example:

$$\texttt{SCHUR}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right) \text{ returns}$$

$$\left\{\begin{bmatrix}0.4159... & 0.9093...\\0.9093... & 0.4159...\end{bmatrix},\begin{bmatrix}5.3722... & 1\\5.55\times10^{-17} & -0.3722\end{bmatrix}\right\}$$

SVD Singular Value Decomposition. Factorizes an *m* × *n matrix* into two matrices and a vector:
{[[$m \times m$ *square orthogonal*]],[[$n \times n$ *square orthogonal*]], [*real*]}.

`SVD`(*matrix*)

Example:

$$\texttt{SVD}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right) \text{ returns}$$

$$\left\{\begin{bmatrix}0.4045... & -0.9145...\\0.9145... & 0.4045...\end{bmatrix},\begin{bmatrix}5.4649... & 0.3659...\end{bmatrix},\begin{bmatrix}0.5760... & 0.8174...\\0.8174... & -0.5760\end{bmatrix}\right\}$$

SVL Singular Values. Returns a vector containing the singular values of *matrix.*

`SVL`(*matrix*)

Example:

`SVL` $\left(\begin{bmatrix}1 & 2\\ 3 & 4\end{bmatrix}\right)$ returns $\begin{bmatrix}5.4649... & 0.3659...\end{bmatrix}$

Vector

Cross Product Cross Product of *vector1* with *vector2*.

`CROSS`(*vector1*, *vector2*)

Example:

`CROSS` $(\begin{bmatrix}1 & 2\end{bmatrix}, \begin{bmatrix}3 & 4\end{bmatrix})$ returns $\begin{bmatrix}0 & 0 & -2\end{bmatrix}$

Dot Product Dot Product of two arrays, matrix1 and matrix2.

`DOT`(matrix1, matrix2)

Example:

`DOT` $(\begin{bmatrix}1 & 2\end{bmatrix}, \begin{bmatrix}3 & 4\end{bmatrix})$ returns `11`

L^2 Norm Returns the l^2 norm (sqrt(x1^2+x2^2+...xn^2)) of a vector.

`l2norm(Vect)`

Example:

`l2norm` $(\begin{bmatrix}3 & 4 & -2\end{bmatrix})$ returns √`29`

L^1 Norm Returns the l^1 norm (sum of the absolute values of the coordinates) of a vector.

`l1norm(Vect)`

Example:

`l1norm` $(\begin{bmatrix}3 & 4 & -2\end{bmatrix})$ returns `9`

Max Norm

Returns the l^{∞} norm (the maximum of the absolute values of the coordinates) of a vector.

```
maxnorm(Vect or Mtrx)
```

Example:

maxnorm ($\begin{bmatrix}1 & 2 & 3 & -4\end{bmatrix}$) returns 4

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(I ≠ J,4,4) creates a 4 × 4 matrix showing the numeral 1 for all elements except zeros on the diagonal. The logical operator (≠) returns 0 when I (the row number) and J (the column number) are equal, and returns 1 when they are not equal. (You can insert ≠ by choosing it from the relations palette: Shift 6 ≤,≥,≠ W.)

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

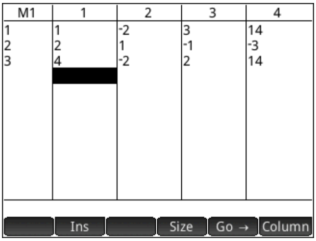
The set of equations

$$\begin{aligned} x - 2y + 3z &= 14 \\ 2x + y - z &= -3 \\ 4x - 2y + 2z &= 14 \end{aligned}$$

can be written as the augmented matrix

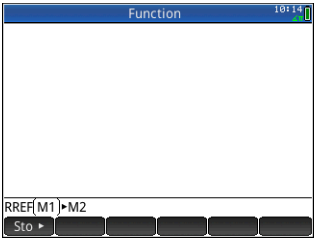
$$\left[\begin{array}{ccc|c} 1 & -2 & 3 & 14 \\ 2 & 1 & -1 & -3 \\ 4 & -2 & 2 & 14 \end{array}\right]$$

which can then be stored as a 3×4 real matrix in any matrix variable. M1 is used in this example.



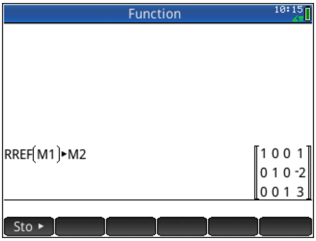
M1	1	2	3	4
1	1	-2	3	14
2	2	1	-1	-3
3	4	-2	2	14

You can then use the `RREF` function to change this to reduced-row echelon form, storing it in any matrix variable. M2 is used in this example.



RREF(M1)▸M2

The reduced row echelon matrix gives the solution to the linear equation in the fourth column.



RREF(M1)▸M2

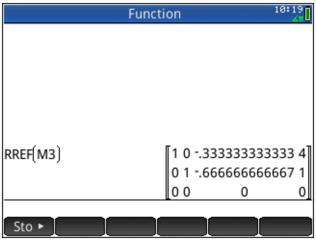
$$\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & -2 \\ 0 & 0 & 1 & 3 \end{bmatrix}$$

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.



RREF(M3)

$$\begin{bmatrix} 1 & 0 & -.333333333333 & 4 \\ 0 & 1 & -.666666666667 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

26

Notes and Info

The HP Prime has two text editors for entering notes:

- The Note Editor: opens from within the Note Catalog (which is a collection of notes independent of apps).
- The Info Editor: opens from the Info view of an app. A note created in the Info view is associated with the app and stays with it if you send the app to another calculator.

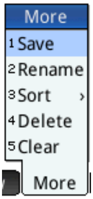
The Note Catalog

Subject to available memory, you can store as many notes as you want in the Note Catalog. These notes are independent of any app. The Note Catalog lists the notes by name. This list excludes notes that were created in any app's Info view, but these can be copied and then pasted into the Note Catalog via the clipboard. From the Note Catalog, you create or edit individual notes in the Note Editor.

Note Catalog: button and keys

Press Shift 0 (Notes) to enter the Note Catalog. While you are in the Note Catalog, you can use the following buttons and keys. Note that some buttons will not be available if there are no notes in the Note Catalog.

Button or Key	Purpose
Edit	Opens the selected note for editing.
New	Begins a new note, and prompts you for a name.
More	Tap to provide additional features. See below.

Button or Key	Purpose (Continued)
 More 1 Save 2 Rename 3 Sort › 4 Delete 5 Clear More	**Save**: creates a copy of the selected note and prompts you to save it under a new name. **Rename**: renames the selected note. **Sort**: sorts the list of notes (sort options are alphabetical and chronological). **Delete**: deletes the selected note. **Clear**: deletes all notes. **Send**: sends the selected note to another HP Prime.
⌫ Del	Deletes the selected note.
Shift Esc Clear	Deletes all notes in the catalog.

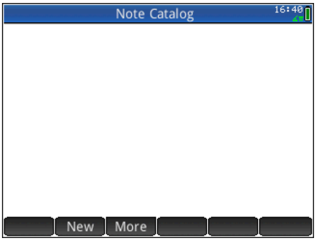
The Note Editor

The Note Editor is where you create and edit notes. You can launch the Note Editor from the Notes Catalog, and also from within an app. Notes created within an app stay with that app even if you send the app to another calculator. Such notes do not appear in the Notes Catalog. They can only be read when the associated app is open. Notes created via the Notes Catalog are not specific to any app and can be viewed at any time by opening the Notes Catalog. Such notes can also be sent to another calculator.

To create a note from the Notes Catalog

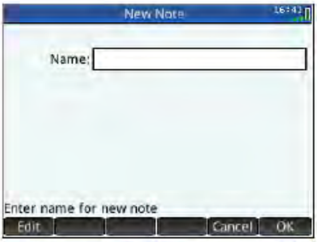
1. Open the Note Catalog.

   Shift 0 Notes " "



2. Create a new note.

   New

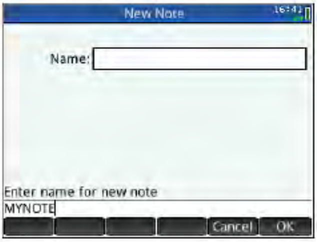


Enter name for new note

3. Enter a name for your note. In this example, we'll call the note MYNOTE.

   ALPHA ALPHA MYNOTE

   OK OK



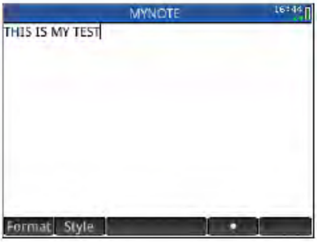
Enter name for new note

MYNOTE

4. Write your note, using the editing keys and formatting options described in the following sections.

   When you are finished, exit the Note Editor by pressing ⌂ Settings or pressing Apps Info and opening an app. Your work is automatically saved.

   To access your new note, return to the Notes Catalog.



THIS IS MY TEST

To create a note for an app

You can also create a note that is specific to an app and which stays with the app should you send the app to another calculator. See "Adding a note to an app" on page 106. Notes created this way take advantage of all the formatting features of the Note Editor (see below).

Note Editor: buttons and keys

The following buttons and keys are available while you are adding or editing a note.

Button or Key	Purpose
Format	Opens the text formatting menu. See “Formatting options” on page 494.
Style	Provides bold, italic, underline, full caps, superscript and subscript options. See “Formatting options” on page 494
•	A toggle button that offers three types of bullet. See “Formatting options” on page 494
Insert	Starts a 2D editor for entering mathematical expressions in textbook format; see “Inserting mathematical expressions” on page 495
␣	Enters a space during text entry.
▲ Page ▼	Moves from page to page in a multi-page note.
Shift View Copy	Shows options for copying text in a note. See below.
Begin	Copy option. Mark where to begin a text selection.
End	Copy option. Mark where to end a text selection.
All	Copy option. Select the entire note.
Cut	Copy option. Cut the selected text.
Copy	Copy option. Copy the selected text.
⌫ Del	Deletes the character to the left of the cursor.

Button or Key	Purpose (Continued)
Enter	Starts a new line.
Shift Esc (Clear)	Erases the entire note.
Vars	Menu for entering variable names, and the contents of variables.
Mem	Menu for entering math commands.
Shift Vars (Chars)	Displays a palette of special characters. To type one, highlight it and tap OK or press Enter. To copy a character *without* closing the Chars menu, select it and tap Echo.

Entering uppercase and lowercase characters

The following table below describes how to quickly enter uppercase and lowercase characters.

Keys	Purpose
ALPHA	Make the next character upper-case
ALPHA ALPHA	Lock mode: make all characters uppercase until the mode is reset
Shift	With uppercase locked, make next character lowercase
Shift ALPHA	With uppercase locked, make all characters lowercase until the mode is reset
ALPHA	Reset uppercase lock mode
ALPHA Shift	Make the next character lower-case
ALPHA Shift ALPHA	Lock mode: make all characters lowercase until the mode is reset
Shift	With lowercase locked, make next character uppercase

Keys	Purpose (Continued)
Shift ALPHA alpha	With lowercase locked, make all characters uppercase until the mode is reset
ALPHA alpha	Reset lowercase lock mode

The left side of the notification area of the title bar will indicate what case will be applied to the character you next enter.

Text formatting

You can enter text in different formats in the Note Editor. Choose a formatting option before you start entering text. The formatting options are described in “Formatting options” below.

Formatting options

Formatting options are available from three touch buttons in the Note Editor and in the Info view of an app:

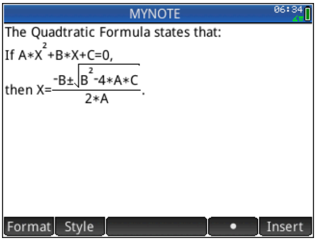
Format Style •

The formatting options are listed in the table below.

Category	Options
Format Font Size	• 10–22 pt
Format Foreground Color	Select from twenty colors.
Format Background Color	Select from twenty colors.
Format Align (text alignment)	• Left • Center • Right

Category	Options (Continued)
Style Font Style	• Bold • Italic • Underline • Strikethrough • Superscript • Subscript
• Bullets	• • • ◦ • ▻ • × [Cancels bullet]

Inserting mathematical expressions



The Quadtratic Formula states that:

If $A*X^2+B*X+C=0$,

then $X=\frac{-B\pm\sqrt{B^2-4*A*C}}{2*A}$.

You can insert a mathematical expression in textbook format into your note, as shown in the figure to the right. The Note Editor uses the same 2D editor that the Home and CAS views employ, activated via the Insert menu button.

1. Enter the text you want. When you come to the point where you want to start a mathematical expression, tap Insert.
2. Enter the mathematical expression just as you would in Home or CAS views. You can use the math template as well as any function in the Toolbox menus.
3. When you have finished entering your mathematical expression, press ▶ 2 or 3 times (depending on the complexity of your expression) to exit the editor. You can now continue to enter text.

To import a note

You can import a note from the Note Catalog into an app’s Info view and vice versa.

Suppose you want to copy a note named *Assignments* from the Note Catalog into the Function Info view:

1. Open the Note Catalog.

   Shift Notes

2. Select the note `Assignments` and tap Edit
3. Open the copy options for copying to the clipboard.

   Shift Copy (Copy)

   The menu buttons change to give you options for copying:

   Begin: Marks where the copying or cutting is to begin.

   End: Marks where the copying or cutting is to end.

   All: Select the entire program.

   Cut: Cut the selection.

   Copy: Copy the selection.
4. Select what you want to copy or cut (using the options listed immediately above).
5. Tap Copy or Cut.
6. Open the Info view of the Function app.

   Apps, tap the Function app icon, press Shift Info.
7. Move the cursor to the location where you want the copied text to be pasted and open the clipboard.

   Shift Paste

8. Select the text from the clipboard and press OK.

Sharing notes

You can send a note to another HP Prime. See “Sharing data” on page 44.

27

Programming in HP PPL

This chapter describes the HP Prime Programming Language (HP PPL). In this chapter you'll learn about:

- programming commands
- writing functions in programs
- using variables in programs
- executing programs
- debugging programs
- creating programs for building custom apps
- sending a program to another HP Prime

HP Prime Programs

An HP Prime program contains a sequence of commands that execute automatically to perform a task.

Command Structure

Commands are separated by a semicolon (;). Commands that take multiple arguments have those arguments enclosed in parentheses and separated by a comma(,). For example,

`PIXON` (*xposition*, *yposition*);

Sometimes, arguments to a command are optional. If an argument is omitted, a default value is used in its place. In the case of the PIXON command, a third argument could be used that specifies the color of the pixel:

`PIXON` (*xposition*, *yposition* [,*color*]);

In this manual, optional arguments to commands appear inside square brackets, as shown above. In the `PIXON` example, a graphics variable (G) could be specified as the first argument. The default is G0, which always contains the currently displayed screen. Thus, the full syntax for the PIXON command is:

`PIXON (`[*G*,] *xposition*, *yposition* [,*color*]);

Some built-in commands employ an alternative syntax whereby function arguments do not appear in parentheses. Examples include RETURN and RANDOM.

Program Structure

Programs can contain any number of subroutines (each of which is a function or procedure). Subroutines start with a heading consisting of the name, followed by parentheses that contain a list of parameters or arguments, separated by commas. The body of a subroutine is a sequence of statements enclosed within a BEGIN–END; pair. For example, the body of a simple program, called MYPROGRAM, could look like this:

```
EXPORT MYPROGAM()
BEGIN
PIXON(1,1);
END;
```

Comments

When a line of a program begins with two forward slashes, //, the rest of the line will be ignored. This enables you to insert comments in the program:

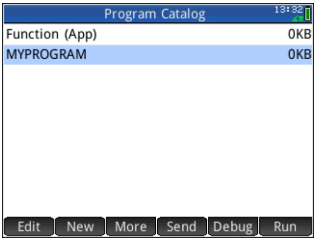
```
EXPORT MYPROGAM()
BEGIN
PIXON(1,1);
//This line is just a comment.
END;
```

The Program Catalog

The Program Catalog is where you run and debug programs, and send programs to another HP Prime. You can also rename and remove programs, and it is where you start the Program Editor. The Program Editor is where you create and edit programs. Programs can also be run from Home view or from other programs.

Open the Program Catalog

Press Shift 1 (Program) to open the Program Catalog.



Program Catalog 13:32

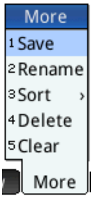
Function (App) 0KB

MYPROGRAM 0KB

The Program Catalog displays a list of program names. The first item in the Program Catalog is a built-in entry that has the same name as the active app. This entry is the app program for the active app, if such a program exists. See “App programs” on page 520 for more information.

Program Catalog: buttons and keys

Button or Key	Purpose
Edit	Opens the highlighted program for editing.
New	Prompts for a new program name, then opens the Program Editor.
More	Opens further menu options for the selected program: • Save • Rename • Sort • Delete • Clear These options are described immediately below. To redisplay the initial menu, press On or Esc.

Button or Key	Purpose (Continued)
 More 1 Save 2 Rename 3 Sort › 4 Delete 5 Clear More	**Save** creates a copy of the selected program with a new name you are prompted to give. **Rename** renames the selected program. **Sort** sorts the list of programs. (Sort options are alphabetical and chronological). **Delete** deletes the selected program. **Clear** deletes all programs.
Send	Transmits the highlighted program to another HP Prime.
Debug	Debugs the selected program.
Run	Runs the highlighted program.
Shift ▲ or Shift ▼	Moves to the beginning or end of the Program Catalog.
⌫ Del	Deletes the selected program.
Shift Esc Clear	Deletes all programs.

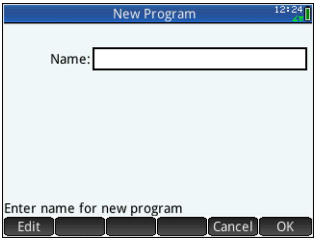
Creating a new program

In the following few sections, we will create a simple program that counts to three as an introduction to using the Program editor and its menus.

1. Open the Program Catalog and start a new program.

   Shift 1 (Program)

   New



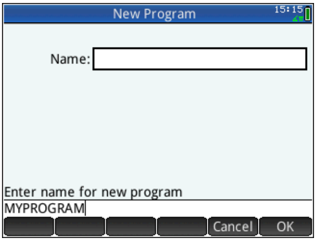
Enter name for new program

2. Enter a name for the program.

   ALPHA ALPHA (to lock alpha mode)

   MYPROGRAM

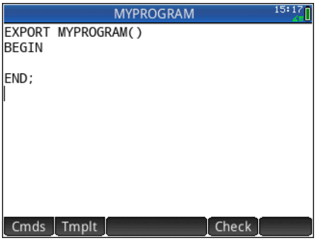
   OK.



Enter name for new program

MYPROGRAM

3. Press OK again. A template for your program is then automatically created. The template consists of a heading for a function with the same name as the program, `EXPORT MYPROGRAM()`, and a `BEGIN–END;` pair that will enclose the statements for the function.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

Tip A program name can contain only alphanumeric characters (letters and numbers) and the underscore character. The first character must be a letter. For example, `GOOD_NAME` and `Spin2` are valid program names, while `HOT STUFF` (contains a space) and `2Cool!` (starts with number and includes !) are not valid.

The Program Editor

Until you become familiar with the HP Prime commands, the easiest way to enter commands is to select them from the Catalog menu (Mem B Catlg), or from the Commands menu in the Program Editor (Cmds). To enter variables, symbols, mathematical functions, units, or characters, use the keyboard keys.

Program Editor: buttons and keys

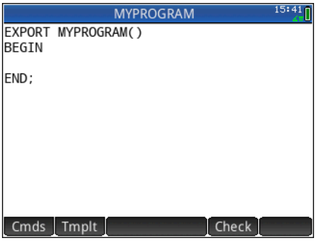
The buttons and keys in the Program Editor are:

Button or Key	Meaning
Check	Checks the current program for errors.
▲ Page ▼ or Shift ▲ and Shift ▼	If your program goes beyond one screen, you can quickly jump from screen to screen by tapping either side of this button. Tap the left side of the button to display the previous page; tap the right side to display the next page. (The left tap will be inactive if you have the first page of the program displayed.)
Cmds	Opens a menu from which you can choose from common programming commands. The commands are grouped under the options: • Strings • Drawing • Matrix • App Functions • Integer • I/O • More

Button or Key	Meaning (Continued)
	Press Esc Clear to return to the main menu. The commands in this menu are described in “Commands under the Cmds menu”, beginning on page 534.
Tmplt	Opens a menu from which you can select common programming commands. The commands are grouped under the options: • Block • Branch • Loop • Variable • Function Press Esc Clear to return to the main menu. The commands in this menu are described in “Commands under the Tmplt menu”, beginning on page 528.
Vars Chars A	Displays menus for selecting variable names and values.
Shift Vars Chars A (Chars)	Displays a palette of characters. If you display this palette while a program is open, you can choose a character and it will be be added to your program at the cursor point. To add one character, highlight it and tap OK or press Enter ≈. To add a character *without* closing the characters palette, select it and tap Echo.

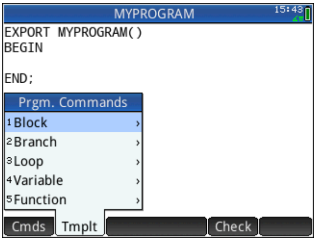
Button or Key	Meaning (Continued)
Shift ▶ and Shift ◀	Moves the cursor to the end (or beginning) of the current line. You can also swipe the screen.
Shift ▲ and Shift ▼	Moves the cursor to the start (or end) of the program. You can also swipe the screen.
ALPHA alpha ▶ and ALPHA alpha ◀	Moves the cursor one screen right (or left). You can also swipe the screen.
Enter ≈	Starts a new line.
⌫ Del	Deletes the character to the left of the cursor.
Shift ⌫ Del	Deletes the character to the right of the cursor.
Shift Esc Clear	Deletes the entire program.

1. To continue the MYPROGRAM example (which we began on page 501), use the cursor keys to position the cursor where you want to insert a command or just tap on the desired location. In this example, you need to position the cursor between `BEGIN` and `END`.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

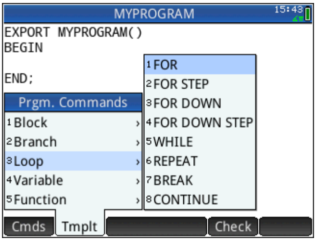
2. Tap Tmplt to open the menu of common programming commands for blocking, branching, looping, variables, and functions.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

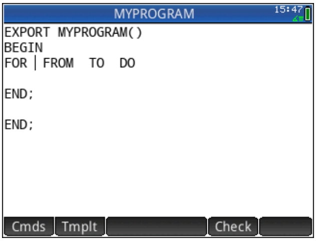
In this example we'll select a LOOP command from the menu.

3. Select `Loop` and then select `FOR` from the sub-menu.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

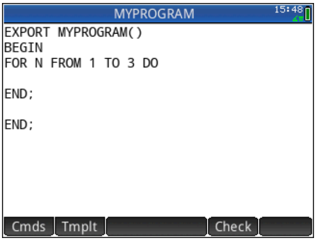
Notice that a FOR_FROM_TO_DO_ template is inserted. All you need do is fill in the missing information.



```
EXPORT MYPROGRAM()
BEGIN
FOR | FROM  TO  DO

END;

END;
```

4. Using the cursor keys and keyboard, fill in the missing parts of the command. In this case, make the statement match the following:

   `FOR N FROM 1 TO 3 DO`

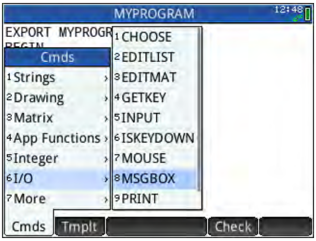


```
EXPORT MYPROGRAM()
BEGIN
FOR N FROM 1 TO 3 DO

END;

END;
```

5. Move the cursor to a blank line below the FOR statement.

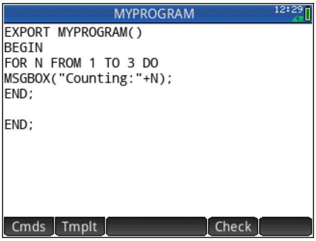
6. Tap Cmds to open the menu of common programming commands.

7. Select `I/O` and then select `MSGBOX` from the sub-menu.



```
EXPORT MYPROGR
BEGIN
```

8. Fill in the arguments of the `MSGBOX` command, and type a semicolon at the end of the command (Shift + Ans ;).



```
EXPORT MYPROGRAM()
BEGIN
FOR N FROM 1 TO 3 DO
MSGBOX("Counting:"+N);
END;

END;
```

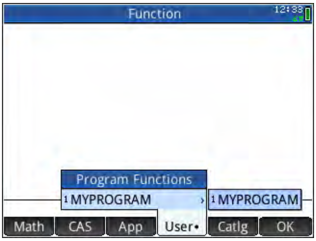
9. Tap Check to check the syntax of your program.
10. When you are finished, press Shift 1 Program Y to return to the Program Catalog or Settings to go to Home view. You are ready now to execute the program.

Run a Program

From Home view, enter the name of the program. If the program takes parameters, enter a pair of parentheses after the program name with the parameters inside them each separated by a comma. To run the program, press Enter ≈.

From the Program Catalog, highlight the program you want to run and tap Run. When a program is executed from the catalog, the system looks for a function named `START()` (no parameters).

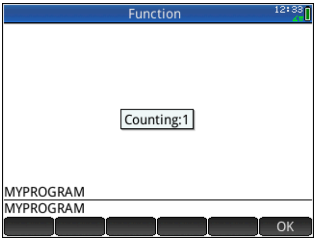
You can also run a program from the USER menu (one of the Toolbox menus):



1. Press Mem B and tap User.
2. Tap `MYPROGRAM >` to expand the menu and select `MYPROGRAM`.

   `MYPROGRAM` appears on the entry line.
3. Tap Enter ≈ and the program executes, displaying a message box.

4. Tap OK three times to step through the `FOR` loop. Notice that the number shown increments by 1 each time.



Counting:1

MYPROGRAM
MYPROGRAM

After the program terminates, you can resume any other activity with the HP Prime.

If a program has arguments, when you press Run a screen appears prompting you to enter the program parameters.

Multi-function programs

If there is more than one EXPORT function in a program, when Run is tapped a list appears for you to choose which function to run. To see this feature, create a program with the text:

```
EXPORT NAME1( )
BEGIN

END;
EXPORT NAME2( )
BEGIN

END;
```

Now note that when you select your program from the Program Catalog and tap Run or Debug, a list with `NAME1` and `NAME2` appears.

Debug a Program

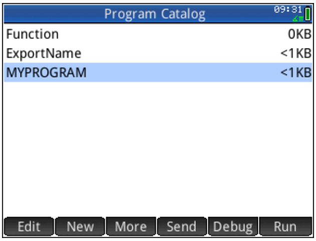
You cannot run a program that contains syntax errors. If the program does not do what you expect it to do, or if there is a run-time error detected by the system, you can execute the program step by step, and look at the values of local variables.

Let’s debug the program created above: MYPROGRAM.

1. In the Program Catalog, select MYPROGRAM.

   Shift 1 Program Y

   Select MYPROGRAM

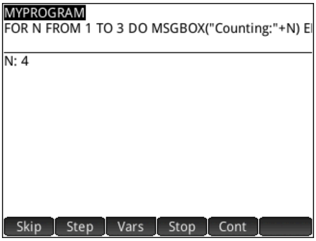


Program Catalog

Function	0KB
ExportName	<1KB
MYPROGRAM	<1KB

2. Tap Debug.

   If there is more than one EXPORT function in a file, a list appears for you to choose which function to debug.



MYPROGRAM

FOR N FROM 1 TO 3 DO MSGBOX("Counting:"+N) El

N: 4

   While debugging a program, the title of the program or intra-program function appears at the top of the display. Below that is the current line of the program being debugged. The current value of each variable is visible in the main body of the screen. The following menu buttons are available in the debugger:

   Skip: Skips to the next line or block of the program

   Step: Executes the current line

   Vars: Opens a menu of variables. You can select one and add it to the list of variables so you can see how it changes as you step through the program.

   Stop: Closes the debugger

   Cont: Continues program execution without debugging

3. Execute the FOR loop command.

   Step

   The `FOR` loop starts and the top of the display shows the next line of the program (the MSGBOX command).

4. Execute the MSGBOX command.

   Step

The message box appears. Note that when each message box is displayed, you still have to dismiss it by tapping OK or pressing Enter.

Tap Step and press Enter repeatedly to execute the program step-by-step.

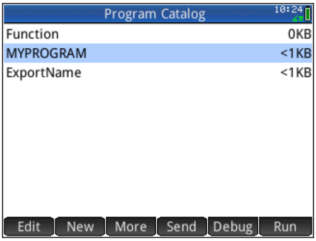
Tap Stop to close the debugger at the current line of the program, or tap Cont to run the rest of the program without using the debugger.

Edit a program

You edit a program using the Program Editor, which is accessible from the Program Catalog.

1. Open the Program Catalog.

   Shift 1 Program Y



Program Catalog 10:24

Function	0KB
MYPROGRAM	<1KB
ExportName	<1KB

2. Tap the program you want to edit (or use the arrow keys to highlight it and press Enter).

   The HP Prime opens the Program Editor. The name of your program appears in the title bar of the display. The buttons and keys you can use to edit your program are listed in “Program Editor: buttons and keys” on page 502.

Copy a program or part of a program

You can use the global `Copy` and `Paste` commands to copy part or all of a program. The following steps illustrate the process:

1. Open the Program Catalog.

   Shift 1 Program Y

2. Tap the program that has the code you want to copy.
3. Press Shift View Copy (Copy).

   The menu buttons change to give you options for copying:

   Begin: Marks where the copying or cutting is to begin.

   End: Marks where the copying or cutting is to end.

   All: Select the entire program.

Cut: Cut the selection.

Copy: Copy the selection.

4. Select what you want to copy or cut (using the options listed immediately above).
5. Tap Copy or Cut.
6. Return to the Program Catalog and open the target program.
7. Move the cursor to where you want to insert the copied or cut code.
8. Press Shift Menu Paste (Paste). The clipboard opens. What you most recently copied or cut will be first in the list and highlighted already, so just tap OK. The code will be pasted into the program, beginning at the cursor location.

Delete a program

To delete a program:

1. Open the Program Catalog.

   Shift 1 Program Y
2. Highlight a program to delete and press Del.
3. At the prompt, tap OK to delete the program or Cancel to cancel.

Delete all programs

To delete all programs at once:

1. Open the Program Catalog.

   Shift 1 Program Y
2. Press Shift Esc Clear (Clear).
3. At the prompt, tap OK to delete all programs or Cancel to cancel.

Delete the contents of a program

You can clear the contents of a program without deleting the program. The program then just has a name and nothing else.

1. Open the Program Catalog.

   Shift 1 Program Y
2. Tap the program to open it.
3. Press Shift Esc Clear (Clear).

To share a program

You can send programs between calculators just as you can send apps, notes, matrices, and lists. See “Sharing data” on page 44.

The HP Prime programming language

The HP Prime programming language allows you to extend the capabilities of the HP Prime by adding programs, functions and variables to the system. The programs you write can be either standalone or attached to an app. The functions and variables you create can be either local or global. If they are declared to be global, then they appear in the User menu when you press Mem B or Vars Chars A. In the following sections, we discuss variables and functions, then create a set of short programs to illustrate the various techniques for creating programs, functions, and variables.

Variables and visibility

Variables in an HP Prime program can be used to store numbers, lists, matrices, graphics objects, and strings. The name of a variable must be a sequence of alphanumeric characters (letters and numbers), starting with a letter. Names are case-sensitive, so the variables named `MaxTemp` and `maxTemp` are different.

The HP Prime has built-in variables of various types, visible globally (that is, visible wherever you are in the calculator). For example, the built-in variables `A` to `Z` can be used to store real numbers, `Z0` to `Z9` can be used to store complex numbers, `M0` to `M9` can be used to store matrices and vectors, and so on. These names are reserved. You cannot use them for other data. For example, you cannot name a program `M1`, or store a real number in a variable named `Z8`. In addition to these reserved variables, each HP app has its own reserved variables. Some examples are `Root`, `Xmin`, and `Numstart`. Most of these app variables are local to their app, though a few are global by design. For example, `C1` is used by the Statistics 2Var app to store statistical data. This variable is global so that you can access that data from anywhere in the system. Again, these names cannot be used to name a program or store data of a type other than their design allows. (A full list of system and app variables is given in chapter 22, "Variables", beginning on page 423.)

In a program you can declare variables for use only within a particular function. This is done using a `LOCAL` declaration. The use of local variables enables you to declare and use variables that will not affect the rest of the calculator. Local variables are not bound to a particular type; that is, you can store floating-point numbers, integers, lists, matrices, and symbolic expressions in a variable with any local name. Although the system will allow you to store different types in the same local variable, this is poor programming practice and should be avoided.

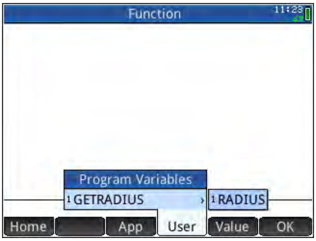
Variables declared in a program should have descriptive names. For example, a variable used to store the radius of a circle is better named `RADIUS` than `VGFTRFG`. You are more likely to remember what the variable is used for if its name matches its purpose.

If a variable is needed after the program executes, it can be exported from the program using the `EXPORT` command. To do this, the first command in the program (that is, on a line above the program name) would be `EXPORT RADIUS`. Then, if a value is assigned to `RADIUS`, the name appears on the variables menu (Vars) and is visible globally. This feature allows for extensive and powerful interactivity among different environments in the HP Prime. Note that if another program exports a variable with the same name, the most recently exported version will be active.

The program below prompts the user for the value of `RADIUS`, and exports the variable for use outside the program.

```
EXPORT RADIUS;
EXPORT GETRADIUS()
BEGIN
INPUT(RADIUS);
END;
```

Note that EXPORT command for the variable RADIUS appears before the heading of the function where RADIUS is assigned. After you execute this program, a new variable named RADIUS appears on the USER GETRADIUS section of the Variables menu.



Qualifying the name of a variable

The HP Prime has many system variables with names that are apparently the same. For example, the Function app has a variable named Xmin, but so too does the Polar app, the Parametric app, the Sequence app, and the Solve app. In a program, and in the Home view, you can refer to a particular version of these variables by qualifying its name. This is done by entering the name of the app (or program) that the variable belongs to, followed by a dot (.), and then the actual variable name. For example, the qualified variable Function.Xmin refers to the value of Xmin within the Function app. Similarly, the qualified variable Parametric.Xmin refers to the value of Xmin in the Parametric app. Despite having the same name—Xmin—the variables could have different values. You do likewise to use a local variable in a program: specify the name of the program, followed by the dot, and then the variable name.

Functions, their arguments, and parameters

You can define your own functions in a program, and data can be passed to a function using parameters. Functions can return a value (using the RETURN statement) or not. When a program is executed from Home view, the program will return the value returned by the *last* statement that was executed.

Furthermore, functions can be defined in a program and exported for use by other programs, in much the same way that variables can be defined and used elsewhere.

In this section, we will create a small set of programs, each illustrating some aspect of programming in the HP Prime. Each program will be used as a building block for a custom app described in the next section, *App Programs*.

Program ROLLDIE

We'll first create a program called ROLLDIE. It simulates the rolling of a single die, returning a random integer between 1 and whatever number is passed into the function.

In the Program Catalog create a new program named ROLLDIE. (For help, see page 501.) Then enter the code in the Program Editor.

```
EXPORT ROLLDIE(N)
BEGIN
RETURN 1+RANDINT(N-1);
END;
```

The first line is the heading of the function. Execution of the RETURN statement causes a random integer from 1 to N to be calculated and returned as the result of the function. Note that the RETURN command causes the execution of the function to terminate. Thus any statements between the RETURN statement and END are ignored.

In Home view (in fact, anywhere in the calculator where a number can be used), you can enter ROLLDIE(6) and a random integer between 1 and 6 inclusive will be returned.

Program ROLLMANY

Because of the EXPORT command in ROLLDIE, another program could use the ROLLDIE function and generate *n* rolls of a die with any number of sides. In the following program, the ROLLDIE function is used to generate *n* rolls of two dice, each with the number of sides given by the local variable sides. The results are stored in list L2, so that L2(1) shows the number of times the dies came up with a combined total of 1, L2(2) shows the number of times the dies came up with a combined total of 2, etc. L2(1) should be 0 (since the sum of the numbers on 2 dice must be at least 2).

```
EXPORT ROLLMANY(n,sides)
BEGIN
  LOCAL k,roll;
  // initialize list of frequencies
  MAKELIST(0,X,1,2*sides,1) ▶ L2;
  FOR k FROM 1 TO n DO
ROLLDIE(sides)+ROLLDIE(sides) ▶ roll;
```

```
    L2(roll)+1 ▶ L2(roll);
    END;
  END;
```

By omitting the EXPORT command when a function is declared, its visibility can be restricted to the program within which it is defined. For example, you could define the ROLLDIE function inside the ROLLMANY program like this:

```
  ROLLDIE();
  EXPORT ROLLMANY(n,sides)
  BEGIN
    LOCAL k,roll;
    // initialize list of frequencies
    MAKELIST(0,X,1,2*sides,1) ▶ L2;
    FOR k FROM 1 TO n DO
  ROLLDIE(sides)+ROLLDIE(sides) ▶ roll;
    L2(roll)+1 ▶ L2(roll);
    END;
  END;
  ROLLDIE(n)
  BEGIN
  RETURN 1+RANDINT(n-1);
  END;
```

In the second version of the ROLLMANY program, there is no ROLLDIE function exported from another program. Instead, ROLLDIE is visible only to ROLLMANY. The ROLLDIE function must be declared before it is called. The first line of the program above contains the declaration of the ROLLDIE function. The definition of the ROLLDIE function is located at the end of the program.

Finally, the list of results could be returned as the result of calling ROLLMANY instead of being stored directly in the global list variable, L2. This way, if the user wanted to store the results elsewhere, it could be done easily.

```
  ROLLDIE();
  EXPORT ROLLMANY(n,sides)
  BEGIN
    LOCAL k,roll,results;
    // initialize list of frequencies
    MAKELIST(0,X,1,2*sides,1) ▶ results;
    FOR k FROM 1 TO n DO
  ROLLDIE(sides)+ROLLDIE(sides) ▶ roll;
    results(roll)+1 ▶ results(roll);
    END;
  RETURN results;
  END;
  ROLLDIE(N)
  BEGIN
  RETURN 1+RANDINT(N-1);
  END;
```

In Home view you would enter `ROLLMANY(100,6)`▶ `L5` and the results of the simulation of 100 rolls of two six-sided dice would be stored in list L5.

The User Keyboard: Customizing key presses

You can assign alternative functionality to any key on the keyboard, including to the functionality provided by the shift and alpha keys. This enables you to customize the keyboard to your particular needs. For example, you could assign SIN ASIN G to a function that is multi-nested on a menu and thus difficult to get to on a menu (such as ALOG).

A customized keyboard is called the *user keyboard* and you activate it when you go into *user mode*.

User mode

There are two user modes:

- Temporary user mode: the next key press, and only the next, enters the object you have assigned to that key. After entering that object, the keyboard automatically returns to its default operation.

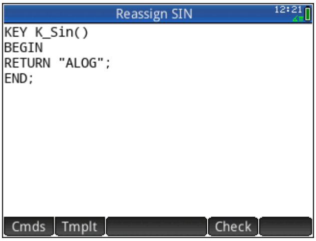
  To activate temporary user mode, press Shift Help User (User). Notice that **1U** appears in the title bar. The **1** will remind you that the user keyboard will be active for just one key press.

- Persistent user mode: each key press *from now until you turn off user mode* will enter whatever object you have assigned to a key.

To activate persistent user mode, press Shift Help User Shift Help User. Notice that ⬆U appears in the title bar. The user keyboard will now remain active until you press Shift Help User again.

If you are in user mode and press a key that hasn't been re-assigned, the key's standard operation is performed.

Re-assigning keys



```
KEY K_Sin()
BEGIN
RETURN "ALOG";
END;
```

Suppose you want to assign a commonly used function—such as ALOG—to its own key on the keyboard. Simply create a new program that mimics the syntax in the image at the right.

The first line of the program specifies the key to be reassigned using its internal name. (The names of all the keys are given in "Key names" on page 518. They are case-sensitive.)

On line 3, enter the text you want produced when the key being re-assigned is pressed. This text must be enclosed in quote marks.

The next time you want to insert `ALOG` at the position of your cursor, you just press Shift Help User SIN ASIN G.

You can enter any string you like in the RETURN line of your program. For example, if you enter "Newton", that text will be returned when you press the re-assigned key. You can even get the program to return user-defined functions as well as system functions, and user-defined variables as well as system variables.

You can also re-assign a shifted key combination. So, for example, ALPHA alpha Shift ÷ x^{-1} T could be re-assigned to produce `SLOPE(F1(X),3)` rather than the lowercase *t*. Then if ALPHA alpha Shift ÷ x^{-1} T is entered in Home view and Enter ≈ pressed, the gradient at X = 3 of whatever function is currently defined as F1(X) in the Function app would be returned.

Tip A quick way to write a program to re-assign a key is to press Menu Paste and select `Create user key` when you are in the Program Editor. You will then be asked to press the key (or key combination) you want to re-assign. A program template appears, with the internal name of the key (or key combination) added automatically.

Key names

The first line of a program that re-assigns a key must specify the key to be reassigned using its internal name. The table below gives the internal name for each key. Note that key names are case-sensitive.

Internal name of keys and key states

Key	Name	Shift + key	ALPHA alpha + key	ALPHA alpha Shift + key
0 Notes " "	K_0	KS_0	KA_0	KSA_0
1 Program Y	K_1	KS_1	KA_1	KSA_1
2 *i* Z	K_2	KS_2	KA_2	KSA_2
3 π #	K_3	KS_3	KA_2	KSA_2
4 Matrix U	K_4	KS_4	KA_4	KSA_4
5 [ ] V	K_5	KS_5	KA_5	KSA_5
6 ≤,≥,≠ W	K_6	KS_6	KA_6	KSA_6
7 List Q	K_7	KS_7	KA_7	KSA_7
8 { } R	K_8	KS_8	KA_8	KSA_8
9 !,∞,→ S	K_9	KS_9	KA_9	KSA_9
a b/c ° ′ ″ E	K_Abc	KS_Abc	KA_Abc	KSA_Abc
ALPHA alpha	K_Alpha	KS_Alpha	KA_Alpha	KSA_Alpha
Apps Info	K_Apps	KS_Apps	KA_Apps	KSA_Apps
⌫ Del	K_Bksp	KS_Bksp	KA_Bksp	KSA_Bksp
, ⤨ Eval O	K_Comma	KS_Comma	KA_Comma	KSA_Comma
COS ACOS H	K_Cos	KS_Cos	KA_Cos	KSA_Cos

Internal name of keys and key states (Continued) (Continued) (Continued)

Key	Name	Shift + key	ALPHA alpha + key	ALPHA alpha Shift + key
÷ x^{-1} T	K_Div	KS_Div	KA_Div	KSA_Div
. =	K_Dot	KS_Dot	KA_Dot	KSA_Dot
▼	K_Down	KS_Down	KA_Down	KSA_Down
Enter ≈	K_Enter	KS_Enter	KA_Enter	KSA_Enter
⌂ Settings	K_Home	KS_Home	KA_Home	KSA_Home
◀	K_Left	KS_Left	KA_Left	KSA_Left
▶	K_Right	KS_Right	KA_Right	KSA_Right
LN e^x J	K_Ln	KS_Ln	KA_Ln	KSA_Ln
LOG 10^x K	K_Log	KS_Log	KA_Log	KSA_Log
− Base :	K_Minus	KS_Minus	KA_Minus	KSA_Minus
+/− |x| M	K_Neg	KS_Neg	KA_Neg	KSA_Neg
Num ▦ ↳Setup	K_Num	KS_Num	KA_Num	KSA_Num
On Off	K_On	–	KA_On	KSA_On
Plot ↳Setup	K_Plot	KS_Plot	KA_Plot	KSA_Plot
+ Ans ;	K_Plus	KS_Plus	KA_Plus	KSA_Plus
x^y $\sqrt[x]{}$ F	K_Power	KS_Power	KA_Power	KSA_Power
SIN ASIN G	K_Sin	KS_Sin	KA_Sin	KSA_Sin
x^2 √ L	K_Sq	KS_Sq	KA_Sq	KSA_Sq
Symb ↳Setup	K_Symb	KS_Symb	KA_Symb	KSA_Symb
TAN ATAN I	K_Tan	KS_Tan	KA_Tan	KSA_Tan
▲	K_Up	KS_Up	KA_Up	KSA_Up
Vars Chars A	K_Vars	KS_Vars	KA_Vars	KSA_Vars
View Copy	K_View	KS_View	KA_View	KSA_View
$x t \theta n$ Define D	K_Xttn	KS_Xttn	KA_Xttn	KSA_Xttn

Internal name of keys and key states (Continued) (Continued) (Continued)

Key	Name	Shift + key	ALPHA alpha + key	ALPHA alpha Shift + key
Help User	K_Help	–	KA_Help	KSA_Help
☰Menu Paste	K_Menu	KS_Menu	KA_Menu	KSA_Menu
Esc Clear	K_Esc	KS_Esc	KA_Esc	KSA_Esc
CAS Settings	K_Cas	KS_Cas	KA_Cas	KSA_Cas
Mem B	K_Math	KS_Math	KA_Math	KSA_Math
√,|| Units C	K_Templ	KS_Templ	KA_Templ	KSA_Templ
( ) N	K_Paren	KS_Paren	KA_Paren	KSA_Paren
EEX Sto ▸ P	K_Eex	KS_Eex	KA_Eex	KSA_Eex
× ∡ X	K_Mul	KS_Mul	KA_Mul	KSA_Mul
Shift	–	–	–	–
␣	K_Space	KS_Space	KA_Space	KSA_Space

App programs

An app is a unified collection of views, programs, notes, and associated data. Creating an app program allows you to redefine the app’s views and how a user will interact with those views. This is done with (a) dedicated program functions with special names and (b) by redefining the views in the View menu.

Using dedicated program functions

There are nine dedicated program function names, as shown in the table below. These functions are called when the corresponding keys shown in the table are pressed. These functions are designed to be written into a program that controls an app and used in the context of that app.

Program	**Name**	**Equivalent Keystrokes**
Symb	Symbolic view	Symb
SymbSetup	Symbolic Setup	Shift Symb
Plot	Plot view	Plot
PlotSetup	Plot Setup	Shift Plot
Num	Numeric view	Num
NumSetup	Numeric Setup	Shift Num
Info	Info view	Shift Apps
START	Starts an app	Start
RESET	Resets or initializes an app	Reset

Redefining the View menu

The View menu allows any app to define views in addition to the standard seven views shown in the table above. By default, each HP app has its own set of additional views contained in this menu. The `VIEW` command allows you to redefine these views to run programs you have created for an app. The syntax for the `VIEW` command is:

```
VIEW "text", function()
```

By adding `VIEW "text", function()` before the declaration of a function, you will override the list of views for the app. For example, if your app program defines three views—"*SetSides*", "*RollDice*" and "*PlotResults*"—when you press View you will see *SetSides*, *RollDice*, and *PlotResults* instead of the app's default view list.

Customizing an app

When an app is active, its associated program appears as the first item in the Program Catalog. It is within this program that you put functions to create a custom app. A useful procedure for customizing an app is illustrated below:

1. Decide on the HP app that you want to customize. The customized app inherits all the properties of the HP app.
2. Go to the Applications Library (Apps Info), highlight the HP app, tap Save and save the app with a unique name.
3. Customize the new app if you need to (for example, by configuring the axes or angle measure settings).
4. Open the Program Catalog, select your new app program, and tap Edit.
5. Develop the functions to work with your customized app. When you develop the functions, use the app naming conventions described above.
6. Put the `VIEW` command in your program to modify the app's View menu.
7. Decide if your app will create new global variables. If so, you should `EXPORT` them from a separate user program that is called from the `Start()` function in the app program. This way they will not have their values lost.
8. Test the app and debug the associated programs.

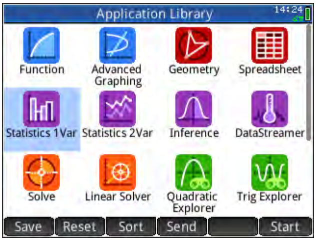
It is possible to link more than one app via programs. For example, a program associated with the Function app could execute a command to start the Statistics 1Var app, and a program associated with the Statistics 1Var app could return to the Function app (or launch any other app).

Example

The following example illustrates the process of creating a custom app. The app is based on the built-in Statistics 1Var app. It simulates the rolling of a pair of dice, each with a number of sides specified by the user. The results are tabulated, and can be viewed either in a table or graphically.

1. In the Application Librray, select the Statistics 1Var app but don't open it.

   Apps Info Select `Statistics 1Var`.

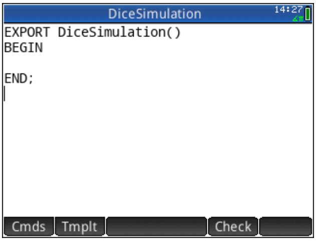


2. Tap Save.
3. Enter a name for the new app (such as `DiceSimulation`.)
4. Tap OK twice.

   The new app appears in the Application Library.
5. Open the Program Catalog.

   Shift 1 Program Y
6. Tap the program to open it.

   Each customised app has one program associated with it. Initially, this program is empty. You customize the app by entering functions into that program.



```
EXPORT DiceSimulation()
BEGIN

END;
```

At this point you decide how you want the user to interact with the app. In this example, we will want the user to be able to:

- start and initialize the app, and display a short note
- specify the number of sides (that is, faces) on each die
- specify the number of times to roll the dice
- graphically display the results of the simulation
- numerically display the results of the simulation.

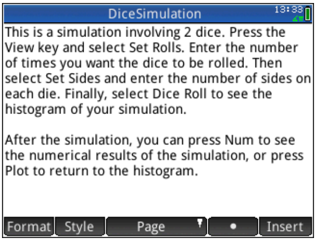
With that in mind, we will create the following views:

START, ROLL DICE, SET SIDES, and SET ROLLS.

The START option will initialize the app and display a note that gives the user instructions. The user will also interact with the app through the Numeric view and the Plot view.

These views will be activated by pressing Num and Plot, but the function `Plot()` in our app program will actually launch the latter view after doing some configuration.

Before entering the following program, press Shift Apps to open the Info editor and enter the text shown in the figure. This note will be attached to the app and will be displayed when the user selects the Start option from the View menu (or presses Shift Apps).



This is a simulation involving 2 dice. Press the View key and select Set Rolls. Enter the number of times you want the dice to be rolled. Then select Set Sides and enter the number of sides on each die. Finally, select Dice Roll to see the histogram of your simulation.

After the simulation, you can press Num to see the numerical results of the simulation, or press Plot to return to the histogram.

The program discussed earlier in this chapter to get the number of sides for a dice is expanded here, so that the possible sums of two such die are stored in dataset `D1`. Enter the following sub-routines into the program for the `DiceSimulation` app.

The DiceSimulation program

```
DICESIMVARS();
ROLLDIE();
 EXPORT SIDES,ROLLS;
EXPORT DiceSimulation()
BEGIN
END;
VIEW "Start",START()
BEGIN
  D1:={};
  D2:={};
  SetSample(H1,D1);
  SetFreq(H1,D2);
  H1Type:=1;
  STARTVIEW(6,1);
END;
VIEW "Roll Dice",ROLLMANY()
BEGIN
  LOCAL k,roll;
  D1:= MAKELIST(X+1,X,1,2*SIDES-1,1);
  D2:= MAKELIST(0,X,1,2*SIDES-1,1);
  FOR k FROM 1 TO ROLLS DO
    roll:=ROLLDIE(SIDES)+ROLLDIE
(SIDES);
    D2(roll-1):= D2(roll-1)+1;
  END;
  Xmin:= -0.1;
  Xmax:= MAX(D1)+1;
  Ymin:= −0.1;
  Ymax:= MAX(D2)+1;
  STARTVIEW(1,1);
END;
VIEW "Set Sides",SETSIDES()
BEGIN
  REPEAT
    INPUT(SIDES,"Die
Sides","N=","Enter# of sides",2);
    SIDES:= FLOOR(SIDES);
    IF SIDES<2 THEN
     MSGBOX("# of sides must be >= 4");
    END;
  UNTIL SIDES >=4;
  STARTVIEW(7,1);
END;

VIEW "Set Rolls",SETROLLS()
BEGIN
  REPEAT
    INPUT(ROLLS,"Num of
rolls","N=","Enter# of rolls",25);
    ROLLS:= FLOOR(ROLLS);
    IF ROLLS<1 THEN
      MSGBOX("You must enter a num
>=1");
    END;
  UNTIL ROLLS>=1;
  STARTVIEW(7,1);
END;
Plot()
```

```
BEGIN
  Xmin:=-0.1;
  Xmax:= MAX(D1)+1;
  Ymin:= −0.1;
  Ymax:= MAX(D2)+1;
  STARTVIEW(1,1);
END;
Symb()
BEGIN
  SetSample(H1,D1);
  SetFreq(H1,D2);
  H1Type:=1;
  STARTVIEW(0,1);
END;
```

The ROLLMANY() routine is an adaptation of the program presented earlier in this chapter. Since you cannot pass parameters to a program called through a selection from a custom View menu, the exported variables SIDES and ROLLS are used in place of the parameters that were used in the previous versions.

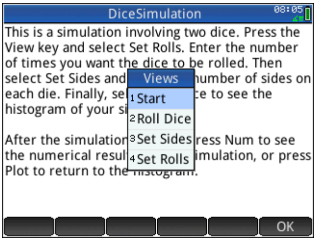
The program above calls two other user programs: ROLLDIE() and DICESIMVARS(). ROLLDIE() appears earlier in this chapter. Here is DICESIMVARS. Create a program with that name and enter the following code.

The program DICESIMVARS

```
EXPORT ROLLS,SIDES;
EXPORT DICESIMVARS()
BEGIN
10 ▶ ROLLS;
6 ▶SIDES;
END;
```

1. Press Apps Info, and open DiceSimulation. The note will appear explaining how the app works.

2. Press View Copy to see the custom app menu. Here you can reset the app (`Start`), set the number of sides of the dice, the number of rolls, and execute a simulation.

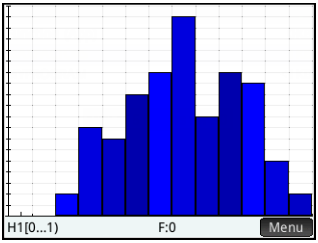


DiceSimulation 08:05

This is a simulation involving two dice. Press the View key and select Set Rolls. Enter the number of times you want the dice to be rolled. Then select Set Sides and umber of sides on each die. Finally, se e to see the histogram of your si

After the simulation ress Num to see the numerical resul imulation, or press Plot to return to the histogram.

3. Select `Set Rolls` and enter 100.
4. Select `Set Sides` and enter `6`.
5. Select `Roll Dice`. You will see a histogram similar to the own shown in the figure.



6. Press Num Setup to see the data and Plot Setup to return to the histogram.
7. To run another simulation, press View Copy and select `Roll Dice`.

Program commands

This section describes each program command. The commands under the Tmplt menu are described first. The commands under the Cmds menu are described in “Commands under the Cmds menu” on page 534.

Commands under the Tmplt menu

Block

The block commands determine the beginning and end of a sub-routine or function. There is also a `Return` command to recall results from sub-routines or functions.

BEGIN END Syntax: `BEGIN command1; command2;…; commandN; END;`

Defines a command or set of commands to be executed together. In the simple program:

```
EXPORT SQM1(X)
BEGIN
RETURN X^2-1;
END;
```

the block is the single RETURN command.

If you entered `SQM1(8)` in Home view, the result returned would be 63.

RETURN Syntax: `RETURN` *expression*;

Returns the current value of *expression*.

KILL Syntax: `KILL`;

Stops the step-by-step execution of the current program (with debug).

Branch

In what follows, the plural word *commands* refers to both a single command or a set of commands.

IF THEN Syntax: `IF` *test* `THEN` *commands* `END`;

Evaluate *test*. If *test* is true (not 0), executes *commands*. Otherwise, nothing happens.

IF THEN ELSE Syntax: `IF` *test* `THEN` *commands1* `ELSE` *commands 2* `END`;

Evaluate *test*. If *test* is true (non 0), executes *commands 1*, otherwise, executes *commands 2*

CASE Syntax:

```
CASE
   IF test1 THEN commands1 END;
   IF test2 THEN commands2 END;
   …
   [DEFAULT commands]
END;
```

Evaluates *test1*. If true, executes `commands1` and ends the CASE. Otherwise, evaluates `test2`. If true, executes `commands2` and ends the CASE. Continues evaluating tests until a true is found. If no true test is found, executes default commands, if provided.

Example:

```
CASE
IF x<0 THEN RETURN "negative"; END;
IF x<1 THEN RETURN "small"; END;
DEFAULT RETURN "large";
END;
```

IFERR `IFERR` *commands1* `THEN` *commands2* `END;`

Executes sequence of *commands1*. If an error occurs during execution of *commands1*, executes sequence of *commands2*.

IFERR ELSE `IFERR` *commands1* `THEN` *commands2* `ELSE` *commands3* `END;`

Executes sequence of *commands1*. If an error occurs during execution of *commands1*, executes sequence of *commands2*. Otherwise, execute sequence of *commands3*.

Loop

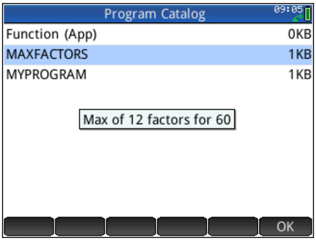
FOR Syntax: `FOR` *var* `FROM` *start* `TO` *finish* `DO` *commands END;*

Sets variable *var* to *start*, and for as long as this variable is less than or equal to *finish*, executes the sequence of *commands*, and then adds 1 (*increment*) to *var*.

Example 1: This program determines which integer from 2 to N has the greatest number of factors.

```
EXPORT MAXFACTORS(N)
BEGIN
LOCAL cur,max,k,result;
1 ▶ max;1 ▶ result;
FOR k FROM 2 TO N DO
 SIZE(CAS.idivis(k)) ▶ cur;
 IF cur(1) > max THEN
  cur(1) ▶ max;
  k ▶ result;
 END;
END;
MSGBOX("Max of "+ max +" factors for "+result);
END;
```

In Home, enter MAXFACTORS(100).



Program Catalog 09:05

Function (App) 0KB

MAXFACTORS 1KB

MYPROGRAM 1KB

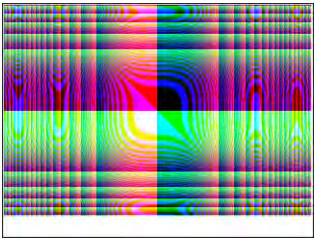
Max of 12 factors for 60

FOR STEP

Syntax: `FOR` *var* `FROM` *start* `TO` *finish* [*STEP increment*] `DO` *commands END;*

Sets variable *var* to *start*, and for as long as this variable is less than or equal to *finish*, executes the sequence of *commands*, and then adds *increment* to *var*.

Example 2: This program draws an interesting pattern on the screen.



```
EXPORT
DRAWPATTERN()
BEGIN
LOCAL
xincr,yincr,co
lor;
STARTAPP("Function");
```

```
RECT();
xincr := (Xmax - Xmin)/318;
yincr := (Ymax - Ymin)/218;
FOR X FROM Xmin TO Xmax STEP xincr DO
FOR Y FROM Ymin TO Ymax STEP yincr DO
color := RGB(X^3 MOD 255,Y^3 MOD 255,
TAN(0.1*(X^3+Y^3)) MOD 255);
PIXON(X,Y,color);
END;
END;
WAIT;
END;
```

FOR DOWN

Syntax: `FOR` *var* `FROM` *start* `DOWNTO` *finish* `DO` *commands END;*

Sets variable *var* to *start*, and for as long as this variable is more than or equal to *finish*, executes the sequence of commands, and then subtracts 1 (decrement) from *var*.

FOR DOWN STEP

Syntax: `FOR` *var* `FROM` *start* `DOWNTO` *finish* [*STEP increment*] `DO` *commands END;*

Sets variable *var* to *start*, and for as long as this variable is more than or equal to *finish*, executes the sequence of commands, and then subtracts *increment* from *var*.

WHILE

Syntax: `WHILE` *test* `DO` *commands* `END;`

Evaluates `test`. If result is true (not 0), executes the *commands*, and repeats.

Example: A perfect number is one that is equal to the sum of all its proper divisors. For example, 6 is a perfect number because 6 = 1+2+3. The example below returns true when its argument is a perfect number.

```
EXPORT ISPERFECT(n)
BEGIN
 LOCAL d, sum;
 2 ▶d;
 1 ▶sum;
WHILE sum <= n AND d < n DO
 IF irem(n,d)==0 THEN
  sum+d ▶sum;
 END;
 d+1 ▶d;
 END;
 RETURN sum==n;
END;
```

The following program displays all the perfect numbers up to 1000:

```
EXPORT PERFECTNUMS()
BEGIN
LOCAL k;
FOR k FROM 2 TO 1000 DO
 IF ISPERFECT(k) THEN
 MSGBOX(k+" is perfect, press OK");
 END;
END;
END;
```

REPEAT Syntax: `REPEAT` *commands* `UNTIL` *test*;

Repeats the sequence of *commands* until *test* is true (not 0).

The example below prompts for a positive value for SIDES, modifying an earlier program in this chapter:

```
EXPORT SIDES;
EXPORT GETSIDES()
BEGIN
 REPEAT
 INPUT(SIDES,"Die Sides","N = ","Enter
num sides",2);
 UNTIL SIDES>0;
END;
```

BREAK Syntax: `BREAK(`*n*`)`

Exits from loops by breaking out of *n* loop levels. Execution picks up with the first statement after the loop. With no argument, exits from a single loop.

CONTINUE Syntax: `CONTINUE`

Transfers execution to the start of the next iteration of a loop

Variable

These commands enable you to control the visibility of a user-defined variable.

LOCAL Local.

Syntax: `LOCAL` *var1,var2,…varn;*

Makes the variables var1, var2, etc. local to the program in which they are found.

EXPORT Syntax: `EXPORT var1, var2, …, varn;`

Exports the variables *var1*, *var2*, etc. so they are globally available and appear on the User menu when you press Vars and select User.

Function

These commands enable you to control the visibility of a user-defined function.

EXPORT Export.

Syntax: `EXPORT FunctionName()`

Exports the function `FunctionName` so that it is globally available and appears on the User menu (Mem User).

VIEW Syntax: `VIEW "text", functionname();`

Replaces the View menu of the current app and adds an entry with `"text"`. If `"text"` is selected and the user presses OK or Enter, then `functionname()` is called.

KEY A prefix to a key name when creating a user keyboard. See “The User Keyboard: Customizing key presses” on page 516.

Commands under the Cmds menu

Strings

A string is a sequence of characters enclosed in double quotes (""). To put a double quote in a string, use two consecutive double quotes. The \ character starts an escape sequence, and the character(s) immediately following are interpreted specially. *n* inserts a new line and two backslashes insert a single backslash. To put a new line into the string, press Enter to wrap the text at that point.

ASC Syntax: `ASC`(*string*)

Returns a list containing the ASCII codes of *string*.

Example: `ASC (`*"AB"*) returns [65,66]

CHAR Syntax: `CHAR(vector)` or `CHAR(integer)`

Returns the string corresponding to the character codes in `vector`, or the single code of `integer`.

Examples: `CHAR (`*65*) returns "A"

`CHAR (`[82,77,72]) returns "RMH"

DIM Syntax: `DIM`(*str*ing)

Returns the number of characters in `string`.

Example: `DIM(`*"12345"*) returns 5, `DIM(`*""""*) and `DIM(`*"\n"*) return 1. (Notice the use of the two double quotes and the escape sequence.)

STRING

Syntax: `STRING`(*object*);

Returns a string representation of *object*. The result varies depending on the type of *object*.

Examples:

String	Result
`string`(F1), when F1(X) = COS(X)	"COS(X)"
`STRING`(*2/3*)	`0.666666666667`
`string`(L1) when L1 = {1,2,3}	"{1,2,3}"
`string`(M1) when M1 = $\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\end{bmatrix}$	"[[1,2,3],[4,5,6]]"

INSTRING

Syntax: `INSTRING`(*str1,str2*)

Returns the index of the first occurrence of *str2* in *str1*. Returns 0 if *str2* is not present in *str1*. Note that the first character in a string is position 1.

Examples:

`INSTRING`(*"vanilla","van"*) returns 1

`INSTRING` (*"banana","na"*) returns 3

`INSTRING`(*"ab","abc"*) returns 0

LEFT

Syntax: `LEFT`(*str,n*)

Return the first *n* characters of string *str*. If *n* ≥ DIM(*str*) or *n* < 0, returns *str*. If *n* == 0 returns the string.

Example: `LEFT`(*"MOMOGUMBO",3*) returns "MOM"

RIGHT

Syntax: RIGHT(*str,n*)

Returns the last n characters of string *str*. If *n* <= 0, returns empty string. If *n* > DIM*(str*), returns str

Example: `RIGHT`("MOMOGUMBO",5) returns "GUMBO"

MID Syntax: `MID(`*str,pos,* [*n*])

Extracts *n* characters from string *str* starting at index *pos*. *n* is optional, if not specified, extracts all the remainder of the string.

Example: `MID(`*"MOMOGUMBO",3,5*) returns "MOGUM", `MID(`*"PUDGE",4*) returns "GE"

ROTATE Syntax: `ROTATE(`*str,n*)

Permutation of characters in string *str*. If 0 <=*n* < DIM*(str*), shifts *n* places to left. If –DIM*(str*) < *n* <= –1, shifts *n* spaces to right. If *n* > DIM*(str*) or *n* < –DIM*(str*), returns *str*.

Examples:

`ROTATE(`*"12345",2*) returns "34512"
`ROTATE(`*"12345",-1*) returns "51234"
`ROTATE(`*"12345",6*) returns "12345"

STRINGFROMID Syntax: STRINGFROMID(*integer*)

Returns, in the current language, the built-in string associated in the internal string table with the specified *integer*.

Examples:

STRINGFROMID(*56*) returns “Complex”

STRINGFROMID(*202*) returns “Real”

REPLACE Syntax: REPLACE(object$_1$, start, object$_2$)

Replaces part of object$_1$ with object$_2$ beginning at *start*. The objects can be matrices, vectors, or stings.

Example:

`REPLACE(`*"12345","3","99"*) returns "12995"

Drawing

There are 10 built-in graphics variables in the HP Prime, called *G0–G9*. *G0* is always the current screen graphic.

G1 to *G9* can be used to store temporary graphic objects (called *GROBs* for short) when programming applications that use graphics. They are temporary and thus cleared when the calculator turns off.

Twenty-six functions can be used to modify graphics variables. Thirteen of them work with Cartesian coordinates using the Cartesian plane defined in the current app by the variables *Xmin, Xmax, Ymin,* and *Ymax*.

The remaining thirteen work with pixel coordinates where the pixel `0,0` is the top left pixel of the *GROB*, and `320, 240` is the bottom right. Functions in this second set have a *_P* suffix to the function name.

C→PX Converts from Cartesian coordinates to screen coordinates.

Syntax: `C→PX(x,y)` or `C→PX({x,y})`

DRAWMENU Syntax: `DRAWMENU({string1, string2, …, string6})`

Draws string1 through string (for *n*≤6) on the menu buttons.

FREEZE Syntax: `FREEZE`

Pauses program execution until a key is pressed. This prevents the screen from being redrawn after the end of the program execution, leaving the modified display on the screen for the user to see.

PX→C Converts from screen coordinates to Cartesian coordinates.

RGB Syntax: RGB(R, G, B, [A])

Returns an integer number that can be used as the color parameter for a drawing function, based on Red-, Green- and Blue-component values (each 0 to 255).

If Alpha is greater than 128, returns the color flagged as transparent. There is no alpha channel blending on Prime.

Examples:

`RGB(255,0,128)` returns `16711808`

`RECT(RGB(0,0,255))` makes a blue screen

`LINE(0,0,8,8,RGB(0,255,0))` draws a green line

Pixels and Cartesian

ARC_P

ARC Syntax; `ARC(`*G, x, y, r* [*, a1, a2, c*])

`ARC_P(`*G, x, y, r* [*, a1, a2, c*])

Draws an arc or circle on *G*, centered on point *x,y*, with radius *r* and color *c* starting at angle *a1* and ending on angle *a2*.

G can be any of the graphics variables and is optional. The default is *G0*

r is given in pixels.

c is optional and if not specified black is used. It should be specified in this way: #RRGGBB (in the same way as a color is specified in HTML).

a1 and *a2* follow the current angle mode and are optional. The default is a full circle.

Example:

`ARC(0,0,60,0,π,RGB(255,0,0))` draws a red semicircle with center at (0,0)—using the current Plot Setup window—and with a radius of 60 pixels. The semicircle is drawn counterclockwise from 0 to π.

BLIT_P

BLIT Syntax: `BLIT(`[*trgtGRB, dx1, dy1, dx2, dy2*],

srcGRB [*,sx1, sy1, sx2, sy2, c*])

`BLIT_P` ([*trgtGRB, dx1, dy1, dx2, dy2*],

srcGRB [*,sx1, sy1, sx2, sy2, c*])

Copies the region of *srcGRB* between point *sx1, sy1* and *sx2, sy2* into the region of *trgtGRB* between points *dx1, dy1* and *dx2, dy2*. Do not copy pixels from *srcGRB* that are color *c*.

trgtGRB can be any of the graphics variables and is optional. The default is G0.

srcGRB can be any of the graphics variables.

dx2, dy2 are optional and if not specified will be calculated so that the destination area is the same size as the source area.

sx2, sy2 are optional and if not specified will be the bottom right of the *srcGRB*.

sx1, sy1 are optional and if not specified will be the top left of *srcGRB*.

dx1, dy1 are optional and if not specified will be the top left of *trgtGRB*.

c can be any color specified as #RRGGBB. If it is not specified, all pixels from *srcGRB* will be copied.

Note Using the same variable for *trgtGRB* and *srcGRB* can be unpredictable when the source and destination overlap.

DIMGROB_P

DIMGROB

Syntax: `DIMGROB_P(G, w, h, [color])` or
`DIMGROB_P(G, list)`

`DIMGROB(G, w, h, [color])` or
`DIMGROB(G, list)`

Sets the dimensions of GROB *G* to *w* × *h*. Initializes the graphic *G* with *color* or with the graphic data provided in *list*. If the graphic is initialized using graphic data, then *list* is a list of integers. Each integer, as seen in base 16, describes one color every 16 bits.

Colors are in A1R5G5B5 format (that is,1 bit for the alpha channel, and 5 bits for R, G, and B).

GETPIX_P

GETPIX

Syntax: `GETPIX`([*G*], *x*, *y*)

`GETPIX_P`([*G*], *x*, *y*)

Returns the color of the pixel *G* with coordinates *x,y*.

G can be any of the graphics variables and is optional. The default is *G0*, the current graphic.

GROBH_P

GROBH

Syntax: `GROBH`(*G*)

`GROBH_P`(*G*)

Returns the height of *G*.

G can be any of the graphics variables and is optional. The default is *G0*.

GROBW_P

GROBW Syntax: `GROBW(`*G*`)`

`GROBW_P(`*G*`)`

Returns the width of *G*.

G can be any of the graphics variables and is optional. The default is *G0*.

INVERT_P

INVERT Syntax: `INVERT(`[*G, x1, y1, x2, y2*]`)`

`INVERT_P(`[*G, x1, y1, x2, y2*]`)`

Executes a reverse video of the selected region. *G* can be any of the graphics variables and is optional. The default is *G0*.

x2, y2 are optional and if not specified will be the bottom right of the graphic.

x1, y1 are optional and if not specified will be the top left of the graphic. If only one x,y pair is specified, it refers to the top left.

LINE_P

LINE Syntax: `LINE(`*G, x1, y1, x2, y2, c*`)`

`LINE_P(`*G, x1, y1, x2, y2, c*`)`

Draws a line of color *c* on *G* between points *x1,y1* and *x2,y2*.

G can be any of the graphics variables and is optional. The default is *G0*.

c can be any color specified as #RRGGBB. The default is black.

PIXOFF_P

PIXOFF Syntax: `PIXOFF(`[*G*], *x, y*`)`

`PIXOFF_P(`[*G*], *x, y*`)`

Sets the color of the pixel *G* with coordinates *x,y* to white. *G* can be any of the graphics variables and is optional. The default is *G0*, the current graphic

PIXON_P

PIXON Syntax: `PIXON(`[*G*], *x, y* [,*color*])

`PIXON_P(`[*G*], *x, y* [,*color*])

Sets the color of the pixel *G* with coordinates *x,y* to *color*. *G* can be any of the graphics variables and is optional. The default is *G0*, the current graphic. *Color* can be any color specified as #RRGGBB. The default is black.

RECT_P

RECT Syntax: `RECT(`[*G, x1, y1, x2, y2, edgecolor, fillcolor*])

`RECT_P(`[*G, x1, y1, x2, y2, edgecolor, fillcolor*])

Draws a rectangle on G between points *x1,y1* and *x2,y2* using edgecolor for the perimeter and fillcolor for the inside.

G can be any of the graphics variables and is optional. The default is *G0*, the current graphic.

x1, y1 are optional. The default values represent the top left of the graphic.

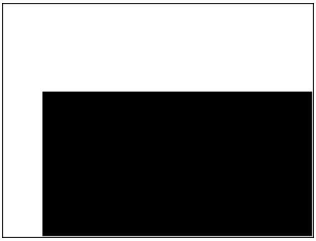
x2, y2 are optional. The default values represent the bottom right of the graphic.

edgecolor and *fillcolor* can be any color specified as #RRGGBB. Both are optional, and *fillcolor* defaults to *edgecolor* if not specified.

To erase a `GROB`, execute `RECT(`*G*`)`. To clear the screen execute `RECT()`.

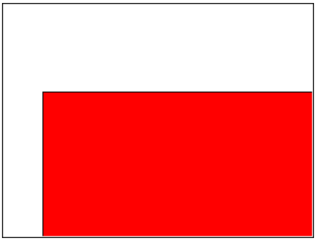
When optional arguments are provided in a command with multiple optional parameters (like `RECT`), the arguments provided correspond to the leftmost parameters first. For example, in the program below, the arguments `40` and `90` in the `RECT_P` command correspond to *x1* and *y1*. The argument `#000000` corresponds to *edgecolor*, since there is only the one additional argument. If there had been two additional arguments, they would have referred to *x2* and *y2* rather than *edgecolor* and *fillcolor*. The program produces a rectangle with a black edge and black fill.

```
EXPORT BOX()
BEGIN
RECT();
RECT_P(40,90,#0
00000);
WAIT;
END;
```



The program below also uses the `RECT_P` command. In this case, the pair of arguments `320` and `240` correspond to `x2` and `y2`. The program produces are rectangle with a black edge and a red fill.

```
EXPORT BOX()
BEGIN
RECT();
RECT_P(40,90,32
0,240,#000000,#
FF0000);
WAIT;
END;
```



SUBGROB_P

SUBGROB

Syntax: `SUBGROB`(*srcGRB* [,*x1, y1, x2, y2*], *trgtGRB*)

`SUBGROB_P`(*srcGRB* [,*x1, y1, x2, y2*], *trgtGRB*)

Sets *trgtGRB* to be a copy of the area of *srcGRB* between points *x1,y1* and *x2,y2.*

srcGRB can be any of the graphics variables and is optional. The default is *G0*.

trgtGRB can be any of the graphics variables except *G0*.

x2, y2 are optional and if not specified will be the bottom right of *srcGRB*.

x1, y1 are optional and if not specified will be the top left of *srcGRB*.

Example: `SUBGROB`(*G1, G4*) will copy G1 in G4.

TEXTOUT_P

TEXTOUT

Syntax: `TEXTOUT(`*text* [,*G*], *x, y* [,*font, c1, width, c2*])

`TEXTOUT_P(`*text* [,*G*], *x, y* [,*font, c1, width, c2*])

Draws text using color *c1* on graphic *G* at position *x, y* using *font*. Do not draw text more than *width* pixels wide and erase the background before drawing the text using color *c2*. *G* can be any of the graphics variables and is optional. The default is *G0*.

Font can be:

0: current font selected on the Homes Settings screen, *1*: small font *2*: large font. Font is optional and if not specified is the current font selected on the Homes Settings screen.

c1 can be any color specified as `#RRGGBB`. The default is black (#000000).

width is optional and if not specified, no clipping is performed.

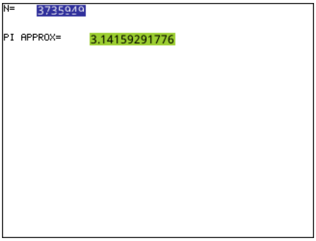
c2 can be any color specified as `#RRGGBB`. *c2* is optional. If not specified the background is not erased.

Example:

The following program displays the successive approximations for π using the series for the arctangent(1). Note that a color for the text, and for background, has been specified (with the width of the text being limited to 100 pixels).

```
EXPORT PISERIES()
BEGIN
LOCAL sign;
K:=2;
A:=4;
sign:=-1;
RECT();
TEXTOUT_P("N=",0,0);
TEXTOUT_P("PI APPROX=",0,30);
REPEAT
A+sign*4/(2*K-1) ▶ A;
```

```
    TEXTOUT_P(K ,35,0,2,#FFFFFF,
    100,#333399);
    TEXTOUT_P(A ,90,30,2,#000000,100,
    #99CC33);
    sign*-1 ▶ sign;
    K+1 ▶ K;
    UNTIL 0;
    END;
    END;
```



```
N=           3735949

PI APPROX=          3.14159291776
```

The program executes until the user presses On Off to terminate.

Matrix

The matrix commands described in this section are in addition to the matrix functions described in “Matrix functions and commands” on page 474. Some matrix commands take as their argument the matrix variable name on which the command is applied. Valid names are the global variables M0–M9 or a local variable that contains a matrix.

ADDCOL

Syntax: `ADDCOL(matrixname, vector, column_number)`

Inserts the values in `vector` into a new column inserted before `column_number` in the specified matrix. The number of values in the vector must be the same as the number of rows in the matrix.

ADDROW

Syntax: `ADDROW(matrixname, vector, row_number)`

Inserts the values in `vector` into a new row inserted before `row_number` in the specified matrix. The number of values in the vector must be the same as the number of columns in the matrix.

DELCOL

Syntax: `DELCOL(`*name ,column_number*)

Deletes *column column_number* from matrix name.

DELROW

Syntax: `DELROW(`*name ,row_number*)

Deletes row *row_number* from matrix name.

EDITMAT Syntax: `EDITMAT(`*name*`)`

Starts the Matrix Editor and displays the specified matrix. If used in programming, returns to the program when user presses OK. Even though this command returns the matrix that was edited, `EDITMAT` cannot be used as an argument in other matrix commands.

REDIM Syntax: `REDIM(`*name, size*`)`

Redimensions the specified matrix (*name*) 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*). Existing values in the matrix are preserved. Fill values will be 0.

REPLACE Syntax: `REPLACE(`*name, start, object*`)`

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, graphics, and strings. For example, REPLACE("123456", 2, "GRM") -> "1GRM56"

SCALE Syntax: `SCALE(`*name, value, rownumber*`)`

Multiplies the specified *row_number* of the specified matrix by *value*.

SCALEADD Syntax: `SCALEADD(`*name, value, row1, row2*`)`

Multiplies the specified `row1` of the matrix (`name`) by `value`, then adds this result to the second specified `row2` of the matrix (`name`) and replaces `row1` with the result.

SUB Syntax: `SUB(`*name, start, end*`)`

Extracts a sub-object—a portion of a list, matrix, or graphic—and stores it in *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(M1{1,2},{2,2})`

SWAPCOL Syntax: `SWAPCOL(`*name, column1, column2*`)`

Swaps *column1* and *column2* of the specified matrix (*name*).

SWAPROW Syntax: `SWAPROW(`*name, row1, row2*`)`

Swaps *row1* and *row2* in the specified matrix (*name*).

App Functions

These commands allow you to launch any HP app, bring up any view of the current app, and change the options in the View menu.

STARTAPP

Syntax: STARTAPP(*"name"*)

Starts the app with *name*. This will cause the app program's START function to be run, if it is present. The app's default view will be started. Note that the START function is always executed when the user taps Start in the Application Library. This also works for user-defined apps.

Example: STARTAPP(*"Function"*) launches the Function app.

STARTVIEW

Syntax: STARTVIEW(*n* [,*draw?*])

Starts the *n*th view of the current app. If *draw?* is true (that is, not 0), it will force an immediate redrawing of the screen for that view.

The view numbers (*n*) are as follows:

```
Symbolic:0
Plot:1
Numeric:2
Symbolic Setup:3
Plot Setup:4
Numeric Setup:5
App Info: 6
View Menu:7
First special view (Split Screen Plot Detail):8
Second special view (Split Screen Plot Table):9
Third special view (Autoscale):10
Fourth special view (Decimal):11
Fifth special view (Integer):12
Sixth special view (Trig):13
```

The special views in parentheses refer to the Function app, and may differ in other apps. The number of a special view corresponds to its position in the View menu for that app. The first special view is launched by STARTVIEW(8), the second with STARTVIEW(9), and so on.

You can also launch views that are not specific to an app by specifying a value for *n* that is less than 0:

```
Home Screen:-1
Home Settings:-2
Memory Manager:-3
Applications Library:-4
Matrix Catalog:-5
List Catalog:-6
Program Catalog:-7
Notes Catalog:-8
```

VIEW Syntax: `VIEW ("string"[,program_name])`

```
BEGIN
Commands;
END;
```

Adds a custom option to the `View` menu. When `string` is selected, runs `program_name`. See "The DiceSimulation program" on page 524.

Integer

BITAND Syntax: `BITAND(int1, int2, … intn)`

Returns the bitwise logical AND of the specified integers.

Example: `BITAND(20,13)` returns `4`.

BITNOT Syntax: `BITNOT(int)`

Returns the bitwise logical NOT of the specified integer.

Example: `BITNOT(47)` returns `549755813840`.

BITOR Syntax: `BITOR(int1, int2, … intn)`

Returns the bitwise logical OR of the specified integers.

Example: `BITOR(9,26)` returns `27`.

BITSL Syntax: `BITSL(int1 [,int2])`

Bitwise Shift Left. Takes one or two integers as input and returns the result of shifting the bits in the first integer to the left by the number places indicated by the second integer. If there is no second integer, the bits are shifted to the left by one place.

Examples:

`BITSL(28,2)` returns `112`

`BITSL(5)` returns `10`.

BITSR Syntax: `BITRL(int1 [,int2])`

Bitwise Shift Right. Takes one or two integers as input and returns the result of shifting the bits in the first integer to the right by the number places indicated by the second integer. If there is no second integer, the bits are shifted to the right by one place.

Examples:

`BITSR(112,2)` returns `28`

`BITSR(10)` returns `5`.

BITXOR Syntax: `BITXOR(int1, int2, … intn)`

Returns the bitwise logical exclusive OR of the specified integers.

Example: `BITXOR(9,26)` returns `19`.

B→R Syntax: `B→R(#integerm)`

Converts an integer in base *m* to a decimal integer (base 10). The base marker *m* can be *b* (for binary), *o* (for octal), or *h* (for hexadecimal).

Example: `B→R(#1101b)` returns `13`

GETBASE Syntax: `GETBASE(#integer[m])`

Returns the base for the specified integer (in whatever is the current default base): 0 = default, 1 = binary, 2 = octal, 3 = hexadecimal.

Examples: `GETBASE(#1101b)` returns `#1h` (if the default base is hexadecimal) while `GETBASE (#1101)` returns #0h.

GETBITS Syntax: `GETBITS(#integer)`

Returns the number of bits used by *integer*, expressed in the default base.

Example: `GETBITS(#22122)` returns `#20h` or `32`

R→B Syntax: `R→B(integer)`

Converts a decimal integer (base 10) to an integer in the default base.

Example: `R→B(13)` returns `#1101b` (if the default base is binary) or #Dh (if the default base is hexadecimal).

SETBITS Syntax: `SETBITS(#integer[m] [,bits])`

Sets the number of bits to represent *integer*. Valid values are in the range –64 to 65. If *m* or *bits* is omitted, the default value is used.

Example: `SETBITS(#1111b, 15)` returns `#1111:b15`

SETBASE Syntax: `SETBASE(#integer[m][c])`

Displays *integer* expressed in base *m* in whatever base is indicated by *c*, where *c* can be 1 (for binary), 2 (for octal), or 3 (for hexadecimal). Parameter m can be b (for binary), d (for decimal), o (for octal), or h (for hexadecimal). If *m* is omitted, the input is assumed to be in the default base. Likewise, if c is omitted, the output is displayed in the default base.

Examples: `SETBASE (#34o,1)` returns `#11100b` while `SETBASE (#1101)` returns #0h ((if the default base is hexadecimal).

I/O

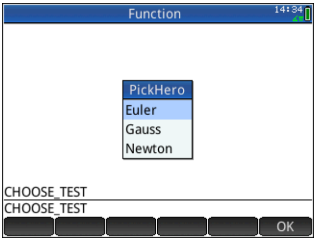
I/O commands are used for inputting data into a program, and for outputting data from a program. They allow users to interact with programs.

CHOOSE Syntax: `CHOOSE (`*var, "title", "item1", "item2",…,"itemn"*)

Displays a choose box with the *title* and containing the choose items. If the user selects an object, the variable whose name is provided will be updated to contain the number of the selected object (an integer, 1, 2, 3, …) or 0 if the user taps Cancel.

Returns true (not zero) if the user selects an object, otherwise return false (0).

Example:



```
CHOOSE_TEST
CHOOSE_TEST
```

```
CHOOSE

(N,"PickHero",
"Euler","Gauss
","Newton");

IF N==1 THEN
PRINT("You
picked
Euler"); ELSE
IF N==2 THEN PRINT("You picked
Gauss");ELSE PRINT("You picked
Newton");

END;

END;
```

After execution of `CHOOSE`, the value of *N* will be updated to contain 0, 1, 2, or 3. The `IF THEN ELSE` command causes the name of the selected person to be printed to the terminal.

EDITLIST Syntax: `EDITLIST`(*listvar*)

Starts the List Editor loading *listvar* and displays the specified list. If used in programming, returns to the program when user taps OK.

Example: `EDITLIST`(*L1*) edits list L1.

EDITMAT Syntax: `EDITMAT`(*matrixvar*)

Starts the Matrix Editor and displays the specified matrix. If used in programming, returns to the program when user taps OK.

Example: `EDITMAT`(*M1*) edits matrix M1.

GETKEY Syntax: `GETKEY`

Returns the ID of the first key in the keyboard buffer, or –1 if no key was pressed since the last call to `GETKEY`. Key IDs are integers from 0 to 50, numbered from top left (key 0) to bottom right (key 50) as shown in figure 27-1.

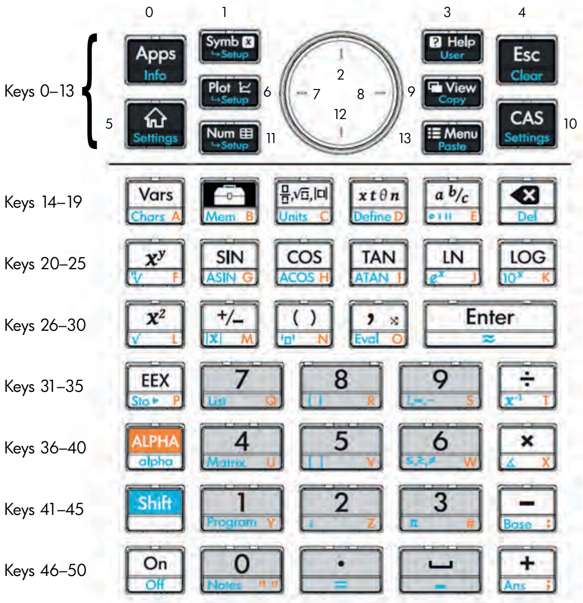


Figure 27-1: Numbers of the keys

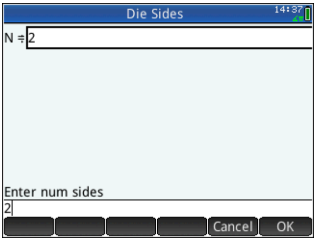
INPUT Syntax: `INPUT(var [,"title", "label", "help", reset]);`

Opens a dialog box with the title text `title`, with one field named `label`, displaying `help` at the bottom and using the `reset` value if Shift Esc is pressed.

Updates the variable *var* if the user taps OK and returns 1. If the user taps Cancel, it does not update the variable, and returns 0.

Example:

```
EXPORT SIDES;

EXPORT
GETSIDES()

BEGIN

INPUT(SIDES,"D
ie Sides","N =
","Enter num
sides",2);

END;
```


Die Sides

N =2

Enter num sides

2

ISKEYDOWN

Syntax: `ISKEYDOWN(`*key_id*`);`

Returns true (non-zero) if the key whose *key_id* is provided is currently pressed, and false (0) if it is not.

MOUSE

Syntax: `MOUSE[(index)]`

Returns two lists describing the current location of each potential pointer (or empty lists if the pointers are not used). The output is {x , y, original z, original y, type} where *type* is 0 (for new), 1 (for completed), 2 (for drag), 3 (for stretch), 4 (for rotate), and 5 (for long click).

The optional parameter index is the *n*th element that would have been returned—x, y, original x, etc.—had the parameter been omitted (or –1 if no pointer activity had occurred).

MSGBOX

Syntax: `MSGBOX(`*expression or string* [,*ok_cancel?*]);

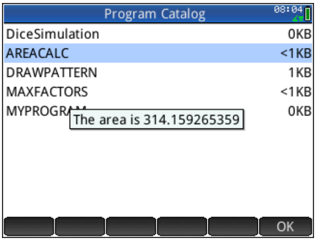
Displays a message box with the value of the given expression or *string*.

If *ok_cancel?* is true, displays the OK and Cancel buttons, otherwise only displays the OK button. Default value for *ok_cancel* is false.

Returns true (non-zero) if the user taps OK, false (0) if the user presses Cancel.

```
EXPORT AREACALC()
BEGIN
LOCAL radius;
INPUT(radius, "Radius of Circle","r =
","Enter radius",1);
MSGBOX("The area is " +π*radius^2);
END;
```

If the user enters 10 for the radius, the message box shows this:



DiceSimulation	0KB
AREACALC	<1KB
DRAWPATTERN	1KB
MAXFACTORS	<1KB
MYPROGRA	0KB

The area is 314.159265359

PRINT Syntax: `PRINT` (*expression* or *string*);

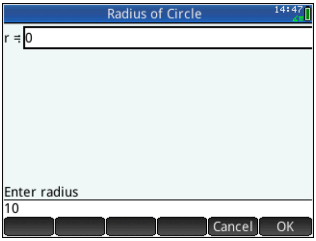
Prints the result of *expression* or *string* to the terminal.

The terminal is a program text output viewing mechanism which is displayed only when `PRINT` commands are executed. When visible, you can press ▼ or ▲ to view the text, ⌫ Del to erase the text and any other key to hide the terminal. Pressing On Off stops the interaction with the terminal. `PRINT` with no argument clears the terminal.

There are also commands for outputting data in the Graphics section. In particular, the commands `TEXTOUT` and `TEXTOUT_P` can be used for text output.

This example prompts the user to enter a value for the radius of a circle, and prints the area of the circle on the terminal.

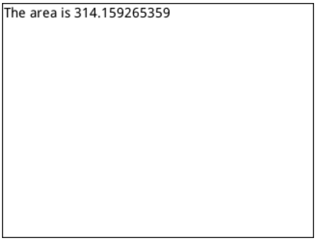
```
EXPORT AREACALC()

BEGIN

LOCAL radius;

INPUT(radius,
"Radius of
Circle","r =
","Enter
radius",1);

PRINT("The
area is "
+π*radius^2);

END;
```


Radius of Circle

r = 0

Enter radius

10



```
The area is 314.159265359
```

Notice the use of the `LOCAL` variable for the radius, and the naming convention that uses lower case letters for the local variable. Adhering to such a convention will improve the readability of your programs.

WAIT Syntax: `WAIT` (*n*);

Pauses program execution for *n* seconds. With no argument or with *n* = 0, pauses program execution for one minute.

More

%CHANGE Syntax: `%CHANGE(x,y)`

The percentage change in going from *x* to *y*.

Example: `%CHANGE(20,50)` returns 150.

%TOTAL Syntax: `%TOTAL(x,y)`

The percentage of *x* that is *y*.

Example: `%TOTAL(20,50)` returns 250.

CAS Syntax: `CAS.function() or CAS.variable`

Executes the function or returns the variable using the CAS.

EVALLIST Syntax: `EVALLIST({list})`

Evaluates the content of each element in a list and returns an evaluated list.

EXECON Syntax: `EXECON(&expr, List1, [list2,…])`

Creates a new list based on the elements in one or more lists by iteratively modifying each element according to an expression that contains the ampersand character (&).

Examples:

`EXECON("&+1",{1,2,3})` returns `{2,3,4}`

Where the & is followed directly by a number, the position in the list is indicated. For example:

`EXECON("&2−&1",{1, 4, 3, 5}"` returns `{3, −1, 2}`

In the example above, &2 indicates the second element and &1 the first element in each pair of elements. The minus operator between them subtracts the first from the second in each pair until there are no more pairs. In this case (with just a single list), the numbers appended to & can only be from 1 to 9 inclusive.

EXECON can also operate on more than one list. For example:

`EXECON("&1+&2",{1,2,3},{4,5,6})` returns `{5,7,9}`

In the example above, &1 indicates an element in the first list and &2 indicates the corresponding element in the second list. The plus operator between them adds the two elements until there are no more pairs. With two lists, the numbers appended to & can have two digits; in this case, the first digit refers to the list number (in order from left to right) and the second digit can still only be from 1 to 9 inclusive.

EXECON can also begin operating on a specified element in a specified list. For example:

`EXECON("&23+&1",{1,5,16},{4,5,6,7})` returns `{7,12}`

In the example above, &23 indicates that operations are to begin on the second list and with the third element. To that element is added the first element in the first list. The process continues until there are no more pairs.

→HMS Syntax: `→HMS(value)`

Converts a decimal *value* to hexagesimal format; that is, in units subdivided into groups of 60. This includes degrees, minutes, and seconds as well as hours, minutes, and seconds.

Example: `→HMS(54.8763)` returns `54°52′34.68″`

HMS→ Syntax: `HMS→(value)`

Converts a *value* expressed hexagesimal format to decimal format.

Example: `HMS→(54°52′34.68″)` returns `54.8763`

ITERATE Syntax: `ITERATE(expr, var, ivalue, #times)`

For `#times`, recursively evaluates `expr` in terms of `var` beginning with `var` = `ivalue`.

Example: `ITERATE(X^2, X, 2, 3)` returns `256`

TICKS Syntax: TICKS

Returns the internal clock value in milliseconds.

TIME Syntax: `TIME`(*program_name*)

Returns the time in milliseconds required to execute the program *program_name*. The results are stored in the variable `TIME`. The variable `TICKS` is similar. It contains the number of milliseconds since boot up.

TYPE Syntax: TYPE(object)

Returns the type of the object:

0: Real

1: Integer

2: String

3: Complex

4: Matrix

5: Error

6: List

8: Function

9: Unit

14.?: cas object. The fractional part is the cas type.

Variables and Programs

The HP Prime has four types of variables: Home variables, App variables, CAS variables, and User variables. You can retrieve these variables from the Variable menu (Vars).

The names of Home variables are reserved; that is, they cannot be deleted from the system and cannot be used to store objects of any other type than that for which they were designed. For example, A–Z and θ are reserved to store real numbers, Z0–Z9 are reserved to store complex numbers, and L0–L9 are reserved to store lists, etc. As a result, you cannot store a matrix in L8 or a list in Z.

Home variables keep the same value in Home and in apps; that is, they are global variables common to the system. They can be used in programs with that understanding.

App variable names are also reserved, though a number of apps may share the same app variable name. In any of these cases, the name of the app variable must be qualified if that variable is not from the current app. For example, if the current app is the Function app, `Xmin` will return the minimum x-value in the Plot view of the Function app. If you want the minimum value in the Plot view of the Polar app, then you must enter `Polar.Xmin`. App variables represent the definitions and settings you make when working with apps interactively. As you work through an app, the app functions may store results in app variables as well. In a program, app variables are used to edit an app's data to customize it and to retrieve results from the app's operation.

CAS variables are similar to the Home real variables A–Z, except that they are lowercase and designed to be used in CAS view and not Home view. Another difference is that Home and App variables always contain values, while CAS variables can be simply symbolic and not contain any particular value. The CAS variables are not typed like the Home and App variables. For example, the CAS variable *t* may contain a real number, a list, or a vector, etc. If a CAS variable has a value stored in it, calling it from Home view will return its contents.

User variables are variables created by the user, either directly or exported from a user program. They provide one of several mechanisms to allow programs to communicate with the rest of the calculator and with other programs. User variables created in a program may be either local to that program or global. Once a variable has been exported from a program, it will appear among the user variables in the `Variables` menu, next to the program that exported it. User variables may be multi-character, but must follow certain rules; see "Variables and visibility" on page 511 for details.

User variables, like CAS variables, are not typed and thus may contain objects of different types.

The following sections deal with using app variables in programs, providing descriptions of each app variable by name and its possible contents. For a list of all the Home and app variables, see chapter 22, "Variables", beginning on page 423. For user variables in programs, see "The HP Prime programming language", beginning on page 511.

App variables

Not all app variables are used in every app. S1Fit, for example, is only used in the Statistics 2Var app. However, many of the variables are common to the Function, Advanced Graphing, Parametric, Polar, Sequence, Solve, Statistics 1Var, and Statistics 2Var apps. If a variable is not available in all of these apps, or is available only in some of these apps (or some other app), then a list of the apps where the variable can be used appears under the variable name.

The following sections list the app variables by the view in which they are used. To see the variables listed by the categories in which they appear on the Variables menu see “App variables”, beginning on page 429.

Plot view variables

Axes

Turns axes on or off.

In Plot Setup view, check (or uncheck) `AXES`.

In a program, type:

`0 ▶ Axes`—to turn axes on.

`1 ▶ Axes`—to turn axes off.

Cursor

Sets the type of cursor. (Inverted or blinking is useful if the background is solid).

In Plot Setup view, choose `Cursor`.

In a program, type:

`0 ▶ Cursor`—for solid crosshairs (default)

`1 ▶ Cursor`—to invert the crosshairs

`2 ▶ Cursor`—for blinking crosshairs.

GridDots

Turns the background dot grid in Plot view on or off.

In Plot Setup view, check (or uncheck) `GRID DOTS`.

In a program, type:

`0 ▶ GridDots`—to turn the grid dots on (default).

`1 ▶ GridDots`—to turn the grid dots off.

GridLines

Turns the background line grid in Plot View on or off.

In Plot Setup view, check (or uncheck) `GRID LINES`.

In a program, type:

`0 ▶ GridLines`—to turn the grid lines on (default).

`1 ▶ GridLines`—to turn the grid lines off.

Hmin/Hmax

Statistics 1Var

Defines the minimum and maximum values for histogram bars.

In Plot Setup view for one-variable statistics, set values for `HRNG`.

In a program, type:

n_1 ▶ `Hmin`

n_2 ▶ `Hmax`

where $n_1 < n_2$

Hwidth

Statistics 1Var

Sets the width of histogram bars.

In Plot Setup view for one-variable statistics, set a value for `Hwidth`.

In a program, type:

n ▶ `Hwidth` where *n* > 0

Labels

Draws labels in Plot View showing X and Y ranges.

In Plot Setup View, check (or uncheck) `Labels.`

In a program, type:

`1 ▶ Labels`—to turn labels on (default)

`0 ▶ Labels`—to turn labels off.

Method

Function, Solve, Parametric, Polar, Statistics 2Var

Defines the graphing method: adaptive, fixed-step segments, or fixed-step dots. (See "Graphing methods" on page 99 for an explanation of the difference between these methods.)

In a program, type:

`0 ▶ Method`—select adaptive

`1 ▶ Method`—select fixed-step segments

`2 ▶ Method`—select fixed-step dots

Nmin/Nmax
Sequence

Defines the minimum and maximum values for the independent variable.

Appears as the `N RNG` fields in the Plot Setup view. In Plot Setup view, enter values for `N Rng`.

In a program, type:

n_1 ▶ `Nmin`

n_2 ▶ `Nmax`

where $n_1 < n_2$

Recenter

Recenters at the cursor when zooming.

From Plot-Zoom-Set Factors, check (or uncheck) `Recenter`.

In a program, type:

`0` ▶ `Recenter`— to turn recenter on (default).

`1` ▶ `Recenter`— to turn recenter off.

S1mark-S5mark
Statistics 2Var

Sets the mark to use for scatter plots.

In Plot Setup view for two-variable statistics, select one of `S1 Mark-S Mark`.

SeqPlot
Sequence

Enables you to choose between a Stairstep or a Cobweb plot.

In Plot Setup view, select `SeqPlot`, then choose `Stairstep` or `Cobweb`.

In a program, type:

`0` ▶ `SeqPlot`—for Stairstep.

`1` ▶ `SeqPlot`—for Cobweb.

θmin/θmax
Polar

Sets the minimum and maximum independent values.

In Plot Setup view enter values for θ `Rng`.

In a program, type:

n_1 ▶ θ `min`

n_2 ▶ θ `max`

where $n_1 < n_2$

θstep
Polar

Sets the step size for the independent variable.

In Plot Setup view, enter a value for θ `Step`.

In a program, type:

n ▶ θ`step`

where $n > 0$

Tmin/Tmax
Parametric

Sets the minimum and maximum independent variable values.

In Plot Setup view, enter values for `T Rng`.

In a program, type:

n_1 ▶ `Tmin`

n_2 ▶ `Tmax`

where $n_1 < n_2$

Tstep
Parametric

Sets the step size for the independent variable.

In Plot Setup view, enter a value for `T Step`.

In a program, type

n ▶ `Tstep`

where $n > 0$

Xtick

Sets the distance between tick marks for the horizontal axis.

In Plot Setup view, enter a value for `X Tick`.

In a program, type:

n ▶ `Xtick` where $n > 0$

Ytick

Sets the distance between tick marks on the vertical axis.

In Plot Setup view, enter a value for `Y Tick`.

In a program, type:

n ▶ `Ytick` where $n > 0$

Xmin/Xmax

Sets the minimum and maximum horizontal values of the plot screen.

In Plot Setup view, enter values for `X Rng`.

In a program, type:

n_1 ▶ `Xmin`

n_2 ▶ `Xmax`

where $n_1 < n_2$

Ymin/Ymax

Sets the minimum and maximum vertical values of the plot screen.

In Plot Setup view, enter the values for `Y Rng`.

In a program, type:

n_1 ▶ `Ymin`

n_2 ▶ `Ymax`

where $n_1 < n_2$

Xzoom

Sets the horizontal zoom factor.

In Plot View, press Menu then Zoom. Scroll to `Set Factors`, select it and tap OK. Enter the value for `X Zoom` and tap OK.

In a program, type:

n ▶ `Xzoom`

where $n > 0$

The default value is 4.

Yzoom

In Plot View, tap Menu then Zoom. Scroll to `Set Factors` and tap OK. Enter the value for `Y Zoom` and tap OK.

Or, in a program, type:

n ▶ `Yzoom` where *n* > 0

The default value is 4.

Symbolic view variables

AltHyp
Inference

Determines the alternative hypothesis used for hypothesis testing.

In Symbolic View, select an option for Alt Hypoth.

In a program, type:

0 ▶ `AltHyp`—for $\mu < \mu_0$

1 ▶ `AltHyp`—for $\mu > \mu_0$

2 ▶ `AltHyp`—for $\mu \neq \mu_0$

E0...E9
Solve

Contains an equation or expression. In Symbolic view, select one of E0 through E9 and enter an expression or equation. The independent variable is selected by highlighting it in Numeric view.

In a program, type (for example):

```
X+Y*X-2=Y ▶E1
```

F0...F9
Function

Contains an expression in X. In Symbolic View, select one of F0 through F9 and enter an expression.

In a program, type (for example):

```
SIN(X) ▶F1
```

H1...H5
Statistics 1Var

Contains a list of the dataset(s) that define a 1-variable statistical analysis. The first column in the list is the independent column and the second (if any) specifies the column used for the frequencies. For example, H1 by default returns {D1, ""}, where D1 is the default independent column and "" indicates that there is no column used for frequencies. In Symbolic view, select one of H1 through H5 and enter an independent column and an optional frequency column.

H1Type...H5Type
Statistics 1Var

Sets the type of plot used to graphically represent the statistical analyses H1 through H5. In Symbolic View, specify the type of plot in the field for Plot1, Plot2, etc.

Or in a program, store one of the following constant integers or names into the variables H1Type, H2Type, etc.

1 Histogram (default)

2 Box and Whisker

3 Normal Probability

4 Line

5 Bar

6 Pareto

Example:

```
2▶H3Type
```

Method
Inference

Determines whether the Inference app is set to calculate hypothesis test results or confidence intervals. In Symbolic view, make a selection for `Method`.

In a program, type:

`0 ▶ Method`—for `Hypothesis Test`

`1 ▶ Method`—for `Confidence Interval`

R0...R9
Polar

Contains an expression in θ . In Symbolic view, select one of `R0` through `R9` and enter an expression.

In a program, type (for example):

```
SIN(θ) ▶ R1
```

S1...S5
Statistics 2Var

Contains a list that defines a 2-variable statistical analysis. Returns a list containing the independent column name, the dependent column name and the fit equation (if any).

S1Type...S5Type
Statistics 2Var

Sets the type of fit to be used by the `FIT` operation in drawing the regression line. From Symbolic view, specify the fit in the field for `Type1,Type2`, etc.

In a program, store one of the following constant integers into a variable `S1Type,S2Type,` etc.

1 Linear
2 Logarithmic
3 Exponential
4 Power
5 Exponent
6 Inverse
7 Logistic
8 Quadratic
9 Cubic
10 Quartic
11 User Defined

Example:

```
Cubic ▶ S2type
```

or

```
8 ▶ S2type
```

Type
Inference

Determines the type of hypothesis test or confidence interval. Depends upon the value of the variable `Method`. From Symbolic View, make a selection for `Type`.

Or, in a program, store the constant number from the list below into the variable Type. With `Method=0`, the constant values and their meanings are as follows:

0 Z-Test: 1 μ

1 Z-Test: $\mu_1 - \mu_2$

2 Z-Test: 1 π

3 Z-Test: $\pi_1 - \pi_2$

4 T-Test: 1 μ

5 T-Test: $\mu_1 - \mu_2$

With `Method=1`, the constants and their meanings are:

0 Z-Int: 1 μ

1 Z-Int: $\mu_1 - \mu_2$

2 Z-Int: 1 π

3 Z-Int: $\pi_1 - \pi_2$

4 T-Int: 1 μ

5 T-Int: $\mu_1 - \mu_2$

X0, Y0...X9,Y9
Parametric

Contains two expressions in `T`: `X(T)` and `Y(T)`. In Symbolic view, select any of `X0–Y0` through `X9–Y9` and enter expressions in T.

In a program, store expressions in T in Xn and Yn, where n is an integer from 0 to 9.

Example:

```
SIN(4*T)▶ Y1;2*SIN(6*T)▶ X1
```

U0...U9
Sequence

Contains an expression in `N`. In Symbolic view, select any of `U0` through `U9` and enter an expression in `N`, `Un(N-1)`, or `Un(N-2)`.

In a program, use the `RECURSE` command to store the expression in Un, where *n* is an integer from 0 to 9.

Example:

```
   RECURSE (U,U(N-1)*N,1,2) ▶U1
```

Numeric view variables

C0...C9
Statistics 2Var

Contain lists of numerical data. In Numeric view, enter numerical data in `C0` through `C9`.

In a program, type:

```
LIST ▶ Cn
```

where $n = 0$, 1, 2, 3 ... 9 and `LIST` is either a list or the name of a list.

D0...D9
Statistics 1Var

Contain lists of numerical data. In Numeric view, enter numerical data in `D0` through `D9`.

In a program, type:

```
LIST ▶ Dn
```

where $n = 0$, 1, 2, 3 ... 9 and `LIST` is either a list or the name of a list.

NumIndep
Function
Parametric
Polar
Sequence
Advanced
Graphing

Specifies the list of independent values (or two-value sets of independent values) to be used by `Build Your Own Table`. Enter your values one-by-one in the Numeric view.

In a program, type:

```
LIST ▶ NumIndep
```

`List` can be either a list itself or the name of a list. In the case of the Advanced Graphing app, the list will be a list of pairs (a list of 2-element vectors) rather than a list of numbers.

NumStart
Function
Parametric
Polar
Sequence

Sets the starting value for a table in Numeric view.

From Numeric Setup view, enter a value for `NUMSTART`.

In a program, type:

```
n ▶ NumStart
```

NumXStart
Advanced Graphing

Sets the starting number for the X-values in a table in Numeric view.

From Numeric Setup view, enter a value for `NUMXSTART`.

In a program, type:

```
n ▶ NumXStart
```

NumYStart
Advanced Graphing

Sets the starting value for the Y-values in a table in Numeric view.

From Numeric Setup view, enter a value for `NUMYSTART`.

In a program, type:

n ▶ `NumYStart`

NumStep
Function
Parametric
Polar
Sequence

Sets the step size (increment value) for the independent variable in Numeric view.

From Numeric Setup view, enter a value for `NUMSTEP`.

In a program, type:

n ▶ `NumStep`

where $n > 0$

NumXStep
Advanced Graphing

Sets the step size (increment value) for the independent X variable in Numeric view.

From Numeric Setup view, enter a value for `NUMXSTEP`.

In a program, type:

n ▶ `NumXStep`

where $n > 0$

NumYStep
Advanced Graphing

Sets the step size (increment value) for the independent Y variable in Numeric view.

From Numeric Setup view, enter a value for `NUMYSTEP`.

In a program, type:

n ▶ `NumYStep`

where $n > 0$

NumType
Function
Parametric
Polar
Sequence
Advanced Graphing

Sets the table format.

In Numeric Setup view, make a selection for `Num Type`.

In a program, type:

`0` ▶ `NumType`—for `Automatic` (default).

`1` ▶ `NumType`—for `BuildYourOwn`.

NumZoom
Function
Parametric
Polar
Sequence

Sets the zoom factor in the Numeric view.

From Numeric Setup view, type in a value for `NUMZOOM`.

In a program, type:

n ▶ `NumZoom`

where $n > 0$

NumXZoom
Advanced Graphing

Sets the zoom factor for the values in the X column in the Numeric view.

From Numeric Setup view, type in a value for `NUMXZOOM`.

In a program, type:

n ▶ `NumXZoom`

where $n > 0$

NumYZoom
Advanced Graphing

Sets the zoom factor for the values in the Y column in the Numeric view.

From Numeric Setup view, type in a value for `NUMYZOOM`.

In a program, type:

n ▶ `NumYZoom`

where $n > 0$

Inference app variables

The following variables are used by the Inference app. They correspond to fields in the Inference app Numeric view. The set of variables shown in this view depends on the hypothesis test or the confidence interval selected in the Symbolic view.

Alpha

Sets the alpha level for the hypothesis test. From the Numeric view, set the value of `Alpha`.

In a program, type:

n ▶ `Alpha`

where $0 < n < 1$

Conf

Sets the confidence level for the confidence interval. From Numeric view, set the value of `C`.

In a program, type:

n ▶ `Conf`

where $0 < n < 1$

Mean$_1$

Sets the value of the mean of a sample for a 1-mean hypothesis test or confidence interval. For a 2-mean test or interval, sets the value of the mean of the first sample. From Numeric view, set the value of $\bar{x}$ or $\bar{x}_1$.

In a program, type:

n ▶ Mean$_1$

Mean$_2$

For a 2-mean test or interval, sets the value of the mean of the second sample. From Numeric view, set the value of $\bar{x}_2$.

In a program, type:

n ▶ Mean$_2$

μ_0

Sets the assumed value of the population mean for a hypothesis test. From the Numeric view, set the value of μ_0.

In a program, type:

n ▶ μ_0

where $0 < \mu_0 < 1$

n$_1$

Sets the size of the sample for a hypothesis test or confidence interval. For a test or interval involving the difference of two means or two proportions, sets the size of the first sample. From the Numeric view, set the value of n$_1$.

In a program, type:

n ▶ n$_1$

n$_2$

For a test or interval involving the difference of two means or two proportions, sets the size of the second sample. From the Numeric view, set the value of n$_2$.

In a program, type:

n ▶ n$_2$

π_0

Sets the assumed proportion of successes for the One-proportion Z-test. From the Numeric view, set the value of π_0.

In a program, type:

n ▶ π_0

where $0 < \pi_0 < 1$

Pooled

Determine whether or not the samples are pooled for tests or intervals using the Student's T-distribution involving two means. From the Numeric view, set the value of `Pooled`.

In a program, type:

`0 ▶ Pooled`—for not pooled (default).

`1 ▶ Pooled`—for pooled.

s_1

Sets the sample standard deviation for a hypothesis test or confidence interval. For a test or interval involving the difference of two means or two proportions, sets the sample standard deviation of the first sample. From the Numeric view, set the value of s_1.

In a program, type:

n ▶ s_1

s_2

For a test or interval involving the difference of two means or two proportions, sets the sample standard deviation of the second sample. From the Numeric view, set the value of s_2.

In a program, type:

n ▶ s_2

σ_1

Sets the population standard deviation for a hypothesis test or confidence interval. For a test or interval involving the difference of two means or two proportions, sets the population standard deviation of the first sample. From the Numeric view, set the value of σ_1.

In a program, type:

n ▶ σ_1

σ_2

For a test or interval involving the difference of two means or two proportions, sets the population standard deviation of the second sample. From the Numeric view, set the value of σ_2.

In a program, type:

n ▶ σ_2

x_1

Sets the number of successes for a one-proportion hypothesis test or confidence interval. For a test or interval involving the difference of two proportions, sets the number of successes of the first sample. From the Numeric view, set the value of x_1.

In a program, type:

n ▶ x_1

x_2

For a test or interval involving the difference of two proportions, sets the number of successes of the second sample. From the Numeric view, set the value of x_2.

In a program, type:

n ▶ x_2

Finance app variables

The following variables are used by the Finance app. They correspond to the fields in the Finance app Numeric view.

CPYR

Compounding periods per year. Sets the number of compounding periods per year for a cash flow calculation. From the Numeric view of the Finance app, enter a value for `C/YR`.

In a program, type:

n▶`CPYR`

where $n > 0$

BEG

Determines whether interest is compounded at the beginning or end of the compounding period. From the Numeric view of the Finance app, check or uncheck `End`.

In a program, type:

`1`▶`BEG`—for compounding at the end of the period (Default)

`0`▶`BEG`—for compounding at the beginning of the period

FV

Future value. Sets the future value of an investment. From the Numeric view of the Finance app, enter a value for `FV`.

In a program, type:

n▶`FV`

Positive values represent return on an investment or loan.

IPYR

Interest per year. Sets the annual interest rate for a cash flow. From the Numeric view of the Finance app, enter a value for `I%YR`.

In a program, type:

n ▶`IPYR`

where $n > 0$

NbPmt

Number of payments. Sets the number of payments for a cash flow. From the Numeric view of the Finance app, enter a value for `N`.

In a program, type:

n ▶`NbPmt`

where $n > 0$

PMTV

Payment value. Sets the value of each payment in a cash flow. From the Numeric view of the Finance app, enter a value for `PMTV`.

In a program, type:

n ▶`PMTV`

Note that payment values are negative if you are making the payment and positive if you are receiving the payment.

PPYR

Payments per year. Sets the number of payments made per year for a cash flow calculation. From the Numeric view of the Finance app, enter a value for `P/YR`.

In a program, type:

n ▶`PPYR`

where $n > 0$

PV

Present value. Sets the present value of an investment. From the Numeric view of the Finance app, enter a value for `PV`.

In a program, type:

n ▶`PV`

Note: negative values represent an investment or loan.

GSize

Group size. Sets the size of each group for the amortization table. From the Numeric view of the Finance app, enter a value for `Group Size`.

In a program, type:

```
n▶GSize
```

Linear Solver app variables

The following variables are used by the Linear Solver app. They correspond to the fields in the app's Numeric view.

LSystem

Contains a 2x3 or 3x4 matrix which represents a 2x2 or 3x3 linear system. From the Numeric view of the Linear Solver app, enter the coefficients and constants of the linear system.

In a program, type:

```
matrix▶LSystem
```

where `matrix` is either a matrix or the name of one of the matrix variables M0-M9.

Triangle Solver app variables

The following variables are used by the Triangle Solver app. They correspond to the fields in the app's Numeric view.

SideA

The length of Side a. Sets the length of the side opposite the angle A. From the Triangle Solver Numeric view, enter a positive value for a.

In a program, type:

```
n▶SideA
```

where $n > 0$

SideB

The length of Side b. Sets the length of the side opposite the angle B. From the Triangle Solver Numeric view, enter a positive value for b.

In a program, type:

```
n▶SideB
```

where $n > 0$

SideC

The length of Side c. Sets the length of the side opposite the angle C. From the Triangle Solver Numeric view, enter a positive value for c.

In a program, type:

```
n▶SideC
```

where $n > 0$

AngleA

The measure of angle A. Sets the measure of angle A. The value of this variable will be interpreted according to the angle mode setting (Degrees or Radians). From the Triangle Solver Numeric view, enter a positive value for angle A.

In a program, type:

```
n▶AngleA
```

where $n > 0$

AngleB

The measure of angle B. Sets the measure of angle B.

The value of this variable will be interpreted according to the angle mode setting (Degrees or Radians). From the Triangle Solver Numeric view, enter a positive value for angle B.

In a program, type:

```
n▶AngleB
```

where $n > 0$

AngleC

The measure of angle C. Sets the measure of angle C.

The value of this variable will be interpreted according to the angle mode setting (Degrees or Radians). From the Triangle Solver Numeric view, enter a positive value for angle C.

In a program, type:

```
n▶AngleC
```

where $n > 0$

RECT

Corresponds to the status of ⊿ in the Numeric view of the Triangle Solver app. Determines whether a general triangle solver or a right triangle solver is used. From the Triangle Solver view, tap ⊿.

In a program, type:

`0▶RECT`—for the general Triangle Solver

`1▶RECT`—for the right Triangle Solver

Home Settings variables

The following variables (except Ans) are found in **Home Settings**. The first four can all be over-written in an app's Symbolic Setup view.

Ans

Contains the last result calculated in the Home view.

HAngle

Sets the angle format for the Home view. In **Home Settings**, choose `Degrees` or `Radians` for angle measure.

In a program, type:

`0 ▶ HAngle`—for Degrees.

`1 ▶ HAngle`—for Radians.

HDigits

Sets the number of digits for a number format other than Standard in the Home view. In **Home Settings**, enter a value in the second field of **Number Format**.

In a program, type:

n ▶ `HDigits`, where $0 < n < 11$.

HFormat

Sets the number display format used in the Home view. In **Home Settings**, choose `Standard`, `Fixed`, `Scientific`, or `Engineering` in the **Number Format** field.

In a program, store one of the following the constant numbers (or its name) into the variable `HFormat`:

0 Standard

1 Fixed

2 Scientific

3 Engineering

HComplex

Sets the complex number mode for the Home view. In **Home Settings**, check or uncheck the **Complex** field. Or, in a program, type:

`0 ▶ HComplex`—for OFF.

`1 ▶ HComplex`—for ON.

Date

Contains the system date. The format is `YYYY.MMDD`. This format is used irrespective of the format set on the **Home Settings** screen. On page 2 of **Home Settings**, enter values for `Date`.

In a program, type:

`YYYY.MMDD ▶ Date`, where `YYYY` are the four digits of the year, `MM` are the two digits of the month, and `DD` are the two digits of the day.

Time

Contains the system time. The format is `HH°MM′SS′′`, with the hours in 24-hour format. This format is used irrespective of the format set on the **Home Settings** screen. On page 2 of **Home Settings**, enter values for Time.

In a program, type:

`HH°MM′SS′′ ▶ Time`, where `HH` are the two digits of the hour (0≤HH<24), `MM` are the two digits of the minutes, and `SS` are the two digits of the seconds.

Language

Contains an integer indicating the system language. From **Home Settings**, choose a language for the **Language** field.

In a program, store one of the following constant numbers into the variable Language:

1 ▶ `Language` (English)

2 ▶ `Language` (Chinese)

3 ▶ `Language` (French)

4 ▶ `Language` (German)

5 ▶ `Language` (Spanish)

6 ▶ `Language` (Dutch)

7 ▶ `Language` (Portuguese)

Entry

Contains an integer that indicates the entry mode. In **Home Settings**, select an option for **Entry**.

In a program, enter:

`0 ▶ Entry`—for Textbook

`1 ▶ Entry`—for Algebraic

`2 ▶ Entry`—for RPN

Integer

Base

Returns or sets the integer base. In **Home Settings**, select an option for the first field next to **Integers**. In a program, enter:

`0 ▶ Base`—for Binary

`1 ▶ Base`—for Octal

`2 ▶ Base`—for Decimal

`3 ▶ Base`—for Hexadecimal

Bits

Returns or sets the number of bits for representing integers. In **Home Settings**, enter a value for the second field next to **Integers**. In a program, enter:

n ▶ `Bits` where *n* is the number of bits.

Signed

Returns the status of, or sets a flag, indicating that the integer wordsize is signed or not. In **Home Settings**, check or uncheck the **±** field to the right of **Integers**. In a program, enter:

`0 ▶ Signed`—for unsigned

`1 ▶ Signed`—for signed

Symbolic Setup variables

The following variables are found in the Symbolic setup of an app. They can be used to overwrite the value of the corresponding variable in **Home Settings**.

AAngle

Sets the angle mode.

From Symbolic setup, choose `System`, `Degrees`, or `Radians` for angle measure. `System` (default) will force the angle measure to agree with that in **Home Settings**.

In a program, type:

`0 ▶ AAngle`—for System (default).

`1 ▶ AAngle`—for Degrees.

`2 ▶ AAngle`—for Radians.

AComplex

Sets the complex number mode.

From Symbolic setup, choose `System`, `ON`, or `OFF`. `System` (default) will force the complex number mode to agree with the corresponding setting in **Home Settings**.

In a program, type:

`0 ▶ AComplex`—for System (default).

`1 ▶ AComplex`—for ON.

`2 ▶ AComplex`—for OFF.

ADigits

Contains the number of decimal places to use for the Fixed, Scientific, or Engineering number formats in the app's Symbolic Setup.

From Symbolic setup, enter a value in the second field of `Number Format`.

In a program, type:

n `▶ ADigits`

where $0 < n < 11$

AFormat

Defines the number display format used for number display in the Home view and to label axes in the Plot view.

From Symbolic setup, choose `Standard`, `Fixed`, `Scientific`, or `Engineering` in the Number Format field.

In a program, store the constant number into the variable `AFormat`.

0 System

1 Standard

2 Fixed

3 Scientific

4 Engineering

Example:

```
3 ▶ AFormat
```

Results variables

The Function, Statistics 1Var, Statistics 2Var, and Inference apps offer functions that generate results that can be re-used outside those apps (such as in a program). For example, the Function app can find a root of a function, and that root is written to a variable called `Root`. That variable can then be used elsewhere.

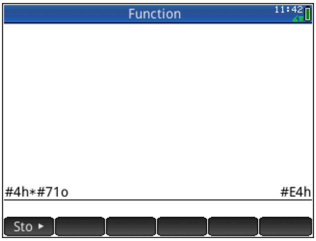
The results variables are listed with the apps that generate them. See “App variables” on page 429.

28

Basic integer arithmetic

The common number base used in contemporary mathematics is base 10. By default, all calculations performed by the HP Prime are carried out in base 10, and all results are displayed in base 10.

However, the HP Prime enables you to carry out integer arithmetic in four bases: decimal (base 10), binary, (base 2), octal (base 8), and hexadecimal (base 16). For example, you could multiply 4 in base 16 by 71 in base 8 and the answer is E4 in base 16. This is equivalent in base 10 to multiplying 4 by 57 to get 228.



```
#4h*#71o                                    #E4h
```

You indicate that you are about to engage in integer arithmetic by preceding the number with the pound symbol (#, got by pressing ALPHA 3). You indicate what base to use for the number by appending the appropriate base marker:

Base marker	Base
[blank]	Adopt the default base (see “The default base” on page 582)
d	decimal
b	binary
o	octal
h	hexadecimal

Thus `#11b` represents 3_{10}. The base marker *b* indicates that the number is to interpreted as a binary number: 11_2. Likewise #E4h represents 228_{10}. In this case, the base marker *h* indicates that the number is to interpreted as a hexadecimal number: $E4_{16}$.

Note that with integer arithmetic, the result of any calculation that would return a remainder in floating-point arithmetic is truncated: only the integer portion is presented. Thus #100b/#10b gives the correct answer: #10b (since $4_{10}/2_{10}$ is 2_{10}). However, #100b/ #11b gives just the integer component of the correct result: #1b.

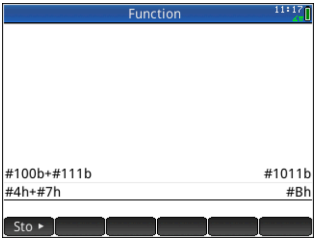
Note too that the accuracy of integer arithmetic can be limited by the integer wordsize. The wordsize is the maximum number of bits that can represent an integer. You can set this to any value between 1 and 64. The smaller the wordsize, the smaller the integer that can be accurately represented. The default wordsize is 32, which is adequate for representing integers up to approximately 2×10^9. However, integers larger than that would be truncated, that is, the most significant bits (that is, the leading bits) would be dropped. thus the result of any calculation involving such a number would not be accurate.

The default base

Setting a default base only affects the entry and display of numbers being used in integer arithmetic. If you set the default base to binary, 27 and 44 will still be represented that way in Home view, and the result of adding those numbers will still be represented as 71. However, if you entered #27b, you would get a syntax error, as 2 and 7 are not integers found in binary arithmetic. You would have to enter 27 as #11011b (since $27_{10}=11011_2$).

Setting a default base means that you do not always have to specify a base marker for numbers when doing integer arithmetic. The exception is if you want to include a number from the non-default base: it will have to include the base marker. Thus if your default base is 2 and you want to enter 27 for an integer arithmetic operation, you could enter just #11011 without the *b* suffix. But if you wanted to enter $E4_{16}$, you need to enter it with the suffix: #E4h. (The HP Prime adds any omitted base markers when the calculation is displayed in history.)

Note that if you change the default base, any calculation in history that involves integer arithmetic *for which you did not explicitly add a base marker* will be resisplayed in the new base. In the example at the right, the first calculation explicitly included base markers (*b* for each operand). The second calculation was a copy of the first but without the base markers. The default base was then changed to hex. The first calculation remained as it was, while the second—without base markers being explicitly added to the operands—was redisplayed in base 16.



```
#100b+#111b                                  #1011b
#4h+#7h                                         #Bh
```

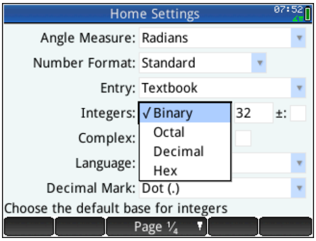
Changing the default base

The calculator's default base for integer arithmetic is 16 (hexadecimal). To change the default base:

1. Display the **Home Settings** screen:

   Shift Settings

2. Choose the base you want from the **Integers** menu: `Binary`, `Octal`, `Decimal` or `Hex`.



Angle Measure: Radians
Number Format: Standard
Entry: Textbook
Integers: √Binary 32 ±:
Complex:
Language:
Decimal Mark: Dot (.)
Choose the default base for integers

3. The field to the right of Integers is the wordsize field. This is the maximum number of bits that can represent an integer. The default value is 32, but you can change it to any value between 1 and 64.

4. If you want to allow for signed integers, select the **±** option to the right of the wordsize field. Choosing this option reduces the maximum size of an integer to one bit less than the wordsize.

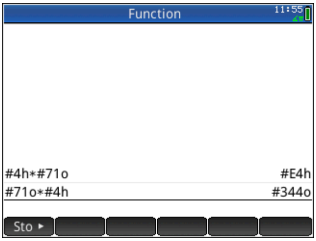
Examples of integer arithmetic

The operands in integer arithmetic can be of the same base or of mixed bases.

Integer calculation	Decimal equivalent
#10000b+#10100b =#100100b	16 + 20 = 36
#71 o–#10100b = #45o	57 – 20 = 37
#4Dh * #11101b = #8B9h	77 × 29 = 2233
#32Ah/#5o = #A2h	810/5 = 162

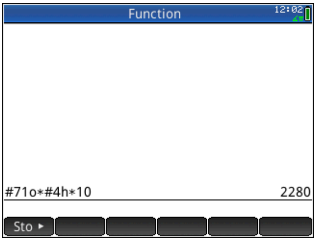
Mixed-base arithmetic

With one exception, where you have operands of different bases, the result of the calculation is presented in the base of the first operand. The example at the right shows two equivalent calculations: the first multiplies 4_{10} by 57_{10} and the second multiplies 57_{10} by 4_{10}. Obviously the results too are mathematically equivalent. However, each is presented in the base of the operand entered first: 16 in the first case and 8 in the second.



```
#4h*#71o                 #E4h
#71o*#4h                #344o
```

The exception is if an operand is not marked as an integer by preceding it with #. In these cases, the result is presented in base 10.



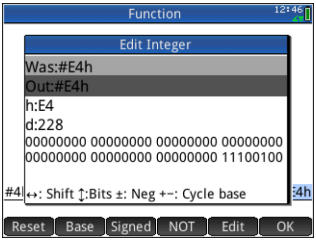
```
#71o*#4h*10              2280
```

Integer manipulation

The result of integer arithmetic can be further analyzed, and manipulated, by viewing it in the **Edit Integer** dialog.

1. In Home view, use the cursor keys to select the result of interest.
2. Press Shift − (Base).

   The **Edit Integer** dialog appears. The **Was** field at the top shows the result you selected in Home view.

   Function 12:46

   Edit Integer

   Was:#E4h
   Out:#E4h
   h:E4
   d:228
   00000000 00000000 00000000 00000000
   00000000 00000000 00000000 11100100

   ↔: Shift ↕:Bits ±: Neg +−: Cycle base

   Reset | Base | Signed | NOT | Edit | OK

   The hex and decimal equivalents are shown under the **Out** field, followed by a bit-by-bit representation of the integer.

   Symbols beneath the bit representation show the keys you can press to edit the integer. (Note that this doesn't change the result of the calculation in Home view.) The keys are:

   – ◀ or ▶ (Shift): these keys shift the bits one space to the left (or right). With each press, the new integer represented appears in the **Out** field (and in the hex and decimal fields below it).

   – ▲ or ▼ (Bits): these keys increase (or decrease) the wordsize. The new wordsize is appended to the value shown in the **Out** field.

   – +/− (Neg): returns the two's complement (that is, each bit in the specified wordsize is inverted and one is added. The new integer represented appears in the **Out** field (and in the hex and decimal fields below it).

   – + or − (Cycle base): displays the integer in the **Out** field in another base.

   Menu buttons provide some additional options:

   Reset: returns all changes to their original state

   Base: cycles through the bases; same as pressing +

   Signed: toggles the wordsize between signed and unsigned

NOT: returns the one's complement (that is, each bit in the specified wordsize is inverted: a 0 is replaced by 1 and a 1 by 0. The new integer represented appears in the **Out** field (and in the hex and decimal fields below it).

Edit: activates edit mode. A cursor appears and you can move abut the dialog using the cursor keys. The hex and decimal fields can be modified, as can the bit representation. A change in one such field automatically modifies the other fields.

OK: closes the dialog and saves your changes. If you don't want to save your changes, press Esc Clear instead.

3. Make whatever changes you want.
4. To save your changes, tap OK; otherwise press Esc Clear.

Note If you save changes, the next time you select that same result in Home view and open the **Edit Integer** dialog, the value shown in the **Was** field will be the value you saved, not the value of the result.

Base functions

Numerous functions related to integer arithmetic can be invoked from Home view and within programs:

- BITAND
- BITNOT
- BITOR
- BITSL
- BITSR
- BITXOR
- B→R
- GETBASE
- GETBITS
- R→B
- SETBASE
- SETBITS

These are described in "Integer", beginning on page 547.

Appendix A

Glossary

app

A small application, designed for the study of one or more related topics or to solve problems of a particular type. The built-in apps are Function, Advanced Graphing, Geometry, Spreadsheet, Statistics 1Var, Statistics 2Var, Inference, DataStreamer, Solve, Linear Solver, Triangle Solver, Finance, Parametric, Polar, Sequence, Linear Explorer, Quadratic Explorer, and Trig Explorer. An app 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.

button

An option or menu shown at the bottom of the screen and activated by touch. Compare with *key*.

CAS

Computer Algebra System. Use the CAS to perform exact or symbolic calculations. Compare to calculations done in Home view, which often yield numerical approximations. You can share results and variables between the CAS and Home view (and vice versa).

catalog

A collection of items, such as matrices, lists, programs and the like. New items you create are saved to a catalog, and you choose a specific item from a catalog to work on it. A special catalog that lists the apps is called the Application Library.

command

An operation for use in programs. Commands can store results in variables, but do not display results.

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.

Home view

The basic starting point of the calculator. Most calculations can be done in Home view. However, such calculations only return numeric approximations. For exact results, you can use the CAS. You can share results and variables between the CAS and Home view (and vice versa).

input form

A screen where you can set values or choose options. Another name for a dialog box.

key

A key on the keypad (as opposed to a button, which appears on the screen and needs to be tapped to be activated).

Library

A collection of items, more specifically, the apps. See also *catalog*.

list

A set of objects separated by commas and enclosed in curly braces. Lists are commonly used to contain statistical data and to evaluate a function with multiple values. Lists can be created and manipulated by the List Editor and stored in the List Catalog.

matrix

A two-dimensional array of real or complex numbers enclosed by square brackets. Matrices can be created and manipulated by the Matrix Editor and stored in the Matrix Catalog. 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 touch buttons across the bottom of the display.

note

Text that you write in the Note Editor. It can be a general, standalone note or a note specific to an app.

open sentence

An open sentence consists of two expressions (algebraic or arithmetic), separated by a relational operator such as =, <, etc. Examples of open sentences include $y^2<x^{-1}$ and $x^2-y^2=3+x$.

program

A reusable set of instructions that you record using the Program Editor.

variable

A name given to an object—such as a number, list, matrix, graphic and so on—to assist in later retrieving it. The Sto ▸ command assigns a variable, and the object can be retrieved by selecting the associated variable from the variables menu (Vars Chars A).

vector

A one-dimensional array of real or complex numbers enclosed in single square brackets. Vectors can be created and manipulated by the Matrix Editor and stored in the Matrix Catalog.

views

The primary environments of HP apps. Examples of app views include Plot, Plot Setup, Numeric, Numeric Setup, Symbolic, and Symbolic Setup.

Appendix B

Troubleshooting

Calculator not responding

If the calculator does not respond, you should first try to reset it. This is much like restarting a PC. It cancels certain operations, restores certain conditions, and clears temporary memory locations. However, it does not clear stored data (variables, apps, programs, etc.).

To reset

Turn the calculator over and insert a paper clip into the Reset hole just above the battery compartment cover. The calculator will reboot and return to Home view.

If the calculator does not turn on

If the HP Prime 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, contact Customer Support for further information.

1. Charge the calculator for at least one hour.
2. After an hour of charging, turn the calculator on.
3. If it does not turn on, reset the calculator as per the preceding section.

Operating limits

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.*

The battery operates at 3.7V with a capacity of 1500mAh (5.55Wh).

Status messages

The table below lists the most common general error messages and their meanings. Some apps and the CAS have more specific error messages that are self-explanatory.

Message	Meaning
Bad argument type	Incorrect input for this operation.
Insufficient memory	You must recover some memory to continue operation. Delete one or more customized apps, matrices, lists, notes, or programs.
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.
Statistics data size not equal	Need two columns with equal numbers of data values.

Message	**Meaning (Continued)**
Syntax error	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.
No functions checked	You must enter and check an equation in the Symbolic view before entering the Plot view.
Receive error	Problem with data reception from another calculator. Re-send the data.
Undefined name	The global variable named does not exist.
Out of memory	You must recover a lot of memory to continue operation. Delete one or more customized apps, matrices, lists, notes, or programs.
Two decimal separators input	One of the numbers you have entered has two or more decimal points.
X/0	Division by zero error.
0/0	Undefined result in division.
LN(0)	LN(0) is undefined.
Inconsistent units	The calculation involves incompatible units (eg., adding length and mass).

Appendix C

Product regulatory information

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. Applicable only for products with connectivity to PC/laptop.

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.

If you have questions about the product that are not related to this declaration, write to:
Hewlett-Packard Company
P.O. Box 692000, Mail Stop 530113
Houston, TX 77269-2000

For questions regarding this FCC declaration, write to:
Hewlett-Packard Company
P.O. Box 692000, Mail Stop 510101 Houston, TX 77269-2000 or call HP at 281-514-3333

To identify your product, refer to the part, series, or model number located 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

Products bearing the CE marking comply with the following EU Directives:

- Low Voltage Directive 2006/95/EC
- EMC Directive 2004/108/EC
- Ecodesign Directive 2009/125/EC, where applicable

CE compliance of this product is valid if powered with the correct CE-marked AC adapter provided by HP.

Compliance with these directives implies conformity to applicable harmonized European standards (European Norms) that are listed in the EU Declaration of Conformity issued by HP for this product or product family and available (in English only) either within the product documentation or at the following web site: **www.hp.eu/certificates** (type the product number in the search field).

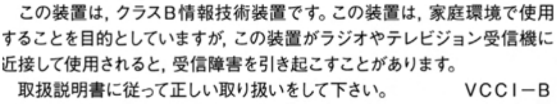
The compliance is indicated by one of the following conformity markings placed on the product:

CE	For non-telecommunications products and for EU harmonized telecommunications products, such as Bluetooth® within power class below 10mW.
CE (!)	For EU non-harmonized telecommunications products (If applicable, a 4-digit notified body number is inserted between CE and !).

Please refer to the regulatory label provided on the product.

The point of contact for regulatory matters is:
Hewlett-Packard GmbH, Dept./MS: HQ-TRE, Herrenberger Strasse 140, 71034 Boeblingen, GERMANY.

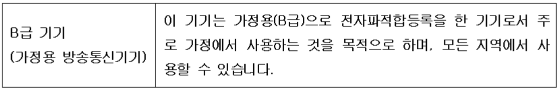
Japanese Notice



この装置は，クラスB情報技術装置です。この装置は，家庭環境で使用することを目的としていますが，この装置がラジオやテレビジョン受信機に近接して使用されると，受信障害を引き起こすことがあります。

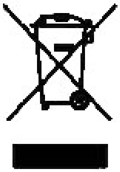
取扱説明書に従って正しい取り扱いをして下さい。　　　　VCCI－B

Korean Class Notice



B급 기기 (가정용 방송통신기기)	이 기기는 가정용(B급)으로 전자파적합등록을 한 기기로서 주로 가정에서 사용하는 것을 목적으로 하며, 모든 지역에서 사용할 수 있습니다.

Disposal of Waste Equipment by Users in Private Household in the European Union



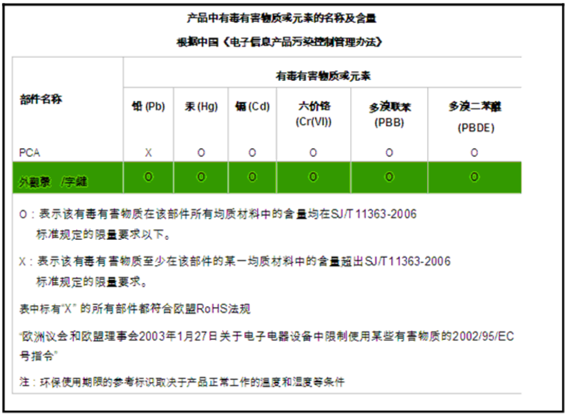
This symbol on the product or on its packaging indicates that this product must not be disposed of with your other household waste. Instead, it is your responsibility to dispose of your waste equipment by handing it over to a designated collection point for the recycling of waste electrical and electronic 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.

Chemical Substances

HP is committed to providing our customers with information about the chemical substances in our products as needed to comply with legal requirements such as REACH (*Regulation EC No 1907/2006 of the European Parliament and the Council).* A chemical information report for this product can be found at:

http://www.hp.com/go/reach

Perchlorate Material - special handling may apply
This calculator's Memory Backup battery may contain perchlorate and may require special handling when recycled or disposed in California.



产品中有毒有害物质或元素的名称及含量

根据中国《电子信息产品污染控制管理办法》

部件名称	有毒有害物质或元素					
	铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (Cr(VI))	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
PCA	X	O	O	O	O	O
外觀殼 /字鍵	O	O	O	O	O	O

O：表示该有毒有害物质在该部件所有均质材料中的含量均在SJ/T 11363-2006
标准规定的限量要求以下。

X：表示该有毒有害物质至少在该部件的某一均质材料中的含量超出SJ/T 11363-2006
标准规定的限量要求。

表中标有"X" 的所有部件都符合欧盟RoHS法规

"欧洲议会和欧盟理事会2003年1月27日关于电子电器设备中限制使用某些有害物质的2002/95/EC
号指令"

注：环保使用期限的参考标识取决于产品正常工作的温度和湿度等条件

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HP Prime Graphing Calculator

User Guide Supplement

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About this guide

The information in this guide updates the information in the following chapters of the *HP Prime Calculator User Guide*:

- Geometry
- Inference app
- Functions and commands
- Variables
- Programming in HP PPL

If there is a conflict between the information in these guides, use the information provided in this guide.

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1

Geometry

The Geometry app enables you to draw and explore geometric constructions. A geometric construction can be composed of any number of geometric objects, such as points, lines, polygons, curves, tangents, and so on. You can take measurements (such as areas and distances), manipulate objects, and note how measurements change.

There are five app views:

- Plot view: provides drawing tools for you to construct geometric objects
- Symbolic view: provides editable definitions of the objects in Plot view
- Numeric view: for making calculations about the objects in Plot view
- Plot Setup view: for customizing the appearance of Plot view
- Symbolic Setup view: for overriding certain system-wide settings

There is no Numeric Setup view in this app.

To open the Geometry app, press Apps Info and select **Geometry**. The app opens in Plot view.

Getting started with the Geometry app

The following example shows how you can graphically represent the derivative of a curve, and have the value of the derivative automatically update as you move a point of tangency along the curve. The curve to be explored is $y = 3\sin(x)$.

Since the accuracy of our calculation in this example is not too important, we will first change the number format to fixed at 3 decimal places. This will also help keep our geometry workspace uncluttered.

Preparation

1. Press Shift CAS Settings.
2. On the first **CAS settings** page, set the number format to `Standard` and the number of decimal places to 4.

Open the app and plot the graph

3. Press Apps Info and select **Geometry**.

   If there are objects showing that you don't need, press Shift Esc Clear and confirm your intention by tapping OK.

   The app opens in Plot view. This view displays a Cartesian plane with a menu bar at the bottom. Next to the menu bar, this view displays the coordinates of the cursor. After you interact with the app, the bottom of the display displays the currently active tool or command, help for the current tool or command, and a list of all objects recognized as being under the current pointer location.

4. Select the type of graph you want to plot. In this example we are plotting a simple sinusoidal function, so choose:

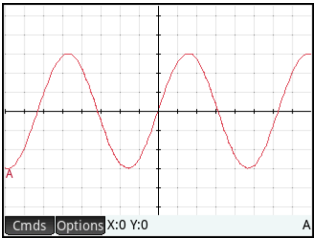
   Cmds > `Plot` > `Function`

5. With `plotfunc(` on the entry line, enter 3*sin(*x*):

   3 × SIN ASIN ALPHA alpha Shift × Enter ≈

   Note that *x* must be entered in lowercase in the Geometry app.

   If your graph doesn't resemble the illustration at the right, adjust the **X Rng** and **Y Rng** values in Plot Setup view (Shift Plot Setup).



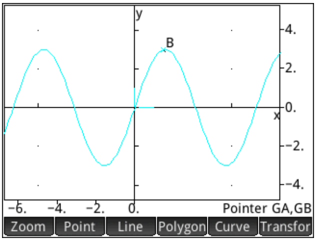
   We'll now add a point to the curve, a point that will be constrained always to follow the contour of the curve.

Add a constrained point

6. Tap Cmds, tap `Point`, and then select `Point On`.

   Choosing `Point On` rather than `Point` means that the point will be constrained to whatever it is placed on.

7. Tap anywhere on the graph, press Enter ≈ and then press Esc Clear.



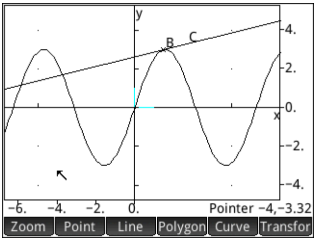
Notice that a point is added to the graph and given a name (B in this example). Tap a blank area of the screen to deselect everything. (Objects colored light blue are selected.)

Add a tangent

8. We will now add a tangent to the curve, making point B the point of tangency:

Cmds > Line > Tangent

9. When prompted to select a curve, tap anywhere on the curve and press Enter ≈. When prompted to select a point, tap point B and press Enter ≈ to see the tangent. Press Esc Clear to close the Tangent tool.



Depending on where you placed point B, your illustration might be different from the one at the right. Now, make the tangent stand out by giving it a bright color.

10. Tap on the tangent to select it. After the tangent is selected, the new menu key Options appears. Tap Options or press Menu Paste, and then select Choose color.

11. Pick a color, and then tap on a blank area of the screen to see the new color of the tangent line.

12. Tap point B and drag it along the curve; the tangent moves accordingly. You can also drag the tangent line itself.

13. Tap point B and then press Enter ≈ to select the point. The point turns light blue to show that it has been selected. Now, you can either drag the point with your finger or use the cursor keys for finer control of the

movement of point B. To deselect point B, either press Esc Clear or tap point B and press Enter.

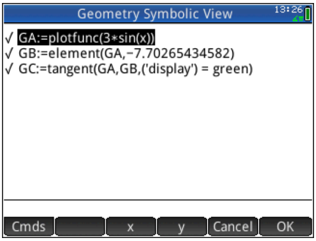
Note that whatever you do, point B remains constrained to the curve. Moreover, as you move point B, the tangent moves as well. If it moves off the screen, you can bring it back by dragging your finger across the screen in the appropriate direction.

Create a derivative point

The derivative of a graph at any point is the slope of its tangent at that point. We'll now create a new point that will be constrained to point B and whose ordinate value is the derivative of the graph at point B. We'll constrain it by forcing its *x* coordinate (that is, its abscissa) to always match that of point B, and its *y* coordinate (that is, its ordinate) to always equal the slope of the tangent at that point.

14. To define a point in terms of the attributes of other geometric objects, you need to go to Symbolic view:

    Symb Setup

    Geometry Symbolic View

    ```
    √ GA:=plotfunc(3*sin(x))
    √ GB:=element(GA,−7.70265434582)
    √ GC:=tangent(GA,GB,('display') = green)
    ```

    Note that each object you have so far created is listed in Symbolic view. Note too that the name for an object in Symbolic view is the name it was given in Plot view but prefixed with a "G". Thus the graph—labeled A in Plot view—is labeled GA in Symbolic view.

15. Highlight the blank definition following *GC* and tap New.

    When creating objects that are dependent on other objects, the order in which they appear in Symbolic view is important. Objects are drawn in Plot view in the order in which they appear in Symbolic view. Since we are about to create a new point that is dependent on the attributes of GB and GC, it is important that we place its definition after that of both GB and GC. That is why we made sure we were at the bottom the list of definitions before tapping New. If the new definition appeared higher up in Symbolic view, the point created in the following step would not be active in Plot view.

16. Tap Cmds and choose `Point` > `point`

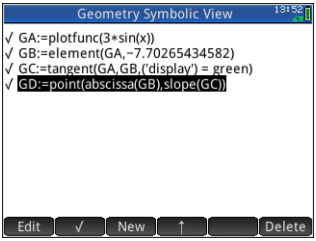
    You now need to specify the *x* and *y* coordinates of the new point. The former is defined as the abscissa of point `B` (referred to as `GB` in Symbolic view) and the latter is defined as the slope of tangent line `C` (referred to as `GC` in Symbolic view).

17. You should have `point()` on the entry line. Between the parentheses, add:

    `abscissa(GB),slope(GC)`

For the abscissa command, tap Cmds, select `Cartesian`, and then select `abscissa`. For the slope command, tap Cmds, select `Measure`, and then select `slope`.

18. Tap OK.

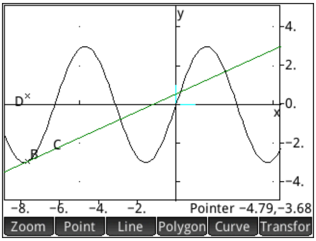


Geometry Symbolic View 13:52

√ GA:=plotfunc(3*sin(x))
√ GB:=element(GA,−7.70265434582)
√ GC:=tangent(GA,GB,('display') = green)
√ GD:=point(abscissa(GB),slope(GC))

    The definition of your new point is added to Symbolic view. When you return to Plot view, you will see a point named `D` and it will have the same *x*-coordinate as point `B`.

19. Press Plot Setup.



    If you can't see point `D`, pan until it comes into view. The y coordinate of `D` will be the derivative of the curve at point `B`.

    Since it is difficult to read coordinates off the screen, we'll add a calculation that will give the exact derivative (to three decimal places) and which we can display in Plot view.

Add some calculations

20. Press Num Setup.

    Numeric view is where you enter calculations.

21. Tap New.

22. Tap Cmds and choose `Measure` > `slope`

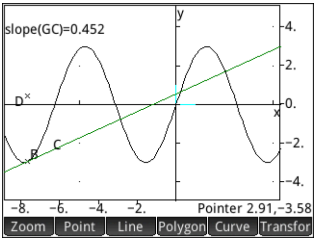
23. Between parentheses, add the name of the tangent, namely `GC`, and tap OK.

    Notice that the current slope is calculated and displayed. The value here is dynamic, that is, if the slope of the tangent changes in Plot view, the value of the slope is automatically updated in Numeric view.

24. With the new calculation highlighted in Numeric view, tap √.

    Selecting a calculation in Numeric view means that it will also be displayed in Plot view.

25. Press Plot Setup to return to Plot view.

    
    slope(GC)=0.452

    Notice the calculation that you have just created in Numeric view is displayed at the top left of the screen.

    Let's now add two more calculations to Numeric view and have them displayed in Plot view.

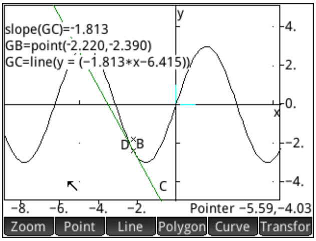
26. Press Num Setup to return to Numeric view.

27. Tap the last blank field to select it, and then tap New to start a new calculation. Tap Cmds, select `Cartesian`, and then select `Coordinates`. Between the parentheses, enter `GB` and then tap OK.

28. To start a third calculation, tap Cmds, select `Cartesian`, and then select `Equation of`. Between the parentheses, enter `GC` and then tap OK.

29. Make sure both of these new equations are selected (by choosing each one and pressing √).

30. Press Plot Setup to return to Plot view.

    
    slope(GC)=-1.813
    GB=point(-2.220,-2.390)
    GC=line(y = (-1.813*x-6.415))

    Notice that your new calculations are displayed.

31. Tap point B and then press Enter to select it.

32. Use the cursor keys to move point B along the graph. Note that with each move, the results of the calculations shown at the top left of the screen change. To deselect point B, tap point B and then press Enter.

Calculations in Plot view

By default, calculations in Plot view are docked to the upper left of the screen. You can drag a calculation from its dock and position it anywhere you like; however, after being undocked, the calculation scrolls with the display. Tap and hold a calculation to edit its label. An edit line opens so that you can enter your own label. You can also tap Choose and select a different color for the calculation and its label. Tap OK when you are done.

Trace the derivative

Point D is the point whose ordinate value matches the derivative of the curve at point B. It is easier to see how the derivative changes by looking at a plot of it rather than comparing subsequent calculations. We can do that by tracing point D as it moves in response to movements of point B.

First we'll hide the calculations so that we can better see the trace curve.

33. Press Num Setup to return to Numeric view.

34. Select each calculation in turn and tap √. All calculations should now be deselected.

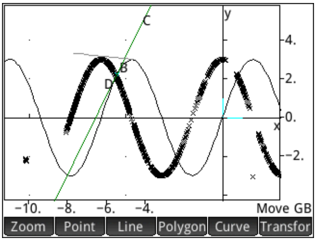
35. Press Plot Setup to return to Plot view.

36. Tap point D and then press Enter to select it.

37. Tap Options (or press Menu Paste) and then select Trace. Press Enter to deselect point D.

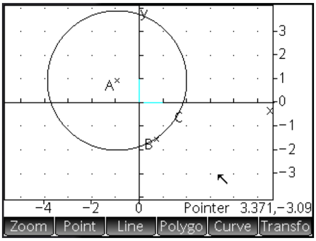
38. Tap point B and then press Enter to select it.

39. Using the cursor keys, move point B along the curve. Notice that a shadow curve is traced out as you move point B. This is the curve of the



derivative of 3sin(*x*). Tap point `B` and then press Enter to deselect it.

Plot view in detail



In Plot view you can directly draw objects on the screen using various drawing tools. For example, to draw a circle, tap Cmds, tap `Curve`, and then select `Circle`. Now, tap where you want the center of the circle to be and press Enter. Next, tap a point that is to be on the circumference and press Enter. A circle is drawn with a center at the location of your first tap, and with a radius equal to the distance between your first tap and second tap.

Note that there are on-screen instructions to help you. These instructions appear near the bottom of the screen, next to the command listing for the active tool (circle, point, and so on).

You can draw any number of geometric objects in Plot view. See “Plot view: Cmds menu” on page 23 for a list of the objects you can draw. The drawing tool you choose—line, circle, hexagon, and so on—remains selected until you deselect it. This enables you to quickly draw a number of objects of the same type (such as a number of hexagons). After you have finished drawing objects of a particular type, deselect the drawing tool by pressing Esc. You can tell if a drawing tool is still active by the presence of the on-screen instructions and the command name at the bottom of the screen.

An object in Plot view can be manipulated in numerous ways, and its mathematical properties can be easily determined (see page 20).

Selecting objects

Selecting an object involves at least two steps: tapping the object and pressing Enter. Pressing Enter is necessary to confirm your intention to select an object.

When you tap a location, objects recognized as being under the pointer are colored light red and added to the list of objects in the bottom right corner of the display. You can select any or all of these objects by pressing Enter. You can tap the screen and then use the cursor keys to accurately position the pointer before pressing Enter.

When more than one object is recognized as being under the pointer, in most cases, preference is given to any point under the pointer when Enter is pressed. In other cases, a pop-up box appears enabling you to select the desired objects.

You can also select multiple objects using a selection box. Tap and hold your finger at the location on the screen that represents one corner of the selection rectangle. Then drag your finger to the opposite corner of the selection rectangle. A light blue selection rectangle is drawn as you drag. Objects that touch this rectangle are selected.

Hiding names

You can choose to hide the name of an object in Plot view:

1. Select the object whose label you want to hide.
2. Tap Options or press Menu Paste.
3. Select `Hide Label`.

Redisplay a hidden name by repeating this procedure and selecting `Show Label`.

Moving objects

There are many ways to move objects. First, to move an object quickly, you can drag the object without selecting it.

Second, you can tap an object and press Enter to select it. Then, you can drag the object to move it quickly or use the cursor keys to move it one pixel at a time. With the second method, you can select multiple objects to move together. When you have finished moving objects, tap a location where there are no objects and press Enter to deselect everything. If you have selected a single object, you can tap the object and press Enter to deselect it.

Third, you can move a point on an object. Each point on an object has a calculation labeled with its name in Plot view. Tap and hold this item to display a slider bar. You can drag the slider or use the cursor keys to move it. Edit appears as a new menu key. Tap this key to display a dialog box where you can specify the start, step, and stop values for the slider. Also, you can create an animation based on this point using the slider. You can set the speed and pause for the animation, as well as its type. To start or stop an animation, select it, tap Options, and then select or clear the `Animate` option.

Coloring objects

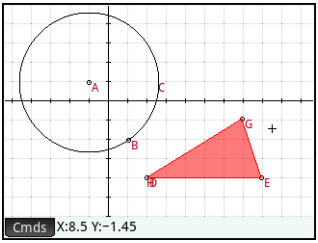
Objects are colored black by default. The procedure to change the color of an object depends on which view you are in. In both the Symbolic and Numeric view, each item includes a set of color icons. Tap these icons and select a color. In Plot view, select the object, tap Options (or press Menu Paste), tap `Choose Color`, and then select a color.

Filling objects

An object with closed contours (such as a circle or polygon) can be filled with color.

1. Select the object.
2. Tap Options or press Menu Paste.
3. Select `Filled`.

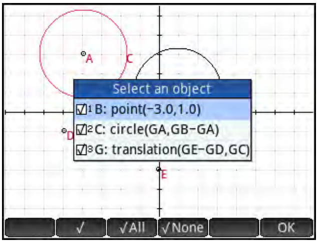
Filled is a toggle. To remove a fill, repeat the above procedure.



Clearing an object

To clear one object, select it and tap Del. Note that an object is distinct from the points you entered to create it. Thus deleting the object does not delete the points that define it. Those points remain in the app. For example, if you select a circle and press Del, the circle is deleted but the center point and radius point remain.

If other objects are dependent on the one you have selected for deletion, a pop-up displays the selected object and all dependent objects checked for deletion. Confirm your intention by tapping OK.


Select an object
☑1 B: point(−3.0,1.0)
☑2 C: circle(GA,GB−GA)
☑3 G: translation(GE−GD,GC)

You can select multiple items for deletion. Either select them one at a time or use a selection box, and then press Del.

Note that points you add to an object once the object has been defined are cleared when you clear the object. Thus if you place a point (say `D`) on a circle and delete the circle, the circle and D are deleted, but the defining points—the center and radius points—remain.

Clearing all objects

To clear the app of all geometric objects, press Shift Esc. You will be asked to confirm your intention to do so. Tap OK to clear all objects defined in Symbolic view or Cancel to keep the app as it is. You can clear all measurements and calculations in Numeric view in the same way.

Gestures in Plot view

You can pan by dragging a finger across the screen: either up, down, left, or right. You can also use the cursor keys to pan once the cursor is at the edge of the screen. You can use a pinch gesture to zoom in or out. Place two fingers on the screen. Move them apart to zoom in or bring them together to zoom out. You can also press + to zoom in on the pointer or press − to zoom out on the pointer.

Zooming

You can zoom by tapping Zoom and choosing a zoom option. The zoom options are the same as you find in the Plot view of many apps in the calculator.

Plot view: buttons and keys

Button or key	Purpose
Cmds	Opens the Commands menu. See “Plot view: Cmds menu” on page 23.
Options	Opens the Options menu for the selected object.
Vars	Hides (or displays) the axes.
▯,√▯,|▯|	Selects the circle drawing tool. Follow the instructions on the screen (or see page 28).
a b/c	Erases all trace lines.
TAN	Selects the intersection drawing tool. Follow the instructions on the screen (or see page 24).
x^2	Selects the line drawing tool. Follow the instructions on the screen (or see page 25).
EEX	Selects the point drawing tool. Follow the instructions on the screen (or see page 24).
9	Selects the segment drawing tool. Follow the instructions on the screen (or see page 25).
÷	Selects the triangle drawing tool. Follow the instructions on the screen (or see page 26).
Del	Deletes a selected object (or the character to the left of the cursor if the entry line is active).
Esc	Deselects the current drawing tool.
Shift Esc	Clears the Plot view of all geometric objects or the Numeric view of all measurements and calculations.

The Options menu

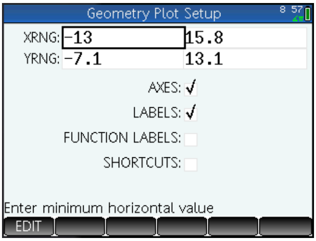
When you select an object, a new menu key appears: Options. Tap this key to view and select options for the selected object, such as color. The Options menu changes depending on the type of object selected. The complete set of Geometry options are listed in the following table and are also displayed when you press Menu Paste.

Option	Purpose
`Choose Color`	Displays a set of color icons so you can select a color for the selected object.
`Hide`	Hides the selected object. This is a shortcut for deselecting the object in Symbolic view. To select an object to display after it has been hidden, go to Symbolic or Numeric view.
`Hide Label`	Hides the label of a selected object. This option changes to `Show Label` if the selected object has a hidden label.
`Filled`	Fills the selected object with a color. Clear this option to remove the fill.
`Trace`	Starts tracing for any selected point if selected, then stops tracing for the selected point.
`Clear Trace`	Erases the current trace of the selected point but does not stop tracing.
`Animate`	Starts the current animation of a selected point on an object. If the selected point is currently animated, this option stops the animation.

Plot Setup view

The Plot Setup view enables you to configure the appearance of Plot view.

The fields and options are as follows:



Geometry Plot Setup

XRNG: -13 15.8

YRNG: -7.1 13.1

AXES: ✓

LABELS: ✓

FUNCTION LABELS: □

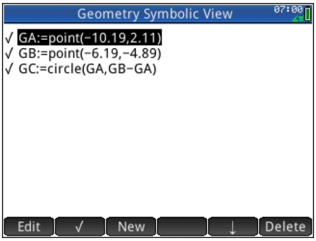
SHORTCUTS: □

Enter minimum horizontal value

- **X Rng**: There are two boxes, but only the minimum x-value is editable. The maximum x-value is calculated automatically, based on the minimum value and the pixel size. You can also change the x range by panning and zooming in Plot view.
- **Y Rng**: There are two boxes, but only the minimum y-value is editable. The maximum y-value is calculated automatically, based on the minimum value and the pixel size. You can also change the y range by panning and zooming in Plot view.
- **Pixel Size**: Each pixel in the Plot view must be square. You can change the size of each pixel. The lower left corner of the Plot view display remains the same, but the upper right-corner coordinates are automatically recalculated.
- **Axes**: A toggle option to hide (or show) the axes in Plot view.

  Keyboard shortcut: Vars
- **Labels**: A toggle option to hide (or show) the labels for the axes.
- **Grid Dots**: A toggle option to hide (or show) the grid dots.
- **Grid Lines**: A toggle option to hide (or show) the grid lines.

Symbolic view in detail



√ GA:=point(−10.19,2.11)
√ GB:=point(−6.19,−4.89)
√ GC:=circle(GA,GB−GA)

Every object—whether a point, segment, line, polygon, or curve—is given a name, and its definition is displayed in Symbolic view (Symb Setup). The name is the name for it you see in Plot view, but prefixed by "G". Thus a point labeled A in Plot view is given the name GA in Symbolic view.

The G-prefixed name is a variable that can be read by the computer algebra system (CAS). Thus in the CAS you can include such variables in calculations. Note in the illustration above that GC is the name of the variable that represents a circle drawn in Plot view. If you are working in the CAS and wanted to know what the area of that circle is, you could enter `area(GC)` and press Enter.

Note Calculations referencing geometry variables can be made in the CAS or in the Numeric view of the Geometry app (explained below on page 20).

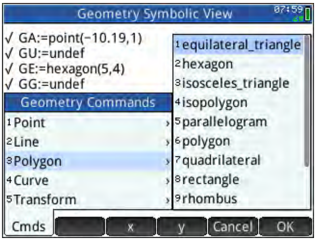
You can change the definition of an object by selecting it, tapping Edit, and altering one or more of its defining parameters. The object is modified accordingly in Plot view. For example, if you selected point `GB` in the illustration above, tapped Edit, changed one or both of the point's coordinates, and tapped OK, you would find, on returning to Plot view, a circle of a different size.

Creating objects

You can also create an object in Symbolic view. Tap New, define the object—for example, `point(4,6)`—and press Enter. The object is created and can be seen in Plot view.

Another example: to draw a line through points P and Q, enter `line(GP,GQ)` in Symbolic view and press Enter. When you return to Plot view, you will see a line passing through points P and Q.

The object-creation commands available in Symbolic view can be seen by tapping Cmds. The syntax for each command is given in “Geometry functions and commands” on page 39.



```
√ GA:=point(−10.19,1)
√ GU:=undef
√ GE:=hexagon(5,4)
√ GG:=undef
```

Re-ordering entries

You can re-order the entries in Symbolic view. Objects are drawn in Plot view in the order in which they are defined in Symbolic view. To change the position of an entry, highlight it and tap either ↓ (to move it down the list) or ↑ (to move it up).

Hiding an object

To prevent an object displaying in Plot view, deselect it in Symbolic view:

1. Highlight the item to be hidden.
2. Tap √.

Repeat the procedure to make the object visible again.

Deleting an object

As well as deleting an object in Plot view (see page 14) you can delete an object in Symbolic view.

1. Highlight the definition of the object you want to delete.
2. Press ⌫ Del.

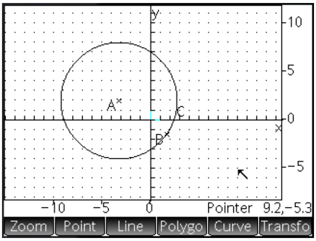
To delete all objects, press Shift Esc Clear. When prompted, tap OK to confirm the deletion.

Symbolic Setup view

The Symbolic view of the Geometry app is common with many apps. It is used to override certain system-wide settings.

Numeric view in detail

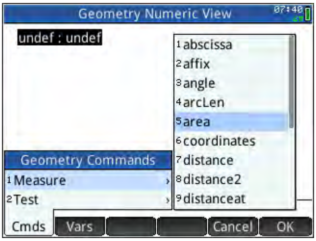
Numeric view (Num ↳Setup) enables you to do calculations in the Geometry app. The results displayed are dynamic—if you manipulate an object in Plot view or Symbolic view, any calculations in Numeric view that refer to that object are automatically updated to reflect the new properties of that object.



Consider circle C in the illustration at the right. To calculate the area and radius of C:

1. Press Num Setup to open Numeric view.
2. Tap New.
3. Tap Cmds and choose Measure > Area.

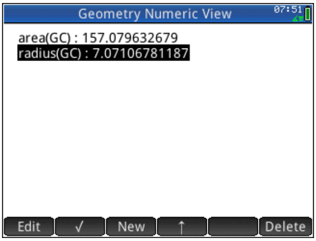
   Note that area() appears on the entry line, ready for you to specify the object whose area you are interested in.



4. Tap Vars, choose Curves and then the curve whose area you are interested in.

   The name of the object is placed between the parentheses.

   You could have entered the command and object name manually, that is, without choosing them from menus. If you enter object names manually, remember that the name of the object in Plot view must be given a "G" prefix if it is used in any calculation. Thus the circle named C in Plot view must be referred to as GC in Numeric view and Symbolic view.
5. Press Enter ≈ or tap OK. The area is displayed.
6. Tap New.
7. Enter radius(GC) and tap OK. The radius is displayed. Use √ to verify both of these measurements so that they will be available in Plot view.


area(GC) : 157.079632679
radius(GC) : 7.07106781187

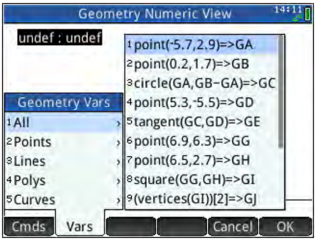
Note that the syntax used here is the same as you use in the CAS to calculate the properties of geometric objects.

The Geometry functions and their syntax are described in “Geometry functions and commands” on page 39.

8. Press Plot Setup to go back to Plot view. Now, manipulate the circle in some way that changes its area and radius. For example, select the center point (A) and use the cursor keys to move it to a new location. Notice that the area and radius calculations update automatically as you move the point. Remember to press Esc Clear when you are finished.

Note If an entry in Numeric view is too long for the screen, you can press ▶ to scroll the rest of the entry into view. Press ◀ to scroll back to the original view.

Listing all objects

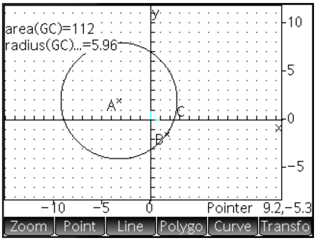


1 point(-5.7,2.9)=>GA
2 point(0.2,1.7)=>GB
3 circle(GA,GB-GA)=>GC
4 point(5.3,-5.5)=>GD
5 tangent(GC,GD)=>GE
6 point(6.9,6.3)=>GG
7 point(6.5,2.7)=>GH
8 square(GG,GH)=>GI
9 (vertices(GI))[2]=>GJ

When you are creating a new calculation in Numeric view, the Vars menu item appears. Tapping Vars gives you a list of all the objects in your Geometry workspace.

If you are building a calculation, you can select an object’s variable name from this menu. The name of the selected object is placed at the insertion point on the entry line.

Displaying calculations in Plot view



To have a calculation made in Numeric view appear in Plot view, just highlight it in Numeric view and tap √. A checkmark appears beside the calculation.

Repeat the procedure to prevent the calculation being displayed in Plot view. The checkmark is cleared.

Editing a calculation

1. Highlight the calculation that you want to edit.
2. Tap Edit to change the calculation or tap Label to change the label.
3. Make your changes and tap OK.

Deleting a calculation

1. Highlight the calculation you want to delete.
2. Press Del.

To delete all calculations, press Shift Esc Clear. Note that deleting a calculation does not delete any geometric objects from either the Plot or Symbolic view.

Plot view: Cmds menu

The geometric objects discussed in this section are those that can be created in either Plot view or Symbolic view using the Commands menu (Cmds). This section discusses how to use the commands in Plot view. Objects can also be created in Symbolic view—more, in fact, than in Plot view—but these are discussed in “Geometry functions and commands” on page 39. Finally, measurements and other calculations can be performed in Plot view as well.

In Plot view, you choose a drawing tool to draw an object. The tools are listed in this section. Note that once you select a drawing tool, it remains selected until you deselect it. This enables you to quickly draw a number of objects of the same type (such as a number of circles). To deselect the current drawing tool, press Esc Clear. You can tell if a drawing tool is still active by the presence of the on-screen help in the bottom left-side of the screen and the current command statement to its right.

The steps provided in this section are based on touch entry. For example, to add a point, the steps will tell you to *tap* on the screen where you want the point to be and press Enter ≈. However, you can also use the cursor keys to position the cursor where you want the point to be and then press Enter ≈.

The drawing tools for the geometric objects listed in this section can be selected from the Commands menu at the bottom of the screen (Cmds). Some objects can also be entered using a keyboard shortcut. For example, you can select the triangle drawing tool by pressing ÷. See "Plot view: buttons and keys" on page 16.

Point

Tap Point to display a menu and submenus of options for entering various types of points. The menus and submenus are:

Point

Tap where you want the point to be and press Enter.

Keyboard shortcut: EEX

Point On

Tap the object where you want the new point to be and press Enter. If you select a point that has been placed on an object and then move that point, the point will be constrained to the object on which it was placed. For example, a point placed on a circle will remain on that circle regardless of how you move the point.

Midpoint

Tap where you want one point to be and press Enter. Tap where you want the other point to be and press Enter. A point is automatically created midway between those two points.

If you choose an object first—such as a segment—choosing the Midpoint tool and pressing Enter adds a point midway between the ends of that object. (In the case of a circle, the midpoint is created at the circle's center.)

Center

Tap a circle and press Enter. A point is created at the center of the circle.

Intersection

Tap the desired intersection and press Enter. A point is created at one of the points of intersection.

Keyboard shortcut: TAN

Intersections

Tap one object other than a point and press Enter. Tap another object and press Enter. The point(s) where the two objects intersect are created and named. Note that an intersections object is created in Symbolic view even if the two objects selected do not intersect.

Random Points Press Enter to randomly create a point in Plot view. Continue pressing Enter to create more random points. Press Esc when you are done.

Line

Segment Tap where you want one endpoint to be and press Enter. Tap where you want the other endpoint to be and press Enter. A segment is drawn between the two end points.

Keyboard shortcut: 9

Ray Tap where you want the endpoint to be and press Enter. Tap a point that you want the ray to pass through and press Enter. A ray is drawn from the first point and through the second point.

Line Tap at a point you want the line to pass through and press Enter. Tap at another point you want the line to pass through and press Enter. A line is drawn through the two points.

Keyboard shortcut: x^2

Tap a third point (C) and press Enter. A line is drawn through A bisecting the angle formed by $\overline{AB}$ and $\overline{AC}$.

Parallel Tap on a point (*P*) and press Enter. Tap on a line (*L*) and press Enter. A new line is draw parallel to *L* and passing through *P*.

Perpendicular Tap on a point (*P*) and press Enter. Tap on a line (*L*) and press Enter. A new line is draw perpendicular to *L* and passing through *P*.

Tangent Tap on a curve (*C*) and press Enter. Tap on a point (*P*) and press Enter. If the point (*P*) is on the curve (*C*), then a single tangent is drawn. If the point *(P*) is not on the curve (*C*), then zero or more tangents may be drawn.

Median Tap on a point (A) and press Enter. Tap on a segment and press Enter. A line is drawn through the point (A) and the midpoint of the segment.

Altitude

Tap on a point (A) and press Enter. Tap on a segment and press Enter. A line is drawn through the point (A) perpendicular to the segment (or its extension).

Angle bisector

Tap the point that is the vertex of the angle to be bisected (A) and press Enter. Tap another point (B) and press Enter.

Polygon

The **Polygon** menu provides tools for drawing various polygons.

Triangle

Tap at each vertex, pressing Enter after each tap.

Keyboard shortcut: ÷

Isosceles Triangle

Draws an isosceles triangle defined by two of its vertices and an angle. The vertices define one of the two sides equal in length and the angle defines the angle between the two sides of equal length. Like `equilateral_triangle`, you have the option of storing the coordinates of the third point into a CAS variable.

```
isosceles_triangle(point1, point2, angle)
```

Example:

`isosceles_triangle(GA, GB, angle(GC, GA, GB)` defines an isosceles triangle such that one of the two sides of equal length is AB, and the angle between the two sides of equal length has a measure equal to that of ∡ ACB.

Right Triangle

Draws a right triangle given two points and a scale factor. One leg of the right triangle is defined by the two points, the vertex of the right angle is at the first point, and the scale factor multiplies the length of the first leg to determine the length of the second leg.

```
right_triangle(point1, point2, realk)
```

Example:

`right_triangle(GA, GB, 1)` draws an isosceles right triangles with its right angle at point A, and with both legs equal in length to segment AB.

Quadrilateral

Tap at each vertex, pressing Enter after each tap.

Parallelogram

Tap at one vertex and press Enter. Tap at another vertex and press Enter. Tap at a third vertex and press Enter. The location of the fourth vertex is automatically calculated and the parallelogram is drawn.

Rhombus

Draws a rhombus, given two points and an angle. As with many of the other polygon commands, you can specify optional CAS variable names for storing the coordinates of the other two vertices as points.

```
rhombus(point1, point2, angle)
```

Example

`rhombus(GA, GB, angle(GC, GD, GE))` draws a rhombus on segment AB such that the angle at vertex A has the same measure as ∡ DCE.

Rectangle

Draws a rectangle given two consecutive vertices and a point on the side opposite the side defined by the first two vertices or a scale factor for the sides perpendicular to the first side. As with many of the other polygon commands, you can specify optional CAS variable names for storing the coordinates of the other two vertices as points.

```
rectangle(point1, point2, point3) or
rectangle(point1, point2, realk)
```

Examples:

`rectangle(GA, GB, GE)` draws a rectangle whose first two vertices are points A and B (one side is segment AB). Point E is on the line that contains the side of the rectangle opposite segment AB.

`rectangle(GA, GB, 3, p, q)` draws a rectangle whose first two vertices are points A and B (one side is segment AB). The sides perpendicular to segment AB have length 3*AB. The third and fourth points are stored into the CAS variables *p* and *q*, respectively.

Polygon

Draws a polygon from a set of vertices.

```
polygon(point1, point2, …, pointn)
```

Example:

`polygon(GA, GB, GD)` draws ΔABD

Regular Polygon

Draws a regular polygon given the first two vertices and the number of sides, where the number of sides is greater than 1. If the number of sides is 2, then the segment is drawn. You can provide CAS variable names for storing the coordinates of the calculated points in the order they were created. The orientation of the polygon is counterclockwise.

```
isopolygon(point1, point2, realn), where realn
is an integer greater than 1.
```

Example

`isopolygon(GA, GB, 6)` draws a regular hexagon whose first two vertices are the points A and B.

Square

Tap at one vertex and press Enter. Tap at another vertex and press Enter. The location of the third and fourth vertices are automatically calculated and the square is drawn.

Curve

Circle

Tap at the center of the circle and press Enter. Tap at a point on the circumference and press Enter. A circle is drawn about the center point with a radius equal to the distance between the two tapped points.

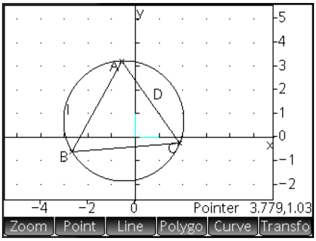
Keyboard shortcut: Units C

You can also create a circle by first defining it in Symbolic view. The syntax is `circle(GA,GB)` where `A` and `B` are two points. A circle is drawn in Plot view such that `A` and `B` define the diameter of the circle.

Circumcircle

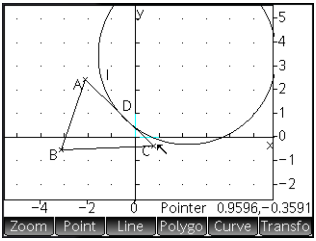
A circumcircle is the circle that passes through each of the triangle's three vertices, thus enclosing the triangle.

Tap at each vertex of the triangle, pressing Enter after each tap.



Excircle

An excircle is a circle that is tangent to one segment of a triangle and also tangent to the rays through the segment's endpoints from the vertex of the triangle opposite the segment.



Tap at each vertex of the triangle, pressing Enter after each tap.

The excircle is drawn tangent to the side defined by the last two vertices tapped. In the example at the right, the last two vertices tapped were A and C (or C and A). Thus the excircle is drawn tangent to the segment $\overline{AC}$.

Incircle

An incircle is a circle that is tangent to all three sides of a triangle. Tap each vertex of the triangle, pressing Enter after each tap.

Ellipse

Tap at one focus point and press Enter. Tap at the second focus point and press Enter. Tap at point on the circumference and press Enter.

Hyperbola

Tap at one focus point and press Enter. Tap at the second focus point and press Enter. Tap at point on one branch of the hyperbola and press Enter.

Parabola

Tap at the focus point and press Enter. Tap either on a line (the directrix) or a ray or segment nd press Enter.

Conic

Plots the graph of a conic section defined by an expression in x and y.

```
conic(expr)
```

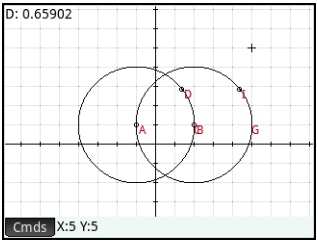
Example:

`conic(x^2+y^2-81)` draws a circle with center at (0,0) and radius of 9

Locus

Takes two points as its arguments: the first is the point whose possible locations form the locus; the second is a point on an object. This second point drives the first through its locus as the second moves on its object.

In the example at the right, circle C has been drawn and point D is a point placed on C (using the `Point On` function described above). Point I is a translation of point D. Choosing `Curve` > `Special` > `Locus` places `locus(` on the entry line. Complete the command as `locus(GI,GD)` and point I traces a path (its locus) that parallels point D as it moves around the circle to which it is constrained.

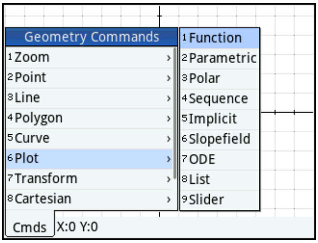


Plot

You can plot expressions of the following types in Plot view:

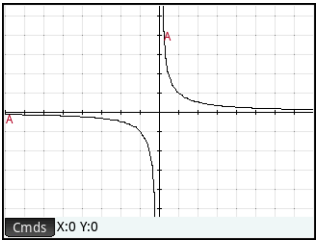
- Function
- Parametric
- Polar
- Sequence

Tap Curve, select **Plot**, and then the type of expression you want to plot. The entry line is enabled for you to define the expression.



Note that the variables you specify for an expression must be in lowercase.

In this example, **Function** has been selected as the plot type and the graph of y = 1/ x is plotted.



Function

Syntax: `plotfunc(Expr)`

Draws the plot of a function, given an expression in the independent variable x. An edit line appears. Enter your expression and press Enter. Note the use of lowercase x.

Example:

`plotfunc(3*sin(x))` draws the graph of `y=3*sin(x)`

Parametric

Syntax: `plotparam(f(Var)+i*g(Var), Var= Start..Stop, [tstep=Value])`

Takes a complex expression in one variable and an interval for that variable as arguments. Interprets the complex expression `f(t)+i*g(t)` as `x=f(t)` and `y=g(t)` and plots the parametric equation over the interval specified in the second argument. An edit line opens for you to enter the complex expression and the interval.

Examples:

`plotparam(cos(t)+ i*sin(t), t=0..2*π)` plots the unit circle

`plotparam(cos(t)+ i*sin(t), t=0..2*π, tstep=π/3)` plots a regular hexagon inscribed in the unit circle (note the tstep value)

Polar

Syntax: `plotpolar(Expr,Var=Interval, [Step])` or `plotpolar(Expr, Var, Min, Max, [Step])`

Draws a polar graph in Plot view. An edit line opens for you to enter an expression in x as well as an interval (and optional step).

`plotpolar(f(x),x,a,b)` draws the polar curve `r=f(x)` for x in `[a,b]`

Sequence

Syntax: `plotseq(f(Var), Var={Start, Xmin, Xmax}, Integer n)`

Given an expression in x and a list containing three values, draws the line y=x, the plot of the function defined by the expression over the domain defined by the interval between the last two values, and draws the cobweb plot for the first `n` terms of the sequence defined recursively by the expression (starting at the first value).

Example:

`plotseq(1-x/2, x={3 -1 6}, 5)` plots `y=x` and `y=1-x/2` (from `x=-1` to `x=6`), then draws the first 5 terms of the cobweb plot for `u(n)=1-(u(n-1)/2`, starting at `u(0)=3`

Implicit

Syntax: `plotimplicit(Expr, [XIntrvl, YIntrvl])`

Plots an implicitly defined curve from Expr (in x and y). Specifically, plots Expr=0. Note the use of lowercase x and y. With the optional x-interval and y-interval, this command plots only within those intervals.

Example:

`plotimplicit((x+5)^2+(y+4)^2-1)` plots a circle, centered at the point `(-5, -4)`, with a radius of `1`

Slopefield

Syntax: `plotfield(Expr, [x=X1..X2  y=Y1..Y2], [Xstep, Ystep], [Option])`

Plots the graph of the slopefield for the differential equation y′=f(x,y) over the given x-range and y-range. If Option is `normalize`, the slopefield segments drawn are equal in length.

Example:

`plotfield(x*sin(y), [x=-6..6, y=-6..6],normalize)` draws the slopefield for `y'=x*sin(y)`, from `-6` to `6` in both directions, with segments that are all of the same length

ODE

Syntax: `plotode(Expr, [Var1, Var2, ...], [Val1, Val2. ...])`

Draws the solution of the differential equation y′=f(Var1, Var2, ...) that contains as initial condition for the variables Val1, Val2,... The first argument is the expression f(Var1, Var2,...), the second argument is the vector of variables, and the third argument is the vector of initial conditions.

Example:

`plotode(x*sin(y), [x,y], [-2, 2])` draws the graph of the solution to `y′=x*sin(y)` that passes through the point `(-2, 2)` as its initial condition

List

Syntax: `plotlist(Matrix 2xn)`

Plots a set of n points and connects them with segments. The points are defined by a 2xn matrix, with the abscissas in the first row and the ordinates in the second row.

Example:

`plotlist([[0,3],[2,1],[4,4],[0,3]])` draws a triangle

Slider

Creates a slider bar that can be used to control the value of a parameter. A dialog box displays the slider bar definition and any animation for the slider.

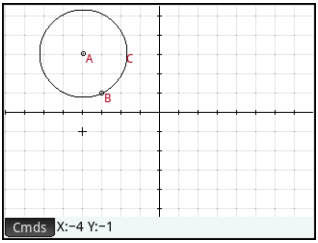
Transform

The **Transform** menu provides numerous tools for you to perform transformations on geometric objects in Plot view. You can also define transformations in Symbolic view

Translation

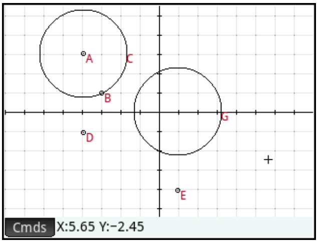
A translation is a transformation of a set of points that moves each point the same distance in the same direction. T: (x,y) → (x+a, y+b).

Suppose you want to translate circle B at the right down a little and to the right:

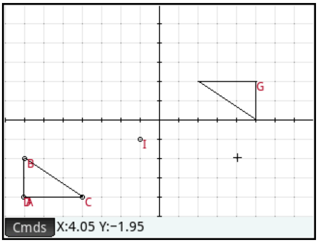


1. Tap Cmds, tap `Transform`, and select `Translation`.
2. Tap the object to be moved and press Enter.
3. Tap an initial location and press Enter.
4. Tap a final location and press Enter.

   The object is moved the same distance and direction from the initial to the final locations.
   The original object is left in place.



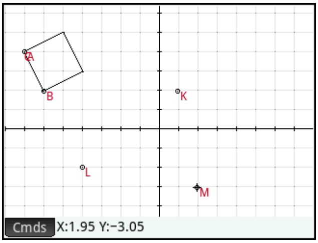
Reflection



A reflection is a transformation which maps an object or set of points onto its mirror image, where the mirror is either a point or a line. A reflection through a point is sometimes called a half-turn. In either case, each point on the mirror image is the same distance from the mirror as the corresponding point on the original. In the example at the right, the original triangle D is reflected through point I.

1. Tap Cmds, tap `Transform`, and select `Reflection`.
2. Tap the point or straight object (segment, ray, or line) that will be the symmetry axis (that is, the mirror) and press Enter.
3. Tap the object that is to be reflected across the symmetry axis and press Enter. The object is reflected across the symmetry axis defined in step 2.

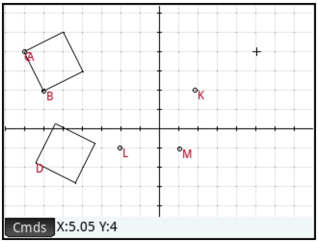
Rotation



A rotation is a mapping that rotates each point by a fixed angle around a center point. The angle is defined using the `angle()` command, with the vertex of the angle as the first argument. Suppose you wish to rotate the square (GC) around point K (GK) through ∡ LKM in the figure to the right.

1. Tap Cmds, tap `Transform`, and select `Rotation`.

   `rotation()` appears on the entry line.



2. Between the parentheses, enter:

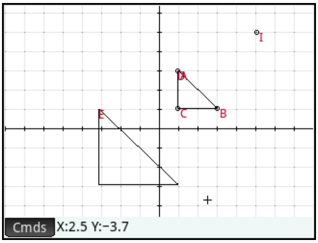
   `GK,angle(GK,GL,GM),GC`

3. Press Enter or tap OK.

4. Press Plot to return to Plot view to see the rotated square.

Dilation

A dilation (also called a homothety or uniform scaling) is a transformation where an object is enlarged or reduced by a given scale factor around a given point as center.



In the illustration at the right, the scale factor is 2 and the center of dilation is indicated by a point near the top right of the screen (named *I*). Each point on the new triangle is collinear with its corresponding point on the original triangle and point I. Further, the distance from point *I* to each new point will be twice the distance to the original point (since the scale factor is 2).

1. Tap Cmds, tap `Transform`, and select `Dilation`.
2. Tap the point that is to be the center of dilation and press Enter.
3. Enter the scale factor and press Enter.
4. Tap the object that is to be dilated and press Enter.

Similarity

Dilates and rotates a geometric object about the same center point.

similarity(point, real*k*, angle, object)

Example:

`similarity(0, 3, angle(0,1,i),point(2,0))` dilates the point at (2,0) by a scale factor of 3 (a point at (6,0)), then rotates the result 90° counterclockwise to create a point at (0, 6).

Projection

A projection is a mapping of one or more points onto an object such that the line passing through the point and its image is perpendicular to the object at the image point.

1. Tap Cmds, tap `Transform`, and select `Projection`.
2. Tap the object onto which points are to be projected and press Enter.

3. Tap the point that is to be projected and press Enter.

   Note the new point added to the target object.

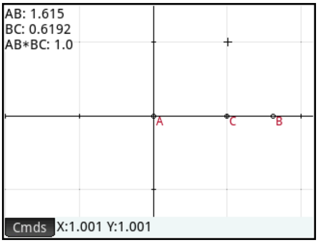
Inversion

An inversion is a mapping involving a center point and a scale factor. Specifically, the inversion of point A through center C, with scale factor k, maps A onto A′, such that A′ is on line CA and CA*CA′=k, where CA and CA′ denote the lengths of the corresponding segments. If k=1, then the lengths CA and CA′ are reciprocals.

Suppose you wish to find the inversion of point B with respect to point A.

1. Tap Cmds, tap `Transform`, and select `Inversion`.
2. Tap point A and press Enter.
3. Enter the inversion ratio—use the default value of 1—and press Enter.
4. Tap point B and press Enter.

   In the figure, point C is the inversion of point B in respect to point A.



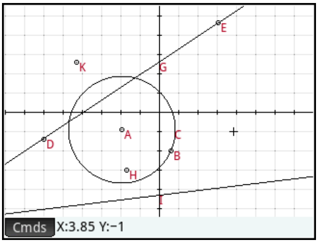
AB: 1.615
BC: 0.6192
AB*BC: 1.0

Cmds X:1.001 Y:1.001

Reciprocation

A reciprocation is a special case of inversion involving circles. A reciprocation with respect to a circle transforms each point in the plane into its polar line. Conversely, the reciprocation with respect to a circle maps each line in the plane into its pole.

1. Tap Cmds, tap `Transform`, and select `Reciprocation`.
2. Tap the circle and press Enter.



3. Tap a point and press Enter to see its polar line.
4. Tap a line and press Enter to see its pole.

   In the illustration to the right, point K is the reciprocation of line DE (G) and Line I (at the bottom of the display) is the reciprocation of point H.

Cartesian

Abcissa

Tap a point and press Enter to select it. The abscissa (x-coordinate) of the point will appear at the top left of the screen.

Ordinate

Tap a point and press Enter to select it. The ordinate (y-coordinate) of the point will appear at the top left of the screen.

Coordinates

Tap a point and press Enter to select it. The coordinates of the point will appear at the top left of the screen.

Equation of

Tap an object other than a point and press Enter to select it. The equation of the object (in x and/or y) is displayed.

Parametric

Tap an object other than a point and press Enter to select it. The parametric equation of the object (x(t)+i*y(t)) is displayed.

Polar coordinates

Tap a point and press Enter to select it. The polar coordinates of the point will appear at the top left of the screen.

Measure

Distance

Tap a point and press Enter to select it. Repeat to select a second point. The distance between the two points is displayed.

Radius Tap a circle and press Enter to select it. The radius of the circle is displayed.

Perimeter Tap a circle and press Enter to select it. The perimeter of the circle is displayed.

Slope Tap a straight object (segment, line, and so on) and press Enter to select it. The slope of the object is displayed.

Area Tap a circle or polygon and press Enter to select it. The area of the object is displayed.

Angle Tap a point and press Enter to select it. Repeat to select three points. The measure of the directed angle from the second point through the third point, with the first point as vertex, is displayed.

Arc Length Tap a curve and press Enter to select it. Then, enter a start value and a stop value. The length of the arc on the curve between the two x-values is displayed.

Tests

Collinear Tap a point and press Enter to select it. Repeat to select three points. The test appears at the top of the display, along with its result. The test returns 1 if the points are collinear; otherwise, it returns 0.

On circle Tap a point and press Enter to select it. Repeat to select four points. The test appears at the top of the display, along with its result. The test returns 1 if the points are on the same circle; otherwise, it returns 0.

On object Tap a point and press Enter to select it. Then tap an object and press Enter. The test appears at the top of the display, along with its result. The test returns 1 if the point is on the object; otherwise, it returns 0.

Parallel Tap a straight object (segment, line, and so on) and press Enter to select it. Then tap another straight object and press Enter. The test appears at the top of the display, along with its result. The test returns 1 if the objects are parallel; otherwise, it returns 0.

Perpendicular Tap a straight object (segment, line, and so on) and press Enter to select it. Then tap another straight object and press Enter. The test appears at the top of the display, along with its result. The test returns 1 if the objects are perpendicular; otherwise, it returns 0.

Isosceles Tap a triangle and press Enter to select it. Or select three points in order. Returns 0 if the triangle is not isosceles or if the three points do not form an isosceles triangle. If the triangle is isosceles (or the three points form an isosceles triangle), returns the number order of the common point of the two sides of equal length (1, 2, or 3). Returns 4 if the three points form an equilateral triangle or if the selected triangle is equilateral.

Equilateral Tap a triangle and press Enter to select it. Or select three points in order. Returns 1 if the triangle is equilateral or if the three points form an equilateral triangle; otherwise, it returns 0.

Parallelogram Tap a point and press Enter to select it. Repeat to select four points. The test appears at the top of the display, along with its result. The test returns 0 if the points do not form a parallelogram. Returns 1 if they form a parallelogram, 2 if they form a rhombus, 3 if they form a rectangle, and 4 if they form a square.

Conjugate Tap a circle and press Enter to select it. Then, select two points or two lines. The test returns 1 if the two points or lines are conjugates for the circle; otherwise, it returns 0.

Geometry functions and commands

The list of geometry-specific functions and commands in this section covers those that can be found by tapping Cmds in both Symbolic and Numeric view and those that are only available from the Catlg menu.

The sample syntax provided has been simplified. Geometric objects are referred to by a single uppercase character (such as A, B,C and so on). However, calculations referring to geometric objects—in the Numeric view of the Geometry app and in the CAS—must use the G-prefixed name given for it in Symbolic view. For example:

`altitude(A,B,C)` is the simplified form given in this section

`altitude(GA,GB,GC)` is the form you need to use in calculations

Further, in many cases the specified parameters in the syntax below—A, B, C etc.—can be the name of a point (such as GA) or a complex number representing a point. Thus `angle(A,B,C)` could be:

- `angle(GP,GR,GB)`
- `angle(3+2i,1−2i,5+i)` or
- a combination of named points and points defined by a complex number, as in `angle(GP,1−2*i,i)`.

Symbolic view: Cmds menu

For the most part, the Commands menu in Symbolic View is the same as it is in Plot view. The Zoom category does not appear in Symbolic view, nor do the Cartesian, Measure, and Tests categories, although the latter three appear in Numeric view. In Symbolic view, the commands are entered using their syntax. Highlight a command and press ? Help User to learn its syntax. The advantage of entering or editing a definition in Symbolic view is that you can specify the exact location of points. After the exact locations of points are entered, the properties of any dependent objects (lines, circles, and so on) are reported exactly by the CAS. Use this fact to test conjectures on geometric objects using the Test commands. All these commands can be used in the CAS view, where they return the same objects.

Point

Point

Creates a point, given the coordinates of the point. Each coordinate may be a value or an expression involving variables or measurements on other objects in the geometric construction.

```
point(real1, real2) or point(expr1, expr2)
```

Examples:

point(3,4) creates a point whose coordinates are (3,4). This point may be selected and moved later.

point(abscissa(A), ordinate(B)) creates a point whose x-coordinate is the same as that of a point A and whose y-coordinate is the same as that of a point B. This point will change to reflect the movements of point A or point B.

Point on

Creates a point on a geometric object whose abscissa is a given value or creates a real value on a given interval.

```
element(object, real) or element(real1..real2)
```

Examples:

element(plotfunc(x^2),–2) creates a point on the graph of $y = x^2$. Initially, this point will appear at (–2,4). You can move the point, but it will always remain on the graph of its function.

element(0..5) creates a slider bar with a value of 2.5 initially. Tap and hold this value to open the slider. Select ▶ or ◀ to increase or decrease the value on the slider bar. Press Esc Clear to close the slider bar. The value that you set can be used as a coefficient in a function that you subsequently plot or in some other object or calculation.

Midpoint

Returns the midpoint of a segment. The argument can be either the name of a segment or two points that define a segment. In the latter case, the segment need not actually be drawn.

```
midpoint(segment) or midpoint(point1, point2)
```

Example: midpoint(0,6+6i) returns point(3,3)

Center

Syntax: `center(Circle)`

Plots the center of a circle. The circle can be defined by the circle command or by name (for example, `GC`).

Example: `center(circle(x^2+y2-x-y))` plots `point(1/2,1/2)`

Intersection

Syntax: `single_inter(Curve1, Curve2, [Point])`

Plots the intersection of Curve1 and Curve2 that is closest to Point.

Example:

`single_inter(line(y=x), circle(x^2+y^2=1), point(1,1))` plots `point((1+i)*√2/2)`

Intersections

Returns the intersection of two curves as a vector.

```
inter(Curve1, Curve2)
```

Example:

`inter(8-x^2/6, x/2-1)` returns `[[6 2],[-9 -11/2]]`

Line

Segment

Draws a segment defined by its endpoints.

```
segment(point1, point2)
```

Examples:

`segment(1+2i, 4)` draws the segment defined by the points whose coordinates are (1, 2) and (4, 0).

`segment(GA, GB)` draws segment AB.

Ray

Given 2 points, draws a ray from the first point through the second point.

```
half_line((point1, point2)
```

Line

Draws a line. The arguments can be two points, a linear expression of the form a**x*+b**y*+c, or a point and a slope as shown in the examples.

`line(point1, point2)` or `line(a*x+b*y+c)` or
`line(point1, slope=realm)`

Examples:

`line(2+i, 3+2i)` draws the line whose equation is y=x–1; that is, the line through the points (2,1) and (3,2).

`line(2x–3y–8)` draws the line whose equation is 2x–3y=8

`line(3–2i,slope=1/2)` draws the line whose equation is x–2y=7; that is, the line through (3, –2) with slope m=1/2.

Parallel

Draws a line through a given point that is parallel to a given line.

`parallel(point,line)`

Examples:

`parallel(A, B)` draws the line through point A that is parallel to line B.

`parallel(3–2i, x+y–5)` draws the line through the point (3, –2) that is parallel to the line whose equation is x+y=5; that is, the line whose equation is y=–x+1.

Perpendicular

Draws a line through a given point that is perpendicular to a given line. The line may be defined by its name, two points, or an expression in x and y.

```
perpendicular(point, line) or
perpendicular(point1, point2, point3)
```

Examples:

`perpendicular(GA, GD)` draws a line perpendicular to line D through point A.

`perpendicular(3+2i, GB, GC)` draws a line through the point whose coordinates are (3, 2) that is perpendicular to line BC.

`perpendicular(3+2i,line(x-y=1))` draws a line through the point whose coordinates are (3, 2) that is perpendicular to the line whose equation is x – y = 1; that is, the line whose equation is y=–x+5.

Tangent

Draws the tangent(s) to a given curve through a given point. The point does not have to be a point on the curve.

```
tangent(curve, point)
```

Examples:

`tangent(plotfunc(x^2), GA)` draws the tangent to the graph of y=x^2 through point A.

`tangent(circle(GB, GC-GB), GA)` draws one or more tangent lines through point A to the circle whose center is at point B and whose radius is defined by segment BC.

Median

Given three points that define a triangle, creates the median of the triangle that passes through the first point and contains the midpoint of the segment defined by the other two points.

```
median_line(point1, point2, point3)
```

Example:

`median_line(0, 8i, 4)` draws the line whose equation is y=2x; that is, the line through (0,0) and (2,4), the midpoint of the segment whose endpoints are (0, 8) and (4, 0).

Altitude

Given three non-collinear points, draws the altitude of the triangle defined by the three points that passes through the first point. The triangle does not have to be drawn.

```
altitude(point1, point2, point3)
```

Example: `altitude(A, B, C)` draws a line passing through point A that is perpendicular to $\overline{BC}$.

Bisector

Given three points, creates the bisector of the angle defined by the three points whose vertex is at the first point. The angle does not have to be drawn in the Plot view.

```
bisector(point1, point2, point3)
```

Examples:

`bisector(A,B,C)` draws the bisector of ∡ BAC.

`bisector(0,-4i,4)` draws the line given by y=–x

Polygon

Triangle

Draws a triangle, given its three vertices.

```
triangle(point1, point2, point3)
```

Example:

`triangle(GA, GB, GC)` draws ΔABC.

Isosceles Triangle

Draws an isosceles triangle defined by two of its vertices and an angle. The vertices define one of the two sides equal in length and the angle defines the angle between the two sides of equal length. Like `equilateral_triangle`, you have the option of storing the coordinates of the third point into a CAS variable.

```
isosceles_triangle(point1, point2, angle)
```

Example:

`isosceles_triangle(GA, GB, angle(GC, GA, GB)` defines an isosceles triangle such that one of the two sides of equal length is AB, and the angle between the two sides of equal length has a measure equal to that of ∡ ACB.

Right Triangle

Draws a right triangle given two points and a scale factor. One leg of the right triangle is defined by the two points, the vertex of the right angle is at the first point, and the scale factor multiplies the length of the first leg to determine the length of the second leg.

```
right_triangle(point1, point2, realk)
```

Example:

`right_triangle(GA, GB, 1)` draws an isosceles right triangles with its right angle at point A, and with both legs equal in length to segment AB.

Quadrilateral

Draws a quadrilateral from a set of four points.

```
quadrilateral(point1, point2, point3, point4)
```

Example:

`quadrilateral(GA, GB, GC, GD)` draws quadrilateral ABCD.

Parallelogram

Draws a parallelogram given three of its vertices. The fourth point is calculated automatically but is not defined symbolically. As with most of the other polygon commands, you can store the fourth point's coordinates into a CAS variable. The orientation of the parallelogram is counterclockwise from the first point.

```
parallelogram(point1, point2, point3)
```

Example:

`parallelogram(0,6,9+5i)` draws a parallelogram whose vertices are at (0, 0), (6, 0), (9, 5), and (3,5). The coordinates of the last point are calculated automatically.

Rhombus

Draws a rhombus, given two points and an angle. As with many of the other polygon commands, you can specify optional CAS variable names for storing the coordinates of the other two vertices as points.

```
rhombus(point1, point2, angle)
```

Example

`rhombus(GA, GB, angle(GC, GD, GE))` draws a rhombus on segment AB such that the angle at vertex A has the same measure as ∡ DCE.

Rectangle

Draws a rectangle given two consecutive vertices and a point on the side opposite the side defined by the first two vertices or a scale factor for the sides perpendicular to the first side. As with many of the other polygon commands, you can specify optional CAS variable names for storing the coordinates of the other two vertices as points.

```
rectangle(point1, point2, point3) or
rectangle(point1, point2, realk)
```

Examples:

`rectangle(GA, GB, GE)` draws a rectangle whose first two vertices are points A and B (one side is segment AB). Point E is on the line that contains the side of the rectangle opposite segment AB.

`rectangle(GA, GB, 3, p, q)` draws a rectangle whose first two vertices are points A and B (one side is segment AB). The sides perpendicular to segment AB have length 3*AB. The third and fourth points are stored into the CAS variables *p* and *q*, respectively.

Polygon

Draws a polygon from a set of vertices.

```
polygon(point1, point2, …, pointn)
```

Example:

`polygon(GA, GB, GD)` draws ΔABD

Regular Polygon

Draws a regular polygon given the first two vertices and the number of sides, where the number of sides is greater than 1. If the number of sides is 2, then the segment is drawn. You can provide CAS variable names for storing the coordinates of the calculated points in the order they were created. The orientation of the polygon is counterclockwise.

```
isopolygon(point1, point2, realn), where realn
is an integer greater than 1.
```

Example

`isopolygon(GA, GB, 6)` draws a regular hexagon whose first two vertices are the points A and B.

Square

Draws a square, given two consecutive vertices as points.

```
square(point1, point2)
```

Example:

Example: square(0, 3+2i, *p*, *q*) draws a square with vertices at (0, 0), (3, 2), (1, 5), and (-2, 3). The last two vertices are computed automatically and are saved into the CAS variables *p* and *q*.

Curve

Circle

Draws a circle, given the endpoints of the diameter, or a center and radius, or an equation in x and y.

circle(point1, point2) or circle(point1, point 2-point1) or circle(equation)

Examples:

`circle(GA, GB)` draws the circle with diameter AB.

`circle(GA, GB-GA)` draws the circle with center at point A and radius AB.

`circle(x^2+y^2=1)` draws the unit circle.

This command can also be used to draw an arc.

`circle(GA, GB, 0, π/2)` draws a quarter-circle with diameter AB.

Circumcircle

Draws the circumcircle of a triangle; that is, the circle circumscribed about a triangle.

```
circumcircle(point1, point2, point3)
```

Example:

`circumcircle(GA, GB, GC)` draws the circle circumscribed about ΔABC

Excircle

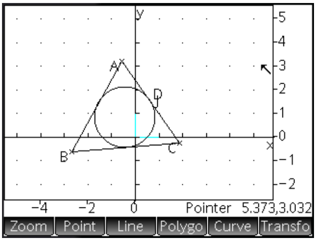
Given three points that define a triangle, draws the excircle of the triangle that is tangent to the side defined by the last two points and also tangent to the extensions of the two sides where the common vertex is the first point.

Example:

`excircle(GA, GB, GC)` draws the circle tangent to segment BC and to the rays AB and AC.

Incircle

An incircle is a circle that is tangent to each of a polygon's sides. The HP Prime can draw an incircle that is tangent to the sides of a triangle.



Tap at each vertex of the triangle, pressing Enter after each tap.

Ellipse

Draws an ellipse, given the foci and either a point on the ellipse or a scalar that is one half the constant sum of the distances from a point on the ellipse to each of the foci.

```
ellipse(point1, point2, point3) or
ellipse(point1, point2, realk)
```

Examples:

`ellipse(GA, GB, GC)` draws the ellipse whose foci are points A and B and which passes through point C.

`ellipse(GA, GB, 3)` draws an ellipse whose foci are points A and B. For any point P on the ellipse, AP+BP=6.

Hyperbola

Draws a hyperbola, given the foci and either a point on the hyperbola or a scalar that is one half the constant difference of the distances from a point on the hyperbola to each of the foci.

```
hyperbola(point1, point2, point3) or
hyperbola(point1, point2, realk)
```

Examples:

`hyperbola(GA, GB, GC)` draws the hyperbola whose foci are points A and B and which passes through point C.

`hyperbola(GA, GB, 3)` draws a hyperbola whose foci are points A and B. For any point P on the hyperbola, |AP-BP|=6.

Parabola

Draws a parabola, given a focus point and a directrix line, or the vertex of the parabola and a real number that represents the focal length.

`parabola(point,line)` or `parabola(vertex,real)`

Examples:

`parabola(GA, GB)` draws a parabola whose focus is point A and whose directrix is line B.

`parabola(GA, 1)` draws a parabola whose vertex is point A and whose focal length is 1.

Conic

Plots the graph of a conic section defined by an expression in x and y.

`conic(expr)`

Example:

`conic(x^2+y^2-81)` draws a circle with center at (0,0) and radius of 9

Locus

Given a first point and a second point that is an element of (a point on) a geometric object, draws the locus of the first point as the second point traverses its object.

`locus(point,element)`

Plot

Function

Draws the plot of a function, given an expression in the independent variable x. Note the use of lowercase x.

Syntax: `plotfunc(Expr)`

Example:

`plotfunc(3*sin(x))` draws the graph of `y=3*sin(x)`

Parametric

Takes a complex expression in one variable and an interval for that variable as arguments. Interprets the complex expression `f(t)+i*g(t)` as `x=f(t)` and `y=g(t)` and plots the parametric equation over the interval specified in the second argument.

Syntax: `plotparam(f(Var)+i*g(Var), Var= Start..Stop, [tstep=Value])`

Examples:

`plotparam(cos(t)+ i*sin(t), t=0..2*π)` plots the unit circle

`plotparam(cos(t)+ i*sin(t), t=0..2*π, tstep=π/3)` plots a regular hexagon inscribed in the unit circle (note the tstep value)

Polar

Draws a polar plot.

Syntax: `plotpolar(Expr,Var=Interval, [Step])` or `plotpolar(Expr, Var, Min, Max, [Step])`

`plotpolar(f(x),x,a,b)` draws the polar curve `r=f(x)` for x in `[a,b]`

Sequence

Given an expression in x and a list containing three values, draws the line y=x, the plot of the function defined by the expression over the domain defined by the interval between the last two values, and draws the cobweb plot for the first n terms of the sequence defined recursively by the expression (starting at the first value).

Syntax: `plotseq(f(Var), Var={Start, Xmin, Xmax}, Integern)`

Example:

`plotseq(1-x/2, x={3 -1 6}, 5)` plots `y=x` and `y=1-x/2` (from `x=-1` to `x=6`), then draws the first 5 terms of the cobweb plot for `u(n)=1-(u(n-1)/2`, starting at `u(0)=3`

Implicit

Plots an implicitly defined curved from Expr (in x and y). Specifically, plots Expr=0. Note the use of lowercase x and y. With the optional x-interval and y-interval, plots only within those intervals.

Syntax: `plotimplicit(Expr, [XIntrvl, YIntrvl])`

Example:

`plotimplicit((x+5)^2+(y+4)^2-1)` plots a circle, centered at the point `(-5, -4)`, with a radius of `1`

Slopefield

Plots the graph of the slopefield for the differential equation y'=f(x,y), where f(x,y) is contained in Expr. VectorVar is a vector containing the variables. If VectorVar is of the form [x=Interval, y=Interval], then the slopefield is plotted over the specified x-range and y-range. Given xstep and ystep values, plots the slopefield segments using these steps. If Option is `normalize`, then the slopefield segments drawn are equal in length.

Syntax: `plotfield(Expr, VectorVar, [xstep=Val, ystep=Val, Option])`

Example: p`lotfield(x*sin(y), [x=-6..6, y=-6..6],normalize)` draws the slopefield for `y'=x*sin(y)`, from `-6` to `6` in both directions, with segments that are all of the same length.

ODE

Draws the solution of the differential equation y'=f(Va1, Var2, ...) that contains as initial condition for the variables Val1, Val2,... The first argument is the expression f(Var1, Var2,...), the second argument is the vector of variables, and the third argument is the vector of initial conditions.

Syntax: `plotode(Expr, [Var1, Var2, ...], [Val1, Val2. ...])`

Example:

`plotode(x*sin(y), [x,y], [-2, 2])` draws the graph of the solution to `y'=x*sin(y)` that passes through the point `(-2, 2)` as its initial condition

List

Plots a set of n points and connects them with segments. The points are defined by a 2xn matrix, with the abscissas in the first row and the ordinates in the second row.

Syntax: `plotlist(Matrix 2xn)`

Example:

`plotlist([[0,3],[2,1],[4,4],[0,3]])` draws a triangle

Slider

Creates a slider bar that can be used to control the value of a parameter. A dialog box displays the slider bar definition and any animation for the slider. When completed, the slider bar appears near the top left of Plot view. You can then move it to another location.

Transform

Translation

Translates a geometric object along a given vector. The vector is given as the difference of two points (head-tail).

```
translation(vector, object)
```

Examples:

`translation(0-i, GA)` translates object A down one unit.

`translation(GB-GA, GC)` translates object C along the vector AB.

Reflection

Reflects a geometric object over a line or through a point. The latter is sometimes referred to as a half-turn.

```
reflection(line, object) or reflection(point,
object)
```

Examples:

`reflection(line(x=3),point(1,1))` reflects the point at (1, 1) over the vertical line x=3 to create a point at (5,1).

`reflection(1+i, 3-2i)` reflects the point at (3,–2) through the point at (1, 1) to create a point at (–1, 4).

Rotation

Rotates a geometric object, about a given center point, through a given angle.

```
rotate(point, angle, object)
```

Example:

`rotate(GA, angle(GB, GC, GD),GK)` rotates the geometric object labeled K, about point A, through an angle equal to ∡ CBD.

Dilation

Dilates a geometric object, with respect to a center point, by a scale factor.

```
homothety(point, realk, object)
```

Example:

`homothety(GA, 2, GB)` creates a dilation centered at point A that has a scale factor of 2. Each point P on geometric object B has its image P′ on ray AP such that AP′=2AP.

Similarity

Dilates and rotates a geometric object about the same center point.

similarity(point, real*k*, angle, object)

Example:

`similarity(0, 3, angle(0,1,i),point(2,0))` dilates the point at (2,0) by a scale factor of 3 (a point at (6,0)), then rotates the result 90° counterclockwise to create a point at (0, 6).

Projection

Draws the orthogonal projection of a point onto a curve.

```
projection(curve, point)
```

Inversion

Draws the inversion of a point, with respect to another point, by a scale factor.

```
inversion(point1, realk, point2)
```

Example:

`inversion(GA, 3, GB)` draws point C on line AB such that AB*AC=3. In this case, point A is the center of the inversion and the scale factor is 3. Point B is the point whose inversion is created.

In general, the inversion of point A through center C, with scale factor k, maps A onto A′, such that A′ is on line CA and CA*CA′=k, where CA and CA′ denote the lengths of the corresponding segments. If k=1, then the lengths CA and CA′ are reciprocals.

Reciprocation

Given a circle and a vector of objects that are either points or lines, returns a vector where each point is replaced with its polar line and each line is replaced with its pole, with respect to the circle.

```
reciprocation(Circle, [Obj1, Obj2,...Objn])
```

Example:

`reciprocation(circle(0,1),[line(1+i,2),point(1+i*2)])` returns `[point(1/2, 1/2)  line(y=-x/2+1/2)]`

Numeric view: Cmds menu

Cartesian

Abscissa

Returns the x coordinate of a point or the x length of a vector.

`abscissa(point)` or `abscissa(vector)`

Example:

`abscissa(GA)` returns the x-coordinate of the point A.

Ordinate

Returns the y coordinate of a point or the y length of a vector.

```
ordinate(point) or ordinate(vector)
```

Example:

Example: `ordinate(GA)` returns the *y*-coordinate of the point A.

Coordinates

Given a vector of points, returns a matrix containing the x- and y-coordinates of those points. Each row of the matrix defines one point; the first column gives the x-coordinates and the second column contains the y-coordinates.

```
coordinates([point1, point2, …, pointn]))
```

Equation of

Returns the Cartesian equation of a curve in x and y, or the Cartesian coordinates of a point.

```
equation(curve) or equation(point)
```

Example:

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as circle(GA, GB-GA), then `equation(GC)` returns $x_2 + y_2 = 1$.

Parametric

Works like the **equation** command, but returns parametric results in complex form.

```
parameq(GeoObj )
```

Polar Coordinates

Returns a vector containing the polar coordinates of a point or a complex number.

```
polar_coordinates(point) or
polar_coordinates(complex)
```

Example:

`polar_coordinates(√2, √2)` returns `[2, π/4])`

Measure

Distance

Returns the distance between two points or between a point and a curve.

```
distance(point1, point2) or distance(point,
curve)
```

Examples:

`distance(1+i, 3+3i)` returns 2.828… or 2√2.

if GA is the point at (0, 0) and GB is defined as plotfunc(4–x^2/4), then distance (GA, GB) returns 3.464… or 2√3.

Radius

Returns the radius of a circle.

```
radius(circle)
```

Example:

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as circle(GA, GB-GA), then `radius(GC)` returns 1.

Perimeter

Returns the perimeter of a polygon or the circumference of a circle.

`perimeter(polygon)` or `perimeter(circle)`

Examples:

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as circle(GA, GB-GA), then `perimeter(GC)` returns 2π.

If GA is the point at (0, 0), GB is the point at (1, 0), and GC is defined as square(GA, GB-GA), then `perimeter(GC)` returns 4.

Slope

Returns the slope of a straight object (segment, ray, or line).

```
slope(Object)
```

Example:

`slope(line(point(1, 1), point(2, 2)))` returns 1.

Area

Returns the area of a circle or polygon.

```
area(circle) or area(polygon)
```

This command can also return the area under a curve between two points.

```
area(expr, value1, value2)
```

Examples:

If GA is defined to be the unit circle, then `area(GA)` returns π.

`area(4-x^2/4, -4,4)` returns 14.666...

Angle

Returns the measure of a directed angle. The first point is taken as the vertex of the angle as the next two points in order give the measure and sign.

```
angle(vertex, point2, point3)
```

Example:

`angle(GA, GB, GC)` returns the measure of ∡ BAC.

Arc Length

Returns the length of the arc of a curve between two points on the curve. The curve is an expression, the independent variable is declared, and the two points are defined by values of the independent variable.

This command can also accept a parametric definition of a curve. In this case, the expression is a list of 2 expressions (the first for *x* and the second for *y*) in terms of a third independent variable.

```
arcLen(expr, real1, real2)
```

Examples:

`arcLen(x^2, x, –2, 2)` returns 9.29....

`arcLen({sin(t), cos(t)}, t, 0, π/2)` returns 1.57...

Tests

Collinear

Takes a set of points as argument and tests whether or not they are collinear. Returns 1 if the points are collinear and 0 otherwise.

```
is_collinear(point1, point2, …, pointn)
```

Example:

`is_collinear(point(0,0), point(5,0), point(6,1))` returns 0

On circle

Takes a set of points as argument and tests if they are all on the same circle. Returns 1 if the points are all on the same circle and 0 otherwise.

```
is_concyclic(point1, point2, …, pointn)
```

Example:

`is_concyclic(point(-4,-2), point(-4,2), point(4,-2), point(4,2))` returns 1

On object

Tests if a point is on a geometric object. Returns 1 if it is and 0 otherwise

```
is_element(point, object)
```

Example:

`is_element(point(`$\frac{\sqrt{2}}{2}$,$\frac{\sqrt{2}}{2}$`), circle(0,1))` returns 1.

Parallel

Tests whether or not two lines are parallel. Returns 1 if they are and 0 otherwise.

```
is_parallel(line1, line2)
```

Example:

`is_parallel(line(2x+3y=7),line(2x+3y=9)` returns 1.

Perpendicular

Similar to **is_orthogonal**. Tests whether or not two lines are perpendicular.

```
is_perpendicular(line1, line2)
```

Isosceles

Takes three points and tests whether or not they are vertices of a single isosceles triangle. Returns 0 if they are not. If they are, returns the number order of the common point of the two sides of equal length (1, 2, or 3). Returns 4 if the three points form an equilateral triangle.

```
is_isosceles(point1, point2, point3)
```

Example:

`is_isoscelesl(point(0,0), point(4,0), point(2,4))` returns 3.

Equilateral

Takes three points and tests whether or not they are vertices of a single equilateral triangle. Returns 1 if they are and 0 otherwise.

```
is_equilateral(point1, point2, point3)
```

Example:

`is_equilateral(point(0,0), point(4,0), point(2,4))` returns 0.

Parallelogram

Tests whether or not a set of four points are vertices of a parallelogram. Returns 0 if they are not. If they are, then returns 1 if they form only a parallelogram, 2 if they form a rhombus, 3 if they form a rectangle, and 4 if they form a square.

```
is_parallelogram(point1, point2, point3,
point4)
```

Example:

`is_parallelogram(point(0,0), point(2,4), point(0,8), point(-2,4))` returns 2.

Conjugate

Tests whether or not two points or two lines are conjugates for the given circle. Returns 1 if they are and 0 otherwise.

```
is_conjugate(circle, point1, point2) or
is_conjugate(circle, line1, line2)
```

Other Geometry functions

The following functions are not available from a menu in the Geometry app, but are available from the Catlg menu.

affix

Returns the coordinates of a point or both the *x*- and *y*-lengths of a vector as a complex number.

```
affix(point) or affix(vector)
```

Example:

if GA is a point at (1, –2), then `affix(GA)` returns 1–2i.

barycenter

Calculates the hypothetical center of mass of a set of points, each with a given weight (a real number). Each point, weight pair is enclosed in square brackets as a vector.

```
barycenter([[point1, weight1], [point2,
weight2],…,[pointn, weightn]])
```

Example:

`barycenter` $\left(\begin{bmatrix} \text{point}(1) & 1 \\ \text{point}(1+i) & 2 \\ \text{point}(1-i) & 1 \end{bmatrix}\right)$ returns point `(1/2, 1/4)`

convexhull

Returns a vector containing the points that serve as the convex hull for a given set of points.

```
convexhull(point1, point2, …, pointn)
```

Example:

`convexhull(0,1,1+i,1+2i,-1-i,1-3i,-2+i)` returns `[1-3*i 1+2*i -2+ i -1- i ]`

distance2

Returns the square of the distance between two points or between a point and a curve.

`distance2(point1, point2)` or `distance2(point, curve)`

Examples:

`distance2(1+i, 3+3i)` returns 8.

If GA is the point at (0, 0) and GB is defined as plotfunc(4-x^2/4), then `distance2(GA, GB)` returns 12.

division_point

For two points A and B, and a numerical factor *k*, returns a point C such that C-B=*k**(C-A).

```
division_point(point1, point2, realk)
```

Example: `division_point(0,6+6*i,4)` returns point (8,8)

equilateral_triangle

Draws an equilateral triangle defined by one of its sides; that is, by two consecutive vertices. The third point is calculated automatically, but is not defined symbolically. If a lowercase variable is added as a third argument, then the coordinates of the third point are stored in that variable. The orientation of the triangle is counterclockwise from the first point.

```
equilateral_triangle(point1, point2) or
equilateral_triangle(point1, point2, var)
```

Examples:

`equilateral triangle(0,6)` draws an equilateral triangle whose first two vertices are at (0, 0) and (6,0); the third vertex is calculated to be at (3,3*√3).

`equilateral triangle(0,6, v)` draws an equilateral triangle whose first two vertices are at (0, 0) and (6,0); the third vertex is calculated to be at (3,3*√3) and these coordinates are stored in the CAS variable *v*. In CAS view, entering v returns point(3*(√3*i+1)), which is equal to (3,3*√3).

exbisector

Given three points that define a triangle, creates the bisector of the exterior angles of the triangle whose common vertex is at the first point. The triangle does not have to be drawn in the Plot view.

```
exbisector(point1, point2, point3)
```

Examples:

`exbisector(A,B,C)` draws the bisector of the exterior angles of ΔABC whose common vertex is at point A.

`exbisector(0,-4i,4)` draws the line given by y=x

extract_measure

Returns the definition of a geometric object. For a point, that definition consists of the coordinates of the point. For other objects, the definition mirrors their definition in Symbolic view, with the coordinates of their defining points supplied.

```
extract_measure(Var)
```

harmonic_conjugate

Returns the harmonic conjugate of 3 points. Specifically, returns the harmonic conjugate of point3 with respect to point1 and point2. Also accepts three parallel or concurrent lines; in this case, it returns the equation of the harmonic conjugate line.

`harmonic_conjugate(point1, point2, point3)` or
`harmonic_conjugate(line1, line2, line3)`

Example:

`harmonic_conjugate(point(0, 0), point(3, 0), point(4, 0))` returns `point(12/5, 0)`

harmonic_division

Returns the harmonic conjugate of 3 points. Specifically, returns the harmonic conjugate of point3 with respect to point1 and point2 and stores the result in the variable `var`. Also accepts three parallel or concurrent lines; in this case, it returns the equation of the harmonic conjugate line.

`harmonic_division(point1, point2, point3, var)`
or `harmonic_division(line1, line2, line3, var)`

Example:

`harmonic_division(point(0, 0), point(3, 0), point(4, 0), p)` returns `point(12/5, 0)` and stores it in the variable `p`

isobarycenter

Returns the hypothetical center of mass of a set of points. Works like barycenter but assumes that all points have equal weight.

`isobarycenter(point1, point2, …,pointn)`

Example: `isobarycenter(-3,3,3*√3*i)` returns point(3*√3*i/3), which is equivalent to (0,√3).

is_harmonic

Tests whether or not 4 points are in a harmonic division or range. Returns 1 if they are or 0 otherwise.

is_harmonic(point1, point2, point3, point4)

`is_harmonic(point1, point2, point3, point4)`

Example:

`is_harmonic(point(0, 0), point(3, 0), point(4, 0), point(12/5, 0))` returns `1`

is_harmonic_circle_bundle

Returns 1 if the circles build a beam, 2 if they have the same center, 3 if they are the same circle and 0 otherwise.

```
is_harmonic_circle_bundle({circle1, circle2,
…, circlen})
```

is_harmonic_line_bundle

Returns 1 if the lines are concurrent, 2 if they are all parallel, 3 if they are the same line and 0 otherwise.

```
is_harmonic_line_bundle({line1, line2, …,
linen}))
```

is_orthogonal

Tests whether or not two lines or two circles are orthogonal (perpendicular). In the case of two circles, tests whether or not the tangent lines at a point of intersection are orthogonal. Returns 1 if they are and 0 otherwise.

`is_orthogonal(line1, line2)` or
`is_orthogonal(circle1, circle2)`

Example:

`is_orthogonal(line(y=x),line(y=-x))` returns 1.

is_rectangle

Tests whether or not a set of four points are vertices of a rectangle. Returns 0 if they are not, 1 if they are, and 2 if they are vertices of a square.

```
is_rectangle(point1, point2, point3, point4)
```

Examples:

`is_rectangle(point(0,0), point(4,2), point(2,6), point(-2,4))` returns 2.

With a set of only three points as argument, tests whether or not they are vertices of a right triangle. Returns 0 if they are not. If they are, returns the number order of the common point of the two perpendicular sides (1, 2, or 3).

`is_rectangle(point(0,0), point(4,2), point(2,6))` returns 2.

is_rhombus

Tests whether or not a set of four points are vertices of a rhombus. Returns 0 if they are not, 1 if they are, and 2 if they are vertices of a square.

```
is_rhombus(point1, point2, point3, point4)
```

Example:

`is_rhombus(point(0,0), point(-2,2), point(0,4), point(2,2))` returns `2`

is_square

Tests whether or not a set of four points are vertices of a square. Returns 1 if they are and 0 otherwise.

```
is_square(point1, point2, point3, point4)
```

Example:

`is_square(point(0,0), point(4,2), point(2,6), point(-2,4))` returns 1.

LineHorz

Draws the horizontal line y=a.

```
LineHorz(a)
```

Example:

`LineHorz(-2)` draws the horizontal line whose equation is y = –2

LineVert

Draws the vertical line x=a.

```
LineVert(a)
```

Example:

`LineVert(–3)` draws the vertical line whose equation is x = –3

open_polygon

Connects a set of points with line segments, in the given order, to produce a polygon. If the last point is the same as the first point, then the polygon is closed; otherwise, it is open.

`open_polygon(point1, point2, …, point1)` or
`open_polygon(point1, point2, …, pointn)`

orthocenter

Returns the orthocenter of a triangle; that is, the intersection of the three altitudes of a triangle. The argument can be either the name of a triangle or three non-collinear points that define a triangle. In the latter case, the triangle does not need to be drawn.

```
orthocenter(triangle) or orthocenter(point1,
point2, point3)
```

Example: `orthocenter(0,4i,4)` returns `(0,0)`

perpendicular bisector

Draws the perpendicular bisector of a segment. The segment is defined either by its name or by its two endpoints.

```
perpen_bisector(segment) or
perpen_bisector(point1, point2)
```

Examples:

`perpen_bisector(GC)` draws the perpendicular bisector of segment C.

`perpen_bisector(GA, GB)` draws the perpendicular bisector of segment AB.

`perpen_bisector(3+2i, i)` draws the perpendicular bisector of a segment whose endpoints have coordinates (3, 2) and (0, 1); that is, the line whose equation is y=x/3+1.

point2d

Randomly re-distributes a set of points such that, for each point, x ∈ [–5,5] and y ∈ [–5,5]. Any further movement of one of the points will randomly re-distribute all of the points with each tap or direction key press.

```
point2d(point1, point2, …, pointn)
```

polar

Returns the polar line of the given point as pole with respect to the given circle.

```
polar(circle, point)
```

Example:

`polar(circle(x^2+y^2=1),point(1/3,0))` returns `x=3`

pole

Returns the pole of the given line with respect to the given circle.

```
pole(circle, line)
```

Example:

`pole(circle(x^2+y^2=1), line(x=3))` returns `point(1/3, 0)`

powerpc

Given a circle and a point, returns the difference between the square of the distance from the point to the circle''s center and the square of the circle's radius.

```
powerpc(circle, point)
```

Example

`powerpc(circle(point(0,0), point(1,1)-point(0,0)), point(3,1))` returns `8`

radical_axis

Returns the line whose points all have the same powerpc values for the two given circles.

```
radical_axis(circle1, circle2)
```

Example:

`radical_axis(circle(((x+2)²+y²) = 8),circle(((x-2)²+y²) = 8))` returns `line(x=0)`

vector

Creates a vector from point1 to point2. With one point as argument, the origin is used as the tail of the vector.

```
vector(point1, point2) or vector(point)
```

Example:

`vector(point(1,1), point(3,0))` creates a vector from (1, 1) to (3, 0).

vertices

Returns a list of the vertices of a polygon.

```
vertices(polygon)
```

vertices_abca

Returns the closed list of the vertices of a polygon.

```
vertices_abca(polygon)
```

2

Inference app

The Inference app calculates hypothesis tests, confidence intervals, and chi-square tests, in addition to both tests and confidence intervals based on inference for linear regression. In addition to the Inference app, the Math menu has a full set of probability functions based on various distributions (chi-square, F, binomial, poisson, and so on).

Based on 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

You can also perform goodness of fit tests and tests on two-way tables based on the chi-square distribution. Finally, you can perform calculations based on inference for linear regression:

- linear t-test
- confidence interval for slope
- confidence interval for the intercept
- confidence interval for mean response
- prediction interval for a future response

Sample data

For many of the calculations, the Numeric view of the Inference app comes with sample data (which you can restore by resetting the app). This sample data is useful in helping you gain an understanding of the app.

Getting started with the Inference app

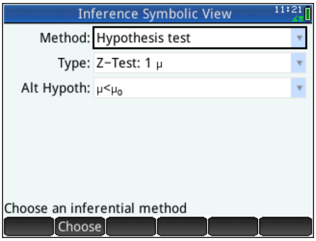
Let's conduct a Z-Test on one mean using the sample data.

Open the Inference app

1. Open the Inference app:

   Apps Info Select `Inference`

   The Inference app opens in Symbolic view.



Method: Hypothesis test

Type: Z-Test: 1 μ

Alt Hypoth: $\mu<\mu_0$

Choose an inferential method

Symbolic view options

The following table summarizes the options available in Symbolic view.

Symbolic view options	
Hypothesis Tests	
Z-Test: 1 μ	The Z-Test on one mean
Z-Test: $\mu_1 - \mu_2$	The Z-Test on the difference between two means
Z-Test: 1 π	The Z-Test on one proportion
Z-Test: $\pi_1 - \pi_2$	The Z-Test on the difference between two proportions
T-Test: 1 μ	The T-Test on one mean
T-Test: $\mu_1 - \mu_2$	The T-Test on the difference between two means
Confidence Intervals	
Z-Int: 1 μ	The confidence interval for one mean, based on the Normal distribution
Z-Int: $\mu_1 - \mu_2$	The confidence interval for the difference between two means, based on the Normal distribution

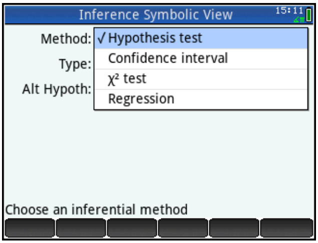
Symbolic view options	
Z-Int: 1 π	The confidence interval for one proportion, based on the Normal distribution
Z-Int: $\pi_1 - \pi_2$	The confidence interval for the difference between two proportions, based on the Normal distribution
T-Int: 1 μ	The confidence interval for one mean, based on the Student's t-distribution
T-Int: $\mu_1 - \mu_2$	The confidence interval for the difference between two means, based on the Student's t-distribution
X^2 test	
Goodness of fit	The chi-square goodness of fit test, based on categorical data
2-way test	The chi-square test, based on categorical data in a two-way table
Regression	
Linear t-test	The t-test for linear regression
Interval: Slope	The confidence interval for the slope of the true linear regression line, based on the t-distribution
Interval: Intercept	The confidence interval for the y-intercept of the true linear regression line, based on the t-distribution
Interval: Mean response	The confidence interval for a mean response, based on the t-distribution
Prediction interval	The prediction interval for a future response, based on the t-distribution

If you choose one of the hypothesis tests, you can choose an 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 ≠.

In this section, we will conduct a Z-Test on one mean on the example data to illustrate how the app works.

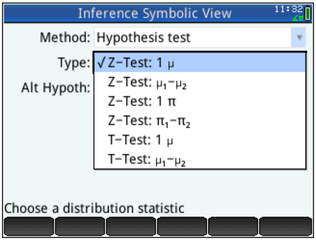
Select the inference method

2. `Hypothesis Test` is the default inference method. If it is not selected, tap on the Method field and select it.



Choose an inferential method

3. Choose the type of test. In this case, select `Z-Test: 1` μ from the **Type** menu.

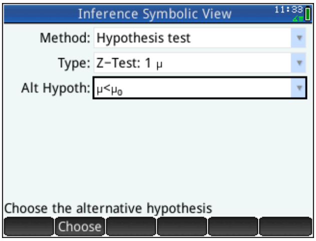


Method: Hypothesis test

Type: Z-Test: 1 μ

Choose a distribution statistic

4. Select an alternative hypothesis. In this case, select $\mu < \mu_0$ from the **Alt Hypoth** menu.



Method: Hypothesis test

Type: Z-Test: 1 μ

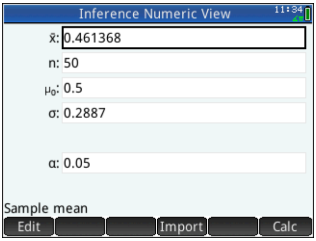
Alt Hypoth: $\mu<\mu_0$

Choose the alternative hypothesis

Enter data

5. Go to Numeric view to see the sample data.

Num ↳Setup



$\bar{x}$: 0.461368

n: 50

μ_0: 0.5

σ: 0.2887

α: 0.05

Sample mean

The table below describes the fields in this view for the sample data.

Field name	Definition
$\bar{x}$	Sample mean
n	Sample size
μ_0	Assumed population mean
σ	Population standard deviation
α	Alpha level for the test

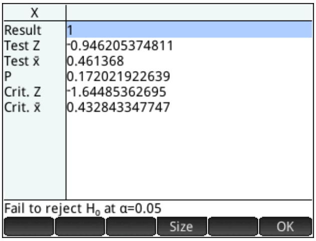
The Numeric view is where you enter the sample statistics and population parameters for the situation you are examining. The sample data supplied here belong to the case in which a student has generated 50 pseudo-random numbers on his graphing calculator. If the algorithm is working properly, the mean would be near 0.5 and the population standard deviation is known to be approximately 0.2887. The student is concerned that the sample mean (0.461368) seems a bit low and it testing the less than alternative hypothesis against the null hypothesis.

Display the test results

6. Display the test results:

   Calc

   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. In this case, the test indicates that one should not reject the null hypothesis.



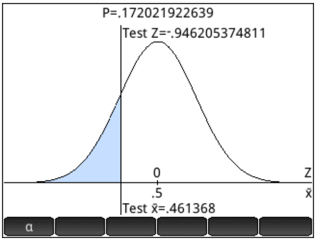
```
X
Result    1
Test Z    -0.946205374811
Test x̄    0.461368
P         0.172021922639
Crit. Z   -1.64485362695
Crit. x̄   0.432843347747
Fail to reject H0 at α=0.05
```

Tap OK to return to Numeric view.

Plot the test results

7. Display a graphical view of the test results:

   Plot Setup



P=.172021922639

Test Z=-.946205374811

Test x̄=.461368

   The graph of the distribution is displayed, with the test Z-value marked. The corresponding X-value is also shown.

   Tap α to see the critical Z-value. With the alpha level showing, you can press ▼ or ▲ to decrease or increase the α-level.

Importing statistics

For many of the calculations, the Inference app can import summary statistics from data in the Statistics 1Var and Statistics 2Var apps. For the others, the data can be manually imported. The following example illustrates the process.

A series of six experiments gives the following values as the boiling point of a liquid:

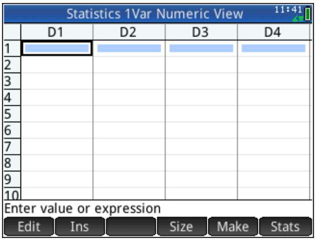
82.5, 83.1, 82.6, 83.7, 82.4, and 83.0

Based on this sample, we want to estimate the true boiling point at the 90% confidence level.

Open the Statistics 1Var app

1. Open the Statistics 1Var app:

   Apps Info Select `Statistics 1Var`



Statistics 1Var Numeric View

Enter value or expression

Clear unwanted data

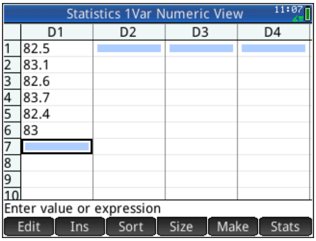
2. If there is unwanted data in the app, clear it:

   Shift Esc Clear All columns

Enter data

3. In column D1, enter the boiling points found during the experiments.

   82 . 5 Enter
   83 . 1 Enter
   82 . 6 Enter
   83 . 7 Enter
   82 . 4 Enter
   83 Enter



Statistics 1Var Numeric View 11:07

	D1	D2	D3	D4
1	82.5			
2	83.1			
3	82.6			
4	83.7			
5	82.4			
6	83			
7				
8				
9				
10				

Enter value or expression

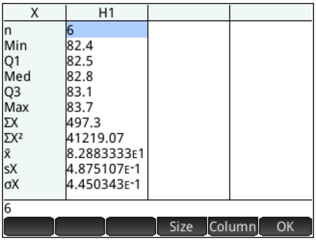
Calculate statistics

4. Calculate statistics:

   Stats

   The statistics calculated will now be imported into the Inference app.

5. Tap OK to close the statistics window.



X	H1		
n	6		
Min	82.4		
Q1	82.5		
Med	82.8		
Q3	83.1		
Max	83.7		
ΣX	497.3		
ΣX²	41219.07		
x̄	8.2883333E1		
sX	4.875107E-1		
σX	4.450343E-1		

6

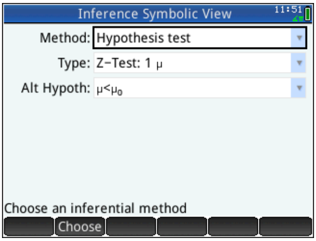
Open the Inference app

6. Open the Inference app and clear the current settings.

   Apps Info Select

   `Inference`

   Shift Esc Clear



Inference Symbolic View 11:51

Method: Hypothesis test

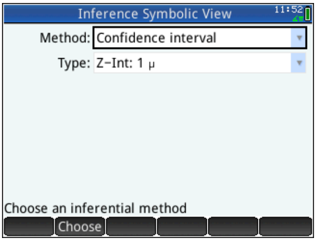
Type: Z-Test: 1 μ

Alt Hypoth: $\mu<\mu_0$

Choose an inferential method

Select inference method and type

7. Tap on the **Method** field and select `Confidence Interval`.



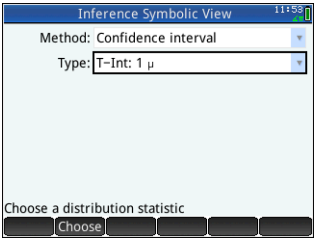
Inference Symbolic View 11:52

Method: Confidence interval

Type: Z-Int: 1 μ

Choose an inferential method

8. Tap on **Type** and select `T-Int: 1 µ`


Inference Symbolic View

Method: Confidence interval

Type: T-Int: 1 µ

Choose a distribution statistic

Import the data

9. Open Numeric view:

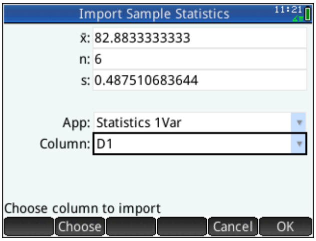
   Num Setup

10. Specify the data you want to import:

    Tap Import.

11. From the **App** field select the statistics app that has the data you want to import.

12. In the **Column** field specify the column in that app where the data is stored. (D1 is the default.)


Import Sample Statistics

x̄: 82.8833333333

n: 6

s: 0.487510683644

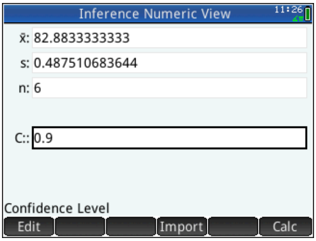
App: Statistics 1Var

Column: D1

Choose column to import

13. Tap OK.

14. Specify a 90% confidence interval in the **C** field.


Inference Numeric View

x̄: 82.8833333333

s: 0.487510683644

n: 6

C:: 0.9

Confidence Level

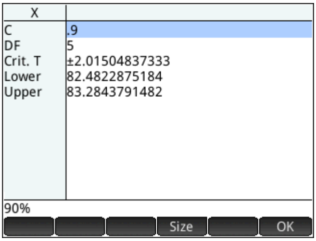
Display results numerically

15. Display the confidence interval in Numeric view:

    Calc

16. Return to Numeric view:

    OK


X	
C	.9
DF	5
Crit. T	±2.01504837333
Lower	82.4822875184
Upper	83.2843791482

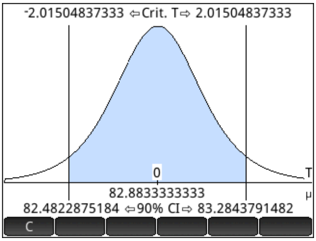
90%

Display results graphically

17. Display the confidence interval in Plot view.

    Plot

    The 90% confidence interval is [82.48…, 83.28…].



-2.01504837333 ⇦Crit. T⇨ 2.01504837333

82.8833333333

82.4822875184 ⇦90% CI⇨ 83.2843791482

Hypothesis tests

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

The HP Prime hypothesis tests use the Normal Z-distribution or the Student’s t-distribution to calculate probabilities. If you wish to use other distributions, please use the Home view and the distributions found within the Probability category of the Math menu.

One-Sample Z-Test

Menu name

Z-Test: 1 μ

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 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:

$$H_0\!: \mu < \mu_0$$
$$H_0\!: \mu > \mu_0$$
$$H_0\!: \mu \neq \mu_0$$

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
Test $\bar{x}$	Value of $\bar{x}$ associated with the test Z-value
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\bar{x}$	Boundary value(s) of $\bar{x}$ 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 means of the two populations are equal, H_0: $\mu_1 = \mu_2$.

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

$$H_0: \mu_1 < \mu_2$$
$$H_0: \mu_1 > \mu_2$$
$$H_0: \mu_1 \neq \mu_2$$

Inputs

The inputs are:

Field name	Definition
$\bar{x}_1$	Sample 1 mean
$\bar{x}_2$	Sample 2 mean
n_1	Sample 1 size
n_2	Sample 2 size
σ_1	Population 1 standard deviation
σ_2	Population 2 standard deviation
α	Significance level

Results

The results are:

Result	Description
Test Z	Z-Test statistic
Test $\Delta\ \bar{x}$	Difference in the means associated with the test Z-value
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\Delta\ \bar{x}$	Difference in the means associated with the α level you supplied

One-Proportion Z-Test

Menu name

Z-Test: $1\ \pi$

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 is an assumed value, $H_0: \pi = \pi_0$.

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

$$H_0: \pi < \pi_0$$
$$H_0: \pi > \pi_0$$
$$H_0: \pi \neq \pi_0$$

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 Z	Z-Test statistic
Test $\hat{p}$	Proportion of successes in the sample
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\hat{p}$	Proportion of successes 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, this test measures the strength of the evidence for a selected hypothesis against the null hypothesis. The null hypothesis is that the proportions of successes in the two populations are equal, H_0: $\pi_1 = \pi_2$.

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

$$H_0: \pi_1 < \pi_2$$
$$H_0: \pi_1 > \pi_2$$
$$H_0: \pi_1 \neq \pi_2$$

Inputs

The inputs are:

Field name	Definition
x_1	Sample 1 success count

Field name	Definition
x_2	Sample 2 success count
n_1	Sample 1 size
n_2	Sample 2 size
α	Significance level

Results

The results are:

Result	Description
Test Z	Z-Test statistic
Test $\Delta\ \hat{p}$	Difference between the proportions of successes in the two samples that is associated with the test Z-value
P	Probability associated with the Z-Test statistic
Critical Z	Boundary value(s) of Z associated with the α level that you supplied
Critical $\Delta\ \hat{p}$	Difference in the proportion of successes in the two samples associated with the α level you supplied

One-Sample T-Test

Menu name

T-Test: 1 μ

This 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:

$$H_0: \mu < \mu_0$$
$$H_0: \mu > \mu_0$$
$$H_0: \mu \neq \mu_0$$

Inputs

The inputs are:

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

Results

The results are:

Result	Description
Test T	T-Test statistic
Test $\bar{x}$	Value of $\bar{x}$ associated with the test t-value
P	Probability associated with the T-Test statistic
DF	Degrees of freedom
Critical T	Boundary value(s) of T associated with the α level that you supplied
Critical $\bar{x}$	Boundary value(s) of $\bar{x}$ required by the α value that you supplied

Two-Sample T-Test

Menu name

T-Test: $\mu_1 - \mu_2$

This 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:

$$H_0: \mu_1 < \mu_2$$
$$H_0: \mu_1 > \mu_2$$
$$H_0: \mu_1 \neq \mu_2$$

Inputs

The inputs are:

Field name	Definition
$\bar{x}_1$	Sample 1 mean
$\bar{x}_2$	Sample 2 mean
s_1	Sample 1 standard deviation
s_2	Sample 2 standard deviation
n_1	Sample 1 size
n_2	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
Test $\Delta\bar{x}$	Difference in the means associated with the test t-value
P	Probability associated with the T-Test statistic
DF	Degrees of freedom
Critical T	Boundary values of T associated with the α level that you supplied
Critical $\Delta\bar{x}$	Difference in the means associated with the α level you supplied

Confidence intervals

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

One-Sample Z-Interval

Menu name

Z-Int: 1 μ

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

Inputs

The inputs are:

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

Results

The results are:

Result	**Description**
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for μ
Upper	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
n_1	Sample 1 size
n_2	Sample 2 size
σ_1	Population 1 standard deviation
σ_2	Population 2 standard deviation
C	Confidence level

Results

The results are:

Result	Description
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for $\Delta\mu$
Upper	Upper bound for $\Delta\mu$

One-Proportion Z-Interval

Menu name

Z-Int: 1π

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
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for π
Upper	Upper bound for π

Two-Proportion Z-Interval

Menu name

Z-Int: $\pi_1 - \pi_2$

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
n_1	Sample 1 size
n_2	Sample 2 size
C	Confidence level

Results

The results are:

Result	Description
C	Confidence level
Critical Z	Critical values for Z
Lower	Lower bound for $\Delta\pi$
Upper	Upper bound for $\Delta\pi$

One-Sample T-Interval

Menu name

T-Int: 1 μ

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

Inputs

The inputs are:

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

Results

The results are:

Result	Description
C	Confidence level
DF	Degrees of freedom
Critical T	Critical values for T
Lower	Lower bound for μ
Upper	Upper bound for μ

Two-Sample T-Interval

Menu name

T-Int: $\mu_1 - \mu_2$

This option uses the Student's t-distribution to calculate a confidence interval for the difference between the means of two populations, $\mu_1 - \mu_2$, when the population standard deviations, $\sigma_1$and σ_2, are unknown.

Inputs

The inputs are:

Result	Definition
$\bar{x}_1$	Sample 1 mean
$\bar{x}_2$	Sample 2 mean
s_1	Sample 1 standard deviation
s_2	Sample 2 standard deviation
n_1	Sample 1 size
n_2	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
C	Confidence level
DF	Degrees of freedom
Critical T	Critical values for T
Lower	Lower bound for $\Delta\mu$
Upper	Upper bound for $\Delta\mu$

Chi-square tests

An HP Prime calculator can perform tests on categorical data based on the chi-square distribution. Specifically, HP Prime calculators support both goodness of fit tests and tests on two-way tables.

Goodness of fit test

Menu name

Goodness of Fit

This option uses the chi-square distribution to test the goodness of fit of categorical data on observed counts against either expected probabilities or expected counts. In the Symbolic view, make your selection in the `Expected` box: choose either `Probability` (the default) or `Count`.

Inputs

With **Expected Probability** selected, the Numeric view inputs are as follows:

Field name	Definition
ObsList	The list of observed count data
ProbList	The list of expected possibilities

Results

When Calc is tapped, the results are as follows:

Field name	Definition
x^2	The value of the chi-square test statistic
P	The probability associated with the chi-square value
DF	The degrees of freedom

Menu keys

The menu key options are as follows:

Menu key	Definition
Stats	Displays the default test results, as listed previously
Exp	Displays the expected counts
Cont	Displays the list of contributions of each category to the chi-square value
Size	Selects a small, medium, or large font
OK	Returns to the Numeric view

With Expected Count selected, the Numeric view inputs include `ExpList` for the expected counts instead of `ProbList` and the menu key labels in the Results screen do not include `Exp`.

Two-way table test

Menu name

2-way test

This option uses the chi-square distribution to test the goodness of fit of categorical data of observed counts contained in a two-way table.

Inputs

The Numeric view inputs are as follows:

Field name	Definition
ObsMat	The matrix of the observed count data in the two-way table

Results

When Calc is tapped, the results are as follows:

Field name	Definition
x^2	The value of the chi-square test statistic
P	The probability associated with the chi-square value
DF	The degrees of freedom

Menu keys

The menu key options are as follows:

Menu key	Definition
Exp	Displays the matrix of expected counts. Press OK to exit.
Cont	Displays the matrix of contributions of each category to the chi-square value. Press OK to exit.
Size	Selects a small, medium, or large font.
OK	Returns to the Numeric view.

Inference for regression

An HP Prime calculator can perform tests and calculate intervals based on inference for linear regression. These calculations are based on the t-distribution.

Hint: If you have been using the Statistics 2Var app to explore a linear regression and you want to use the same data for this procedure, you will have to import it manually. For example, suppose your x-values are in list C1 of the Statistics 2Var app and your y-values are in list C2.

To import the data into the Inference app:

1. Open the Statistics 2Var app and press Settings to enter Home view.
2. Type L1:=C1 and press Enter.
3. Type L2:=C2 and press Enter.
4. Open the Inference app and press Settings to enter Home view.
5. Type Xlist:=L1 and press Enter.
6. Type Ylist:=L2 and press Enter.
7. Press Symb Setup to enter Symbolic view, and then select **Regression** for the Method field.
8. Press Num Setup to enter Numeric view. Your data is imported to Xlist and Ylist.

Linear t-test

Menu name

Linear t test

This option performs a t-test on the true linear regression equation, based on a list of explanatory data and a list of response data. You must choose an alternative hypothesis in Symbolic view using the `Alt Hypoth` field.

Inputs

The Numeric view inputs are as follows:

Field name	**Definition**
Xlist	The list of explanatory data
Ylist	The list of response data

Results

When Calc is tapped, the results are as follows:

Field name	**Definition**
Test T	The value of the t-test statistic
P	The probability associated with the t-statistic
DF	The degrees of freedom

Field name	Definition
β_0	The intercept of the calculated regression line
β_1	The slope of the calculated regression line
serrLine	The standard error of the calculated regression line
serrSlope	The standard error of the slope of the calculated regression line
serrInter	The standard error of the intercept of the calculated regression line
r	The correlation coefficient of the data
R^2	The coefficient of determination of the data

Menu keys

The menu key options are as follows:

Menu key	Definition
Size	Selects a small, medium, or large font.
OK	Returns to the Numeric view.

Confidence interval for slope

Menu name

Interval: Slope

This option calculates a confidence interval for the slope of the true linear regression equation, based on a list of explanatory data, a list of response data, and a confidence level. After you enter your data in Numeric view and tap Calc, enter the confidence level in the prompt that appears.

Inputs

The Numeric view inputs are as follows:

Field name	Definition
Xlist	The list of explanatory data
Ylist	The list of response data
C	The confidence level (0 < C < 1)

Results

When Calc is tapped, the results are as follows:

Field name	Definition
C	The input confidence level
Crit. T	The critical value of t
DF	The degrees of freedom
β_1	The slope of the calculated regression line
serrSlope	The standard error of the slope of the regression line
Lower	The lower bound of the confidence interval for the slope
Upper	The upper bound of the confidence interval for the slope

Menu keys

The menu key options are as follows:

Menu key	Definition
Size	Selects a small, medium, or large font.
OK	Returns to the Numeric view.

Confidence interval for intercept

Menu name

Interval: Intercept

This option calculates a confidence interval for the intercept of the true linear regression equation, based on a list of explanatory data, a list of response data, and a confidence level. After you enter your data in Numeric view and tap Calc, enter the confidence level in the prompt that appears.

Inputs

The Numeric view inputs are as follows:

Field name	Definition
Xlist	The list of explanatory data
Ylist	The list of response data
C	The confidence level (0 < C < 1)

Results

When Calc is tapped, the results are as follows:

Field name	Definition
C	The input confidence level
Crit. T	The critical value of t
DF	The degrees of freedom
β_0	The intercept of the calculated regression line
serrInter	The standard error of the y-intercept of the regression line
Lower	The lower bound of the confidence interval for the intercept
Upper	The upper bound of the confidence interval for the intercept

Menu keys

The menu key options are as follows:

Menu key	Definition
Size	Selects a small, medium, or large font.
OK	Returns to the Numeric view.

Confidence interval for a mean response

Menu name

Interval: Mean response

This option calculates a confidence interval for the mean response (ŷ), based on a list of explanatory data, a list of response data, a value of the explanatory variable (X), and a confidence level. After you enter your data in Numeric view and tap Calc, enter the confidence level and the value of the explanatory variable (X) in the prompt that appears.

Inputs

The Numeric view inputs are as follows:

Field name	Definition
Xlist	The list of explanatory data
Ylist	The list of response data
X	The value of the explanatory variable for which you want a mean response and a confidence interval
C	The confidence level (0 < C < 1)

Results

When Calc is tapped, the results are as follows:

Field name	Definition
C	The input confidence level
Crit. T	The critical value of t
DF	The degrees of freedom
ŷ	The mean response for the input X-value
serr ŷ	The standard error of ŷ

Field name	Definition
Lower	The lower bound of the confidence interval for the mean response
Upper	The upper bound of the confidence interval for the mean response

Menu keys

The menu key options are as follows:

Menu key	Definition
Size	Selects a small, medium, or large font.
OK	Returns to the Numeric view.

Prediction interval

Menu name

Prediction interval

This option calculates a prediction interval for a future response, based on a list of explanatory data, a list of response data, a value of the explanatory variable (X), and a confidence level. After you enter your data in Numeric view and tap Calc, enter the confidence level and the value of the explanatory variable (X) in the prompt that appears.

Inputs

The Numeric view inputs are as follows:

Field name	Definition
Xlist	The list of explanatory data
Ylist	The list of response data
X	The value of the explanatory variable for which you want a future response and a confidence interval
C	The confidence level (0 < C < 1)

Results

When Calc is tapped, the results are as follows:

Field name	Definition
C	The input confidence level
Crit. T	The critical value of t
DF	The degrees of freedom
ŷ	The future response for the input X-value
serr ŷ	The standard error of ŷ
Lower	The lower bound of the confidence interval for the mean response
Upper	The upper bound of the confidence interval for the mean response

Menu keys

The menu key options are as follows:

Menu key	Definition
Size	Selects a small, medium, or large font.
OK	Returns to the Numeric view.

3

Functions and commands

Many mathematical functions are available from the calculator's keyboard. These are described in "Keyboard functions" on page 101. Other functions and commands are collected together in the Toolbox menus (Mem B). There are five Toolbox menus:

- **Math**

  A collection of non-symbolic mathematical functions (see "Math menu" on page 105)

- **CAS**

  A collection of symbolic mathematical functions (see "CAS menu" on page 116)

- **App**

  A collection of app functions that can be called from elsewhere in the calculator, such as Home view, CAS view, the Spreadsheet app, and in a program (see "App menu" on page 138)

  Note that the Geometry app functions can be called from elsewhere in the calculator, but they are designed to be used in the Geometry app. For that reason, the Geometry functions are not described in this chapter. They are described in the Geometry chapter.

- **User**

  The functions that you have created (see "Creating your own functions" on page 213) and the programs you have created that contain functions that have been exported.

- **Catlg**

  All the functions and commands:

  – on the **Math** menu

  – on the **CAS** menu

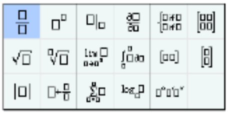
  – used in the Geometry app

- used in programming
- used in the Matrix Editor
- used in the List Editor
- and some additional functions and commands

See “Ctlg menu” on page 172.

Although the **Catlg** menu includes all the programming commands, the Commands menu (Cmds) in the Program Editor contains all the programming commands *grouped by category*. It also contains the Template menu (Tmplt), which contains the common programming structures.

Some functions can be chosen from the math template (displayed by pressing).



You can also create your own functions. See “Creating your own functions” on page 213.

Setting the form of menu items

You can choose to have entries on the Math and CAS menus presented either by their descriptive name or their command name. (The entries on the Catlg menu are always presented by their command name.)

Descriptive name	**Command name**
Factor List	ifactors
Complex Zeros	cZeros
Groebner Basis	gbasis
Factor by Degree	factor_xn
Find Roots	proot

The default menu presentation mode is to provide the descriptive names for the Math and CAS functions. If you prefer the functions to be presented by their command name, deselect the **Menu Display** option on the second page of the **Home Settings** screen.

Abbreviations used in this chapter

In describing the syntax of functions and commands, the following abbreviations and conventions are used:

`Eqn`: an equation

`Expr`: a mathematical expression

`Fnc`: a function

`Frac`: a fraction

`Intgr`: an integer

`Obj`: signifies that objects of more than one type are allowable here

`Poly`: a polynomial

`RatFrac`: a rational fraction

`Val`: a real value

`Var`: a variable

Parameters that are optional are given in square brackets, as in `NORMAL_ICDF([μ,σ,]p)`.

For ease of reading, commas are used to separate parameters, but these are only necessary to separate parameters. Thus a single-parameter command needs no comma after the parameter even if, in the syntax shown below, there is a comma between it and an optional parameter. An example is the syntax `zeros(Expr,[Var])`. The comma is needed only if you are specifying the optional parameter `Var`.

Keyboard functions

The most frequently used functions are available directly from the keyboard. Many of the keyboard functions also accept complex numbers as arguments. Enter the keys and inputs shown below and press Enter = to evaluate the expression.

In the examples below, shifted functions are represented by the actual keys to be pressed, with the function name shown in parentheses. For example, Shift SIN ASIN G (ASIN) means that to make an arc sine calculation (ASIN), you press Shift SIN ASIN G.

The examples below show the results you would get in Home view. If you are in the CAS, the results are given in simplified symbolic format. For example:

Shift x^2 320 returns `17.88854382` in Home view, and 8*√5 in the CAS.

+, −, ×, ÷

Add, subtract, multiply, divide. Also accepts complex numbers, lists, and matrices.

value1 + *value2*, etc.

LN

Natural logarithm. Also accepts complex numbers.

LN(*value*)

Example:

LN`(1)` returns `0`

Shift LN (e^X)

Natural exponential. Also accepts complex numbers.

e^{value}

Example:

e^5 returns `148.413159103`

LOG

Common logarithm. Also accepts complex numbers.

LOG(*value*)

Example:

LOG`(100)` returns `2`

Shift LOG (10^X)

Common exponential (antilogarithm). Also accepts complex numbers.

ALOG(value)

Example:

`ALOG(3)` returns `1000`

SIN COS TAN

Sine, cosine, tangent. Inputs and outputs depend on the current angle format: degrees or radians.

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

Example:

TAN(45) returns 1 (degrees mode)

Shift SIN (ASIN)

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

ASIN(*value*)

Example:

ASIN(1) returns 90 (degrees mode)

Shift COS (ACOS)

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

ACOS(*value*)

Example:

ACOS(1) returns 0 (degrees mode)

Shift TAN (ATAN)

Arc tangent: $\tan^{-1}x$. Output range is from –90° to 90° or –π/2 to π/2. 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 x^2

Square root. Also accepts complex numbers.

√*value*

Example:

√320 returns 17.88854382

x^y

x raised to the power of *y*. Also accepts complex numbers.

$value^{power}$

Example:

2^8 returns 256

Shift x^y

The *n*th root of *x*.

root√*value*

Example:

3√8 returns 2

Shift ÷

Reciprocal.

$value^{-1}$

Example:

3^{-1} returns .333333333333

+/–

Negation. Also accepts complex numbers.

–*value*

Example:

-(1+2*i) returns -1-2*i

Shift +/– (|x|)

Absolute value.

|*value*|
|*x*+*y***i*|

|*matrix*|

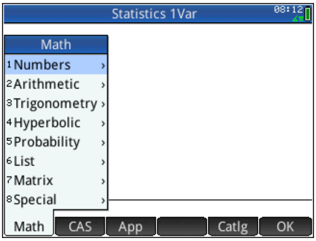
For a complex number, |*x*+*y***i*| returns $\sqrt{x^2+y^2}$. For a matrix, |*matrix*| returns the Frobenius norm of the matrix.

Example:

|-1| returns 1
|(1,2)|returns 2.2360679775

Math menu

Press Mem to open the Toolbox menus (one of which is the Math menu). The functions and commands available on the Math menu are listed as they are categorized on the menu.



Numbers

Ceiling Smallest integer greater than or equal to *value*.

`CEILING(value)`

Examples:

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

Floor Greatest integer less than or equal to *value*.

`FLOOR(value)`

Example:

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

IP Integer part.

`IP(value)`

Example:

`IP(23.2)` returns `23`

FP Fractional part.

`FP(value)`

Example:

`FP (23.2)` returns `.2`

Round Rounds *value* to decimal *places*. Also accepts complex numbers.

`ROUND(value,places)`

`ROUND` can also round to a number of significant digits if *places* is a negative integer (as shown in the second example below).

Examples:

`ROUND(7.8676,2)` returns `7.87`
`ROUND(0.0036757,-3)` returns `0.00368`

Truncate Truncates *value* to decimal *places*. Also accepts complex numbers.

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

`TRUNCATE` can also round to a number of significant digits if *places* is a negative integer (as shown in the second example below).

Examples:

`TRUNCATE(2.3678,2)` returns `2.36`
`TRUNCATE(0.0036757,-3)` returns `0.00367`

Mantissa Mantissa—that is, the significant digits—of *value*, where value is a floating-point number.

```
MANT(value)
```

Example:

`MANT(21.2E34)` returns `2.12`

Exponent Exponent of *value*. That is, the integer component of the power of 10 that generates *value*.

```
XPON(value)
```

Example:

`XPON(123456)` returns `5` (since $10^{5.0915...}$ equals 123456)

Arithmetic

Maximum Maximum. The greater of two values.

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

Example:

`MAX(8/3,11/4)` returns `2.75`

Note that in Home view a non-integer result is given as a decimal fraction. If you want to see the result as a common fraction, press a b/c ≐. This key cycles through decimal, fraction, and mixed number representations. Or, if you prefer, press CAS Settings. This opens the computer algebra system. If you want to return to Home view to make further calculations, press ⌂ Settings.

Minimum Minimum. Returns the least of the values given, or the least value of a list.

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

Example:

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

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

```
value1 MOD value2
```

Example:

`74 MOD 5` returns `4`

Find Root Function root-finder (like the Solve app). 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((A*9.8/600)-1,A,1)` returns `61.2244897959.`

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

```
%(x,y)
```

Example:

`%(20,50)` returns `10`

Complex

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

```
ARG(x+y*i)
```

Example:

`ARG(3+3*i)` returns `45` (degrees mode)

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

```
CONJ(x+y*i)
```

Example:

CONJ(3+4*i) returns (3-4*i)

Real Part Real part x, of a complex number, $(x+y*i)$.

```
RE(x+y*i)
```

Example:

RE(3+4*i) returns 3

Imaginary Part Imaginary part, y, of a complex number, $(x+y*i)$.

```
IM(x+y*i)
```

Example:

IM(3+4*i) returns 4

Unit Vector 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(POLYEVAL([1,2,-25,-26,2],-2)) returns -1
SIGN((3,4)) returns (.6+.8i)

Exponential

ALOG Antilogarithm (exponential).

```
ALOG(value)
```

EXPM1 Exponential minus 1: $e^x - 1$.

```
EXPM1(value)
```

LNP1 Natural log plus 1: $\ln(x+1)$.

```
LNP1(value)
```

Trigonometry

The trigonometry functions can also take complex numbers as arguments. For SIN, COS, TAN, ASIN, ACOS, and ATAN, see “Keyboard functions” on page 101.

CSC Cosecant: 1/sin*x*.

```
CSC(value)
```

ACSC Arc cosecant.

```
ACSC(value)
```

SEC Secant: 1/cos*x*.

```
SEC(value)
```

ASEC Arc secant.

```
ASEC(value)
```

COT Cotangent: cos*x*/sin*x*.

```
COT(value)
```

ACOT Arc cotangent.

```
ACOT(value)
```

Hyperbolic

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

SINH Hyperbolic sine.

```
SINH(value)
```

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

```
ASINH(value)
```

COSH Hyperbolic cosine

```
COSH(value)
```

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

```
ACOSH(value)
```

TANH Hyperbolic tangent.

```
TANH(value)
```

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

```
ATANH(value)
```

Probability

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

```
value!
```

Example:

`5!` returns `120`

Combination The number of combinations (without regard to order) of *n* things taken *r* at a time.

```
COMB(n,r)
```

Example: Suppose you want to know how many ways five things can be combined two at a time.

`COMB(5,2)` returns `10.`

Permutation Number of permutations (with regard to order) of n things taken r at a time: n!/(n–r)!.

```
PERM (n,r)
```

Example: Suppose you want to know how many permutations there are for five things taken two at a time.

`PERM(5,2)` returns `20.`

Random

Number Random number. With no argument, this function returns a random number between zero and one. With one argument *a*, it returns a random number between 0 and *a*. With two arguments, *a*, and *b*, returns *a* random number between *a* and *b*. With three arguments, *n*, *a*, and *b*, returns *n* random number between *a* and *b*.

```
RANDOM
RANDOM(a)
RANDOM(a,b
RANDOM(n,a,b)
```

Integer Random integer. With no argument, this function returns either 0 or 1 randomly. With one integer argument *a*, it returns a random integer between 0 and *a*. With two arguments, *a*, and *b*, returns *a* random integer between *a* and *b*. With three integer arguments, *n*, *a*, and *b*, returns *n* random integers between *a* and *b*.

```
RANDINT
RANDINT(a)
RANDINT(a,b)
RANDINT(n,a,b)
```

Normal Random normal. Generates a random number from a normal distribution.

```
RANDNORM(μ,σ)
```

Example:

`RANDNORM(0,1)` returns a random number from the standard Normal distribution.

Seed Sets the seed value on which the random functions operate. By specifying the same seed value on two or more calculators, you ensure that the same random numbers appear on each calculator when the random functions are executed.

```
RANDSEED(value)
```

Density

Normal Normal probability density function. Computes the probability density at value *x*, given the mean, μ, and standard deviation, σ, of a normal distribution. If only one argument is supplied, it is taken as *x*, and the assumption is that μ=0 and σ=1.

```
NORMALD([μ,σ,]x)
```

Example:

`NORMALD(0.5)` and `NORMALD(0,1,0.5)` both return `0.352065326764.`

T Student’s t probability density function. Computes the probability density of the Student's t-distribution at *x*, given *n* degrees of freedom.

```
STUDENT(n,x)
```

Example:

`STUDENT(3,5.2)` returns `0.00366574413491.`

χ^2 χ^2 probability density function. Computes the probability density of the χ^2 distribution at *x*, given *n* degrees of freedom.

```
CHISQUARE(n,x)
```

Example:

`CHISQUARE(2,3.2)` returns `0.100948258997.`

F Fisher (or Fisher–Snedecor) probability density function. Computes the probability density at the value *x*, given numerator *n* and denominator *d* degrees of freedom.

```
FISHER(n,d,x)
```

Example:

`FISHER(5,5,2)` returns `0.158080231095.`

Binomial Binomial probability density function. Computes the probability of *k* successes out of *n* trials, each with a probability of success of *p*. Returns Comb(n,k) if there is no third argument. Note that *n* and *k* are integers with $k \leq n$.

```
BINOMIAL(n,k,p)
```

Example: Suppose you want to know the probability that just 6 heads would appear during 20 tosses of a fair coin.

`BINOMIAL(20,6,0.5)` returns `0.0369644165039.`

Poisson Poisson probability mass function. Computes the probability of *k* occurrences of an event during a future interval given μ, the mean of the occurrences of that event during that interval in the past. For this function, *k* is a non-negative integer and μ is a real number.

```
POISSON(μ,k)
```

Example: Suppose that on average you get 20 emails a day. What is the probability that tomorrow you will get 15?

`POISSON(20,15)` returns `0.0516488535318.`

Cumulative

Normal Cumulative normal distribution function. Returns the lower-tail probability of the normal probability density function for the value *x*, given the mean, μ, and standard deviation, σ, of a normal distribution. If only one argument is supplied, it is taken as *x*, and the assumption is that μ=0 and σ=1.

```
NORMALD_CDF([μ,σ,]x)
```

Example:

`NORMALD_CDF(0,1,2)` returns `0.977249868052.`

T Cumulative Student's t distribution function. Returns the lower-tail probability of the Student's t-probability density function at *x*, given *n* degrees of freedom.

```
STUDENT_CDF(n,x)
```

Example:

`STUDENT_CDF(3,-3.2)` returns `0.0246659214814.`

χ^2 Cumulative χ^2 distribution function. Returns the lower-tail probability of the χ^2 probability density function for the value *x*, given *n* degrees of freedom.

```
CHISQUARE_CDF(n,k)
```

Example:

`CHISQUARE_CDF(2, 6.3)` returns `0.957147873133.`

F Cumulative Fisher distribution function. Returns the lower-tail probability of the Fisher probability density function for the value *x*, given numerator *n* and denominator *d* degrees of freedom.

```
FISHER_CDF(n,d,x)
```

Example:

`FISHER_CDF(5,5,2)` returns `0.76748868087.`

Binomial Cumulative binomial distribution function. Returns the probability of *k* or fewer successes out of *n* trials, with a probability of success, *p* for each trial. Note that *n* and *k* are integers with $k \leq n$.

```
BINOMIAL_CDF(n,p,k)
```

Example: Suppose you want to know the probability that during 20 tosses of a fair coin you will get either 0, 1, 2, 3, 4, 5, or 6 heads.

`BINOMIAL_CDF(20,0.5,6)` returns `0.05765914917.`

Poisson Cumulative Poisson distribution function. Returns the probability *x* or fewer occurrences of an event in a given time interval, given μ expected occurrences.

```
POISSON_CDF(μ,x)
```

Example:

`POISSON_CDF(4,2)` returns `0.238103305554.`

Inverse

Normal Inverse cumulative normal distribution function. Returns the cumulative normal distribution value associated with the lower-tail probability, *p*, given the mean, μ, and standard deviation, σ, of a normal distribution. If only one argument is supplied, it is taken as *p*, and the assumption is that μ=0 and σ=1.

```
NORMALD_ICDF([μ,σ,]p)
```

Example:

`NORMALD_ICDF(0,1,0.841344746069)` returns `1.`

T Inverse cumulative Student's t distribution function. Returns the value *x* such that the Student's-t lower-tail probability of *x*, with *n* degrees of freedom, is *p*.

```
STUDENT_ICDF(n,p)
```

Example:

`STUDENT_ICDF(3,0.0246659214814)` returns `–3.2.`

χ^2 Inverse cumulative χ^2 distribution function. Returns the value *x* such that the χ^2 lower-tail probability of *x*, with *n* degrees of freedom, is *p*.

```
CHISQUARE_ICDF(n,p)
```

Example:

`CHISQUARE_ICDF(2, 0.957147873133)` returns `6.3.`

F Inverse cumulative Fisher distribution function. Returns the value *x* such that the Fisher lower-tail probability of *x*, with numerator *n* and denominator *d* degrees of freedom, is *p*.

```
FISHER_ICDF(n,d,p)
```

Example:

`FISHER_ICDF(5,5,0.76748868087)` returns `2.`

Binomial Inverse cumulative binomial distribution function. Returns the number of successes, *k,* out of *n* trials, each with a probability of *p,* such that the probability of *k* or fewer successes is *q*.

```
BINOMIAL_ICDF(n,p,q)
```

Example:

`BINOMIAL_ICDF(20,0.5,0.6)` returns `11.`

Poisson Inverse cumulative Poisson distribution function. Returns the value *x* such that the probability of *x* or fewer occurrences of an event, with μ expected (or mean) occurrences of the event in the interval, is *p*.

```
POISSON_ICDF(μ,p)
```

Example:

`POISSON_ICDF(4,0.238103305554)` returns `3.`

List

These functions work on data in a list. For more information, see the Lists chapter of the *Prime Calculator User Guide*.

Matrix

These functions work on matrix data stored in matrix variables. For more information, see the Matrices chapter of the *Prime Calculator User Guide*.

Special

Beta Returns the value of the beta function (B) for two numbers *a* and *b*.

```
Beta(a,b)
```

Gamma Returns the value of the gamma function (Γ) for a number *a*.

```
Gamma(a)
```

Psi Returns the value of the *n*th derivative of the digamma function at *x*=*a*, where the digamma function is the first derivative of ln(Γ(*x*)).

```
Psi(a,n)
```

Zeta Returns the value of the zeta function (Z) for a real *x*.

```
Zeta(x)
```

erf Returns the floating point value of the error function at *x*=*a*.

```
erf(a)
```

erfc Returns the value of the complementary error function at *x*=*a*.

```
erfc(a)
```

Ei Returns the exponential integral of an expression.

```
Ei(Expr)
```

Si Returns the sine integral of an expression.

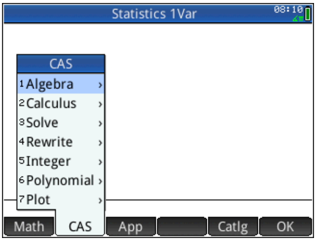
```
Si(Expr)
```

Ci Returns the cosine integral of an expression.

```
Ci(Expr)
```

CAS menu

Press to open the Toolbox menus (one of which is the CAS menu). The functions on the CAS menu are those most commonly used. Many more functions are available. See “Ctlg menu”, beginning on page 172.



Note that the Geometry functions appear on the App menu.

The result of a CAS command may vary depending on the CAS settings. The examples in this chapter assume the default CAS settings unless otherwise noted.

Algebra

Simplify

Returns an expression simplified.

```
simplify(Expr)
```

Example:

`simplify(4*atan(1/5)-atan(1/239))` yields `(1/4)*pi`

Collect

Collects like terms in a polynomial expression (or in a list of polynomial expressions). Factorizes the results, depending on the CAS settings.

`collect(Poly)` or `collect({Poly1, Poly2,..., Polyn})`

Examples:

`collect(x+2*x+1-4)` returns `3*x-3`

`collect(x^2-9*x+5*x+3+1)` returns `(x-2)^2`

Expand

Returns an expression expanded.

```
expand(Expr)
```

Example:

`expand((x+y)*(z+1))` gives `y*z+x*z+y+x`

Factor

Returns a polynomial factorized.

```
factor(Poly)
```

Example:

`factor(x^4-1)` gives `(x-1)*(x+1)*(x^2+1)`

Substitute Substitutes a value for a variable in an expression.

```
Syntax: subst(Expr,Var=value)
```

Example:

`subst(x/(4-x^2),x=3)` returns `-3/5`

Partial Fraction Performs partial fraction decomposition on a fraction.

```
partfrac(RatFrac or Opt)
```

Example:

`partfrac(x/(4-x^2))` returns `(-1/2)/(x-2)-(1/2)/((x+2)`

Extract

Numerator Simplified Numerator. For the integers a and b, returns the numerator of the fraction a/b after simplification.

```
numer(a/b)
```

Example:

`numer(10/12)` returns `5`

Denominator Simplified Denominator. For the integers a and b, returns the denominator of the fraction a/b after simplification.

```
denom(a/b)
```

Example:

`denom(10/12)` returns `6`

Left Side Returns the left side of an equation or the left end of an interval.

```
left(Expr1=Expr2) or left(Real1..Real2)
```

Example:

`left(x^2-1=2*x+3)` returns `x^2-1`

Right Side Returns the right side of an equation or the right end of an interval.

`right(Expr1=Expr2)` or `right(Real1..Real2)`

`Example:`

`right(x^2-1=2*x+3)` returns `2*x+3`

Calculus

Differentiate With one expression as argument, returns derivative of the expression with respect to *x*. With one expression and one variable as arguments, returns the derivative or partial derivative of the expression with respect to the variable. With one expression and more than one variable as arguments, returns the derivative of the expression with respect to the variables in the second argument. These arguments can be followed by $*k* (*k* is an integer) to indicate the number of times the expression should be derived with respect to the variable. For example, diff(exp(x*y),x$3,y$2,z) is the same as diff(exp(x*y),x,x,x,y,y,z).

```
diff(Expr,[var])
```

or

```
diff(Expr,var1$k1,var2$k2,...)
```

Example:

`diff(x^3-x)` gives `3*x^2-1`

Integrate Returns the indefinite integral of an expression. With one expression as argument, returns the indefinite integral with respect to *x*. With the optional second, third and fourth arguments you can specify the variable of integration and the bounds of the integrate.

```
int(Expr,[Var(x)],[Real(a)],[Real(b)])
```

Example:

`int(1/x)` gives `ln(abs(x))`

Limit Returns the limit of an expression when the variable approaches a limit point *a* or +/– infinity. With the optional fourth argument you can specify whether it is the limit from below, above or bidirectional (–1 for limit from below, +1 for limit from above, and 0 for bidirectional limit). If the fourth argument is not provided, the limit returned is bidirectional.

```
limit(Expr,Var,Val,[Dir(1, 0, -1)])
```

Example:

`limit((n*tan(x)-tan(n*x))/(sin(n*x)-n*sin(x)),x,0)` gives `2`

Series Returns the series expansion of an expression in the vicinity of a given equality variable. With the optional third and fourth arguments you can specify the order and direction of the series expansion. If no order is specified the series returned is fifth order. If no direction is specified, the series is bidirectional.

```
series(Expr,Equal(var=limit_point),[Order],[Dir(1,0,-1)])
```

Example:

`series((x^4+x+2)/(x^2+1),x=0,5)` gives `2+x-2x^2-x^3+3x^4+x^5+x^6*order_size(x)`

Summation Returns the discrete sum of Expr with respect to the variable Var from Real1 to Real2. You can also use the summation template in the Template menu. With only the first two arguments, returns the discrete antiderivative of the expression with respect to the variable.

```
sum(Expr,Var,Real1, Real2,[Step])
```

Example:

`sum(n^2,n,1,5)` returns `55`

Differential

Curl Returns the rotational curl of a vector field. Curl([A B C], [x y z]) is defined to be [dC/dy-dB/dz dA/dz-dC/dx dB/dx-dA/dy].

```
curl([Expr1, Expr2, …, ExprN], [Var1, Var2, …, VarN])
```

Example:

`curl([2*x*y,x*z,y*z],[x,y,z])` returns `[z-x,0,z-2*x]`

Divergence Returns the divergence of a vector field, defined by:

divergence([A,B,C],[x,y,z])=dA/dx+dB/dy+dC/dz.

```
divergence([Expr1, Expr2, …, ExprN], [Var1, Var2, …, VarN])
```

Example:

`divergence([x^2+y,x+z+y,z^3+x^2],[x,y,z])` gives `2*x+3*z^2+1`

Gradient Returns the gradient of an expression. With a list of variables as second argument, returns the vector of partial derivatives.

```
grad(Expr,LstVar)
```

Example:

`grad(2*x^2*y-x*z^3,[x,y,z])` gives `[2*2*x*y-z^3,2*x^2,-x*3*z^2]`

Hessian Returns the Hessian matrix of an expression.

```
hessian(Expr,LstVar)
```

Example:

`hessian(2*x^2*y-x*z,[x,y,z])` gives `[[4*y,4*x,-1],[2*2*x,0,0],[-1,0,0]]`

Integral

By Parts u Performs integration by parts of the expression f(x)=u(x)*v'(x), with f(x) as the first argument and u(x) (or 0) as the second argument. Specifically, returns a vector whose first element is u(x)*v(x) and whose second element is v(x)*u'(x). With the optional third, fourth and fifth arguments you can specify a variable of integration and bounds of the integration. If no variable of integration is provided, it is taken as x.

```
ibpu(f(Var), u(Var), [Var], [Real1],
[Real2])
```

Example:

`ibpu(x*ln(x), x)` returns `[x*(x*ln(x) -x*ln(x)+x]`

By Parts v Performs integration by parts of the expression f(x)=u(x)*v'(x), with f(x) as the first argument and v(x) (or 0) as the second argument. Specifically, returns a vector whose first element is u(x)*v(x) and whose second element is v(x)*u'(x). With the optional third, fourth and fifth arguments you can specify a variable of integration and bounds of the integration. If no variable of integration is provided, it is taken as x.

```
ibpdv(f(Var), v(Var), [Var], [Real1],
[Real2])
```

Example:

`ibpdv(ln(x),x)` gives `x*ln(x)-x`

F(b)–F(a) Returns F(*b*)–F(*a*).

```
preval(Expr(F(var)),Real(a),Real(b),[Var])
```

Example:

`preval(x^2-2,2,3)` gives `5`

Limits

Riemann Sum Returns an equivalent of the sum of Expr for var2 from var2=1 to var2=var1 (in the neighborhood of *n*=+∞) when the sum is looked at as a Riemann sum associated with a continuous function defined on [0,1].

```
sum_riemann(Expr, [Var1 Var2])
```

Example:

`sum_riemann(1/(n+k),[n,k])` gives `ln(2)`

Taylor Returns the Taylor series expansion of an expression at a point or at infinity (by default, at x=0 and with relative order=5).

```
taylor(Expr,[Var=Value],[Order])
```

Example:

`taylor(sin(x)/x,x=0)` returns `1-(1/6)*x^2+(1/120)*x^4+x^6*order_size(x)`

Taylor of Quotient Returns the n-degree Taylor polynomial for the quotient of 2 polynomials.

```
divpc(Poly1,Poly2,Integer)
```

Example:

`divpc(x^4+x+2,x^2+1,5)` returns the 5th-degree polynomial `x^5+3*x^4-x^3-2*x^2+x+2`

Transform

Laplace Returns the Laplace transform of an expression.

```
laplace(Expr,[Var],[LapVar])
```

Example:

`laplace(exp(x)*sin(x))` gives `1/(x^2-2*x+2)`

Inverse Laplace Returns the inverse Laplace transform of an expression.

```
ilaplace(Expr,[Var],[IlapVar])
```

Example:

`ilaplace(1/(x^2+1)^2)` returns `((-x)*cos(x))/2+sin(x)/2`

FFT With one argument (a vector), returns the discrete Fourier transform in R.

```
fft(Vect)
```

With two additional integer arguments a and p, returns the discrete Fourier transform in the field Z/pZ, with a as primitive nth root of 1 (n=size(vector)).

```
fft((Vector, a, p)
```

Example:

`fft([1,2,3,4,0,0,0,0])` gives `[10.0,-0.414213562373-7.24264068712*(i),-2.0+2.0*i,2.41421356237-1.24264068712*i,-2.0,2.41421356237+1.24264068712*i,-2.0-2.0*i]`

Inverse FFT Returns the inverse discrete Fourier transform.

```
ifft(Vector)
```

Example:

`ifft([100.0,-52.2842712475+6*i,-8.0*i,4.28427124746-6*i,4.0,4.28427124746+6*i,8*i,-52.2842712475-6*i])` gives `[0.99999999999,3.99999999999,10.0,20.0,25.0,24.0,16.0,-6.39843733552e-12]`

Solve

Solve Returns a list of the solutions (real and complex) to a polynomial equation or a set of polynomial equations.

```
solve(Eq,[Var]) or solve({Eq1, Eq2,…},
[Var])
```

Examples:

`solve(x^2-3=1)` returns `{-2,2}`

`solve({x^2-3=1, x+2=0},x)` returns `{-2}`

Zeros With an expression as argument, returns the real zeros of the expression; that is, the solutions when the expression is set equal to zero.

With a list of expressions as argument, returns the matrix where the rows are the real solutions of the system formed by setting each expression equal to zero.

```
zeros(Expr,[Var]) or zeros({Expr1,
Expr2,…},[{Var1, Var2,…}])
```

Example:

`zeros(x^2-4)` returns `[-2  2]`

Complex Solve Returns a list of the complex solutions to a polynomial equation or a set of polynomial equations.

```
cSolve(Eq,[Var])
```

or

```
cSolve({Eq1, Eq2,…}, [Var])
```

Example:

`cSolve(x^4-1=0, x)` returns `{1  -1  -i  i}`

Complex Zeros With an expression as argument, returns a vector containing the complex zeros of the expression; that is, the solutions when the expression is set equal to zero.

With a list of expressions as argument, returns the matrix where the rows are the complex solutions of the system formed by setting each expression equal to zero.

```
cZeros(Expr,[Var]
```

or

```
cZeros({Expr1, Expr2,…},[{Var1, Var2,…}])
```

Example:

`cZeros(x^4-1)` returns `[1  -1  -i  i]`

Numerical Solve Returns the numerical solution of an equation or a system of equations.

```
nSolve(Eq,Var) or nSolve(Expr, Var=Guess)
```

Example:

`nSolve(cos(x)=x,x=1.3)` gives `0.739085133215`

Differential Equation

Returns the solution to a differential equation.

```
deSolve(Eq,[TimeVar],Var)
```

Example:

`desolve(y''+y=0,y)` returns `G_0*cos(x)+G_1*sin(x)`

ODE Solve

Ordinary Differential Equation solver. Solves an ordinary differential equation given by Expr, with variables declared in VectrVar and initial conditions for those variables declared in VectrInit. For example, odesolve(f(t,y),[t,y],[t0,y0],t1) returns the approximate solution of y'=f(t,y) for the variables t and y with initial conditions t=t0 and y=y0.

```
odesolve(Expr,VectVar,VectInitCond,Final
Val,[tstep=Val,curve])
```

Example:

`odesolve(sin(t*y),[t,y],[0,1],2)` returns `[1.82241255674]`

Linear System

Given a vector of linear equations and a corresponding vector of variables, returns the solution to the system of linear equations.

```
linsolve([LinEq1, LinEq2,…], [Var1,
Var2,…])
```

Example:

`linsolve([x+y+z=1,x-y=2,2*x-z=3],[x,y,z])` returns `[3/2,-1/2,0]`

Rewrite

lncollect

Rewrites an expression with the logarithms collected. Applies ln(*a*)+*n**ln(*b*) = ln(*a***b*^*n*) for an integer *n*.

```
lncollect(Expr)
```

Example:

`lncollect(ln(x)+2*ln(y))` returns `ln(x*y^2)`

powexpand

Rewrites an expression containing a power that is a sum or product as a product of powers. Applies *a*^(*b*+*c*)=(*a*^*b*)*(*a*^*c*).

```
powexpand(Expr)
```

Example:

`powexpand(2^(x+y))` yields `(2^x)*(2^y)`

texpand Expands a transcendental expression.

```
texpand(Expr)
```

Example:

`texpand(sin(2*x)+exp(x+y))` returns `exp(x)*exp(y)+2*cos(x)*sin(x))`

Exp & Ln

$e^{y*\ln x}$ → x^y Returns an expression of the form $e^{n*\ln(x)}$ rewritten as a power of x. Applies $e^{n*\ln(x)}=x^n$.

```
exp2pow(Expr)
```

Example:

`exp2pow(exp(3*ln(x)))` gives `x^3`

x^y → $e^{y*\ln x}$ Returns an expression with powers rewritten as an exponential. Essentially the inverse of `exp2pow`.

```
pow2exp(Expr)
```

Example:

`pow2exp(a^b)` gives `exp(b*ln(a))`

exp2trig Returns an expression with complex exponentials rewritten in terms of sine and cosine.

```
exp2trig(Expr)
```

Example:

`exp2trig(exp(i*x))` gives `cos(x)+(i)*sin(x)`

expexpand Returns an expression with exponentials in expanded form.

```
expexpand(Expr)
```

Example:

`expexpand(exp(3*x))` gives `exp(x)^3`

Sine

asinx → acosx Returns an expression with asin(*x*) rewritten as π/2– acos(*x*).

```
asin2acos(Expr)
```

Example:

`asin2acos(acos(x)+asin(x))` returns `π/2`

asinx → atanx Returns an expression with asin(*x*) rewritten as:

$$\text{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

```
asin2atan(Expr)
```

Example:

`asin2atan(2*asin(x))` returns

$$2\cdot\text{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

sinx → cosx*tanx Returns an expression with sin(*x*) rewritten as cos(*x*)*tan(*x*).

```
sin2costan(Expr)
```

Example:

`sin2costan(sin(x))` gives `tan(x)*cos(x)`

Cosine

acosx → asinx Returns an expression with acos(*x*) rewritten as π/2–asin(*x*).

```
acos2asin(Expr)
```

Example:

`acos2asin(acos(x)+asin(x))` returns `π/2`

acosx → atanx Returns an expression with acos(*x*) rewritten as:

$$\frac{\pi}{2}-\text{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

```
acos2atan(Expr)
```

Example:

`acos2atan(2*acos(x))` gives

$$2\cdot\left(\frac{\pi}{2}-\text{atan}\left(\frac{x}{\sqrt{1-x^2}}\right)\right)$$

cosx → sinx/tanx Returns an expression with cos(*x*) rewritten as sin(*x*)/tan(*x*).

```
cos2sintan(Expr)
```

Example:

`cos2sintan(cos(x))` gives `sin(x)/tan(x)`

Tangent

atanx → asinx Returns an expression with atan(*x*) rewritten as:

$$\operatorname{asin}\left(\frac{x}{\sqrt{1-x^2}}\right)$$

```
atan2asin(Expr)
```

Example:

`atan2asin(atan(2*x))` returns

$$\operatorname{asin}\left(\frac{2\cdot x}{\sqrt{1-(2\cdot x)^2}}\right)$$

atanx → acosx Returns an expression with atan(*x*) rewritten as:

$$\frac{\pi}{2}-\operatorname{acos}\left(\frac{x}{\sqrt{1+x^2}}\right)$$

```
atan2acos(Expr)
```

tanx → sinx/cosx Returns an expression with tan(*x*) rewritten as sin(*x*)/cos(*x*).

```
tan2sincos(Expr)
```

Example:

`tan2sincos(tan(x))` gives `sin(x)/cos(x)`

halftan Returns an expression with sin(*x*), cos(*x*) or tan(*x*) rewritten as tan(*x*/2).

```
halftan(Expr)
```

Example:

`halftan(sin(x))` returns $\dfrac{2\cdot\tan\left(\frac{x}{2}\right)}{\tan\left(\frac{x}{2}\right)^2+1}$

Trig

trigx → sinx Returns an expression simplified using the formulas sin(x)^2+cos(x)^2=1 and tan(x)=sin(x)/cos(x). Sin(x) is given precedence over cos(x) and tan(x) in the result.

```
trigsin(Expr)
```

Example:

`trigsin(cos(x)^4+sin(x)^2)` returns `sin(x)^4-sin(x)^2+1`

trigx → cosx Returns an expression simplified using the formulas sin(x)^2+cos(x)^2=1 and tan(x)=sin(x)/cos(x). Cos(x) is given precedence over sin(x) and tan(x) in the result.

```
trigcos(Expr)
```

Example:

`trigcos(sin(x)^4+sin(x)^2)` returns `cos(x)^4-3*cos(x)^2+2`

trigx → tanx Returns an expression simplified using the formulas sin(x)^2+cos(x)^2=1 and tan(x)=sin(x)/cos(x). Tan(x) is given precedence over sin(x) and cos(x) in the result.

```
trigtan(Expr)
```

Example:

`trigtan(cos(x)^4+sin(x)^2)` returns `(tan(x)^4+tan(x)^2+1)/(tan(x)^4+2*tan(x)^2+1)`

atrig2ln Returns an expression with inverse trigonometric functions rewritten using the natural logarithm function.

```
atrig2ln(Expr)
```

Example:

`atrig2ln(atan(x))` returns $\frac{i}{2}\cdot\ln\frac{(i+x)}{(i-x)}$

tlin Returns a trigonometric expression with the products and integer powers linearized.

```
tlin(ExprTrig)
```

Example:

`tlin(sin(x)^3)` gives $\frac{3}{4}\cdot\sin(x)-\frac{1}{4}\cdot\sin(3\cdot x)$

tcollect Returns a trigonometric expression linearized and with any sine and cosine terms of the same angle collected together.

```
tcollect(Expr)
```

Example:

`tcollect(sin(x)+cos(x))` returns

$\sqrt{2}\cdot\cos\left(x-\frac{1}{4}\cdot\pi\right)$

trigexpand Returns a trigonometric expression in expanded form.

```
trigexpand(Expr)
```

Example:

`trigexpand(sin(3*x))` gives `(4*cos(x)^2-1)*sin(x)`

trig2exp Returns an expression with trigonometric functions rewritten as complex exponentials (without linearization).

```
trig2exp(Expr)
```

Example:

`trig2exp(sin(x))` returns

$$\frac{-i}{2}\cdot\left(\exp(i\cdot x)-\frac{1}{\exp(i\cdot x)}\right)$$

Integer

Divisors Returns the list of divisors of an integer or a list of integers.

```
idivis(Integer)
```

or

```
idivis({Intgr1, Intgr2,…})
```

Example:

`idivis(12)` returns `[1, 2, 3, 4, 6, 12]`

Factors Returns the prime factor decomposition of an integer.

```
ifactor(Integer)
```

Example:

With the CAS setting `Simplify` set to `None`, `ifactor(150)` returns `2*3*5^2`

Factor List Returns a vector containing the prime factors of an integer or a list of integers, with each factor followed by its multiplicity.

```
ifactors(Integer)
```

or

```
ifactors({Intgr1, Intgr2,…})
```

Example:

`ifactors(150)` returns `[2, 1, 3, 1, 5, 2]`

GCD Returns the greatest common divisor of two or more integers.

`gcd(Intgr1, Intgr2,…)`

Example:

`gcd(32,120,636)` returns `4`

LCM Returns the least common multiple of two or more integers.

`lcm(Intgr1, Intgr2,…)`

Example:

`lcm(6,4)` returns `12`

Prime

Test if Prime Tests whether or not a given integer is a prime number.

`isPrime(Integer)`

Example:

`isPrime(19999)` returns `false`

Nth Prime Returns the *n*th prime number.

`ithprime(Intg(n))` where `n` is between 1 and 200,000

Example:

`ithprime(5)` returns `11`

Next Prime Returns the next prime or pseudo-prime after an integer.

`nextprime(Integer)`

Example:

`nextprime(11)` returns `13`

Previous Prime Returns the prime or pseudo-prime number closest to but smaller than an integer.

`prevprime(Integer)`

Example:

`prevprime(11)` returns `7`

Euler Compute’s Euler's totient for an integer.

`euler(Integer)`

Example:

`euler(6)` returns `2`

Division

Quotient Returns the integer quotient of the Euclidean division of two integers.

```
iquo(Intgr1, Intgr2)
```

Example:

`iquo(63, 23)` returns `2`

Remainder Returns the integer remainder from the Euclidean division of two integers.

```
irem(Intgr1, Intgr2)
```

Example:

`irem(63, 23)` returns `17`

a^n MOD p For the three integers *a*, *n*, and *p*, returns a^n modulo *p* in [0, *p*–1].

```
powmod(a, n, p,[Expr],[Var])
```

Example:

`powmod(5,2,13)` returns `12`

Chinese Remainder Integer Chinese Remainder Theorem for two equations. Takes two vectors of integers, [a p] and [b q], and returns a vector of two integers, [r n] such that x ≡ r mod n. In this case, x is such that x ≡ a mod p and x ≡ b mod q; also n=p*q.

```
ichinrem([a,p],[b,q])
```

Example:

`ichinrem([2, 7], [3, 5])` returns `[-12, 35]`

Polynomial

Find Roots Given a polynomial in x (or a vector containing the coefficients of a polynomial), returns a vector containing its roots.

`proot(Poly)` or `proot(Vector)`

Example:

`proot([1,0,-2])` returns
`[-1.41421356237,1.41421356237]`

Coefficients Given a polynomial in x, returns a vector containing the coefficients. If the polynomial is in a variable other than x, then declare the variable as the second argument. With an integer as the optional third argument, returns the coefficient of the polynomial whose degree matches the integer.

```
coeff(Poly, [Var], [Integer])
```

Examples:

`coeff(x^2-2)` returns `[1 0 -2]`

`coeff(y^2-2, y, 1)` returns `0`

Divisors Given a polynomial, returns a vector containing the divisors of the polynomial.

```
divis(Poly) or divis({Poly1, Poly2,…})
```

Example:

`divis(x^2-1)` returns `[1  -1+x  1+x  (-1+x)*(1+x)]`

Factor List Returns a vector containing the prime factors of a polynomial or a list of polynomials, with each factor followed by its multiplicity.

```
factors(Poly) or factors({Poly1,
Poly2,…})
```

Example:

`factors(x^4-1)` returns [x-1 1 x+1 1 x^2+1 1]

GCD Returns the greatest common divisor of two or more polynomials.

```
gcd(Poly1,Poly2...)
```

Example:

`gcd(x^4-1, x^2-1)` returns `x^2-1`

LCM Returns the least common multiple of two or more polynomials.

```
lcm(Poly1, Poly2,…)
```

Example:

`lcm(x^2-2*x+1,x^3-1)` gives `(x-1)*(x^3-1)`

Create

Poly to Coef Given a polynomial, returns a vector containing the coefficients of the polynomial. With a variable as second argument, returns the coefficients of a polynomial with respect to the variable. With a list of variables as the second argument, returns the internal format of the polynomial.

```
symb2poly(Expr,[Var])
```

or

```
symb2poly(Expr, {Var1, Var2,…})
```

Example:

`symb2poly(x*3+2.1)` returns `[3  2.1]`

Coef to Poly With one vector as argument, returns a polynomial in *x* with coefficients (in decreasing order) obtained from the argument vector. With a variable as second argument, returns a similar polynomial in that variable.

```
poly2symb(Vector, [Var]))
```

Example:

`poly2symb([1,2,3],x)` returns `(x+2)*x+3`

Roots to Coef Returns a vector containing the coefficients (in decreasing order) of the univariate polynomial whose roots are specified in the argument vector.

```
pcoef(List)
```

Example:

`pcoeff({1,0,0,0,1})` returns `[1 -2 1 0 0 0]`

Roots to Poly Takes as argument a vector. The vector contains each root or pole of a rational function. Each root or pole is followed by its order, with poles having negative order. Returns the rational function in x that has the roots and poles (with their orders) specified in the argument vector.

`fcoeff(Vector)` where `Vector` has the form `[Root1, Oder1, Root2, Order2, …])`

Example:

`fcoeff([1,2,0,1,3,-1])` returns `(x-1)^2*x*(x-3)^-1`

Random

Returns a vector of the coefficients of a polynomial of degree `Integer` and where the coefficients are random integers in the range –99 through 99 with uniform distribution or in an interval specified by `Interval`. Use with poly2symbol to create a random polynomial in any variable.

`randpoly(Integer, Interval, [Dist])`, where `Interval` is of the form `Real1..Real2`.

Example:

`randpoly(t, 8, -1..1)` returns a vector of 9 random integers, all of them between –1 and 1.

Minimum

With only a matrix as argument, returns the minimal polynomial in *x* of a matrix written as a list of its coefficients. With a matrix and a variable as arguments, returns the minimum polynomial of the matrix written in symbolic form with respect to the variable.

```
pmin(Mtrx,[Var])
```

Example:

`pmin([[1,0],[0,1]],x)` gives `x-1`

Algebra

Quotient

Returns a vector containing the coefficients of the Euclidean quotient of two polynomials. The polynomials may be written as a list of coefficients or in symbolic form.

```
quo(List1, List2, [Var])
```

or

```
quo(Poly1, Poly2, [Var])
```

Example:

`quo({1, 2, 3, 4}, {-1, 2})` returns `[-1  -4  -11]`

Remainder

Returns a vector containing the coefficients of the remainder of the Euclidean quotient of two polynomials. The polynomials may be written as a list of coefficients or in symbolic form.

```
rem(List1, List2, [Var])
```

or

```
rem(Poly1, Poly2, [Var])
```

Example:

`rem({1, 2, 3, 4}, {-1, 2})` returns `[26]`

Degree Returns the degree of a polynomial.

```
degree(Poly)
```

Example:

`degree(x^3+x)` gives `3`

Factor by Degree For a given polynomial in *x* of degree *n*, factors out x^n and returns the resulting product.

```
factor_xn(Poly)
```

Example:

`factor_xn(x^4-1)` gives `x^4*(1-x^-4)`

Coef. GCD Returns the greatest common divisor (GCD) of the coefficients of a polynomial.

```
content(Poly,[Var])
```

Example:

`content(2*x^2+10*x+6)` gives `2`

Zero Count If *a* and *b* are real, this returns the number of sign changes in the specified polynomial in the interval [*a*,*b*]. If *a* or *b* are non-real, it returns the number of complex roots in the rectangle bounded by *a* and *b*. If *Var* is omitted, it is assumed to be *x*.

```
sturmab(Poly[,Var],a,b)
```

Examples:

`sturmab(x^2*(x^3+2),-2,0)` returns `1`

`sturmab(n^3-1,n,-2-i,5+3i)` returns `3`

Chinese Remainder Given two matrices whose two rows each contain the coefficients of polynomials, returns the Chinese remainder of the polynomials, also written as a matrix.

```
chinrem(Matrix1,Matrix2)
```

Example:

`chinrem` $\left(\begin{bmatrix}1&2&0\\1&0&1\end{bmatrix},\begin{bmatrix}1&1&0\\1&1&1\end{bmatrix}\right)$ returns

```
[[2  2  1] [1  1  2  1  1]]
```

Special

Cyclotomic Returns the list of coefficients of the cyclotomic polynomial of an integer.

```
cyclotomic(Integer)
```

Example:

`cyclotomic(20)` gives [1 0 –1 0 1 0 –1 0 1]

Groebner Basis Given a vector of polynomials and a vector of variables, returns the Groebner basis of the ideal spanned by the set of polynomials.

```
gbasis([Poly1  Poly2…], [Var1  Var2…])
```

Example:

`gbasis([x^2-y^3,x+y^2],[x,y])` returns `[y^4-y^3,x+y^2]`

Groebner Remainder Given a polynomial and both a vector of polynomials and a vector of variables, returns the remainder of the division of the polynomial by the Groebner basis of the vector of polynomials.

```
greduce(Poly1, [Poly2  Poly3 …], [Var1
Var2…])
```

Example:

`greduce(x*y-1,[x^2-y^2,2*x*y-y^2,y^3],[x,y])` returns `1/2*y^2-1`

Hermite Returns the Hermite polynomial of degree *n,* where *n* is an integer less than 1556.

```
hermite(Integer)
```

Example:

`hermite(3)` gives `8*x^3-12*x`

Lagrange Given a vector of abscissas and a vector of ordinates, returns the Lagrange polynomial for the points specified in the two vectors. This function can also take a matrix as argument, with the first row containing the abscissas and the second row containing the ordinates.

```
lagrange([X1 X2…], [Y1  Y2…]))
```

or

$$\texttt{lagrange}\left(\begin{bmatrix} X1 & X2 & ... \\ Y1 & Y2 & ... \end{bmatrix}\right)$$

Example:

`lagrange([1,3],[0,1])` gives `(x-1)/2`

Laguerre Given an integer *n*, returns the Laguerre polynomial of degree *n.*

```
laguerre(Integer))
```

Example:

`laguerre(4)` returns `1/24*a^4+(-1/6)*a^3*x+5/12*a^3+1/4*a^2*x^2+(-3/2)*a^2*x+35/24*a^2+(-1/6)*a*x^3+7/4*a*x^2+(-13/3)*a*x+25/12*a+1/24*x^4+(-2/3)*x^3+3*x^2-4*x+1`

Legendre Given an integer *n*, returns the Legendre polynomial of degree *n.*

```
legendre(Integer)
```

Example:

`legendre(4)` returns $\frac{35}{8} \cdot x^4 + \frac{15}{4} \cdot x^2 + \frac{3}{8}$

Chebyshev Tn Given an integer *n*, returns the Tchebyshev polynomial (of the first kind) of degree *n*.

```
tchebyshev1(Integer)
```

Example:

`tchebyshev1(3)` gives `4*x^3-3*x`

Chebyshev Un Given an integer *n*, returns the Tchebyshev polynomial (of the second kind) of degree *n*.

```
tchebyshev2(Integer)
```

Example:

`tchebyshev2(3)` gives `8*x^3-4*x`

Plot

Function Used to define a function graph in the Symbolic view of the Geometry app. Plots the graph of an expression written in terms of the independent variable *x*. Note that the variable is lowercase.

```
plotfunc(Expr)
```

Example:

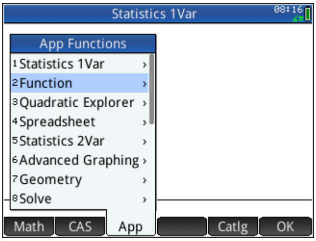
`plotfunc(3*sin(x))` draws the graph of y=3*sin(x)

Contour Used to define a contour graph in the Symbolic view of the Geometry app. Given an expression in *x* and *y*, as well as a list of variables and a list of values, plots the contour graph of the surface *z*=f(*x*,*y*). Specifically, plots the contour lines z1, z2, etc. defined by the list of values.

Example:

`plotcontour(x^2+2*y^2-2, {x, y}, {2, 4, 6})` draws the three contour lines of z=x^2+2*y^2–2 for z=2, z=4, and z=6.

App menu



Press to open the Toolbox menus (one of which is the App menu). App functions are used in HP apps to perform common calculations. For example, in the Function app, the Plot view **Fcn** menu has a function called `SLOPE` that calculates the slope of a given function at a given point. The `SLOPE` function can also be used from the Home view or a program to give the same results. The app functions described in this section are grouped by app.

Function app functions

The Function app functions provide the same functionality found in the Function app's Plot view under the FCN menu. All these operations work on functions. The functions may be expressions in X or the names of the Function app variables F0 through F9.

AREA

Area under a curve or between curves. Finds the signed area under a function or between two functions. Finds the area under the function Fn or below Fn and above the function Fm, from lower X-value to upper X-value.

```
AREA(Fn,[Fm,]lower,upper)
```

Example:

`AREA(-X,X`^{2}`-2,-2,1)` returns `4.5`

EXTREMUM

Extremum of a function. Finds the extremum (if one exists) of the function Fn that is closest to the X-value guess.

```
EXTREMUM(Fn, guess)
```

Example:

`EXTREMUM(X`^{2}`-X-2,0)` returns `0.5`

ISECT

Intersection of two functions. Finds the intersection (if one exists) of the two functions Fn and Fm that is closest to the X-value guess.

```
ISECT(Fn,Fm,guess)
```

Example:

`ISECT(X,3-X,2)` returns `1.5`

ROOT

Root of a function. Finds the root of the function Fn (if one exists) that is closest to the X-value guess.

```
ROOT(Fn,guess)
```

Example:

`ROOT(3-X`^{2}`,2)` returns `1.732...`

SLOPE

Slope of a function. Returns the slope of the function Fn at the X-value (if the function’s derivative exists at that value).

```
SLOPE(Fn,value)
```

Example:

`SLOPE(3-X`^{2}`,2)` returns `-4`

Solve app functions

The Solve app has a single function that solves a given equation or expression for one of its variables. *En* may be an equation or expression, or it may be the name of one of the Solve Symbolic variables E0–E9.

SOLVE

Solve. Solves an equation for one of its variables. Solves the equation *En* for the variable *var*, using the value of *guess* as the initial value for the value of the variable *var*. If *En* is an expression, then the value of the variable *var* that makes the expression equal to zero is returned.

```
SOLVE(En,var,guess)
```

Example:

`SOLVE(X`^{2}`-X-2,X,3)` returns `2`

This function also returns an integer that is indicative of the type of solution found, as follows:

`0`—an exact solution was found

`1`—an approximate solution was found

`2`—an extremum was found that is as close to a solution as possible

`3`—neither a solution, an approximation, nor an extremum was found

Spreadsheet app functions

The spreadsheet app functions can be selected from the App Toolbox menu: press Mem B, tap App and select `Spreadsheet`. They can also be selected from the View menu (View Copy) when the Spreadsheet app is open.

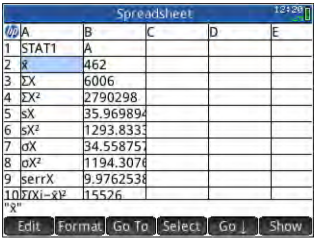
The syntax for many, but not all, the spreadsheet functions follows this pattern:

```
functionName(input,[optional
parameters])
```

`Input` is the input list for the function. This can be a cell range reference, a simple list or anything that results in a list of values.

One useful optional parameter is `Configuration`. This is a string that controls which values are output. Leaving the parameter out produces the default output. The order of the values can also be controlled by the order that they appear in the string.

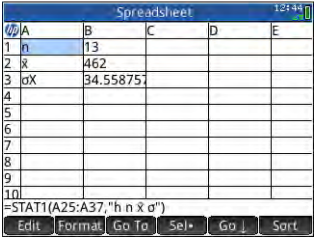
For example: `=STAT1(A25:A37)` produces the following default output, based on the numerical values in cells A25 through A37.



	A	B	C	D	E
1	STAT1	A			
2	x̄	462			
3	ΣX	6006			
4	ΣX^2	2790298			
5	sX	35.969894			
6	sX^2	1293.8333			
7	σX	34.558757			
8	σX^2	1194.3076			
9	serrX	9.9762538			
10	$\Sigma(Xi-\bar{x})^2$	15526			

"x̄"

However, if you just wanted to see the number of data-points, the mean, and the standard deviation, you would enter `=STAT1(A25:A37,”h n x̄ σ”)`. What the configuration string is indicating here is that row headings are required (h), but just return the number of data-points (n), the mean ($\bar{x}$), and the standard deviation (σ). See page 143 for details on the configuration string for this command.



	A	B	C	D	E
1	n	13			
2	x̄	462			
3	σX	34.558757			
4					
5					
6					
7					
8					
9					
10					

=STAT1(A25:A37,"h n x̄ σ")

SUM

Calculates the sum of a range of numbers.

```
SUM([input])
```

For example, `SUM(B7:B23)` returns the sum of the numbers in the range B7 to B23. You can also specify a block of cells, as in `SUM(B7:C23)`.

An error is returned if a cell in the specified range contains a non-numeric object.

AVERAGE

Calculates the arithmetic mean of a range of numbers.

```
AVERAGE([input])
```

For example, `AVERAGE(B7:B23)` returns the arithmetic mean of the numbers in the range B7 to B23. You can also specify a block of cells, as in `AVERAG(B7:C23)`.

An error is returned if a cell in the specified range contains a non-numeric object.

AMORT

Amortization. Calculates the principal, interest, and balance of a loan over a specified period. Corresponds to pressing Amort in the Finance app.

```
AMORT(Range, NbPmt, IPYR, PV, PMTV[, PPYR=12,
CPYR=PPYR, GSize=PPYR, BEG=0, fix=current],
"configuration"])
```

`Range`: the cell range where the results are to be placed. If only one cell is specified, then the range is automatically calculated starting from that cell.

`Configuration`: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

h – show row headers

H – show column headers

S – show the start of the period

E – show the end of the period

P – show the principal paid this period

B – show the balance at the end of the period

I – show the interest paid this period

All the other input parameters (except `fix`) are Finance app Numeric view variables; see page 234 for details. Note that only the first four are required. `fix` is the number of decimal places to be used in the displayed results.

STAT1

The STAT1 function provides a range of one-variable statistics. It can calculate all or any of $\bar{x}$, Σ, Σ^2, s, s^2, σ, σ^2, serr, $\sum(x_i - \bar{x})^2$, n, min, q1, med, q3, and max.

```
STAT1(Input range, [mode], [outlier
removal Factor], ["configuration"])
```

Input range is the data source (such as A1:D8).

Mode defines how to treat the input. The valid values are:

1 = Single data. Each column is treated as an independent dataset.

2 = Frequency data. Columns are used in pairs and the second column is treated as the frequency of appearance of the first column.

3 = Weight data. Columns are used in pairs and the second column is treated as the weight of the first column.

4 = One–Two data. Columns are used in pairs and the 2 columns are multiplied to generate a data point.

If more than one column is specified, they are each treated as a different input data set. If only one row is selected, it is treated as 1 data set. If two columns are selected, the mode defaults to frequency.

Outlier Removal Factor: This allows for the removal of any datapoint that is more than *n* times the standard deviation (where *n* is the outlier removal factor). By default this factor is set to 2.

Configuration: indicates which values you want to place in which row and if you want row or columns headers. Place the symbol for each value in the order that you want to see the values appear in the spreadsheet. The valid symbols are:

H (Place column headers)			h (Place row headers)		
$\bar{x}$	Σ	Σ^2	s	s^2	σ
σ^2	serr	$\sum(x_i - \bar{x})^2$	n	min	q1
med	q3	max			

For example if you specify "h n Σ $\bar{x}$", the first column will contain row headers, the first row will be the number of items in the input data, the second the sum of the items and the third the mean of the data. If you do not specify a configuration string, a default string will be used.

Notes:

The STAT1 f function only updates the content of the destination cells when the cell that contains the formula is calculated. This means that if the spreadsheet view contains at the same time results and inputs, but not the cell that contains the call to the STAT1 function, updating the data will not update the results as the cell that contains STAT1 is not recalculated (since it is not visible).

The format of cells that receive headers is changed to have `Show " "` set to false.

The STAT1 function will overwrite the content of destination cells, potentially erasing data.

Examples:

```
STAT1(A25:A37)
STAT1(A25:A37,”h n x̄ σ”).
```

REGRS

Attempts to fit the input data to a specified function (default is linear).

```
REGRS(Input range,[model],
["configuration"])
```

- Input range: specifies the data source; for example A1:D8. It must contain an even number of columns. Each pair will be treated as a distinct set of datapoints.
- model: specifies the model to be used for the regression:

  1 y= sl**x*+int

  2 y= sl*ln(*x*)+int

  3 y= int*exp(sl**x*)

  4 y= int**x*^sl

  5 y= int*sl^*x*

  6 y= sl/*x*+int

7 y= L/(1 + a*exp(b*x))

8 y= a*sin(b*x+c)+d

9 y= cx^2+bx+a

10 y= dx^3+cx^2+bx+a

11 y= ex^4+dx^3+cx^2+bx+a

- Configuration: a string which indicates which values you want to place in which row and if you want row and columns headers. Place each parameter in the order that you want to see them appear in the spreadsheet. (If you do not provide a configuration string, a default one will be provided.) The valid parameters are:
  - H (Place column headers)
  - h (Place row headers)
  - sl (slope, only valid for models 1–6)
  - int (intercept, only valid for models 1–6)
  - cor (correlation, only valid for models 1–6)
  - cd (Coefficient of determination, only valid for models 1–6, 8–10)
  - sCov (Sample covariance, only valid for models 1–6)
  - pCov (Population covariance, only valid for models 1–6)
  - L (L parameter for model 7)
  - a (a parameter for models 7—11)
  - b (b parameter for models 7—11)
  - c (c parameter for models 8–11)
  - d (d parameter for models 8, 10–11)
  - e (e parameter for model 11)
  - py (place 2 cells, one for user input and the other to display the predicted y for the input)
  - px (place 2 cells, one for user input and the other to display the predicted x for the input)

Example: `REGRS(A25:B37,2)`

PredY

Returns the predicted Y for a given x.

```
PredY(mode, x, parameters)
```

- `Mode` governs the regression model used:

  1 y= sl*x+int

  2 y= sl*ln(x)+int

  3 y= int*exp(sl*x)

  4 y= int*x^sl

  5 y= int*sl^x

  6 y= sl/x+int

  7 y= L/(1 + a*exp(b*x))

  8 y= a*sin(b*x+c)+d

  9 y= cx^2+bx+a

  10 y= dx^3+cx^2+bx+a

  11 y= ex^4+dx^3+cx^2+bx+a
- `Parameters` is either one argument (a list of the coefficients of the regression line), or the n coefficients one after another.

PredX

Returns the predicted x for a given y.

```
PredX(mode, y, parameters)
```

- `Mode` governs the regression model used:

  1 y= sl*x+int

  2 y= sl*ln(x)+int

  3 y= int*exp(sl*x)

  4 y= int*x^sl

  5 y= int*sl^x

  6 y= sl/x+int

  7 y= L/(1 + a*exp(b*x))

  8 y= a*sin(b*x+c)+d

  9 y= cx^2+bx+a

  10 y= dx^3+cx^2+bx+a

  11 y= ex^4+dx^3+cx^2+bx+a
- `Parameters` is either one argument (a list of the coefficients of the regression line), or the n coefficients one after another.

HypZ1mean The one-sample Z-test for a mean.

```
HypZ1mean(x̄, n,μ0,σ,α,mode, ["configuration"])
```

The input parameters can be a range reference, a list of cell references, or a simple list of values.

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tZ: the test Z-value
- tM: the input $\bar{x}$ value
- prob: the lower-tail probability
- cZ: the critical Z-value associated with the input a-level
- cx1: the lower critical value of the mean associated with the critical Z-value
- cx2: the upper critical value of the mean associated with the critical Z-value
- std: the standard deviation

Example:

`HypZ1mean(0.461368, 50, 0.5, 0.2887, 0.05, 1, "")` returns two columns into the Spreadsheet app. The first column contains the headers and the second column contains the values for each of the following: Reject/Fail=1, Test Z = -0.94621, Test $\bar{x}$ = 0.461368, P= 0.172022, Critical Z= -1.64485, Critical $\bar{x}$ = 0.432843.

HYPZ2mean The two-sample Z-test for the difference of two means.

```
HypZ2mean(x̄1, x̄2, n1, n2,σ1,σ2,α,mode,
["configuration"])
```

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$
- Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.
- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tZ: Test Z
- tM: the input $\Delta \bar{x}$ value
- prob: the lower-tail probability
- cZ: the critical Z-value associated with the input a-level
- cx1: the lower critical value of $\Delta \bar{x}$ associated with the critical Z-value
- cx2: the upper critical value of $\Delta \bar{x}$ associated with the critical Z-value
- std: the standard deviation

Example:

```
HypZ2mean(0.461368, 0.522851, 50, 50, 0.2887,
0.2887, 0.05, 1, "")
```

HypZ1prop

The one-sample Z-test for a proportion.

`HypZ1prop(x,n,π0,α,mode,`
`[”configuration”])` where *x* is the success count of the sample

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi < \pi_0$
- 2: $\pi > \pi_0$
- 3: $\pi \neq \pi_0$

- Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.
- h: header cells will be created
- acc:0 or 1 to reject or fail to reject the null hypothesis
- tZ: the test Z-value
- tP: the test proportion of successes
- prob: the lower-tail probability
- cZ: The critical Z-value associated with the input a-level
- cp1: the lower critical proportion of successes associated with the critical Z-value
- cp2: the upper critical proportion of successes associated with the critical Z-value
- std: the standard deviation

Example:

```
HypZ1prop(21, 50, 0.5, 0.05,1, "")
```

HypZ2prop The two-sample Z-test for comparing two proportions.

`HypZ2prop(x1,x2,n1,n2,α,mode,[”configuration”])` where x_1 and x_2 are the success counts of the two samples)

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi_1 < \pi_2$
- 2: $\pi_1 > \pi_2$
- 3: $\pi_1 \neq \pi_2$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: 0 or 1 to reject or fail to reject the null hypothesis
- tZ: the test Z-value
- tP: the test $\Delta\pi$ value

- prob: the lower-tail probability
- cZ: The critical Z-value associated with the input a-level
- cp1: The lower critical value of Δπ associated with the critical Z-value
- cp2: The upper critical value of Δπ associated with the critical Z-value

Example:

```
HypZ2prop(21, 26, 50, 50, 0.05, 1, "")
```

HypT1mean

The one-sample t-test for a mean.

```
HypT1mean(x̄,s,n,μ0,α,mode,[”configuration”])
```

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tT: the test T-value
- tM: the input $\bar{x}$ value
- prob: the lower-tail probability
- df: the degrees of freedom
- cT: the critical T-value associated with the input a-level
- cx1: the lower critical value of the mean associated with the critical T-value
- cx2: the upper critical value of the mean associated with the critical T-value

Example:

```
HypT1mean(0.461368, 0.2776, 50, 0.5, 0.05, 1,
"")
```

HypT2mean

The two-sample T-test for the difference of two means.

```
HypT2mean((x1,x2,s1,s2,n1,n2,α,pooled,mode,
["configuration"])
```

Pooled: Specifies whether or not the samples are pooled

- 0: not pooled
- 1: pooled

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- acc: the test result, 0 or 1 to reject or fail to reject the null hypothesis
- tT: the test T-value
- tM: the input $\Delta\bar{x}$ value
- prob: the lower-tail probability
- cT: the critical T-value associated with the input a-level
- cx1: the lower critical value of $\Delta\bar{x}$ associated with the critical T-value
- cx2: the upper critical value of $\Delta\bar{x}$ associated with the critical T-value

Example:

```
HypT2mean(0.461368, 0.522851, 0.2776,
0.2943,50, 50, 0, 0.05, 1, "")
```

ConfZ1mean

The one-sample Normal confidence interval for a mean.

```
ConfZ1mean(x̄,n,s,C,["configuration"])
```

Configuration is a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval
- zXh: the upper bound of the confidence interval
- std: the standard deviation

Example:

```
ConfZ1mean(0.461368, 50, 0.2887, 0.95, "")
```

ConfZ2mean

The two-sample Normal confidence interval for the difference of two means.

ConfZ2mean($\bar{x}_1$, $\bar{x}_2$, n_1, n_2, s_1, s_2, C, [”configuration”])

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval
- zXh: the upper bound of the confidence interval
- zXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfZ2mean(0.461368, 0.522851, 50, 50, 0.2887,
0.2887, 0.95, "")
```

ConfZ1prop

The one-sample Normal confidence interval for a proportion.

```
ConfZ1prop(x,n,C,[”configuration”])
```

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval

- zXh: the upper bound of the confidence interval
- zXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfZ1prop(21, 50, 0.95, "")
```

ConfZ2prop

The two-sample Normal confidence interval for the difference of two proportions.

ConfZ2prop(x_1,x_2,n_1,n_2,C,[”configuration”])

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- Z: the critical Z-value
- zXl: the lower bound of the confidence interval
- zXh: the upper bound of the confidence interval
- zXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfZ2prop(21, 26, 50, 50, 0.95, "")
```

ConfT1mean

The one-sample Student’s T confidence interval for a mean.

ConfT1mean($\bar{x}$,s,n,C,[”configuration”])

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- DF: the degrees of freedom
- T: the critical T-value
- tXl: the lower bound of the confidence interval
- tXh: the upper bound of the confidence interval
- std: the standard deviation

Example:

```
ConfT1mean(0.461368, 0.2776, 50, 0.95,
"")
```

ConfT2mean

The two-sample Student's T confidence interval for the difference of two means.

ConfT2mean($\bar{x}_1$, $\bar{x}_2$, s_1, s_2, n_1, n_2, C, pooled, [”configuration”])

Configuration: a string that controls what results are shown and the order in which they appear. An empty string "" displays the default: all results, including headers. The options in the configuration string are separated by spaces.

- h: header cells will be created
- DF: the degrees of freedom
- T: the critical T-value
- tXl: the lower bound of the confidence interval
- tXh: the upper bound of the confidence interval
- tXm: the midpoint of the confidence interval
- std: the standard deviation

Example:

```
ConfT2mean(0.461368, 0.522851, 0.2776, 0.2943,
50, 50, 0, 0.95, "")
```

Statistics 1Var app functions

The Statistics 1Var app has three functions designed to work together to calculate summary statistics based on one of the statistical analyses (`H1-H5`) defined in the Symbolic view of the Statistics 1Var app.

Do1VStats

Do1-variable statistics. Performs the same calculations as tapping Stats in the Numeric view of the Statistics 1Var app and stores the results in the appropriate Statistics 1Var app results variables. *Hn* must be one of the Statistics 1Var app Symbolic view variables `H1-H5`.

```
Do1VStats(Hn)
```

Example:

`Do1VStats(H1)` executes summary statistics for the currently defined `H1` analysis.

SetFreq

Set frequency. Sets the frequency for one of the statistical analyses (`H1-H5`) defined in the Symbolic view of the Statistics 1Var app. The frequency can be either one of the columns `D0-D9`, or any positive integer. *Hn* must be one of the Statistics 1Var app Symbolic view variables `H1-H5`. If used, *Dn* must be one of the column variables `D0-D9`; otherwise, *value* must be a positive integer.

```
SetFreq(Hn,Dn)
```

or

```
SetFreq(Hn,value)
```

Example:

`SetFreq(H2,D3)` sets the **Frequency** field for the `H2` analysis to use the list `D3`.

SetSample

Set sample data. Sets the sample data for one of the statistical analyses (`H1-H5`) defined in the Symbolic view of the Statistics 1Var app. Sets the data column to one of the column variables `D0-D9` for one of the statistical analyses `H1-H5`.

```
SetSample(Hn,Dn)
```

Example:

`SetSample(H2,D2)` sets the **Independent Column** field for the `H2` analysis to use the data in the list `D2`.

Statistics 2Var app functions

The Statistics 2Var app has a number of functions. Some are designed to calculate summary statistics based on one of the statistical analyses (`S1–S5`) defined in the Symbolic view of the Statistics 2Var app. Others predict X- and Y-values based on the fit specified in one of the analyses.

PredX

Predict X. Uses the fit from the first active analysis (`S1–S5`) found to predict an x-value given the y-value.

```
PredX(value)
```

PredY

Predict Y. Uses the fit from the first active analysis (`S1–S5`) found to predict a y-value given the x-value.

```
PredY(value)
```

Resid

Residuals. Returns the list of residuals for the given analysis (`S1–S5`), based on the data and a fit defined in the Symbolic view for that analysis.

```
Resid(Sn) or Resid()
```

Resid() looks for the first defined analysis in the Symbolic view (S1-S5).

Do2VStats

Do 2-variable statistics. Performs the same calculations as tapping **Stats** in the Numeric view of the Statistics 2Var app and stores the results in the appropriate Statistics 2Var app results variables. `Sn` must be one of the Statistics 2Var app Symbolic view variables `S1–S5`.

```
Do2VStats(Sn)
```

Example:

`Do1VStats(S1)` executes summary statistics for the currently defined `S1` analysis.

SetDepend

Set dependent column. Sets the dependent column for one of the statistical analyses `S1–S5` to one of the column variables `C0–C9`.

```
SetDepend(Sn,Cn)
```

Example:

`SetDepend(S1,C3)` sets the **Dependent Column** field for the `S1` analysis to use the data in list `C3`.

SetIndep

Set independent column. Sets the independent column for one of the statistical analyses `S1–S5` to one of the column variables `C0–C9`.

```
SetIndep(Sn,Cn)
```

Example:

`SetIndep(S1, C2)` sets the **Independent Column** field for the `S1` analysis to use the data in list `C2`.

Inference app functions

The Inference app has a single function that returns the same results as tapping Calc in the Numeric view of the Inference app. The results depend on the contents of the Inference app variables `Method`, `Type`, and `AltHyp`.

DoInference

Calculate confidence interval or test hypothesis. Uses the current settings in the Symbolic and Numeric views to calculate a confidence interval or test an hypothesis. Performs the same calculations as tapping Calc in the Numeric view of the Inference app and stores the results in the appropriate Inference app results variables.

```
DoInference()
```

HypZ1mean

The one-sample Z-test for a mean. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The input $\bar{x}$ value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of the statistic associated with the critical Z-value

```
HypZ1mean(x̄, n,μ0,σ,α,mode)
```

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Example:

HypZ1mean(0.461368, 50, 0.5, 0.2887, 0.05, 1) returns {1, -.9462…, 0.4614, 0.8277…, 1.6448…, 0.5671…}

HYPZ2mean

The two-sample Z-test for means. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The test $\Delta\bar{x}$ value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of $\Delta\bar{x}$ associated with the critical Z-value

HypZ2mean($\bar{x}_1$, $\bar{x}_2$, n_1, n_2, σ_1, σ_2, α, mode)

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$

Example:

HypZ2mean(0.461368, 0.522851, 50, 50, 0.2887, 0.2887, 0.05, 1) returns {1, -1.0648…, -0.0614…, 0.8565…, 1.6448…, 0.0334…}

HypZ1prop

The one-proportion Z-test. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The test π value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of π associated with the critical Z-value

HypZ1prop(x, n, π_0, α, mode)

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi < \pi_0$
- 2: $\pi > \pi_0$
- 3: $\pi \neq \pi_0$

Example:

`HypZ1prop(21, 50, 0.5, 0.05,1)` returns `{1, -1.1313…, 0.42, 0.8710…, 1.6448…, 0.6148…}`

HypZ2prop

The two-sample Z-test for proportions. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test Z-value
- The test $\Delta\pi$ value
- The upper-tail probability
- The upper critical Z-value associated with the input a-level
- The critical value of $\Delta\pi$ associated with the critical Z-value

HypZ2prop(x_1,x_2,n_1,n_2,α,mode)

Mode: Specifies which alternative hypothesis to use:

- 1: $\pi_1 < \pi_2$
- 2: $\pi_1 > \pi_2$
- 3: $\pi_1 \neq \pi_2$

Example:

`HypZ2prop(21, 26, 50, 50, 0.05, 1)` returns `{1, -1.0018…, -0.1, 0.8417…, 1.6448…, 0.0633…}`

HypT1mean

The one-sample t-test for a mean. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test T-value
- The input $\bar{x}$ value
- The upper-tail probability
- The degrees of freedom
- The upper critical T-value associated with the input a-level
- The critical value of the statistic associated with the critical t-value

HypT1mean($\bar{x}$,s,n,μ_0,α,mode)

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu < \mu_0$
- 2: $\mu > \mu_0$
- 3: $\mu \neq \mu_0$

Example:

`HypT1mean(0.461368, 0.2776, 50, 0.5, 0.05, 1)` returns `{1, -.9462…, 0.4614, 0.8277…, 1.6448…, 0.5671…}`

HypT2mean

The two-sample T-test for means. Returns a list containing (in order):

- 0 or 1 to reject or fail to reject the null hypothesis
- The test T-value
- The test $\Delta \bar{x}$ value
- The upper-tail probability
- The degrees of freedom
- The upper critical T-value associated with the input a-level
- The critical value of $\Delta \bar{x}$ associated with the critical T-value

`HypT2mean((x₁,x₂,s₁,s₂,n₁,n₂,α,pooled,mode)`

Pooled: Specifies whether or not the samples are pooled

- 0: not pooled
- 1: pooled

Mode: Specifies which alternative hypothesis to use:

- 1: $\mu_1 < \mu_2$
- 2: $\mu_1 > \mu_2$
- 3: $\mu_1 \neq \mu_2$

Example:

`HypT2mean(0.461368, 0.522851, 0.2776, 0.2943,50, 50, 0.05, 0, 1)` returns `{1, -1.0746…, -0.0614…, 0.8574…, 97.6674…, 1.6606…, 0.0335…}`

ConfZ1mean

The one-sample Normal confidence interval for a mean. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfZ1mean($\bar{x}$,n,σ,C)

Example:

ConfZ1mean(0.461368, 50, 0.2887, 0.95) returns {-1.9599…, 0.3813…, 0.5413…}

ConfZ2mean

The two-sample Normal confidence interval for the difference of two means. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfZ2mean($\bar{x}_1$, $\bar{x}_2$, n_1, n_2,σ_1,σ_2,C)

Example:

ConfZ2mean(0.461368, 0.522851, 50, 50, 0.2887, 0.2887, 0.95) returns {-1.9599…, -0.1746…, 0.0516…)}

ConfZ1prop

The one-sample Normal confidence interval for a proportion. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

```
ConfZ1prop(x,n,C)
```

Example:

ConfZ1prop(21, 50, 0.95) returns {-1.9599…, 0.2831…, 0.5568…}

ConfZ2prop

The two-sample Normal confidence interval for the difference of two proportions. Returns a list containing (in order):

- The lower critical Z-value
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfZ2prop(x_1,x_2,n_1,n_2,C)

Example:

ConfZ2prop(21, 26, 50, 50, 0.95) returns {-1.9599…, -0.2946…, 0.0946…)}

ConfT1mean

The one-sample Student's T confidence interval for a mean. Returns a list containing (in order):

- The degrees of freedom
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfT1mean($\bar{x}$,s,n,C)

Example:

ConfT1mean(0.461368, 0.2776, 50, 0.95) returns {49, -.2009…, 0.5402…}

ConfT2mean

The two-sample Student's T confidence interval for the difference of two means. Returns a list containing (in order):

- The degrees of freedom
- The lower bound of the confidence interval
- The upper bound of the confidence interval

ConfT2mean($\bar{x}_1$, $\bar{x}_2$, s_1,s_2,n_1, n_2,pooled,C)

Example:

ConfT2mean(0.461368, 0.522851, 0.2887, 0.2887, 50, 50, 0.95,0) returns {98.0000…, -1.9844, -0.1760…, 0.0531…)}

Chi2GOF

Chi-square goodness of fit test. Takes as arguments a list of observed count data, a second list, and a value of 0 or 1. If value=0, the second list is taken as a list of expected probabilities. If value=1, then the second list is taken as a list of expected counts. Returns a list containing the chi-square statistic value, the probability, and the degrees of freedom.

```
Chi2GOF(List1, List2, Value)
```

Example:

`Chi2GOF({10,10,12,15,10,6},{.24,.2,.16,.14,.13,.13},0)` returns `{10.1799..., 0.07029..., 5}`

Chi2TwoWay

Chi-square two-way test. Given a matrix of count data, returns a list containing the chi-square statistic value, the probability, and the degrees of freedom.

```
Chi2TwoWay(Matrix)
```

Example:

`Chi2TwoWay([[30,35,30],[11,2,19],[43,35,35]])` returns `{14.4302..., 0.0060..., 4}`

LinRegrTConfSlope

The linear regression confidence interval for the slope. Given a list of explanatory variable data (X), a list of response variable data (Y), and a confidence level, returns a list containing the following values in the order shown:

- C: the given confidence level
- Critical T: the value of t associated with the given confidence level
- DF: the degrees of freedom
- β_1: the slope of the linear regression equation
- serrSlope: the standard error of the slope
- Lower: the lower bound of the confidence interval for the slope
- Upper: the upper bound of the confidence interval for the slope

```
LinRegrTConfSlope(List1, List2, C-value)
```

Example:

`LinRegrTConfSlope({1,2,3,4},{3,2,0,-2},0.95)` returns `{0.95, 4.302..., 2, -1.7, 0.1732..., -2.445..., -0.954...}`

LinRegrTConfInt

The linear regression confidence interval for the intercept. Given a list of explanatory variable data (X), a list of response variable data (Y), and a confidence level, returns a list containing the following values in the order shown:

- C: the given confidence level
- Critical T: the value of t associated with the given confidence level
- DF: the degrees of freedom
- β_0: the intercept of the linear regression equation
- serrInter: the standard error of the intercept
- Lower: the lower bound of the confidence interval for the intercept
- Upper: the upper bound of the confidence interval for the intercept

```
LinRegrTConfInt(List1, List2, C-value)
```

Example:

```
LinRegrTConfInt({1, 2, 3, 4}, {3, 2, 0, -
2},0.95) returns {0.95, 4.302..., 2, 5,
0.474..., 2.959..., 7.040...}
```

LinRegrTMeanResp

The linear regression confidence interval for a mean response. Given a list of explanatory variable data (X), a list of response variable data (Y), an X-value, and a confidence level, returns a list containing the following values in the order shown:

- X: the given X-value
- C: the given confidence level
- DF: the degrees of freedom
- $\hat{Y}$: the mean response for the given X-value
- serr $\hat{Y}$: the standard error of the mean response
- Lower: the lower bound of the confidence interval for the mean response
- Upper: the upper bound of the confidence interval for the mean response

```
LinRegrTMeanResp(List1, List2, X-value, C-
value)
```

Example:

```
LinRegrTMeanResp({1, 2, 3, 4}, {3, 2, 0, -2},
2.5, 0.95) returns {2.5, 0.95, 4.302..., 2,
0.75, 0.193..., −0.083, 1.583...}
```

LinRegrTPredInt The linear regression prediction interval for a future response. Given a list of explanatory variable data (X), a list of response variable data (Y), a future X-value, and a confidence level, returns a list containing the following values in the order shown:

- X: the given future X-value
- C: the given confidence level
- DF: the degrees of freedom
- Ŷ: the mean response for the given future X-value
- serr Ŷ: the standard error of the mean response
- Lower: the lower bound of the prediction interval for the mean response
- Upper: the upper bound of the prediction interval for the mean response

```
LinRegrTPredInt(List1, List2, X-value, C-
value)
```

Example:

```
LinRegrTPredInt({1, 2, 3, 4}, {3, 2, 0, -2},
2.5, 0.95) returns {2.5, 0.95, 4.302..., 2,
0.75, 0.433..., −1.113..., 2.613...}
```

LinRegrTTest The linear regression t-test. Given a list of explanatory variable data (X), a list of response variable data (Y), and a value for AltHyp, returns a list containing the following values in the order shown:

- T: the t-value
- P: the probability associated with the t-value
- DF: the degrees of freedom
- β_0: the y-intercept of the regression line
- β_1: the slope of the regression line
- serrLine: the standard error of the regression line
- serrSlope: the standard error of the slope
- serrInter: the standard error of the y-intercept

- r: the correlation coefficient
- R^2: the coefficient of determination

The values for AltHyp are as follows:

- AltHyp=0 for $\mu<\mu_0$
- AltHyp=1 for $\mu>\mu_0$
- AltHyp=2 for $\mu\neq\mu_0$

Example:

```
LinRegrTTest({1,2,3,4}, {3,2,0,-2}, 0) returns
{-9.814..., 2, 5, -1.7, 0.387..., 0.173...,
0.474..., -0.989..., 0.979...}
```

Finance app functions

The Finance app uses a set of functions that all reference the same set of Finance app variables. These correspond to the fields in the Finance app Numeric view. There are 5 main TVM variables, 4 of which are mandatory for each of these functions, as they each solve for and return the value of the fifth variable to two decimal places. `DoFinance` is the sole exception to this syntax rule. Note that money paid to you is entered as a positive number and money you pay to others as part of a cash flow is entered as a negative number. There are 3 other variables that are optional and have default values. These variables occur as arguments to the Finance app functions in the following set order:

- `NbPmt`—the number of payments
- `IPYR`—the annual interest rate
- `PV`—the present value of the investment or loan
- `PMTV`—the payment value
- `FV`—the future value of the investment or loan
- `PPYR`—the number of payments per year (12 by default)
- `CPYR`—the number of compounding periods per year (12 by default)
- `BEG`—payments made at the beginning or end of the period; the default is BEG=0, meaning that payments are made at the end of each period

The arguments `PPYR`, `CPYR`, and `BEG` are optional; if not supplied, `PPYR`=12, `CPYR`=`PPYR`, and `BEG`=0.

CalcFV

Solves for the future value of an investment or loan.

```
CalcFV(NbPmt,IPYR,PV,PMTV[,PPYR,CPYR,BEG]
```

Example:

`CalcFV(360, 6.5, 150000, -948.10)` returns `-2.25`

CalcIPYR

Solves for the interest rate per year of an investment or loan.

```
CalcIPYR(NbPmt,PV,PMTV,FV[,PPYR,CPYR,
BEG])
```

Example:

`CalcIPYR(360, 150000, -948.10, -2.25)` returns `6.50`

CalcNbPmt

Solves for the number of payments in an investment or loan.

```
CalcNbPmt(IPYR,PV,PMTV,FV[,PPYR,CPYR,BEG])
```

Example:

`CalcNbPmt(6.5, 150000, -948.10, -2.25)` returns `360.00`

CalcPMT

Solves for the value of a payment for an investment or loan.

```
CalcPMT(NbPmt,IPYR,PV,FV[,PPYR,CPYR,BEG])
```

Example:

`CalcPMT(360, 6.5, 150000, -2.25)` returns `-948.10`

CalcPV

Solves for the present value of an investment or loan.

```
CalcPV(NbPmt,IPYR,PMTV,FV[,PPYR,CPYR,BEG])
```

Example:

`CalcPV(360, 6.5, -948.10, -2.25)` returns `150000.00`

DoFinance

Calculate TVM results. Solves a TVM problem for the variable *TVMVar.* The variable must be one of the Finance app's Numeric view variables. Performs the same calculation as tapping Solve in the Numeric view of the Finance app with *TVMVar* highlighted.

```
DoFinance(TVMVar)
```

Example:

`DoFinance(FV)` returns the future value of an investment in the same way as tapping Solve in the Numeric view of the Finance app with `FV` highlighted.

Linear Solver app functions

The Linear Solver app has 3 functions that offer the user flexibility in solving 2x2 or 3x3 linear systems of equations.

Solve2x2

Solves a 2x2 linear system of equations.

`Solve2x2(`*a*, *b*, *c*, *d*, *e*, *f*`)`

Solves the linear system represented by:

ax+by=c

dx+ey=f

Solve3x3

Solves a 3x3 linear system of equations.

`Solve3x3(`*a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*, *l*`)`

Solves the linear system represented by:

ax+by+cz=d

ex+fy+gz=h

ix+jy+kz=l

LinSolve

Solve linear system. Solves the 2x2 or 3x3 linear system represented by matrix.

`LinSolve(`*matrix*`)`

Example:

`LinSolve([[A, B, C], [D, E,F]])` solves the linear system:

ax+by=c

dx+ey=f

Triangle Solver app functions

The Triangle Solver app has a group of functions which allow you to solve a complete triangle from the input of three consecutive parts of the triangle (one of which must be a side length). The names of these commands use A to signify an angle and S to signify a side length. To use these commands, enter three inputs in the specified order given by the command name. These commands all return a list of the three unknown values (lengths of sides and/or measures of angles).

AAS

Angle-Angle-Side. Takes as arguments the measures of two angles and the length of the side opposite the first angle and returns a list containing the length of the side opposite the second angle, the length of the third side, and the measure of the third angle (in that order).

```
AAS(angle,angle,side)
```

Example:

`AAS(30, 60, 1)` in degree mode returns `{1.732…, 2, 90}`

ASA

Angle-Side-Angle. Takes as arguments the measure of two angles and the length of the included side and returns a list containing the length of the side opposite the first angle, the length of the side opposite the second angle, and the measure of the third angle (in that order).

```
ASA(angle,side,angle)
```

Example:

`ASA(30, 2, 60)` in degree mode returns `{1, 1.732…, 90}`

SAS

Side-Angle-Side. Takes as arguments the length of two sides and the measure of the included angle and returns a list containing the length of the third side, the measure of the angle opposite the third side and the measure of the angle opposite the second side.

```
SAS(side,angle,side)
```

Example:

`SAS(2, 60, 1)` in degree mode returns `{1.732…, 30, 90}`

SSA

Side-Side-Angle. Takes as arguments the lengths of two sides and the measure of a non-included angle and returns a list containing the length of the third side, the measure of the angle opposite the second side, and the measure of the angle opposite the third side. Note: In an ambiguous case, this command will only give you one of the two possible solutions.

```
SSA(side,side,angle)
```

Example:

`SSA(1, 2, 30)` returns `{1.732…, 90, 60}`

SSS

Side-Side-Side Takes as arguments the lengths of the three sides of a triangle and returns the measures of the angles opposite them, in order.

```
SSS(side,side,side)
```

Example:

`SSS(3, 4, 5)` in degree mode returns `{36.8…, 53.1…, 90}`

DoSolve

Solves the current problem in the Triangle Solver app. The Triangle Solver app must have enough data entered to ensure a successful solution; that is, there must be at least three values entered, one of which must be a side length. Returns a list containing the unknown values in the Numeric view, in their order of appearance in that view (left to right and top to bottom).

```
DoSolve()
```

Linear Explorer functions

SolveForSlope

Solve for slope. Takes as input the coordinates of two points (x_1, y_1) and (x_2, y_2) and returns the slope of the line containing those two points.

$\texttt{SolveForSlope(}x_1\texttt{, }x_2\texttt{, }y_1\texttt{, }y_2\texttt{)}$

Example:

`SolveForSlope(3,2,4,2)` returns `2`

SolveForYIntercept

Solve for y-intercept. Takes as input the coordinates of a point (*x*, *y*), and a slope *m*, and returns the *y*-intercept of the line with the given slope that contains the given point.

```
SolveForYIntercept(x, y, m)
```

Example:

`SolveForYIntercept(2,3,-1)` returns `5`

Quadratic Explorer functions

SOLVE

Solve quadratic. Given the coefficients of a quadratic equation ax^2+bx+c=0, returns the real solutions.

```
SOLVE(a, b, c)
```

Example:

`SOLVE(1,0,-4)` returns `{-2, 2}`

DELTA

Discriminant. Given the coefficients of a quadratic equation ax^2+bx+c=0, returns the value of the discriminant in the Quadratic Formula.

```
DELTA(a, b, c)
```

Example:

`DELTA(1,0,-4)` returns `16`

Common app functions

In addition to the app functions specific to each app, there are three functions common to the following apps. These use as an argument an integer from 0 to 9, which corresponds to one of the Symbolic view variables for that app.

- Function (F0–F9)
- Solve (E0–E9)
- Statistics 1Var (H1–H5)
- Statistics 2Var (S1–S5)
- Parametric (X0/Y0–X9/Y9)
- Polar (R0–R9)
- Sequence (U0–U9)
- Advanced Graphing (V0–V9)

CHECK

Check. Checks—that is, *selects*—the Symbolic view variable corresponding to `Digit`. Used primarily in programming to activate Symbolic view definitions in apps.

```
CHECK(Digit)
```

Example:

With the Function app as the current app, `CHECK(1)` checks the Function app Symbolic view variable F1. The result is that

F1(X) is drawn in the Plot view and has a column of function values in the Numeric view of the Function app. With another app as the current app, you would have to enter Function.CHECK(1).

UNCHECK

Un-Check. Un-checks—that is, deselects—the Symbolic view variable corresponding to Digit. Used primarily in programming to de-activate symbolic view definitions in apps.

```
UNCHECK(Digit)
```

Example:

With the Sequence app as the current app, UNCHECK(2) un-checks the Sequence app Symbolic view variable U2. The result is that U2(N) is no longer drawn in Plot view and has no column of values in the Numeric view of the Sequence app. With another app as the current app, you would have to enter Sequence.UNCHECK(2).

ISCHECK

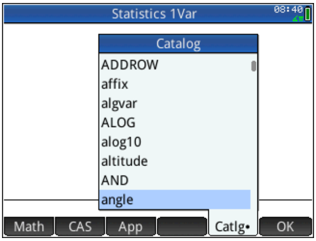
Test for check. Tests whether a Symbolic view variable is checked. Returns 1 if the variable is checked and 0 if it is not checked.

```
ISCHECK(Digit)
```

Example:

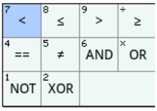
With the Function app as the current app, ISCHECK(3) checks to see if F3(X) is checked in the Symbolic view of the Function app.

Ctlg menu



The Catlg menu brings together all the functions and commands available on the HP Prime. However, this section describes the functions and commands that can only be found on the Catlg menu. The functions and commands that are also on the Math menu are described in "Keyboard functions" on page 101. Those that are also on the CAS menu are described in "CAS menu" on page 116. The functions and commands specific to the Geometry app are described in "Geometry functions and commands" on page 39, and those specific to programming are described in "Program commands" on page 267.

Some of the options on the Catlg menu can also be chosen from the relations palette (Shift 9)



! Factorial. Returns the factorial of a positive integer. For non-integers, ! = Γ(x + 1). This calculates the Gamma function.

```
value!
```

Example:

`6!` returns `720`

% *x* percent of *y*. Returns (x/100)*y.

```
%(x, y)
```

Example:

`%(20,50)` returns `10`

%CHANGE Percent change from x to y. Returns 100*(y-x)/x.

```
%CHANGE(x, y)
```

Example:

`%CHANGE(20,50)` returns `150`

%TOTAL Percent total; the percentage of x that is y. Returns 100*y/x.

```
%TOTAL(x, y)
```

Example:

`%TOTAL(20,50)` returns `250`

(Inserts opening parenthesis.

***** Multiplication symbol. Returns the product of two numbers or the scalar product of two vectors.

+ Addition symbol. Returns the sum of two numbers, the term-by-term sum of two lists or two matrices, or adds two strings together.

– Subtraction symbol. Returns the difference of two numbers, or the term-by-term subtraction of two lists or two matrices.

.* List or matrix multiplication symbol. Returns the term-by-term multiplication of two lists or two matrices.

`List1.*List2` or `Matrix1.*Matrix2`

Example:

`[[1,2],[3,4]].*[[3,4],[5,6]]` gives `[[3,8],[15,24]]`

./ List or matrix division symbol. Returns the term-by-term division of two lists or two matrices.

.^ Returns the list or matrix where each term is the corresponding term of the list or matrix given as argument, raised to a power.

`List.^Integer` or `Matrix.^Integer`

/ Division symbol. Returns the quotient of two numbers, or the term by term quotient of two lists. For division of a matrix by a square matrix, returns the left-multiplication by the inverse of the square matrix.

:= Stores the evaluated expression in the variable. Note that `:=` cannot be used with the graphics variables G0–G9. See the command `BLIT`.

`var:=expression`

Example:

`A:=3` stores the value 3 in the variable A

< Strict less-than-inequality test. Returns 1 if the left side of the inequality is less than the right side, and 0 otherwise. Note that more than two objects can be compared. Thus 6 < 8 < 11 returns 1 (because it is true) whereas 6 < 8 < 3 returns 0 (as it is false).

<= Less than or equal inequality test. Returns 1 if the left side of the inequality is less than the right side or if the two sides are equal, and 0 otherwise. Note that more than two objects can be compared. See comment above regarding <.

<> Inequality test. Returns 1 if the inequality is true, and 0 if the inequality is false.

= Equality symbol. Connects two members of an equation.

== Equality test. Returns 1 if the left side and right side are equal, and 0 otherwise.

> Strict greater than inequality test. Returns 1 if the left side of the inequality is greater than the right side, and 0 otherwise. Note that more than two objects can be compared. See comment above regarding <.

>= Greater than or equal inequality test. Returns 1 if the left side of the inequality is greater than the right side or if the two sides are equal, and 0 otherwise. Note that more than two objects can be compared. See comment above regarding <.

^ Power symbol. Raises a number to a power or a matrix to an integer power.

a2q Given a symmetric matrix and a vector of variables, returns the quadratic form of the matrix using the variables in the vector.

```
a2q(Matrix, [Var1, Var2….])
```

Example:

`a2q([[1,2],[4,4]],[x,y])` returns `x^2+6*x*y+4*y^2`

abcuv Given three polynomials A, B, and C, returns U and V such that A*U+B*V=C. With a variable as the final argument, U and V are expressed in terms of that variable (if needed); otherwise, x is used.

```
abcuv(PolyA, PolyB, PolyC, [Var])
```

Example:

`abcuv(x^2+2*x+1,x^2-1,x+1)` returns `[1/2  -1/2]`

additionally Used in programming with `assume` to state an additional assumption about a variable.

Example:

```
assume(n,integer);

additionally(n>5);
```

algvar Returns the matrix of the symbolic variable names used in an expression. The list is ordered by the algebraic extensions required to build the original expression.

```
algvar(Expr)
```

Example:

`algvar(sqrt(x)+y)` gives $\begin{bmatrix} y \\ x \end{bmatrix}$

AND Logical And. Returns 1 if the left and right sides both evaluate to true and returns 0 otherwise.

```
Expr1 AND Expr2
```

Example:

`3 +1==4 AND 4 < 5` returns `1`

append Appends an element to a list or vector.

```
append((List, Element)
```

or

```
append(Vector, Element)
```

Example:

```
append([1,2,3],4) gives [1,2,3,4]
```

apply Returns a vector or matrix containing the results of applying a function to the elements in the vector or matrix.

`apply(Var→f(Var), Vector)` or `apply(Var→f(Var), Matrix)`

Example:

`apply(x→x^3,[1 2 3])` gives `[1 8 27]`

assume Used in programming to state an assumption about a variable.

```
assume(Var,Expr)
```

Example:

```
assume(n, integer)
```

basis Given a matrix, returns the basis of the linear subspace defined by the set of vectors in the matrix.

```
basis(Matrix))
```

Example:

`basis([[1,2,3],[4,5,6],[7,8,9],[10,11,12]])` gives `[[-3,0,3],[0,-3,-6]]`

bounded_function Argument returned by the limit command, indicating that the function is bounded.

breakpoint Used in programming to insert an intentional stopping or pausing point.

canonical_form Returns a second degree trinomial in canonical form.

```
canonical_form(Trinomial,[Var])
```

Example:

`canonical_form(2*x^2-12*x+1)` gives `2*(x-3)^2-17`

cat Evaluates the objects in a sequence, then returns them concatenated as a string.

```
cat(Object1, Object2,…)
```

Example:

`cat("aaa",c,12*3)` gives `"aaac36"`

cFactor Returns an expression factorized over the complex field (on Gaussian integers if there are more than two).

```
cfactor(Expr)
```

Example:

`cFactor(x^2*y+y)` gives `(x+i)*(x-i)*y`

charpoly Returns the coefficients of the characteristic polynomial of a matrix. With only one argument, the variable used in the polynomial is x. With a variable as second argument, the polynomial returned is in terms of that variable.

```
charpoly(Matrix,[Var])
```

Example:

`charpoly([[1,2],[3,4]], z)` returns `z^2-5*z-2`

chrem Returns a vector containing the Chinese remainders for two sets of integers, contained in either two vectors or two lists.

```
chrem(List1, List2) or chrem(Vector1, Vector2)
```

Example:

`chrem([2,3],[7,5])` returns `[-12,35]`

col Given a matrix and an integer *n*, returns the nth column of the matrix as a vector.

```
col(Matrix, Integer)
```

Example:

`col`$\left(\begin{bmatrix}1 & 2 & 3\\4 & 5 & 6\\7 & 8 & 9\end{bmatrix},2\right)$ returns `[2,5,8]`

colDim Returns the number of columns of a matrix.

```
colDim(Matrix)
```

Example:

`colDim`$\left(\begin{bmatrix}1 & 2 & 3\\4 & 5 & 6\end{bmatrix}\right)$ returns `3`

comDenom Rewrites a sum of rational fractions as a one rational fraction. The denominator of the one rational fraction is the common denominator of the rational fractions in the original expression. With a variable as second argument, the numerator and denominator are developed according to it.

```
comDenom(Expr,[Var])
```

Example:

`comDenom(1/x+1/y^2+1)` gives `(x*y^2+x+y^2)/(x*y^2)`

companion Returns the companion matrix of a polynomial.

```
companion(Poly,Var)
```

Example:

`companion(x^2+5x-7,x)` returns $\left(\begin{bmatrix}0 & 7\\1 & -5\end{bmatrix}\right)$

compare Compares two objects and returns 1 if type(Obj1)<type(Obj2) or if type(Obj1)=type(Obj2) and Obj1<Obj2; otherwise, it returns 0.

```
compare(Obj1, Obj2)
```

Example:

`compare(1,2)` gives `1`

complexroot With a polynomial and a real as its two arguments, returns a matrix. Each row of the matrix contains either a complex root of the polynomial with its multiplicity or an interval containing such a root and its multiplicity. The interval defines a (possibly) rectangular region in the complex plane where a complex root lies.

With two additional complex numbers as third and fourth arguments, returns a matrix as described for two arguments, but only for those roots lying in the rectangular region defined by the diagonal created by the two complex numbers.

```
complexroot(Poly, Real, [Complex1], [Complex2])
```

Example:

`complexroot(x^3+8, 0.01)` returns

$$\begin{bmatrix} -2 & 1 \\ \begin{bmatrix} \frac{1017-1782\cdot i}{1024} & \frac{1026-1773\cdot i}{1024} \end{bmatrix} & 1 \\ \begin{bmatrix} \frac{1395+378\cdot i}{512-512\cdot i} & \frac{-189+702\cdot i}{256+256\cdot i} \end{bmatrix} & 1 \end{bmatrix}$$

This matrix indicates there is 1 complex root at *x*=–2, with another root between the two values in the second row vector and a third root between the two values in the third row vector.

contains Given a list or vector and an element, returns the index of the first occurrence of the element in the list or vector; if the element does not appear in the list or vector, returns 0.

`contains((List, Element)` or `contains(Vector, Element)`

Example:

`contains({0,1,2,3},2)` returns `3`

CopyVar Copies the first variable into the second variable without evaluation.

```
CopyVar(Var1,Var2)
```

correlation Returns the correlation of the elements of a list or matrix.

`correlation(List)` or `correlation(Matrix)`

Example:

`correlation` $\begin{bmatrix} 1 & 2 \\ 1 & 1 \\ 4 & 7 \end{bmatrix}$ returns $\frac{33}{6\cdot\sqrt{31}}$

count There are two uses for this function, in which first argument is always a mapping of a variable onto an expression. If the expression is a function of the variable, the function is applied to each element in the vector or matrix (the second argument) and the sum of the results is returned; if the expression is a

Boolean test, each element in the vector or matrix is tested and the number of elements that pass the test is returned.

count(Var → Function, Matrix) or count(Var → Test, Matrix)

Examples:

`count(x→x`^{2}`,[1 2 3])` returns `14`

`count(x→ x>1, [1 2 3])` returns `2`

covariance

Returns the covariance of the elements in a list or matrix.

`covariance(List)` or `covariance(Matrix)`

Example:

$\texttt{covariance}\left(\begin{bmatrix}1 & 2\\ 1 & 1\\ 4 & 7\end{bmatrix}\right)$ returns $\frac{11}{3}$

covariance_ correlation

Returns a vector containing both the covariance and the correlation of the elements of a list or matrix.

```
covariance_correlation(List) or
covariance_correlation(Matrix)
```

Example:

$\texttt{covariance\_correlation}\left(\begin{bmatrix}1 & 2\\ 1 & 1\\ 4 & 7\end{bmatrix}\right)$ returns $\begin{bmatrix}\frac{11}{3} & \frac{33}{6\cdot\sqrt{31}}\end{bmatrix}$

cpartfrac

Returns the result of partial fraction decomposition of a rational fraction in the complex field.

`cpartfrac(RatFrac)`

Example:

$\texttt{cpartfrac}\left(\frac{x}{4-x^2}\right)$ returns $-\frac{\frac{1}{2}}{x-2}-\frac{\frac{1}{2}}{x+2}$

crationalroot

Returns the list of complex rational roots of a polynomial without indicating the multiplicity.

`crationalroot(Poly)`

Example:

`crationalroot(2*x^3+(-5-7*i)*x^2+`
`(-4+14*i)*x+8-4*i)` returns $\left[\frac{3+i}{2} \; 2\cdot i \; 1+i\right]$

cumSum Accepts as argument either a list or a vector and returns a list or vector whose elements are the cumulative sum of the original argument.

`cumSum(List)` or `cumSum(Vector)`

Example:

`cumSum([0,1,2,3,4])` returns `[0,1,3,6,10]`

delcols Given a matrix and an integer *n*, deletes the *n*th column from the matrix and returns the result. If an interval of two integers is used instead of a single integer, deletes all columns in the interval and returns the result.

`delcols(Matrix, Integer)` or `delcols(Matrix, Intg1..Intg2)`

Example:

$$\texttt{delcols}\left(\begin{bmatrix}1&2&3\\4&5&6\\7&8&9\end{bmatrix},2\right) \text{ returns } \begin{bmatrix}1&3\\4&6\\7&9\end{bmatrix}$$

delrows Given a matrix and an integer n, deletes the nth row from the matrix and returns the result. If an interval of two integers is used instead of a single integer, deletes all rows in the interval and returns the result.

`delrows(Matrix, Integer)` or `delrows(Matrix, Intg1..Intg2)`

Example:

$$\texttt{delrows}\left(\begin{bmatrix}1&2&3\\4&5&6\\7&8&9\end{bmatrix},2..3\right) \text{ returns } \begin{bmatrix}1&2&3\end{bmatrix}$$

deltalist Returns the list of the differences between consecutive terms in the original list.

`deltalist(Lst)`

Example:

`deltalist([1,4,8,9])` gives `[3,4,1]`

Dirac Returns the value of the Dirac delta function for a real number.

```
Dirac(Real)
```

Example:

`Dirac(1)` gives `0`

e Enters the mathematical constant e (Euler's number).

egcd Given two polynomials, A and B, returns three polynomials U, V and D such that:

```
U(x)*A(x)+V(x)*B(x)=D(x),
```

where `D(x)=GCD(A(x),B(x))`, the greatest common divisor of polynomials A and B.

The polynomials can be provided in symbolic form or as lists of coefficients in descending order.

Without a third argument, it is assumed that the polynomials are expressions of *x*. With a variable as third argument, the polynomials are expressions of it.

`egcd((PolyA, PolyB, [Var])` or `egcd(ListA, ListB, [Var])`

Example:

`egcd((x-1)^2,x^3-1)` gives `[-x-2,1,3*x-3]`

eigenvals Returns the sequence of eigenvalues of a matrix.

```
eigenvals(Matrix)
```

Example:

$$\texttt{eigenvals}\left(\begin{bmatrix}-2 & -2 & 1\\ -2 & 1 & -2\\ 1 & -2 & -2\end{bmatrix}\right) \text{ returns } \texttt{[3 -3 -3]}$$

eigenvects Returns the eigenvectors of a diagonalizable matrix.

```
eigenvects(Matrix)
```

Example:

$$\texttt{eigenvects}\left(\begin{bmatrix}-2 & -2 & 1\\ -2 & 1 & -2\\ 1 & -2 & -2\end{bmatrix}\right) \text{ returns } \begin{bmatrix}1 & -3 & -3\\ -2 & 0 & -3\\ 1 & 3 & -3\end{bmatrix}$$

eigVl Returns the Jordan matrix associated with a matrix when the eigenvalues are calculable.

```
eigVl(Matrix)
```

EVAL Evaluates an expression.

```
eval(Expr)
```

Example:

`eval(2+3)` returns `5`

evalc Returns a complex expression written in the form `real+i*imag`.

```
evalc(Expr)
```

Example:

`evalc`$\left(\frac{1}{x+y\cdot i}\right)$ returns $\frac{x}{x^2+y^2}-\frac{i\cdot y}{x^2+y^2}$

evalf Given an expression and a number of significant digits, returns the numerical evaluation of the expression to the given number of significant digits. With just an expression, returns the numerical evaluation based on the CAS settings.

```
evalf(Expr,[Integer])
```

Example:

`evalf(2/3)` gives `0.666666666667`

even Tests whether or not an integer is even. Returns 1 if it is and 0 if it is not.

Example:

`even(1251)` returns `0`

exact Converts a decimal expression to a rational or real expression.

```
exact(Expr)
```

Example:

`exact(1.4141)` gives `14141/10000`

EXP Returns the solution to the mathematical constant e to the power of an expression.

```
exp(Expr)
```

Example:

`exp(0)` gives `1`

exponential_regression Given a set of points, returns a vector containing the coefficients *a* and *b* of `y=b*a^x`, the exponential which best fits the set of points. The points may be the elements in two lists or the rows of a matrix.

`exponential_regression(Matrix)` or
`exponential_regression(List1, List2)`

Example:

$\texttt{exponential\_regression}\left(\begin{bmatrix}1.0 & 2.0\\ 0.0 & 1.0\\ 4.0 & 7.0\end{bmatrix}\right)$ returns

```
1.60092225473,1.10008339351
```

EXPR Parses a string into a number or expression and returns the result evaluated.

```
EXPR(String)
```

Examples:

`expr("2+3")` returns `5`

`expr("X+10")` returns `100`, if the variable *X* has the value 90

ezgcd Uses the EZ GCD algorithm to return the greatest common divisor of two polynomials with at least two variables.

```
ezgcd(Poly1,Poly2)
```

Example:

`ezgcd(x^2-2*x-x*y+2*y,x^2-y^2)` returns `x-y`

f2nd Returns a vector consisting of the numerator and denominator of an irreducible form of a rational fraction.

```
f2nd(RatFrac)
```

Example:

$\texttt{f2nd}\left(\frac{x}{x\cdot\sqrt{x}}\right)$ returns $\begin{bmatrix}1 & \sqrt{x}\end{bmatrix}$

factorial Returns the factorial of an integer or the solution to the gamma function for a non-integer. For an integer n, factorial(n)=n!. For a non-integer real number a, factorial(a)=a! = Gamma(a + 1).

```
factorial(Integer) or factorial(Real)
```

Examples:

`factorial(4)` returns `24`

`factorial(1.2)` returns `1.10180249088`

fMax Given an expression in *x*, returns the value of *x* for which the expression has its maximum value. Given an expression and a variable, returns the value of that variable for which the expression has its maximum value.

```
fMax(Expr,[Var])
```

Example:

`fMax(-x^2+2*x+1,x)` gives `1`

fMin Given an expression in *x*, returns the value of *x* for which the expression has its minimum value. Given an expression and a variable, returns the value of that variable for which the expression has its minimum value.

```
fMin(Expr,[Var])
```

Example:

`fMin(x^2-2*x+1,x)` gives `1`

format Returns a real number as a string with the indicated format (f=float, s=scientific, e=engineering).

```
format(Real, String)
```

Example:

`format(9.3456,"s3")` returns `9.35`

fracmod For a given integer *n* (representing a fraction) and an integer *p* (the modulus), returns the fraction *a/b* such that *n=a/b*(mod *p*).

```
fracmod(Integern, Integerp)
```

Example:

`fracmod(41,121)` gives `2/3`

froot Returns a vector containing the roots and poles of a rational polynomial. Each root or pole is followed by its multiplicity.

```
froot(RatPoly)
```

Example:

`froot` $\left(\frac{x^5-2\cdot x^4+x^3}{x-3}\right)$ returns `[0 3 1 2 3 -1]`

fsolve Returns the numerical solution of an equation or a system of equations. With the optional third argument you can specify a guess for the solution or an interval within which it is expected that the solution will occur. With the optional fourth argument you can name the iterative algorithm to be used by the solver.

```
fsolve(Expr,Var,[Guess or Interval],[Method])
```

Example:

`fsolve(cos(x)=x,x,-1..1,bisection_solver)` gives `[0.739085133215]`

function_diff Returns the derivative function of a function (as a mapping).

```
function_diff(Fnc)
```

Example:

`function_diff(sin)` gives `(_x)→cos(_x)`

gauss Given an expression followed by a vector of variables, uses the Gauss algorithm to return the quadratic form of the expression written as a sum or difference of squares of the variables given in the vector.

```
gauss(Expr,VectVar)
```

Example:

`gauss(x^2+2*a*x*y,[x,y])` gives `(a*y+x)^2+(-y^2)*a^2`

GF Creates a Galois Field of characteristic *p* with *p*^*n* elements.

```
GF(Integerp, Integern)
```

Example:

`GF(5,9)` gives `GF(5,k^9-k^8+2*k^7+2*k^5-k^2+2*k-2,[k,K,g],undef)`

gramschmidt Given a basis of a vector subspace, and a function that defines a scalar product on this vector subspace, returns an orthonormal basis for that function.

```
gramschmidt(Vector, Function)
```

Example:

`gramschmidt` $\left(\begin{bmatrix}1 & 1+x\end{bmatrix}, (p,q) \rightarrow \int_{-1}^{1} p \cdot q dx\right)$ returns

$$\begin{bmatrix}\frac{1}{\sqrt{2}} & \frac{1+x-1}{\frac{\sqrt{6}}{3}}\end{bmatrix}$$

halftan2hypexp Returns an expression with sine, cosine, and tangent rewritten in terms of half-tangent, and sinh, cosh, and tanh rewritten in terms of the natural exponential.

```
halftan_hyp2exp(ExprTrig)
```

Example:

`halftan_hyp2exp(sin(x)+sinh(x))` returns

$$\frac{2 \cdot \tan\left(\frac{x}{2}\right)}{\tan\left(\frac{x}{2}\right)^2+1}+\frac{\exp(x)-\frac{1}{\exp(x)}}{2}$$

halt Used in programming to go into step-by-step debugging mode.

hamdist Returns the Hamming distance between two integers.

```
hamdist(Integer1, Integer2)
```

Example:

`hamdist(0x12,0x38)` gives `3`

has Returns 1 if a variable is in an expression, and returns 0 otherwise.

```
has(Expr,Var)
```

Example:

`has(x+y,x)` gives `1`

head Returns the first element of a given vector, sequence or string.

`head(Vector)` or `head(String)` or
`head(Obj1, Obj2,…)`

Example:

`head(1,2,3)` gives `1`

Heaviside Returns the value of the Heaviside function for a given real number (i.e. 1 if *x*>=0, and 0 if *x*<0).

```
Heaviside(Real)
```

Example:

`Heaviside(1)` gives `1`

hyp2exp Returns an expression with hyperbolic terms rewritten as exponentials.

```
hyp2exp(Expr)
```

Example:

`hyp2exp(cosh(x))` returns $\frac{\exp(x)+\frac{1}{\exp(x)}}{2}$

iabcuv Returns [u,v] such that au+bv=c for three integers a, b, and c. Note that c must be a multiple of the greatest common divisor of a and b for there to be a solution.

```
iabcuv(Intgra, Intgrb, Intgrc)
```

Example:

`iabcuv(21,28,7)` gives `[-1,1]`

ibasis Given two matrices, interprets them as two vector spaces and returns the vector basis of their intersection.

```
ibasis(Matrix1, Matrix2)
```

Example:

$\mathtt{ibasis}\left(\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\end{bmatrix},\begin{bmatrix}1 & 1 & 1\\0 & 0 & 1\end{bmatrix}\right)$ returns `[-1,-1,0]`

icontent Returns the greatest common divisor of the integer coefficients of a polynomial.

```
icontent(Poly,[Var])
```

Example:

`icontent(24x^3+6x^2-12x+18)` gives `6`

id Returns a vector containing the solution to the identity function for the argument(s).

```
id(Object1, [Object2,…])
```

Example:

`id([1  2], 3, 4)` returns `[[1  2]  3  4]`

identity Given an integer *n*, returns the identity matrix of dimension *n*.

`identity(Integer)`

Example:

`identity(3)` returns $\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$

iegcd Returns the extended greatest common divisor of two integers.

`iegcd(Integer1, Integer2)`

Example:

`iegcd(14, 21)` returns `[-1, 1, 7]`

igcd Returns the greatest common divisor of two integers or two rational numbers or two polynomials of several variables.

`igcd((Integer1, Integer2)` or
`igcd(Ratnl1, Ratnl2)` or
`igcd(Poly1, Poly2)`

Examples:

`igcd(24, 36)` returns `12`

`igcd(2/3,3/4)` returns `1/12`

interval2center Returns the center of an interval.

`interval2center(Interval)`

Example:

`interval2center(2..5)` returns `7/2`

inv Returns the inverse of an expression or matrix.

`inv(Expr)` or `inv(Matrix)`

Example:

`inv(9/5)` returns `5/9`

iPart Returns a real number without its fractional part or a list of real numbers each without its fractional part.

`iPart(Real)` or `iPart(List)`

Example:

`iPart(4.3)` returns `4`

iquorem Returns the Euclidean quotient and remainder of two integers.

```
iquorem(Integer1, Integer2)
```

Example:

`iquorem(63, 23)` returns `[2, 17]`

jacobi_symbol Returns the Jacobi symbol of the given integers.

```
jacobi_symbol(Integer1, Integer2)
```

Example:

`jacobi_symbol(132,5)` gives `-1`

laplacian Returns the Laplacian of an expression with respect to a vector of variables.

```
laplacian(Expr, Vector)
```

Example:

`laplacian(exp(z)*cos(x*y),[x,y,z])` returns
`-x^2*cos(x*y)*exp(z)-`
`y^2*cos(x*y)*exp(z)+cos(x*y)*exp(z)`

lcoeff Returns the coefficient of the term of highest degree of a polynomial. The polynomial can be expressed in symbolic form or as a list.

`lcoeff(Poly)` or `lcoeff(List)` or `lcoeff(Vector)`

Example:

`lcoeff(-2*x^3+x^2+7*x)` returns `-2`

legendre_symbol With a single integer *n*, returns the Legendre polynomial of degree *n*. With two integers, returns the Legendre symbol of the second integer, using the Legendre polynomial whose degree is the first integer.

```
legendre_symbol(Integer1, [Integer2])
```

Example:

`legendre(4)` gives `35*x^4/8+-15*x^2/4+3/8` while
`legendre(4,2)` returns `443/8` after simplification

length Returns the length of a list, string or set of objects.

`length(List)` or `length(String)` or
`length(Object1, Object2,…)`

Example:

`length([1,2,3])` gives `3`

lgcd Returns the greatest common divisor of a set of integers or polynomials, contained in a list, a vector, or just entered directly as arguments.

`lgcd(List)` or `lgcd(Vector)` or `lgcd(Integer1, Integer2, …)` or `lgcd(Poly1, Poly2, …)`

Example:

`lgcd([45,75,20,15])` gives `5`

lin Returns an expression with the exponentials linearized.

```
lin(Expr)
```

Example:

`lin((exp(x)^3+exp(x))^2)` gives `exp(6*x)+2*exp(4*x)+exp(2*x)`

linear_interpolate Takes a regular sample from a polygonal line defined by a matrix of two rows.

```
linear_interpolate(Matrix,Xmin,Xmax,Xstep)
```

Example:

`linear_interpolate([[1,2,6,9],[3,4,6,7]],1,9,1)` returns `[[1.0,2.0,3.0,4.0,5.0,6.0,7.0,8.0,9.0],[3.0,4.0,4.5,5.0,5.5,6.0,6.33333333333,6.66666666667,7.0]`

linear_regression Given a set of points, returns a vector containing the coefficients *a* and *b* of y=a*x+b, the linear which best fits the set of points. The points may be the elements in two lists or the rows of a matrix.

`linear_regression(Matrix)` or
`linear_regression(List1, List2)`

Example:

$$\texttt{linear\_regression}\left(\begin{bmatrix}1.0 & 2.0\\ 0.0 & 1.0\\ 4.0 & 7.0\end{bmatrix}\right) \text{ returns } [1.53…, 0.769…]$$

list2mat Returns a matrix of *n* columns made by splitting a list into rows, each containing *n* terms. If the number of elements in the list is not divisible by *n*, then the matrix is completed with zeros.

```
list2mat(List, Integer)
```

Example:

`list2mat({1,8,4,9},1)` returns $\begin{bmatrix}1\\8\\4\\9\end{bmatrix}$

lname Returns a list of the variables in an expression.

```
lname(Expr)
```

Example:

`lname(exp(x)*2*sin(y))` gives `[x,y]`

lnexpand Returns the expanded form of a logarithmic expression.

```
lnexpand(Expr)
```

Example:

`lnexpand(ln(3*x))` gives `ln(3)+ln(x)`

logarithmic_ regression Given a set of points, returns a vector containing the coefficients a and b of y=a*ln(x)+b, the natural logarithmic function which best fits the set of points. The points may be the elements in two lists or the rows of a matrix.

`logarithmic_regression(Matrix)` or
`logarithmic_regression(List1, List2)`

Example:

`logarithmic_regression` $\begin{bmatrix}1.0 & 1.0\\2.0 & 4.0\\3.0 & 9.0\\4.0 & 9.0\end{bmatrix}$ returns

`[6.3299…, 0.7207…]`

logb Returns the logarithm of base *b* of *a*.

```
logb(a,b)
```

Example:

`logb(5,2)` gives `ln(5)/ln(2)` which is approximately 2.32192809489

logistic_ regression Returns y, y', C, y'max, xmax, and R, where y is a logistic function (the solution of y'/y=a*y+b), such that y(x0)=y0 and where [y'(x0),y'(x0+1)...] is the best approximation of the line formed by the elements in the list L.

```
logistic_regression(Lst(L),Real(x0),Real(y0))
```

Example:

`logistic_regression([0.0,1.0,2.0,3.0,4.0],0.0,1.0)` gives `[-17.77/(1+exp(-0.496893925384*x+2.82232341488+3.14159265359*i)),-2.48542227469/(1+cosh(-0.496893925384*x+2.82232341488+3.14159265359*i))]`

lvar Given an expression, returns a list of the functions of the expression which utilize variables, including occurrences of the variables themselves.

```
lvar(Expr)
```

Example:

`lvar(e^(x)*2*sin(y) + ln(x))` returns `[e^(x) sin(y) ln(x)]`

map There are two uses for this function, in which the second argument is always a mapping of a variable onto an expression. If the expression is a function of the variable, the function is applied to each element in the vector or matrix (the first argument) and the resulting vector or matrix is returned; if the expression is a Boolean test, each element in the vector or matrix is tested and the results are returned as a vector or matrix. Each test returns either 0 (fail) or 1 (pass).

map(Matrix, Var → Function) or map(Matrix, Var → Test)

Examples:

`map([1 2 3], x→x`^{3}`)` returns `[1 8 27]`

`map([1 2 3], x→ x>1)` returns `[0 1 1]`

mat2list Returns a vector containing the elements of a matrix.

```
mat2list(Matrix)
```

Example:

`mat2list([[1 8],[4 9]])` gives `[1 8 4 9]`

matpow Given a matrix and an integer n, returns the nth power of the matrix by jordanization.

```
matpow(Matrix, Integer)
```

Example:

```
matpow([[1,2],[3,4]],n) gives [[(sqrt(33)-
3)*((sqrt(33)+5)/2)^n*-6/(-12*sqrt(33))+(-
(sqrt(33))-3)*((-(sqrt(33))+5)/2)^n*6/(-
12*sqrt(33)),(sqrt(33)-3)*((sqrt(33)+5)/
2)^n*(-(sqrt(33))-3)/(-12*sqrt(33))+(-
(sqrt(33))-3)*((-(sqrt(33))+5)/2)^n*(-
(sqrt(33))+3)/(-
12*sqrt(33))],[6*((sqrt(33)+5)/2)^n*-6/(-
12*sqrt(33))+6*((-(sqrt(33))+5)/2)^n*6/(-
12*sqrt(33)),6*((sqrt(33)+5)/2)^n*(-
(sqrt(33))-3)/(-12*sqrt(33))+6*((-
(sqrt(33))+5)/2)^n*(-(sqrt(33))+3)/(-
12*sqrt(33))]]
```

MAXREAL Returns the maximum real number that the HP Prime calculator is capable of representing in Home and CAS views:

In the CAS, MAXREAL=1.79769313486*10^{308}

In Home view, MAXREAL=9.99999999999E499

mean Returns the arithmetic mean of a list (with an optional list as a list of weights). With a matrix as argument, returns the mean of the columns.

`mean(List1, [List2])` or `mean(Matrix)`

Example:

`mean([1,2,3],[1,2,3])` gives `7/3`

median Returns the median of a list (with an optional list as a list of weights). With a matrix as argument, returns the median of the columns.

`median(List1, [List2]) or median(Matrix)`

Example:

`median([1,2,3,5,10,4])` gives `3.0`

member Given a list or vector and an element, returns the index of the first occurrence of the element in the list or vector; if the element does not appear in the list or vector, returns 0. Similar to `contains`, except that the element comes first in the argument order.

`member(( Element, List)` or `contains(Element, Vector)`

Example:

`member(2, {0,1,2,3})` returns `3`

MINREAL Returns the minimum real number (closest to zero) that the HP Prime calculator is capable of representing in Home and CAS views:

In the CAS, MINREAL=$2.22507385851 * 10^{-308}$

In Home view, MINREAL=1 E-499

modgcd Uses the modular algorithm to return the greatest common divisor of two polynomials.

```
modgcd(Poly1,Poly2)
```

Example:

`modgcd(x^4-1,(x-1)^2)` gives `x-1`

mRow Given an expression, a matrix, and an integer *n*, multiplies row *n* of the matrix by the expression.

```
mRow(Expr, Matrix, Integer)
```

Example:

$$\texttt{mRow}\left(12, \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}, 1\right) \text{ returns } \begin{bmatrix} 12 & 24 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

mult_c_conjugate If the given complex expression has a complex denominator, returns the expression after both the numerator and the denominator have been multiplied by the complex conjugate of the denominator. If the given complex expression does not have a complex denominator, returns the expression after both the numerator and the denominator have been multiplied by the complex conjugate of the numerator.

```
mult_c_conjugate(Expr)
```

Example:

$$\texttt{mult\_c\_conjugate}\left(\frac{1}{3+2\cdot i}\right) \text{ returns } \frac{1\cdot(3+2\cdot -i)}{(3+2\cdot i)\cdot(3+2\cdot -i)}$$

mult_conjugate Takes an expression in which the numerator or the denominator contains a square root. If the denominator contains a square root, returns the expression after both the numerator and the denominator have been multiplied by the conjugate of the denominator. If the denominator does not contain a square root, returns the expression after both the numerator and the denominator have been multiplied by the conjugate of the numerator.

```
mult_conjugate(Expr)
```

Example:

`mult_conjugate(`$\sqrt{3}-\sqrt{2}$`)` returns $\frac{(\sqrt{3}-\sqrt{2})\cdot(\sqrt{3}+\sqrt{2})}{\sqrt{3}+\sqrt{2}}$

nDeriv Given an expression, a variable of differentiation, and a real number *h*, returns an approximate value of the derivative of the expression, using `f'(x)=(f(x+h)-f(x+h))/(2*h).`

Without a third argument, the value of *h* is set to 0.001; with a real as third argument, it is the value of h. With a variable as the third argument, returns the expression above with that variable in place of *h*.

`nDeriv(Expr,Var, Real)` or
`nDeriv(Expr, Var1, Var2)`

Example:

`nDeriv(f(x),x,h)` returns `(f(x+h)-(f(x-h)))*0.5/h`

NEG Unary minus. Enters the negative sign.

normal Returns the expanded irreducible form of an expression.

```
normal(Expr)
```

Example:

`normal(2*x*2)` gives `4*x`

normalize Given a vector, returns it divided by its l_2 norm (where the l_2 norm is the square root of the sum of the squares of the vector's coordinates).

Given a complex number, returns it divided by its modulus.

`normalize(Vector)` or `normalize(Complex)`

Example:

`normalize(3+4*i)` gives `(3+4*i)/5`

NOT Returns the logical inverse of a Boolean expression.

```
not(Expr)
```

odd Returns 1 if a given integer is odd, and returns 0 otherwise.

```
odd(Integer)
```

Example:

`odd(6)` gives `0`

OR Logical Or. Returns 1 if either or both sides evaluates to true and 0 otherwise.

```
Expr1 OR Expr2
```

Example:

`3 +1==4 OR 8 < 5` returns `1`

order_size Returns the remainder (O term) of a series expansion: limit(x^a*order_size(x),x=0)=0 if a>0.

```
order_size(Expr)
```

pa2b2 Takes a prime integer n congruent to 1 modulo 4 and returns [a,b] such that a^2+b^2=n.

```
pa2b2(Integer)
```

Example:

`pa2b2(17)` gives `[4 1]`

pade Returns the Pade approximation of an expression, i.e. a rational fraction P/Q such that P/Q=Expr mod x^(n+1) or mod N with degree(P)<p.

```
pade(Expr, Var, Integern, Integerp)
```

Example:

`pade(exp(x), x, 5, 3)` returns $\frac{-3 \cdot x^2 - 24 \cdot x - 60}{x^3 - 9 \cdot x^2 + 36 \cdot x - 60}$

PI Inserts π.

PIECEWISE Used to define a piecewise-defined function. Takes as arguments pairs consisting of a condition and an expression. Each of these pairs defines a sub-function of the piecewise function and the domain over which it is active.

$$\texttt{PIECEWISE}\begin{cases} \text{Case1 } \mathit{if} \text{ Test1} \\ \text{Case2 } \mathit{if} \text{ Test2} \\ \quad \ldots \end{cases}$$

Example:

$$\texttt{PIECEWISE}\begin{cases} -x \ \mathit{if} \ x < 0 \\ x^2 \ \mathit{if} \ x \ge 0 \end{cases}$$

Note that the syntax varies if the Entry setting is not set to Textbook:

```
PIECEWISE(Case1, Test1, ...[ Casen, Testn])
```

plotinequation

Shows the graph of the solution of inequations with 2 variables.

```
plotinequation(Expr,[x=xrange,y=yrange],[xste
p],[ystep])
```

polar_point Given the radius and angle of a point in polar form, returns the point with rectangular coordinates in complex form.

```
polar_point(Radius, Angle)
```

Example:

`polar_point(2, π/3)` returns `point`$\left(2\cdot\left(\frac{1}{2}+\frac{i\cdot\sqrt{3}}{2}\right)\right)$

pole Given a circle and a line, returns the point for which the line is polar with respect to the circle.

```
pole(Crcle,Line)
```

Example:

`pole(circle(0, 1), line(1+i, 2))` returns `point(1/2,1/2)`

POLYCOEF Returns the coefficients of a polynomial with roots given in the vector or list argument.

`POLYCOEF(Vector)` or `POLYCOEF(List)`

Example:

`POLYCOEF({-1, 1})` returns `{1, 0, -1}`

POLYEVAL Given a vector or list of coefficients and a value, evaluates the polynomial given by those coefficients at the given value.

`POLYEVAL(Vector, Value)` or `POLYEVAL(List, Value)`

Example:

`POLYEVAL({1,0,-1},3)` returns `8`

polygon Draws the polygon whose vertices are elements in a list.

```
polygon(Point1, Point2, …, Pointn)
```

Example:

```
polygon(GA,GB,GD) draws ΔABD
```

polygonplot

Used in the Geometry app Symbolic view. Given an *n* × *m* matrix, draws and connects the points (*xk*, *yk*), where *xk* is the element in row *k* and column 1, and *yk* is the element in row k and column *j* (with *j* fixed for *k*=1 to *n* rows). Thus, each column pairing generates its own figure, resulting in *m*–1 figures.

```
polygonplot(Matrix)
```

Example:

`polygonplot`$\left(\begin{bmatrix}1 & 2 & 3\\ 2 & 0 & 1\\ -1 & 2 & 3\end{bmatrix}\right)$ draws two figures, each with three points connected by segments.

polygonscatterplot

Used in the Geometry app Symbolic view. Given an *n* × *m* matrix, draws and connects the points (*xk, yk)*, where *xk* is the element in row *k* and column 1, and *yk* is the element in row k and column *j* (with *j* fixed for *k*=1 to *n* rows). Thus, each column pairing generates its own figure, resulting in *m*– figures.

```
polygonscatterplot(Matrix)
```

Example:

`polygonscatterplot`$\left(\begin{bmatrix}1 & 2 & 3\\ 2 & 0 & 1\\ -1 & 2 & 3\end{bmatrix}\right)$ draws two figures, each with three points connected by segments.

polynomial_ regression

Given a set of points defined by two lists, and a positive integer *n*, returns a vector containing the coefficients (a_n, a_{n-1} ... a_0) of y = a_n*x^n + $a_{n-1}x^{n-1}$+ ... a_1*x + a_0), the *n*th order polynomial which best approximates the given points.

```
polynomial_regression(List1, List2, Integer)
```

Example:

`polynomial_regression({1, 2, 3, 4}, {1, 4, 9, 16},3)` returns `[0  1  0  0]`

POLYROOT

Returns the zeros of the polynomial given as a vector of coefficients.

```
POLYROOT(Vector)
```

Example:

`POLYROOT([1 0 -1])` returns `{-1, 1}`

potential Returns a function whose gradient is the vector field defined by a vector and a vector of variables.

```
potential(Vector1, Vector2)
```

Example:

potential([2*x*y+3,x^2-4*z,-4*y],[x,y,z])
returns x^{2}*y+3*x-4*y*z

power_regression Given a set of points defined by two lists, returns a vector containing the coefficients *m* and *b* of *y=b*x^m*, the monomial which best approximates the given points.

```
power_regression(List1, List2)
```

Example:

power_regression({1, 2, 3, 4}, {1, 4, 9, 16})
returns [2 1]

powerpc Given a circle and a point, returns the real number $d^2–r^2$, where *d* is the distance between the point and the center of the circle, and *r* is the radius of the circle.

```
powerpc(Circle, Point)
```

Example:

powerpc(circle(0,1+i),3+i) gives 8

prepend Adds an element to the beginning of a list or vector.

prepend(List, Element) or
prepend(Vector, Element)

Example:

prepend([1,2],3) gives [3,1,2]

primpart Returns a polynomial divided by the greatest common divisor of its coefficients.

```
primpart(Poly,[Var])
```

Example:

primpart(2x^2+10x+6) gives x^2+5*x+3

product With an expression as the first argument, returns the product of solutions when the variable in the expression goes from a minimum value to a maximum value by a given step. If no step is provided, it is taken as 1.

With a list as the first argument, returns the product of the values in the list.

With a matrix as the first argument, returns the element-by-element product of the matrix.

`product(Expr, Var, Min, Max, Step)` or
`product(List) or product(Matrix)`

Example:

`product(n,n,1,10,2)` gives `945`

propfrac Returns a fraction or rational fraction A/B simplified to Q+r/B, where R<B or the degree of R is less than the degree of B.

`propfrac(Fraction)` or `propfrac(RatFrac)`

Example:

`propfrac(28/12)` gives `2+1/3`

ptayl Given a polynomial P and a value *a*, returns the Taylor polynomial Q such that P(*x*)=Q(*x* – *a*).

`ptayl(Poly, Value, [Var])`

Example:

`ptayl(x^2+2*x+1,1)` gives `x^2+4*x+4`

purge Unassigns a variable name.

`purge(Var)`

q2a Given a quadratic form and a vector of variables, returns the matrix of the quadratic form with respect to the given variables.

`q2a(Expr, Vector)`

Example:

`q2a(x^2+2*x*y+2*y^2,[x,y])` returns $\begin{bmatrix}1 & 1\\1 & 2\end{bmatrix}$

quantile Given a list or vector, and a quantile value between 0 and 1, returns the corresponding quantile of the elements of the list or vector.

`quantile(List, Value)` or
`quantile(Vector, Value)`

Example:

`quantile([0,1,3,4,2,5,6],0.25)` returns `1`

quartile1 Given a list or vector, returns the first quartile of the elements of the list or vector. Given a matrix, returns the first quartile of the columns of the matrix.

`quartile1(List)` or `quartile1(Vector)` or `quartile1(Matrix)`

Example:

`quartile1([1,2,3,5,10,4])` gives `2`

quartile3 Given a list or vector, returns the third quartile of the elements of the list or vector. Given a matrix, returns the third quartile of the columns of the matrix.

`quartile3(List)` or `quartile3(Vector)` or `quartile3(Matrix)`

Example:

`quartile3([1,2,3,5,10,4])` returns `5`

quartiles Returns a matrix containing the minimum, first quartile, median, third quartile, and maximum of the elements of a list or vector. With a matrix as argument, returns the 5-number summary of the columns of the matrix.

`quartiles(List)` or `quartiles(Vector)` or `quartiles(Matrix)`

Example:

`quartiles([1,2,3,5,10,4])` returns $\begin{bmatrix} 1 \\ 2 \\ 3 \\ 5 \\ 10 \end{bmatrix}$

quorem Returns the Euclidean quotient and remainder of the quotient of two polynomials, each expressed either in symbolic form directly or as a vector of coefficients. If the polynomials are expressed as vectors of their coefficients, this command returns a similar vector of the quotient and a vector of the remainder.

`quorem(Poly1, Poly2)` or `quorem(Vector1, Vector2)`

Examples:

`quorem(x^3+2*x^2+3*x+4,-x+2)` returns `[-x^2-4*x-11, 26]`

`quorem([1,2,3,4],[-1,2])` returns `[[-1, -4, -11] [26]]`

QUOTE Returns an expression unevaluated.

```
quote(Expr)
```

randexp Given a positive real number, returns a random real number according to the exponential distribution with real a>0.

```
randexp(Real)
```

randperm Given a positive integer, returns a random permutation of [0,1,2,...,n–1].

```
randperm(Intg(n))
```

Example:

`randperm(4)` returns a random permutation of the elements of the vector `[0 1 2 3]`

ratnormal Rewrites an expression as an irreducible rational fraction.

```
ratnormal(Expr)
```

Example:

$\mathtt{ratnormal}\left(\frac{x^2-1}{x^3-1}\right)$ returns $\frac{x+1}{x^2+x+1}$

rectangular_ coordinate Given a vector containing the polar coordinates of a point, returns a vector containing the rectangular coordinates of the point.

```
rectangular_coordinates(Vector)
```

Example:

`rectangular_coordinates([1, π/4])` returns $\begin{bmatrix}\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2}\end{bmatrix}$

reduced_conic Takes a conic expression and returns a vector with the following items:

- The origin of the conic
- The matrix of a basis in which the conic is reduced
- 0 or 1 (0 if the conic is degenerate)
- The reduced equation of the conic
- A vector of the conic’s parametric equations

```
reduced_conic(Expr, [Vector])
```

Example:

`reduced_conic(x^2+2*x-2*y+1)` returns

$$[[-1\ \ 0]]\begin{bmatrix}0 & 1\\ -1 & 0\end{bmatrix} 1\,y^2+2\cdot x \left[-1+-i\cdot\left(-\frac{1}{2}\cdot x\cdot x+i\cdot x\right)\ x-4\ 4\ 0.1\,x^2+2\cdot x-2\cdot y+1-1+(-i)\cdot\left(\frac{-1}{2}\cdot x\cdot x+(i)\cdot x\right)\ \ \right]$$

ref Performs Gaussian reduction of a matrix.

```
ref(Matrix)
```

Example:

`ref` $\begin{bmatrix}3 & 1 & -2\\ 3 & 2 & 2\end{bmatrix}$ returns $\begin{bmatrix}1 & \frac{1}{3} & \frac{-2}{3}\\ 0 & 1 & 2\end{bmatrix}$

remove Given a vector or list, removes the occurrences of *Value* or removes the values that make *Test* true and returns the resulting vector or list.

```
remove(Value, List) or remove(Test, List)
```

Examples:

`remove(5,{1,2,5,6,7,5})` returns `{1,2,6,7}`

`remove(x→x≥5, [1 2 5 6 7 5])` returns `[1 2]`

reorder Given an expression and a vector of variables, reorders the variables in the expression according to the order given in the vector.

```
reorder(Expr, Vector)
```

Example:

`reorder(x`^{2}`+2*x+y`^{2}`,[y,x])` gives `y`^{2}`+x`^{2}`+2*x`

residue Returns the residue of an expression at *a* value.

```
residue(Expr, Var, Value)
```

Example:

`residue(1/z,z,0)` returns `1`

restart Purges all the variables.

```
restart(NULL)
```

resultant Returns the resultant (i.e. the determinant of the Sylvester matrix) of two polynomials.

```
resultant(Poly1, Poly2, Var)
```

Example:

`resultant(x^3+x+1, x^2-x-2,x)` returns `-11`

revlist Reverses the order of the elements in a list or vector.

`revlist(List)` or `revlist(Vector)`

Example:

`revlist([1,2,3])` returns `[3,2,1]`

romberg Uses Romberg's method to return the approximate value of a definite integral.

`romberg(Expr, Var, Val1, Val2)`

Example:

`romberg(exp(x^2),x,0,1)` gives `1.46265174591`

row Given a matrix and an integer *n*, returns the row *n* of the matrix. Given a matrix and an interval, returns a vector containing the rows of the matrix indicated by the interval.

`row(Matrix, Integer)` or `row(Matrix, Interval)`

Example:

$$\texttt{row}\left(\begin{bmatrix}1&2&3\\4&5&6\\7&8&9\end{bmatrix},2\right) \text{ returns } \texttt{[4 5 6]}$$

rowAdd Given a matrix and two integers, returns the matrix obtained from the given matrix after the row indicated by the second integer is replaced by the sum of the rows indicated by the two integers.

`rowAdd(Matrix, Integer1, Integer2)`

Example:

$$\texttt{rowAdd}\left(\begin{bmatrix}1&2\\3&4\\5&6\end{bmatrix},1,2\right) \text{ returns } \begin{bmatrix}1&2\\4&6\\5&6\end{bmatrix}$$

rowDim Returns the number of rows of a matrix.

`rowDim(Matrix)`

Example:

$$\texttt{rowDim}\left(\begin{bmatrix}1&2&3\\4&5&6\end{bmatrix}\right) \text{ gives } \texttt{2}$$

rowSwap Given a matrix and two integers, returns the matrix obtained from the given matrix after swapping the two rows indicated by the two integers.

```
rowSwap(Matrix,Integer1,Integer2)
```

Example:

$\texttt{rowSwap}\left(\begin{bmatrix}1&2\\3&4\\5&6\end{bmatrix},1,2\right)$ returns $\begin{bmatrix}3&4\\1&2\\5&6\end{bmatrix}$

rsolve Given an expression defining a recurrence relation, a variable, and an initial condition, returns the closed form solution (if possible) of the recurrent sequence. Given three lists, each containing multiple items of the above nature, solves the system of recurrent sequences.

```
rsolve(Expr, Var, Condition) or rsolve(List1,
List2, List3)
```

Example:

`rsolve(u(n+1)=2*u(n)+n,u(n),u(0)=1)` returns $\texttt{[-n+2*2}^{\texttt{n}}\texttt{-1]}$

select Given a test expression in a single variable and a list or vector, tests each element in the list or vector and returns a list or vector containing the elements that satisfy the test.

`select(Test, List)` or `select(Test, Vector)`

Example:

`select(x→x>=5,[1,2,6,7])` returns `[6,7]`

seq Given an expression, a variable defined over an interval, and a step value, returns a vector containing the sequence obtained when the expression is evaluated within the given interval using the given step. If no step is provided, the step used is 1.

```
seq(Expr, Var=Interval, [Step])
```

Example:

$\texttt{seq(2}^{\texttt{k}}\texttt{,k=0..8)}$ gives `[1,2,4,8,16,32,64,128,256]`

seqsolve Similar to rsolve. Given an expression defining a recurrence relation in terms of *n* and/or the previous term (*x*), followed by a vector of variables and an initial condition for *x* (the 0th term), returns the closed form solution (if possible) for the recurrent sequence. Given three lists, each containing multiple items of the above nature, solves the system of recurrent sequences.

```
seqsolve(Expr, Vector, Condition) or
seqsolve(List1, List2, List3)
```

Example:

`seqsolve(2x+n,[x,n],1)` gives $-n-1+2*2^{n}$

shift_phase Returns the result of applying a phase shift of pi/2 to a trigonometric expression.

```
shift_phase(Expr)
```

Example:

`shift_phase(sin(x))` gives `-cos((pi+2*x)/2)`

signature Returns the signature of a permutation.

```
signature(Vector)
```

Example:

`signature([2 1 4 5 3])` returns `-1`

simult Returns the solution to a system of linear equations or several systems of linear equations presented in matrix form. In the case of one system of linear equations, takes a matrix of coefficients and a column matrix of constants, and returns the column matrix of the solution.

```
simult(Matrix1, Matrix2)
```

Example:

$\texttt{simult}\left(\begin{bmatrix}3 & 1\\ 3 & 2\end{bmatrix}, \begin{bmatrix}-2\\ 2\end{bmatrix}\right)$ returns $\begin{bmatrix}-2\\ 4\end{bmatrix}$

sincos Returns an expression with the complex exponentials rewritten in terms of sin and cos.

```
sincos(Expr)
```

Example:

`sincos(exp(i*x))` gives `cos(x)+(i)*sin(x)`

spline Given two lists or vectors (one for the *x*-values and one for the *y*-values), as well as a variable and an integer degree, returns the natural spline through the points given by the two lists. The polynomials in the spline are in terms of the given variable and are of the given degree.

`spline(ListX, ListY, Var, Integer)` or
`spline(VectorX, VectorY, Var, Integer)`

Example:

`spline({0,1,2},{1,3,0},x,3)` returns

$$\left[\frac{-5}{4}\cdot x^3+\frac{13}{4}\cdot x+1 \quad \frac{5}{4}\cdot(x-1)^3+\frac{-15}{4}\cdot(x-1)^2-\frac{1}{2}\cdot(x-1)+3\right]$$

sqrt Returns the square root of an expression.

`sqrt(Expr)`

Example:

`sqrt(50)` gives `5*sqrt(2)`

stddev Returns the standard deviation of the elements of a list or a list of the standard deviations of the columns of a matrix. The optional second list is a list of weights.

`stddev(List1, [List2])` or
`stddev(Vector1, [Vector2])` or `stddev(Matrix)`

Example:

`stddev({1,2,3})` returns $\frac{\sqrt{6}}{3}$

stddevp Returns the population standard deviation of the elements of a list or a list of the population standard deviations of the columns of a matrix. The optional second list is a list of weights.

`stddevp(List1, [List2])` or
`stddevp(Vector1, [Vector2])` or
`stddevp(Matrix)`

Example:

`stddevp({1,2,3})` gives `1`

sto Stores a real or string in a variable.

`sto((Real or Str),Var)`

sturmseq Returns the Sturm sequence for a polynomial or a rational fraction.

`sturmseq(Poly,[Var])`

Example:

`sturmseq(x^3-1,x)` gives `[1 [[1 0 0 -1] [3 0 0] 9] 1]`

subMat Extracts from a matrix a sub matrix whose diagonal is defined by four integers. The first two integers define the row and column of the first element and the last two integers define the row and column of the last element of the sub matrix.

```
subMat(Matrix, Int1, Int2, Int3, Int4)
```

Example:

$$\texttt{subMat}\left(\begin{bmatrix}1 & 2\\3 & 4\\5 & 6\end{bmatrix}, 2, 1, 3, 2\right) \text{ returns } \begin{bmatrix}3 & 4\\5 & 6\end{bmatrix}$$

suppress Given a list and an element, deletes the first occurrence of the element in the list (if there is one) and returns the result.

```
suppress(List, Element)
```

Example:

`suppress([0 1 2 3 2],2)` returns `[0 1 3 2]`

surd Given an expression and an integer *n*, returns the expression raised to the power 1/*n*.

```
surd(Expr, Integer)
```

Example:

`surd(8,3)` gives `2`

sylvester Returns the Sylvester matrix of two polynomials.

```
sylvester(Poly1, Poly2, Var)
```

Example:

$$\texttt{sylvester}(x^2-1,x^3-1,x) \text{ gives } \begin{bmatrix}1 & 0 & -1 & 0 & 0\\0 & 1 & 0 & -1 & 0\\0 & 0 & 1 & 0 & -1\\1 & 0 & 0 & -1 & 0\\0 & 1 & 0 & 0 & -1\end{bmatrix}$$

table Defines an array where the indexes are strings or real numbers.

```
table(SeqEqual(index_name=element_value))
```

tail Given a list, string, or sequence of objects, returns a vector with the first element deleted.

`tail(List)` or `tail(Vector)` or `tail(String)` or
`tail(Obj1, Obj2,…)`

Example:

`tail([3 2 4 1 0]) gives [2 4 1 0]`

tan2cossin2 Returns an expression with tan(x) rewritten as (1–cos(2*x))/sin(2*x).

`tan2cossin2(Expr)`

Example:

`tan2cossin2(tan(x))` gives `(1-cos(2*x))/sin(2*x)`

tan2sincos2 Returns an expression with tan(x) rewritten as sin(2*x)/(1+cos(2*x)).

`tan2sincos2(Expr)`

Example:

`tan2sincos2(tan(x))` gives `sin(2*x)/(1+cos(2*x)`

transpose Returns a matrix transposed (without conjugation).

`transpose(Matrix)`

Example:

$\texttt{transpose}\left(\begin{bmatrix}1 & 2\\3 & 4\end{bmatrix}\right)$ returns $\begin{bmatrix}1 & 3\\2 & 4\end{bmatrix}$

trunc Given a value or list of values, as well as an integer *n*, returns the value or list truncated to *n* decimal places. If *n* is not provided, it is taken as 0. Accepts complex numbers.

`trunc(Real, Integer)` or `trunc(List, Integer)`

Example:

`trunc(4.3)` gives `4`

tsimplify Returns an expression with transcendentals rewritten as complex exponentials.

`tsimplify(Expr)`

Example:

`tsimplify(exp(2*x)+exp(x))` gives
`exp(x)^2+exp(x)`

type Returns the type of an expression (e.g. list, string).

```
type(Expr)
```

Example:

`type("abc")` gives `DOM_STRING`

unapply Returns the function defined by an expression and a variable.

```
unapply(Expr,Var)
```

Example:

`unapply(2*x^2,x)` gives `(x)→2*x^2`

valuation Returns the valuation (degree of the term of lowest degree) of a polynomial. With only a polynomial as argument, the valuation returned is for *x*. With a variable as second argument, the valuation is performed for it.

```
valuation(Poly,[Var])
```

Example:

`valuation(x^4+x^3)` gives `3`

variance Returns the variance of a list or the list of variances of the columns of a matrix. The optional second list is a list of weights.

`variance(List1, [List2])` or `variance(Matrix)`

Example:

`variance({3, 4, 2})` returns `2/3`

vpotential Given a vector V and a vector of variables, returns the vector U such that curl(U)=V.

```
vpotential(Vector1, Vector2)
```

Example:

`vpotential([2*x*y+3,`x^2`-4*z,-2*y*z],[x,y,z])`

`returns` $\begin{bmatrix} 0 & -2 \cdot x \cdot y \cdot z & 4 \cdot x \cdot z - \frac{1}{3} \cdot x^3 + 3 \cdot y \end{bmatrix}$

when Used to introduce a conditional statement.

XOR Exclusive or. Returns 1 if the first expression is true and the second expression is false or if the first expression is false and the second expression is true. Returns 0 otherwise.

```
Expr1 XOR Expr2
```

Example:

`0 XOR 1 returns 1`

zip Applies a bivariate function to the elements of two lists or vectors and returns the results in a vector. Without the default value the length of the vector is the minimum of the lengths of the two lists; with the default value, the shorter list is padded with the default value.

`zip('function'List1, List2, Default)` or
`zip('function', Vector1, Vector2, Default)`

Example:

`zip('+',[a,b,c,d], [1,2,3,4])` returns `[a+1 b+2 c+3 d+4]`

| Inserts a template for substituting a value for a variable in an expression.

`Expr|Var1=Val1, [Var2=Val2, …]`

^{2} Returns the square of an expression.

$(\texttt{Expr})^2$

π Inserts pi.

∂ Inserts a template for a partial derivative expression.

Σ Inserts a template for a summation expression.

– Inserts a minus sign.

√ Inserts a square root sign.

∫ Inserts a template for an antiderivative expression.

≠ Inequality test. Returns 1 if the left and right sides are not equal and 0 if they are equal.

≤ Less than or equal inequality test. Returns 1 if the left side of the inequality is less than the right side or if the two sides are equal, and 0 otherwise.

≥ Greater than or equal inequality test. Returns 1 if the left side of the inequality is greater than the right side or if the two sides are equal, and 0 otherwise.

▶ Evaluates the expression then stores the result in variable var. Note that ▶ cannot be used with the graphics G0–G9. See the command `BLIT`.

```
expression ▶ var
```

i Inserts the imaginary number *i*.

$^{-1}$ Returns the inverse of an expression.

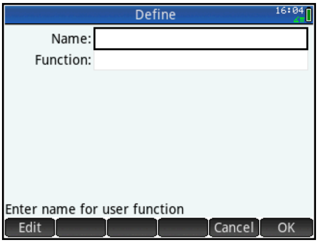
```
(Expr)⁻¹
```

Creating your own functions

You can create your own function by writing a program (see chapter 5) or by using the simpler `DEFINE` functionality. Functions you create yourself appear on the User menu (one of the Toolbox menus).

Suppose you wanted to create the function SINCOS(A,B)=SIN(A)+COS(B)+C.

1. Press Shift xtθn (Define).
2. In the **Name** field, enter a name for the function—for example, SINCOS—and tap OK.
3. In the **Function** field, enter the function.



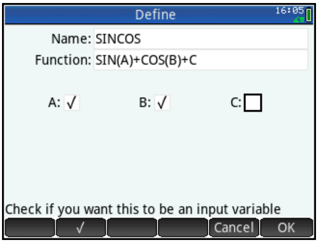
Define 16:04

Name:

Function:

Enter name for user function

SIN ALPHA A ▶ + COS ALPHA B ▶ ALPHA C OK



Define 16:05

Name: SINCOS

Function: SIN(A)+COS(B)+C

A: ✓ B: ✓ C: □

Check if you want this to be an input variable

New fields appear below your function, one for each variable used in defining it. You need to decide which ones are to be input arguments for your functions and which ones are global variables whose values are not input within the function. In this example, we'll make A and B input variables, so our new function takes two arguments. The value of C will be provided by global variable C (which by default is zero).

4. Make sure that `A` and `B` are selected and `C` is not.

5. Tap OK.

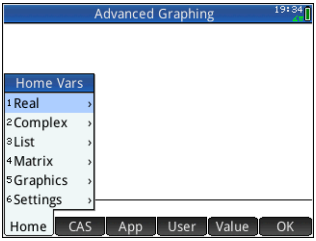
   You can run your function by entering it on the entry line in Home view, or be selecting it from the USER menu. You enter the value for each variable you chose to be a parameter. In this example. we chose A and B to be parameters. Thus you might enter SINCOS(0.5, 0.75). With C=0 and in radians mode, this would return 1.211…

4

Variables

Variables are objects that have names and contain data. They are used to store data, either for later use or to control settings in the Prime system. There are four types of variables, all of which can be found in the **Vars** menu by pressing Vars:

- Home variables
- CAS variables
- App variables
- User variables



The Home and app variables all have names reserved for them. They are also typed; that is, they can contain only certain *types* of objects. For example, the Home variable `A` can only contain a real number. You use Home variables to store data that is important to you, such as matrices, lists, real numbers, etc. You use app variables to store data in apps or to change app settings. You can accomplish these same tasks via the user interface of an app, but app variables give you a quick way of doing these tasks, either from Home or within a program. For example, you can store the expression "`SIN(X)`" in the Function app variable `F1` in Home View, or you could open the Function app, navigate to `F1(X)`, and enter `SIN(X)` in that field.

CAS and user variables can be created by the user and they have no particular type. Their names may be of any length as well. Thus, `diff(t2,t)` returns `2*t` and `diff((bt)2, bt)` returns `2*bt` for the CAS variables `t` and `bt`. Further evaluation of `2*`bt will only return `2*bt`, unless an object has been stored in `bt`. For example, if you enter `bt:={1,2,3}` and then enter `diff((bt)2, bt)`, the CAS will still return `2*bt`. But if you evaluate that result (using the `EVAL` command), the CAS will now return `{2,4,6}`.

User variables are explicitly created by the user. You create user variables either in a program or by assignment in Home view. User variables created in a program are either declared as local or exported as global. User variables created by assignment or exported from a program will show up in the **Vars** User menu. Local variables exist only within their own program.

The following sections describe the various processes associated with variables, such as creating them, storing objects in them, and retrieving their contents. The rest of the chapter contains tables that list all the Home and app variable names.

Working with Home variables

Example 1: Assign π^2 to the Home variable *A* and then calculate 5**A*.

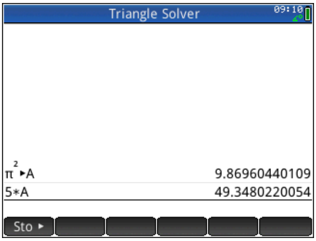
1. Press Settings to display Home view.
2. Assign π^2 to A:

   Shift 3 x^2 Sto ▸ ALPHA Vars Enter

   The result is written to history.
3. Multiply A by 5:

   5 ×

   ALPHA Vars Enter



```
π²▸A                      9.86960440109
5*A                       49.3480220054
```

This example illustrates the process for storing and using any Home variable, not just the Real Home variables A–Z. It is important to match the object you want to store to the correct type of Home variable. See “Home variables” on page 220 for details.

Working with user variables

Example 2: Create a variable called ME and assign π^2 to it.

1. Press Settings to display Home view.
2. Assign π^2 to ME:

   Shift 3 x^2 Sto ▸ ALPHA +/– ALPHA a b/c Enter

3. A message appears asking if you want to create a variable called ME. Tap OK or press Enter to confirm your intention.

   You can now use that variable in subsequent calculations: ME*3 will yield 29.6..., for example.

Example 3: You can also store objects in variables using the assignment operator: Name:=Object. In this example, we'll store {1,2,3} in the user variable YOU.

1. Assign the list to the variable using the assignment operator:=.

   ALPHA ALPHA 1 , 4 – ALPHA Shift .

   Shift 8 1 , 2 , 3 Enter

2. A message appears asking if you want to create a variable called YOU. Tap OK or press Enter to confirm your intention.

   The variable YOU is created and contains the list {1,2,3}. You can now use that variable in subsequent calculations: For example, YOU+60 will return {61,62,63}.

Working with app variables

Just as you can assign values to Home and user variables, you can assign values to app variables. You can modify Home settings on the **Home Settings** screen (Shift Settings). But you can also modify a Home setting from Home view by assigning a value to the variable that represents that setting. For example, entering Base:=0 Enter in Home view forces the Home settings field **Integer** (for the integer base) to binary. A value of 1 would force it to octal, 2 to decimal, and 3 to hex. Another example: you can change the angle measure setting from radians to degrees by entering HAngle :=1 Enter in Home view.

Entering `HAngle:=0` Enter forces the setting to return to radians.

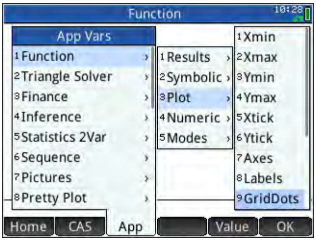
You can see what value has been assigned to a variable—whether Home, app, or user—by entering its name in Home view and pressing Enter. You can enter the name letter by letter, or choose the variable from the Variables menu by pressing Vars.

More about the Vars menu

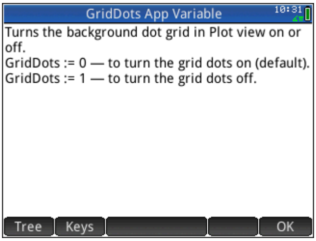
Besides the four variable menus, the **Vars** menu contains a toggle. If you want the value of a variable instead of its name when you choose it from the **Vars** menu, tap Value. A white dot will appear next to the menu button label to indicate that it is active and that variable values rather than names will be returned upon selection.

For the Home and app variables, use the **Vars** menu to get help on the purpose of any of these variables. Select the variable of interest and press Help. Suppose, for example, that you wanted to get help on the Function app variable `GridDots`:

1. Press Vars to open the **Vars** menu.
2. Tap App to open the app variables menu. (If you were interested in a Home variable instead, you would tap Home instead.)



3. Use the cursor keys to navigate to the variable of interest.
4. Press Help to see the help about that variable.



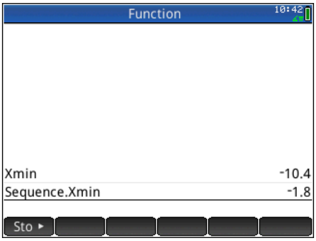
Turns the background dot grid in Plot view on or off.
GridDots := 0 — to turn the grid dots on (default).
GridDots := 1 — to turn the grid dots off.

5. Tap OK to exit or Esc to return to the current **Vars** submenu.

Qualifying variables

Some app variable names are shared by multiple apps. For example, the Function app has a variable named `Xmin`, but so too does the Polar app, the Parametric app, the Sequence app, and the Solve app. Although named identically, these variables usually hold different values. If you attempt to retrieve the contents of a variable that is used in more than one app by entering just its name in Home view, you will get the contents of that version of the variable in the current app. For example, if the Function app is active and you enter `Xmin` in Home view, you will get the value of `Xmin` from the Function app. If you want the value of `Xmin` from, say, the Sequence app, you must qualify the variable name. Enter `Sequence.Xmin` to retrieve the value of `Xmin` from the Sequence app.

In the figure to the right, the value of `Xmin` from the Function app was retrieved first (–10.4…). The qualified variable name entered second retrieved the value of `Xmin` from the Sequence app (–1.8).



```
Xmin                 -10.4
Sequence.Xmin         -1.8
```

Note the syntax required: `app_name.variable_name`.

The app can be any of the 18 HP apps, or one you have created based on a built-in app. The name of the app variable must match a name listed in the app variables tables below. Spaces are not allowed in an app name and must be represented by the underscore character: Shift ␣ _ .

Tip Non-standard characters in variables name—such as Σ and σ—can be entered by selecting them from the special symbols palette (Shift 9) or from the characters menu (Shift Vars Chars A).

Home variables

The Home variables are accessed by pressing Vars Chars A and tapping Home.

Category	Names
Real	A to Z and θ For example, 7.45 Sto ▸ A
Complex	Z0 to Z9 For example, 2+3×*i* Sto ▸ Z1 or (2,3) Sto ▸ Z1 (depending on your Complex number settings)
List	L0 to L9 For example, {1,2,3} Sto ▸ L1.
Matrix	M0 to M9 Store matrices and vectors in these variables. For example, [[1,2],[3,4]] Sto ▸ M1.
Graphics	G0 to G9
Settings	HAngle HFormat HDigits HComplex Date Time Language Entry Integer Base Bits Signed

App variables

The app variables are accessed by pressing Vars and tapping App. They are grouped below by app.

Note that if you have customized a built-in app, your app will appear on the App variables menu under the name you gave it. You access the variables in a customized app in the same way that you access the variables in built-in apps.

Function app variables

Category	Names	
Results [explained below]	SignedArea Extremum Isect	Root Slope

Symbolic	`F1`
	`F2`
	`F3`
	`F4`
	`F5`
		`F6`
		`F7`
		`F8`
		`F9`
		`F0`

Plot	`Axes`
	`Cursor`
	`GridDots`
	`GridLines`
	`Labels`
	`Method`
	`Recenter`
	`Xmax`
		`Xmin`
		`Xtick`
		`Xzoom`
		`Ymax`
		`Ymin`
		`Ytick`
		`Yzoom`

Numeric	`NumStart`
	`NumStep`
	`NumIndep`
		`NumType`
		`NumZoom`

Modes	`AAngle` `AComplex`	`ADigits` `AFormat`

Results variables

Extremum

Contains the value from the last use of the `Extremum` function from the Fcn menu in the Plot view of the

Function app. The app function `EXTREMUM` does not store results to this variable.

Isect

Contains the value from the last use of the `Isect` function from the Fcn menu in the Plot view of the Function app. The app function `ISECT` does not store results to this variable.

Root

Contains the value from the last use of the `Root` function from the Fcn menu in the Plot view of the Function app. The app function `ROOT` does not store results to this variable.

SignedArea

Contains the value from the last use of the `Signed Area` function from the Fcn menu in the Plot view of the Function app. The app function `AREA` does not store results to this variable.

Slope

Contains the value from the last use of the `Slope` function from the Fcn menu in the Plot view of the Function app. The app function `SLOPE` does not store results to this variable.

Geometry app variables

Category	Names	
Plot	`Axes`	`GridDots`
	`GridLines`	`Labels`
	`PixSize`	`ScrollText`
	`Xmax`	`Xmin`
	`Ymax`	`Ymin`
	`XTick`	`YTick`
Modes	`AAngle`	`ADigits`
	`AComplex`	`AFormat`

Spreadsheet app variables

Category	Names	
Numeric	ColWidth	RowHeight
	Row	Col
	Cell	
Modes	AAngle	ADigits
	AComplex	AFormat

Solve app variables

Category	Names	
Symbolic	E1	E6
	E2	E7
	E3	E8
	E4	E9
	E5	E0
Plot	Axes	Xmin
	Cursor	Xtick
	GridDots	Xzoom
	GridLines	Ymax
	Labels	Ymin
	Method	Ytick
	Recenter	Yzoom
	Xmax	
Modes	AAngle	ADigits
	AComplex	AFormat

Advanced Graphing app variables

Category	Names	
Symbolic	V1	V6
	V2	V7
	V3	V8
	V4	V9
	V5	V0
Plot	Axes	Xmin
	Cursor	Xtick
	GridDots	Xzoom
	GridLines	Ymax
	Labels	Ymin
	Recenter	Ytick
	Xmax	Yzoom
Numeric	NumXStart	NumIndep
	NumYStart	NumType
	NumXStep	NumXZoom
	NumYStep	NumYZoom
Modes	AAngle	ADigits
	AComplex	AFormat

Statistics 1Var app variables

Category	Names	
Results [explained below]	NbItem	ΣX
	MinVal	ΣX2
	Q1	MeanX
	MedVal	sX
	Q3	σX
	MaxVal	serrX
Symbolic	H1	H1Type
	H2	H2Type
	H3	H3Type
	H4	H4Type
	H5	H5Type
Plot	Axes	Xmax
	Cursor	Xmin
	GridDots	Xtick
	GridLines	Xzoom
	Hmin	Ymax
	Hmax	Ymin
	Hwidth	Ytick
	Labels	Yzoom
	Recenter	
Numeric	D1	D6
	D2	D7
	D3	D8
	D4	D9
	D5	D0
Modes	AAngle	ADigits
	AComplex	AFormat

Results

NbItem Contains the number of data points in the current 1-variable analysis (H1–H5).

MinVal Contains the minimum value of the data set in the current 1-variable analysis (H1–H5).

Q1 Contains the value of the first quartile in the current 1-variable analysis (H1–H5).

MedVal Contains the median in the current 1-variable analysis (H1–H5).

Q3 Contains the value of the third quartile in the current 1-variable analysis (H1–H5).

MaxVal Contains the maximum value in the current 1-variable analysis (H1–H5).

ΣX Contains the sum of the data set in the current 1-variable analysis (H1–H5).

ΣX2 Contains the sum of the squares of the data set in the current 1-variable analysis (H1–H5).

MeanX Contains the mean of the data set in the current 1-variable analysis (H1–H5).

sX Contains the sample standard deviation of the data set in the current 1-variable analysis (H1–H5).

σX Contains the population standard deviation of the data set in the current 1-variable analysis (H1–H5).

serrX Contains the standard error of the data set in the current 1-variable analysis (H1–H5).

Statistics 2Var app variables

Category	Names	
Results [explained below]	NbItem Corr CoefDet sCov σCov ΣXY MeanX ΣX ΣX2	sX σX serrX MeanY ΣY ΣY2 sY σY serrY
Symbolic	S1 S2 S3 S4 S5	S1Type S2Type S3Type S4Type S5Type
Plot	Axes Cursor GridDots GridLines Labels Method Recenter Xmax	Xmin Xtick Xzoom Ymax Ymin Ytick Yzoom
Numeric	C1 C2 C3 C4 C5	C6 C7 C8 C9 C0
Modes	AAngle AComplex	ADigits AFormat

Results

NbItem Contains the number of data points in the current 2-variable analysis (S1–S5).

Corr Contains the correlation coefficient from the latest calculation of summary statistics. This value is based on the linear fit only, regardless of the fit type chosen.

CoefDet Contains the coefficient of determination from the latest calculation of summary statistics. This value is based on the fit type chosen.

sCov Contains the sample covariance of the current 2-variable statistical analysis (S1–S5).

σCov Contains the population covariance of the current 2-variable statistical analysis (S1–S5).

ΣXY Contains the sum of the X·Y products for the current 2-variable statistical analysis (S1–S5).

MeanX Contains the mean of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

ΣX Contains the sum of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

ΣX2 Contains the sum of the squares of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

sX Contains the sample standard deviation of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

σX Contains the population standard deviation of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

serrX Contains the standard error of the independent values (X) of the current 2-variable statistical analysis (S1–S5).

MeanY Contains the mean of the dependent values (Y) of the current 2-variable statistical analysis (S1–S5).

ΣY Contains the sum of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

ΣY2 Contains the sum of the squares of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

sY Contains the sample standard deviation of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

σY Contains the population standard deviation of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

serrY Contains the standard error of the dependent values (Y) of the current 2-variable statistical analysis (`S1–S5`).

Inference app variables

Category	Names	
Results [explained below]	ContribList Slope Corr serrLine serrInter serrY Result TestScore TestValue Prob	ContribMat Inter CoefDet serrSlope Yval CritScore CritVal1 CritVal2 DF
Symbolic	AltHyp Method	InfType

Category	**Names**	
Numeric	Alpha	Pooled
	Conf	s1
	ExpList	s2
	Mean1	σ1
	Mean2	σ2
	n1	x1
	n2	x2
	μ0	Xlist
	π0	Ylist
	ObsList	Xval
	ObsMat	
Modes	`AAngle`	`ADigits`
	`AComplex`	`AFormat`

Results

CoefDet Contains the value of the coefficient of determination.

ContribList Contains a list of the chi-square contributions by category for the chi-square goodness of fit test.

ContribMat Contains a matrix of the chi-square contributions by category for the chi-square two-way test.

Corr Contains the value of the correlation coefficient.

CritScore Contains the value of the Z- or t-distribution associated with the input α-value

CritVal1 Contains the lower critical value of the experimental variable associated with the negative `TestScore` value which was calculated from the input α-level.

CritVal2 Contains the upper critical value of the experimental variable associated with the positive `TestScore` value which was calculated from the input α-level.

DF Contains the degrees of freedom for the t-tests.

ExpList Contains a list of the expected counts by category for the chi-square goodness of fit test.

ExpMat Contains the matrix of expected counts by category for the chi-square two-way test.

Inter Contains the value of the intercept of the regression line for either the linear t-test or the confidence interval for the intercept

Prob Contains the probability associated with the `TestScore` value.

Result For hypothesis tests, contains 0 or 1 to indicate rejection or failure to reject the null hypothesis.

serrInter Contains the standard error of the intercept for either the linear t-test or the confidence interval for the intercept.

serrLine Contains the standard error of the line for the linear t-test.

serrSlope Contains the standard error of the slope for either the linear t-test or the confidence interval for slope.

serrY Contains the standard error of $\hat{y}$ for either the confidence interval for a mean response or the prediction interval for a future response.

Slope Contains the value of the slope of the regression line for either the linear t-test or the confidence interval for slope.

TestScore Contains the Z- or t-distribution value calculated from the hypothesis test or confidence interval inputs.

TestValue Contains the value of the experimental variable associated with the `TestScore`.

Yval Contains the value of $\hat{y}$ for either the confidence interval for a mean response or the prediction interval for a future response.

Parametric app variables

Category	Names	
Symbolic	X1	X6
	Y1	Y6
	X2	X7
	Y2	Y7
	X3	X8
	Y3	Y8
	X4	X9
	Y4	Y9
	X5	X0
	Y5	Y0
Plot	Axes	Tstep
	Cursor	Xmax
	GridDots	Xmin
	GridLines	Xtick
	Labels	Xzoom
	Method	Ymax
	Recenter	Ymin
	Tmin	Ytick
	Tmax	Yzoom
Numeric	NumStart	NumType
	NumStep	NumZoom
Modes	AAngle	ADigits
	AComplex	AFormat

Polar app variables

Category	Names	
Symbolic	R1	R6
	R2	R7
	R3	R8
	R4	R9
	R5	R0
Plot	θmin	Recenter
	θmax	Xmax
	θstep	Xmin
	Axes	Xtick
	Cursor	Xzoom
	GridDots	Ymax
	GridLines	Ymin
	Labels	Ytick
	Method	Yzoom
Numeric	NumIndep	NumType
	NumStart	NumZoom
	NumStep	
Modes	AAngle	ADigits
	AComplex	AFormat

Finance app variables

Category	Names	
Numeric	CPYR	NbPmt
	BEG	PMT
	FV	PPYR
	IPYR	PV
	GSize	
Modes	AAngle	ADigits
	AComplex	AFormat

Linear Solver app variables

Category	Names	
Numeric	LSystem	LSolution[a]
Modes	AAngle AComplex	ADigits AFormat

[a] Contains a vector with the last solution found by the Linear Solver app.

Triangle Solver app variables

Category	Names	
Numeric	SideA SideB SideC Rect	AngleA AngleB AngleC
Modes	AAngle AComplex	ADigits AFormat

Linear Explorer app variables

Category	Names	
Modes	AAngle AComplex	ADigits AFormat

Quadratic Explorer app variables

Category	Names	
Modes	AAngle AComplex	ADigits AFormat

Trig Explorer app variables

Category	Names	
Modes	AAngle	ADigits
	AComplex	AFormat

Sequence app variables

Category	Names	
Symbolic	U1	U6
	U2	U7
	U3	U8
	U4	U9
	U5	U0
Plot	Axes	Xmax
	Cursor	Xmin
	GridDots	Xtick
	GridLines	Xzoom
	Labels	Ymax
	Nmin	Ymin
	Nmax	Ytick
	Recenter	Yzoom
Numeric	NumIndep	NumType
	NumStart	NumZoom
	NumStep	
Modes	AAngle	ADigits
	AComplex	AFormat

5

Programming in HP PPL

This chapter describes the HP Prime Programming Language (HP PPL). In this chapter you'll learn about:

- programming commands
- writing functions in programs
- using variables in programs
- executing programs
- debugging programs
- creating programs for building custom apps
- sending a program to another HP Prime

HP Prime Programs

An HP Prime program contains a sequence of commands that execute automatically to perform a task.

Command Structure

Commands are separated by a semicolon (;). Commands that take multiple arguments have those arguments enclosed in parentheses and separated by a comma(,). For example,

`PIXON` (*xposition*, *yposition*);

Sometimes, arguments to a command are optional. If an argument is omitted, a default value is used in its place. In the case of the PIXON command, a third argument could be used that specifies the color of the pixel:

`PIXON` (*xposition*, *yposition* [,*color*]);

In this manual, optional arguments to commands appear inside square brackets, as shown above. In the `PIXON` example, a graphics variable (G) could be specified as the first argument. The default is G0, which always contains the currently displayed screen. Thus, the full syntax for the PIXON command is:

`PIXON (`[*G*,] *xposition, yposition* [,*color*]);

Some built-in commands employ an alternative syntax whereby function arguments do not appear in parentheses. Examples include `RETURN` and `RANDOM`.

Program Structure

Programs can contain any number of subroutines (each of which is a function or procedure). Subroutines start with a heading consisting of the name, followed by parentheses that contain a list of parameters or arguments, separated by commas. The body of a subroutine is a sequence of statements enclosed within a BEGIN–END; pair. For example, the body of a simple program, called `MYPROGRAM`, could look like this:

```
EXPORT MYPROGAM()
BEGIN
PIXON(1,1);
END;
```

Comments

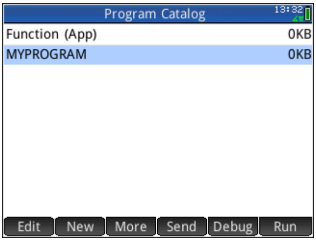
When a line of a program begins with two forward slashes, //, the rest of the line will be ignored. This enables you to insert comments in the program:

```
EXPORT MYPROGAM()
BEGIN
PIXON(1,1);
//This line is just a comment.
END;
```

The Program Catalog

The Program Catalog is where you run and debug programs, and send programs to another HP Prime. You can also rename and remove programs, and it is where you start the Program Editor. The Program Editor is where you create and edit programs. Programs can also be run from Home view or from other programs.

Open the Program Catalog


Program Catalog 13:32

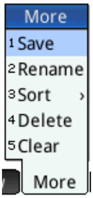
Function (App)	0KB
MYPROGRAM	0KB

Press Shift 1 Program Y (Program) to open the Program Catalog.

The Program Catalog displays a list of program names. The first item in the Program Catalog is a built-in entry that has the same name as the active app. This entry is the app program for the active app, if such a program exists. See "App programs" on page 260 for more information.

Program Catalog: buttons and keys

Button or Key	**Purpose**
Edit	Opens the highlighted program for editing.
New	Prompts for a new program name, then opens the Program Editor.
More	Opens further menu options for the selected program: • Save • Rename • Sort • Delete • Clear These options are described immediately below. To redisplay the initial menu, press On Off or Esc Clear.

Button or Key	Purpose (Continued)
 More 1 Save 2 Rename 3 Sort › 4 Delete 5 Clear More	**Save** creates a copy of the selected program with a new name you are prompted to give. **Rename** renames the selected program. **Sort** sorts the list of programs. (Sort options are alphabetical and chronological). **Delete** deletes the selected program. **Clear** deletes all programs.
Send	Transmits the highlighted program to another HP Prime.
Debug	Debugs the selected program.
Run	Runs the highlighted program.
Shift ▲ or Shift ▼	Moves to the beginning or end of the Program Catalog.
⌫ Del	Deletes the selected program.
Shift Esc Clear	Deletes all programs.

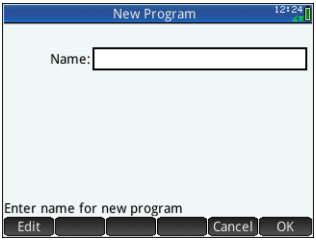
Creating a new program

In the following few sections, we will create a simple program that counts to three as an introduction to using the Program editor and its menus.

1. Open the Program Catalog and start a new program.

   Shift 1 (Program)

   New



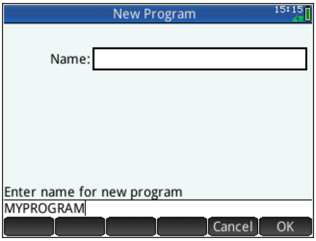
Enter name for new program

2. Enter a name for the program.

   ALPHA ALPHA (to lock alpha mode)

   MYPROGRAM

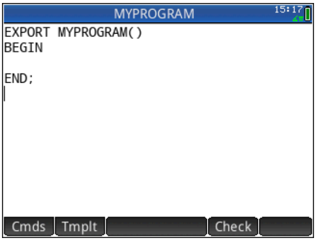
   OK.



Enter name for new program

MYPROGRAM

3. Press OK again. A template for your program is then automatically created. The template consists of a heading for a function with the same name as the program, `EXPORT MYPROGRAM()`, and a `BEGIN-END;` pair that will enclose the statements for the function.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

Tip A program name can contain only alphanumeric characters (letters and numbers) and the underscore character. The first character must be a letter. For example, `GOOD_NAME` and `Spin2` are valid program names, while `HOT STUFF` (contains a space) and `2Cool!` (starts with number and includes !) are not valid.

The Program Editor

Until you become familiar with the HP Prime commands, the easiest way to enter commands is to select them from the Catalog menu (Mem Catlg), or from the Commands menu in the Program Editor (Cmds). To enter variables, symbols, mathematical functions, units, or characters, use the keyboard keys.

Program Editor: buttons and keys

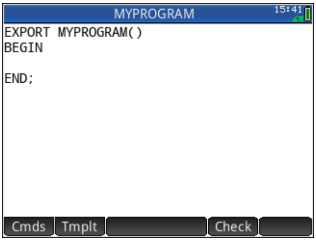
The buttons and keys in the Program Editor are:

Button or Key	Meaning
Check	Checks the current program for errors.
▲ Page ▼ or Shift ▲ and Shift ▼	If your program goes beyond one screen, you can quickly jump from screen to screen by tapping either side of this button. Tap the left side of the button to display the previous page; tap the right side to display the next page. (The left tap will be inactive if you have the first page of the program displayed.)
Cmds	Opens a menu from which you can choose from common programming commands. The commands are grouped under the options: • Strings • Drawing • Matrix • App Functions • Integer • I/O • More

Button or Key	Meaning (Continued)
	Press Esc to return to the main menu. The commands in this menu are described in “Commands under the Cmds menu”, beginning on page 274.
Tmplt	Opens a menu from which you can select common programming commands. The commands are grouped under the options: • Block • Branch • Loop • Variable • Function Press Esc to return to the main menu. The commands in this menu are described in “Commands under the Tmplt menu”, beginning on page 268.
Vars	Displays menus for selecting variable names and values.
Shift Vars (Chars)	Displays a palette of characters. If you display this palette while a program is open, you can choose a character and it will be be added to your program at the cursor point. To add one character, highlight it and tap OK or press Enter. To add a character *without* closing the characters palette, select it and tap Echo.

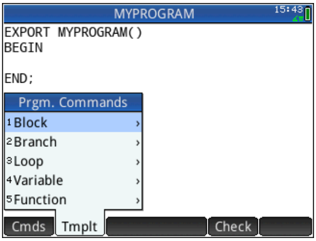
Button or Key	Meaning (Continued)
Shift ▶ and Shift ◀	Moves the cursor to the end (or beginning) of the current line. You can also swipe the screen.
Shift ▲ and Shift ▼	Moves the cursor to the start (or end) of the program. You can also swipe the screen.
ALPHA alpha ▶ and ALPHA alpha ◀	Moves the cursor one screen right (or left). You can also swipe the screen.
Enter ≈	Starts a new line.
⌫ Del	Deletes the character to the left of the cursor.
Shift ⌫ Del	Deletes the character to the right of the cursor.
Shift Esc Clear	Deletes the entire program.

1. To continue the MYPROGRAM example (which we began on page 241), use the cursor keys to position the cursor where you want to insert a command or just tap on the desired location. In this example, you need to position the cursor between `BEGIN` and `END`.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

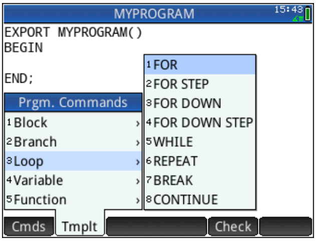
2. Tap Tmplt to open the menu of common programming commands for blocking, branching, looping, variables, and functions.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

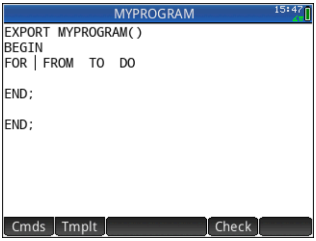
In this example we'll select a LOOP command from the menu.

3. Select `Loop` and then select `FOR` from the sub-menu.



```
EXPORT MYPROGRAM()
BEGIN

END;
```

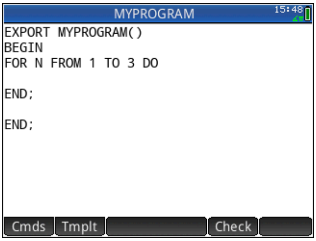
Notice that a FOR_FROM_TO_DO_ template is inserted. All you need do is fill in the missing information.



```
EXPORT MYPROGRAM()
BEGIN
FOR | FROM  TO  DO

END;

END;
```

4. Using the cursor keys and keyboard, fill in the missing parts of the command. In this case, make the statement match the following:

   `FOR N FROM` 1 `TO` 3 `DO`

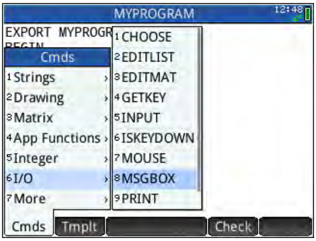


```
EXPORT MYPROGRAM()
BEGIN
FOR N FROM 1 TO 3 DO

END;

END;
```

5. Move the cursor to a blank line below the FOR statement.

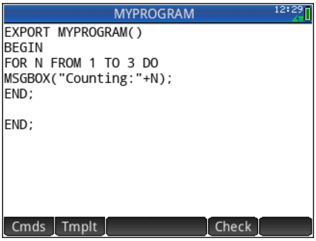
6. Tap Cmds to open the menu of common programming commands.

7. Select `I/O` and then select `MSGBOX` from the sub-menu.



```
EXPORT MYPROGR
BEGIN
```

8. Fill in the arguments of the `MSGBOX` command, and type a semicolon at the end of the command (Shift +).



```
EXPORT MYPROGRAM()
BEGIN
FOR N FROM 1 TO 3 DO
MSGBOX("Counting:"+N);
END;

END;
```

9. Tap Check to check the syntax of your program.

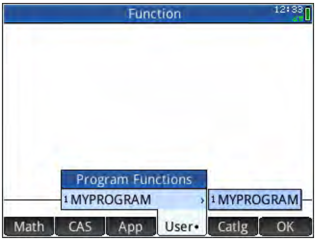
10. When you are finished, press Shift 1 to return to the Program Catalog or Settings to go to Home view. You are ready now to execute the program.

Run a Program

From Home view, enter the name of the program. If the program takes parameters, enter a pair of parentheses after the program name with the parameters inside them each separated by a comma. To run the program, press Enter.

From the Program Catalog, highlight the program you want to run and tap Run. When a program is executed from the catalog, the system looks for a function named `START()` (no parameters).

You can also run a program from the USER menu (one of the Toolbox menus):



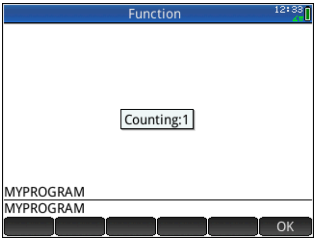
1. Press Mem and tap User.

2. Tap `MYPROGRAM` > to expand the menu and select `MYPROGRAM`.

   `MYPROGRAM` appears on the entry line.

3. Tap Enter and the program executes, displaying a message box.

4. Tap OK three times to step through the FOR loop. Notice that the number shown increments by 1 each time.



Counting:1

MYPROGRAM
MYPROGRAM

After the program terminates, you can resume any other activity with the HP Prime.

If a program has arguments, when you press Run a screen appears prompting you to enter the program parameters.

Multi-function programs

If there is more than one EXPORT function in a program, when Run is tapped a list appears for you to choose which function to run. To see this feature, create a program with the text:

```
EXPORT NAME1( )
BEGIN

END;
EXPORT NAME2( )
BEGIN

END;
```

Now note that when you select your program from the Program Catalog and tap Run or Debug, a list with NAME1 and NAME2 appears.

Debug a Program

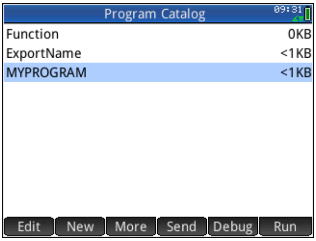
You cannot run a program that contains syntax errors. If the program does not do what you expect it to do, or if there is a run-time error detected by the system, you can execute the program step by step, and look at the values of local variables.

Let’s debug the program created above: MYPROGRAM.

1. In the Program Catalog, select MYPROGRAM.

   Shift 1 Program Y

   Select MYPROGRAM

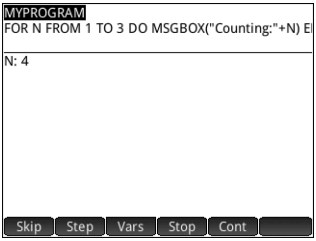


Program Catalog

Function	0KB
ExportName	<1KB
MYPROGRAM	<1KB

2. Tap Debug.

   If there is more than one EXPORT function in a file, a list appears for you to choose which function to debug.



MYPROGRAM
FOR N FROM 1 TO 3 DO MSGBOX("Counting:"+N) EI

N: 4

   While debugging a program, the title of the program or intra-program function appears at the top of the display. Below that is the current line of the program being debugged. The current value of each variable is visible in the main body of the screen. The following menu buttons are available in the debugger:

   Skip: Skips to the next line or block of the program

   Step: Executes the current line

   Vars: Opens a menu of variables. You can select one and add it to the list of variables so you can see how it changes as you step through the program.

   Stop: Closes the debugger

   Con: Continues program execution without debugging

3. Execute the FOR loop command.

   Step

   The `FOR` loop starts and the top of the display shows the next line of the program (the MSGBOX command).

4. Execute the MSGBOX command.

   Step

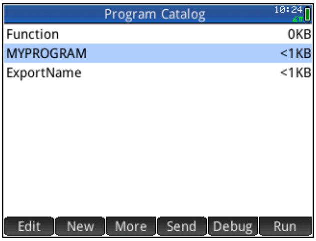
The message box appears. Note that when each message box is displayed, you still have to dismiss it by tapping OK or pressing Enter.

Tap Step and press Enter repeatedly to execute the program step-by-step.

Tap Stop to close the debugger at the current line of the program, or tap Con to run the rest of the program without using the debugger.

Edit a program

You edit a program using the Program Editor, which is accessible from the Program Catalog.


Program Catalog

Function	0KB
MYPROGRAM	<1KB
ExportName	<1KB

1. Open the Program Catalog.

   Shift 1 Program

2. Tap the program you want to edit (or use the arrow keys to highlight it and press Enter).

   The HP Prime opens the Program Editor. The name of your program appears in the title bar of the display. The buttons and keys you can use to edit your program are listed in “Program Editor: buttons and keys” on page 242.

Copy a program or part of a program

You can use the global `Copy` and `Paste` commands to copy part or all of a program. The following steps illustrate the process:

1. Open the Program Catalog.

   Shift 1 Program

2. Tap the program that has the code you want to copy.
3. Press Shift View Copy (Copy).

   The menu buttons change to give you options for copying:

   Begin: Marks where the copying or cutting is to begin.

   End: Marks where the copying or cutting is to end.

   All: Select the entire program.

Cut : Cut the selection.

Copy : Copy the selection.

4. Select what you want to copy or cut (using the options listed immediately above).
5. Tap Copy or Cut .
6. Return to the Program Catalog and open the target program.
7. Move the cursor to where you want to insert the copied or cut code.
8. Press Shift Menu Paste (Paste). The clipboard opens. What you most recently copied or cut will be first in the list and highlighted already, so just tap OK . The code will be pasted into the program, beginning at the cursor location.

Delete a program

To delete a program:

1. Open the Program Catalog.

   Shift 1 Program Y

2. Highlight a program to delete and press ⌫ Del .
3. At the prompt, tap OK to delete the program or Cancel to cancel.

Delete all programs

To delete all programs at once:

1. Open the Program Catalog.

   Shift 1 Program Y

2. Press Shift Esc Clear (Clear).
3. At the prompt, tap OK to delete all programs or Cancel to cancel.

Delete the contents of a program

You can clear the contents of a program without deleting the program. The program then just has a name and nothing else.

1. Open the Program Catalog.

   Shift 1 Program Y

2. Tap the program to open it.
3. Press Shift Esc Clear (Clear).

To share a program

You can send programs between calculators just as you can send apps, notes, matrices, and lists.

The HP Prime programming language

The HP Prime programming language allows you to extend the capabilities of the HP Prime by adding programs, functions and variables to the system. The programs you write can be either standalone or attached to an app. The functions and variables you create can be either local or global. If they are declared to be global, then they appear in the User menu when you press [Mem B] or [Vars Chars A]. In the following sections, we discuss variables and functions, then create a set of short programs to illustrate the various techniques for creating programs, functions, and variables.

Variables and visibility

Variables in an HP Prime program can be used to store numbers, lists, matrices, graphics objects, and strings. The name of a variable must be a sequence of alphanumeric characters (letters and numbers), starting with a letter. Names are case-sensitive, so the variables named `MaxTemp` and `maxTemp` are different.

The HP Prime has built-in variables of various types, visible globally (that is, visible wherever you are in the calculator). For example, the built-in variables `A` to `Z` can be used to store real numbers, `Z0` to `Z9` can be used to store complex numbers, `M0` to `M9` can be used to store matrices and vectors, and so on. These names are reserved. You cannot use them for other data. For example, you cannot name a program `M1`, or store a real number in a variable named `Z8`. In addition to these reserved variables, each HP app has its own reserved variables. Some examples are `Root`, `Xmin`, and `Numstart`. Most of these app variables are local to their app, though a few are global by design. For example, `C1` is used by the Statistics 2Var app to store statistical data. This variable is global so that you can access that data from anywhere in the system. Again, these names cannot be used to name a program or store data of a type other than their design allows. (A full list of system and app variables is given in chapter 4, "Variables", beginning on page 215.)

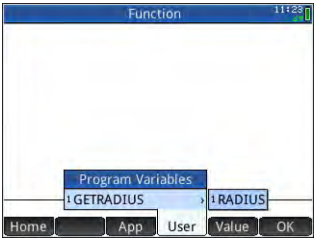
In a program you can declare variables for use only within a particular function. This is done using a LOCAL declaration. The use of local variables enables you to declare and use variables that will not affect the rest of the calculator. Local variables are not bound to a particular type; that is, you can store floating-point numbers, integers, lists, matrices, and symbolic expressions in a variable with any local name. Although the system will allow you to store different types in the same local variable, this is poor programming practice and should be avoided.

Variables declared in a program should have descriptive names. For example, a variable used to store the radius of a circle is better named RADIUS than VGFTRFG. You are more likely to remember what the variable is used for if its name matches its purpose.

If a variable is needed after the program executes, it can be exported from the program using the EXPORT command. To do this, the first command in the program (that is, on a line above the program name) would be EXPORT RADIUS. Then, if a value is assigned to RADIUS, the name appears on the variables menu (Vars Chars A) and is visible globally. This feature allows for extensive and powerful interactivity among different environments in the HP Prime. Note that if another program exports a variable with the same name, the most recently exported version will be active.

The program below prompts the user for the value of RADIUS, and exports the variable for use outside the program.

```
EXPORT RADIUS;
EXPORT GETRADIUS()
BEGIN
INPUT(RADIUS);
END;
```



Note that EXPORT command for the variable RADIUS appears before the heading of the function where RADIUS is assigned. After you execute this program, a new variable named RADIUS appears on the USER GETRADIUS section of the Variables menu.

Qualifying the name of a variable

The HP Prime has many system variables with names that are apparently the same. For example, the Function app has a variable named Xmin, but so too does the Polar app, the Parametric app, the Sequence app, and the Solve app. In a program, and in the Home view, you can refer to a particular version of these variables by qualifying its name. This is done by entering the name of the app (or program) that the variable belongs to, followed by a dot (.), and then the actual variable name. For example, the qualified variable Function.Xmin refers to the value of Xmin within the Function app. Similarly, the qualified variable Parametric.Xmin refers to the value of Xmin in the Parametric app. Despite having the same name—Xmin—the variables could have different values. You do likewise to use a local variable in a program: specify the name of the program, followed by the dot, and then the variable name.

Functions, their arguments, and parameters

You can define your own functions in a program, and data can be passed to a function using parameters. Functions can return a value (using the RETURN statement) or not. When a program is executed from Home view, the program will return the value returned by the *last* statement that was executed.

Furthermore, functions can be defined in a program and exported for use by other programs, in much the same way that variables can be defined and used elsewhere.

In this section, we will create a small set of programs, each illustrating some aspect of programming in the HP Prime. Each program will be used as a building block for a custom app described in the next section, *App Programs*.

Program ROLLDIE

We'll first create a program called ROLLDIE. It simulates the rolling of a single die, returning a random integer between 1 and whatever number is passed into the function.

In the Program Catalog create a new program named ROLLDIE. (For help, see page 241.) Then enter the code in the Program Editor.

```
EXPORT ROLLDIE(N)
BEGIN
RETURN 1+RANDINT(N-1);
END;
```

The first line is the heading of the function. Execution of the RETURN statement causes a random integer from 1 to N to be calculated and returned as the result of the function. Note that the RETURN command causes the execution of the function to terminate. Thus any statements between the RETURN statement and END are ignored.

In Home view (in fact, anywhere in the calculator where a number can be used), you can enter ROLLDIE(6) and a random integer between 1 and 6 inclusive will be returned.

Program ROLLMANY

Because of the EXPORT command in ROLLDIE, another program could use the ROLLDIE function and generate *n* rolls of a die with any number of sides. In the following program, the ROLLDIE function is used to generate *n* rolls of two dice, each with the number of sides given by the local variable sides. The results are stored in list L2, so that L2(1) shows the number of times the dies came up with a combined total of 1, L2(2) shows the number of times the dies came up with a combined total of 2, etc. L2(1) should be 0 (since the sum of the numbers on 2 dice must be at least 2).

```
EXPORT ROLLMANY(n,sides)
BEGIN
  LOCAL k,roll;
  // initialize list of frequencies
  MAKELIST(0,X,1,2*sides,1) ▶ L2;
  FOR k FROM 1 TO n DO
ROLLDIE(sides)+ROLLDIE(sides) ▶ roll;
```

```
    L2(roll)+1 ▶ L2(roll);
    END;
  END;
```

By omitting the EXPORT command when a function is declared, its visibility can be restricted to the program within which it is defined. For example, you could define the ROLLDIE function inside the ROLLMANY program like this:

```
  ROLLDIE();
  EXPORT ROLLMANY(n,sides)
  BEGIN
    LOCAL k,roll;
    // initialize list of frequencies
    MAKELIST(0,X,1,2*sides,1) ▶ L2;
    FOR k FROM 1 TO n DO
  ROLLDIE(sides)+ROLLDIE(sides) ▶ roll;
    L2(roll)+1 ▶ L2(roll);
    END;
  END;
  ROLLDIE(n)
  BEGIN
  RETURN 1+RANDINT(n-1);
  END;
```

In the second version of the ROLLMANY program, there is no ROLLDIE function exported from another program. Instead, ROLLDIE is visible only to ROLLMANY. The ROLLDIE function must be declared before it is called. The first line of the program above contains the declaration of the ROLLDIE function. The definition of the ROLLDIE function is located at the end of the program.

Finally, the list of results could be returned as the result of calling ROLLMANY instead of being stored directly in the global list variable, L2. This way, if the user wanted to store the results elsewhere, it could be done easily.

```
  ROLLDIE();
  EXPORT ROLLMANY(n,sides)
  BEGIN
    LOCAL k,roll,results;
    // initialize list of frequencies
    MAKELIST(0,X,1,2*sides,1) ▶ results;
    FOR k FROM 1 TO n DO
  ROLLDIE(sides)+ROLLDIE(sides) ▶ roll;
    results(roll)+1 ▶ results(roll);
    END;
  RETURN results;
  END;
  ROLLDIE(N)
  BEGIN
  RETURN 1+RANDINT(N-1);
  END;
```

In Home view you would enter `ROLLMANY(100,6)`▶ `L5` and the results of the simulation of 100 rolls of two six-sided dice would be stored in list L5.

The User Keyboard: Customizing key presses

You can assign alternative functionality to any key on the keyboard, including to the functionality provided by the shift and alpha keys. This enables you to customize the keyboard to your particular needs. For example, you could assign SIN to a function that is multi-nested on a menu and thus difficult to get to on a menu (such as ALOG).

A customized keyboard is called the *user keyboard* and you activate it when you go into *user mode*.

User mode

There are two user modes:

- Temporary user mode: the next key press, and only the next, enters the object you have assigned to that key. After entering that object, the keyboard automatically returns to its default operation.

  To activate temporary user mode, press Shift Help (User). Notice that **1U** appears in the title bar. The **1** will remind you that the user keyboard will be active for just one key press.

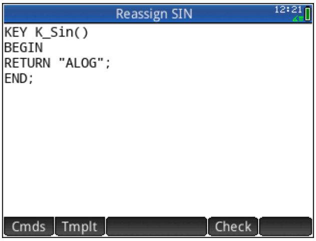
- Persistent user mode: each key press *from now until you turn off user mode* will enter whatever object you have assigned to a key.

To activate persistent user mode, press Shift Help User Shift Help User. Notice that ⬆**U** appears in the title bar. The user keyboard will now remain active until you press Shift Help User again.

If you are in user mode and press a key that hasn't been re-assigned, the key's standard operation is performed.

Re-assigning keys

Suppose you want to assign a commonly used function—such as ALOG—to its own key on the keyboard. Simply create a new program that mimics the syntax in the image at the right.



```
KEY K_Sin()
BEGIN
RETURN "ALOG";
END;
```

The first line of the program specifies the key to be reassigned using its internal name. (The names of all the keys are given in "Key names" on page 258. They are case-sensitive.)

On line 3, enter the text you want produced when the key being re-assigned is pressed. This text must be enclosed in quote marks.

The next time you want to insert `ALOG` at the position of your cursor, you just press Shift Help User SIN ASIN G.

You can enter any string you like in the RETURN line of your program. For example, if you enter "Newton", that text will be returned when you press the re-assigned key. You can even get the program to return user-defined functions as well as system functions, and user-defined variables as well as system variables.

You can also re-assign a shifted key combination. So, for example, ALPHA alpha Shift ÷ could be re-assigned to produce `SLOPE(F1(X),3)` rather than the lowercase *t*. Then if ALPHA alpha Shift ÷ is entered in Home view and Enter ≈ pressed, the gradient at X = 3 of whatever function is currently defined as F1(X) in the Function app would be returned.

Tip A quick way to write a program to re-assign a key is to press Menu Paste and select `Create user key` when you are in the Program Editor. You will then be asked to press the key (or key combination) you want to re-assign. A program template appears, with the internal name of the key (or key combination) added automatically.

Key names

The first line of a program that re-assigns a key must specify the key to be reassigned using its internal name. The table below gives the internal name for each key. Note that key names are case-sensitive.

Internal name of keys and key states

Key	Name	Shift + key	ALPHA alpha + key	ALPHA alpha Shift + key
0 Notes " "	K_0	KS_0	KA_0	KSA_0
1 Program Y	K_1	KS_1	KA_1	KSA_1
2 *i* Z	K_2	KS_2	KA_2	KSA_2
3 π #	K_3	KS_3	KA_2	KSA_2
4 Matrix U	K_4	KS_4	KA_4	KSA_4
5 [ ] V	K_5	KS_5	KA_5	KSA_5
6 ≤,≥,≠ W	K_6	KS_6	KA_6	KSA_6
7 List Q	K_7	KS_7	KA_7	KSA_7
8 { } R	K_8	KS_8	KA_8	KSA_8
9 !,∞,→ S	K_9	KS_9	KA_9	KSA_9
a b/c o ' '' E	K_Abc	KS_Abc	KA_Abc	KSA_Abc
ALPHA alpha	K_Alpha	KS_Alpha	KA_Alpha	KSA_Alpha
Apps Info	K_Apps	KS_Apps	KA_Apps	KSA_Apps
⌫ Del	K_Bksp	KS_Bksp	KA_Bksp	KSA_Bksp
, Eval O	K_Comma	KS_Comma	KA_Comma	KSA_Comma
COS ACOS H	K_Cos	KS_Cos	KA_Cos	KSA_Cos
÷ x^{-1} T	K_Div	KS_Div	KA_Div	KSA_Div

Internal name of keys and key states				
Key	Name	Shift + key	ALPHA alpha + key	ALPHA alpha Shift + key
. =	K_Dot	KS_Dot	KA_Dot	KSA_Dot
▼	K_Down	KS_Down	KA_Down	KSA_Down
Enter ≈	K_Enter	KS_Enter	KA_Enter	KSA_Enter
⌂ Settings	K_Home	KS_Home	KA_Home	KSA_Home
◀	K_Left	KS_Left	KA_Left	KSA_Left
▶	K_Right	KS_Right	KA_Right	KSA_Right
LN e^x J	K_Ln	KS_Ln	KA_Ln	KSA_Ln
LOG 10^x K	K_Log	KS_Log	KA_Log	KSA_Log
− Base :	K_Minus	KS_Minus	KA_Minus	KSA_Minus
+/− |x| M	K_Neg	KS_Neg	KA_Neg	KSA_Neg
Num ▦ ↳Setup	K_Num	KS_Num	KA_Num	KSA_Num
On Off	K_On	–	KA_On	KSA_On
Plot ↳Setup	K_Plot	KS_Plot	KA_Plot	KSA_Plot
+ Ans ;	K_Plus	KS_Plus	KA_Plus	KSA_Plus
x^y $\sqrt[n]{}$ F	K_Power	KS_Power	KA_Power	KSA_Power
SIN ASIN G	K_Sin	KS_Sin	KA_Sin	KSA_Sin
x^2 √ L	K_Sq	KS_Sq	KA_Sq	KSA_Sq
Symb ↳Setup	K_Symb	KS_Symb	KA_Symb	KSA_Symb
TAN ATAN I	K_Tan	KS_Tan	KA_Tan	KSA_Tan
▲	K_Up	KS_Up	KA_Up	KSA_Up
Vars Chars A	K_Vars	KS_Vars	KA_Vars	KSA_Vars
View Copy	K_View	KS_View	KA_View	KSA_View
$x\,t\,\theta\,n$ Define D	K_Xttn	KS_Xttn	KA_Xttn	KSA_Xttn
? Help User	K_Help	–	KA_Help	KSA_Help
☰ Menu Paste	K_Menu	KS_Menu	KA_Menu	KSA_Menu

Internal name of keys and key states				
Key	Name	Shift + key	ALPHA alpha + key	ALPHA alpha Shift + key
Esc Clear	K_Esc	KS_Esc	KA_Esc	KSA_Esc
CAS Settings	K_Cas	KS_Cas	KA_Cas	KSA_Cas
Mem B	K_Math	KS_Math	KA_Math	KSA_Math
Units C	K_Templ	KS_Templ	KA_Templ	KSA_Templ
( ) N	K_Paren	KS_Paren	KA_Paren	KSA_Paren
EEX Sto▸ P	K_Eex	KS_Eex	KA_Eex	KSA_Eex
× X	K_Mul	KS_Mul	KA_Mul	KSA_Mul
Shift	–	–	–	–
␣ _	K_Space	KS_Space	KA_Space	KSA_Space

App programs

An app is a unified collection of views, programs, notes, and associated data. Creating an app program allows you to redefine the app's views and how a user will interact with those views. This is done with (a) dedicated program functions with special names and (b) by redefining the views in the View menu.

Using dedicated program functions

There are nine dedicated program function names, as shown in the table below. These functions are called when the corresponding keys shown in the table are pressed. These functions are designed to be written into a program that controls an app and used in the context of that app.

Program	**Name**	**Equivalent Keystrokes**
Symb	Symbolic view	Symb
SymbSetup	Symbolic Setup	Shift Symb
Plot	Plot view	Plot
PlotSetup	Plot Setup	Shift Plot
Num	Numeric view	Num
NumSetup	Numeric Setup	Shift Num
Info	Info view	Shift Apps
START	Starts an app	Start
RESET	Resets or initializes an app	Reset

Redefining the View menu

The View menu allows any app to define views in addition to the standard seven views shown in the table above. By default, each HP app has its own set of additional views contained in this menu. The `VIEW` command allows you to redefine these views to run programs you have created for an app. The syntax for the `VIEW` command is:

```
VIEW "text", function()
```

By adding `VIEW "text", function()` before the declaration of a function, you will override the list of views for the app. For example, if your app program defines three views—"*SetSides*", "*RollDice*" and "*PlotResults*"—when you press View you will see *SetSides, RollDice,* and *PlotResults* instead of the app's default view list.

Customizing an app

When an app is active, its associated program appears as the first item in the Program Catalog. It is within this program that you put functions to create a custom app. A useful procedure for customizing an app is illustrated below:

1. Decide on the HP app that you want to customize. The customized app inherits all the properties of the HP app.
2. Go to the Applications Library (Apps Info), highlight the HP app, tap Save and save the app with a unique name.
3. Customize the new app if you need to (for example, by configuring the axes or angle measure settings).
4. Open the Program Catalog, select your new app program, and tap Edit.
5. Develop the functions to work with your customized app. When you develop the functions, use the app naming conventions described above.
6. Put the `VIEW` command in your program to modify the app's View menu.
7. Decide if your app will create new global variables. If so, you should `EXPORT` them from a separate user program that is called from the `Start()` function in the app program. This way they will not have their values lost.
8. Test the app and debug the associated programs.

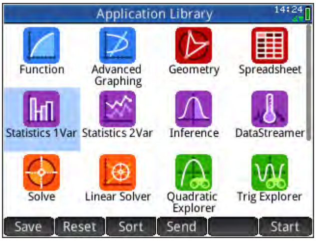
It is possible to link more than one app via programs. For example, a program associated with the Function app could execute a command to start the Statistics 1Var app, and a program associated with the Statistics 1Var app could return to the Function app (or launch any other app).

Example

The following example illustrates the process of creating a custom app. The app is based on the built-in Statistics 1Var app. It simulates the rolling of a pair of dice, each with a number of sides specified by the user. The results are tabulated, and can be viewed either in a table or graphically.

1. In the Application Librray, select the Statistics 1Var app but don't open it.

   Apps Info Select `Statistics 1Var`.

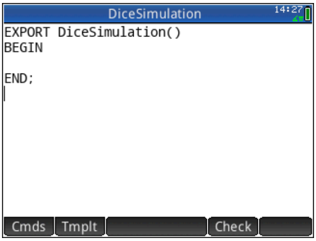


2. Tap Save.
3. Enter a name for the new app (such as `DiceSimulation`.)
4. Tap OK twice.

   The new app appears in the Application Library.
5. Open the Program Catalog.

   Shift 1 Program Y
6. Tap the program to open it.

   Each customised app has one program associated with it. Initially, this program is empty. You customize the app by entering functions into that program.



```
EXPORT DiceSimulation()
BEGIN

END;
```

At this point you decide how you want the user to interact with the app. In this example, we will want the user to be able to:

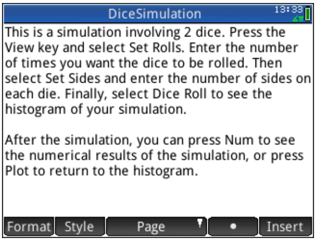
- start and initialize the app, and display a short note
- specify the number of sides (that is, faces) on each die
- specify the number of times to roll the dice
- graphically display the results of the simulation
- numerically display the results of the simulation.

With that in mind, we will create the following views:

START, ROLL DICE, SET SIDES, and SET ROLLS.

The START option will initialize the app and display a note that gives the user instructions. The user will also interact with the app through the Numeric view and the Plot view.

These views will be activated by pressing Num and Plot, but the function Plot() in our app program will actually launch the latter view after doing some configuration.



DiceSimulation

This is a simulation involving 2 dice. Press the View key and select Set Rolls. Enter the number of times you want the dice to be rolled. Then select Set Sides and enter the number of sides on each die. Finally, select Dice Roll to see the histogram of your simulation.

After the simulation, you can press Num to see the numerical results of the simulation, or press Plot to return to the histogram.

Before entering the following program, press Shift Apps to open the Info editor and enter the text shown in the figure. This note will be attached to the app and will be displayed when the user selects the Start option from the View menu (or presses Shift Apps).

The program discussed earlier in this chapter to get the number of sides for a dice is expanded here, so that the possible sums of two such die are stored in dataset D1. Enter the following sub-routines into the program for the DiceSimulation app.

The DiceSimulation program

```
DICESIMVARS();
ROLLDIE();
 EXPORT SIDES,ROLLS;
EXPORT DiceSimulation()
BEGIN
END;
VIEW "Start",START()
BEGIN
  D1:={};
  D2:={};
  SetSample(H1,D1);
  SetFreq(H1,D2);
  H1Type:=1;
  STARTVIEW(6,1);
END;
VIEW "Roll Dice",ROLLMANY()
BEGIN
  LOCAL k,roll;
  D1:= MAKELIST(X+1,X,1,2*SIDES-1,1);
  D2:= MAKELIST(0,X,1,2*SIDES-1,1);
  FOR k FROM 1 TO ROLLS DO
    roll:=ROLLDIE(SIDES)+ROLLDIE
(SIDES);
    D2(roll-1):= D2(roll-1)+1;
  END;
  Xmin:= -0.1;
  Xmax:= MAX(D1)+1;
  Ymin:= -0.1;
  Ymax:= MAX(D2)+1;
  STARTVIEW(1,1);
END;
VIEW "Set Sides",SETSIDES()
BEGIN
  REPEAT
    INPUT(SIDES,"Die
Sides","N=","Enter# of sides",2);
    SIDES:= FLOOR(SIDES);
    IF SIDES<2 THEN
     MSGBOX("# of sides must be >= 4");
    END;
  UNTIL SIDES >=4;
  STARTVIEW(7,1);
END;

VIEW "Set Rolls",SETROLLS()
BEGIN
  REPEAT
    INPUT(ROLLS,"Num of
rolls","N=","Enter# of rolls",25);
    ROLLS:= FLOOR(ROLLS);
    IF ROLLS<1 THEN
      MSGBOX("You must enter a num
>=1");
    END;
  UNTIL ROLLS>=1;
  STARTVIEW(7,1);
END;
Plot()
```

```
BEGIN
  Xmin:=-0.1;
  Xmax:= MAX(D1)+1;
  Ymin:= –0.1;
  Ymax:= MAX(D2)+1;
  STARTVIEW(1,1);
END;
Symb()
BEGIN
  SetSample(H1,D1);
  SetFreq(H1,D2);
  H1Type:=1;
  STARTVIEW(0,1);
END;
```

The ROLLMANY() routine is an adaptation of the program presented earlier in this chapter. Since you cannot pass parameters to a program called through a selection from a custom View menu, the exported variables SIDES and ROLLS are used in place of the parameters that were used in the previous versions.

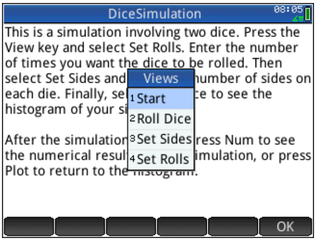
The program above calls two other user programs: ROLLDIE() and DICESIMVARS(). ROLLDIE() appears earlier in this chapter. Here is DICESIMVARS. Create a program with that name and enter the following code.

The program DICESIMVARS

```
EXPORT ROLLS,SIDES;
EXPORT DICESIMVARS()
BEGIN
10 ▶ ROLLS;
6 ▶SIDES;
END;
```

1. Press Apps Info, and open DiceSimulation. The note will appear explaining how the app works.

2. Press View to see the custom app menu. Here you can reset the app (`Start`), set the number of sides of the dice, the number of rolls, and execute a simulation.



DiceSimulation 08:05

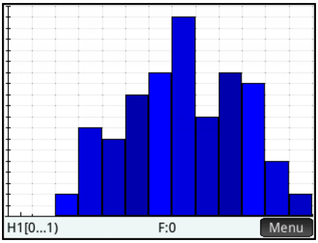
This is a simulation involving two dice. Press the View key and select Set Rolls. Enter the number of times you want the dice to be rolled. Then select Set Sides and umber of sides on each die. Finally, se e to see the histogram of your si

After the simulation ress Num to see the numerical resul imulation, or press Plot to return to the histogram.

3. Select `Set Rolls` and enter 100.

4. Select `Set Sides` and enter `6`.

5. Select `Roll Dice`. You will see a histogram similar to the own shown in the figure.



6. Press Num to see the data and Plot to return to the histogram.

7. To run another simulation, press View and select `Roll Dice`.

Program commands

This section describes each program command. The commands under the Tmplt menu are described first. The commands under the Cmds menu are described in "Commands under the Cmds menu" on page 274.

Commands under the Tmplt menu

Block

The block commands determine the beginning and end of a sub-routine or function. There is also a `Return` command to recall results from sub-routines or functions.

BEGIN END Syntax: `BEGIN command1; command2;…; commandN; END;`

Defines a command or set of commands to be executed together. In the simple program:

```
EXPORT SQM1(X)
BEGIN
RETURN X^2-1;
END;
```

the block is the single RETURN command.

If you entered `SQM1(8)` in Home view, the result returned would be 63.

RETURN Syntax: `RETURN` *expression*;

Returns the current value of *expression*.

KILL Syntax: `KILL`;

Stops the step-by-step execution of the current program (with debug).

Branch

In what follows, the plural word *commands* refers to both a single command or a set of commands.

IF THEN Syntax: `IF` *test* `THEN` *commands* `END`;

Evaluate *test*. If *test* is true (not 0), executes *commands*. Otherwise, nothing happens.

IF THEN ELSE Syntax: `IF` *test* `THEN` *commands1* `ELSE` *commands 2* `END`;

Evaluate *test*. If *test* is true (non 0), executes *commands 1*, otherwise, executes *commands 2*

CASE Syntax:

```
CASE
    IF test1 THEN commands1 END;
    IF test2 THEN commands2 END;
    …
    [DEFAULT commands]
END;
```

Evaluates *test1*. If true, executes `commands1` and ends the CASE. Otherwise, evaluates `test2`. If true, executes `commands2` and ends the CASE. Continues evaluating tests until a true is found. If no true test is found, executes default commands, if provided.

Example:

```
CASE
IF x<0 THEN RETURN "negative"; END;
IF x<1 THEN RETURN "small"; END;
DEFAULT RETURN "large";
END;
```

IFERR `IFERR` *commands1* `THEN` *commands2* `END`;

Executes sequence of *commands1*. If an error occurs during execution of *commands1*, executes sequence of *commands2*.

IFERR ELSE `IFERR` *commands1* `THEN` *commands2* `ELSE` *commands3* `END`;

Executes sequence of *commands1*. If an error occurs during execution of *commands1*, executes sequence of *commands2*. Otherwise, execute sequence of *commands3*.

Loop

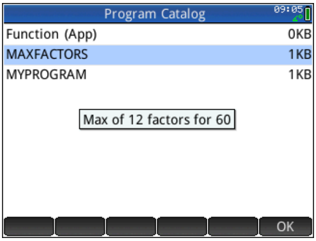
FOR Syntax: `FOR` *var* `FROM` *start* `TO` *finish* `DO` *commands END;*

Sets variable *var* to *start*, and for as long as this variable is less than or equal to *finish*, executes the sequence of *commands*, and then adds 1 (*increment*) to *var*.

Example 1: This program determines which integer from 2 to N has the greatest number of factors.

```
EXPORT MAXFACTORS(N)
BEGIN
LOCAL cur,max,k,result;
1 ▶ max;1 ▶ result;
FOR k FROM 2 TO N DO
 SIZE(CAS.idivis(k)) ▶ cur;
 IF cur(1) > max THEN
  cur(1) ▶ max;
  k ▶ result;
 END;
END;
MSGBOX("Max of "+ max +" factors for "+result);
END;
```

In Home, enter MAXFACTORS(100).



Function (App) 0KB
MAXFACTORS 1KB
MYPROGRAM 1KB

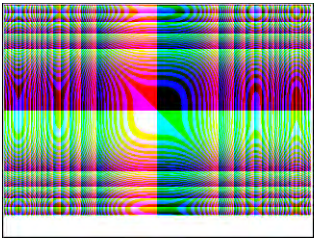
Max of 12 factors for 60

FOR STEP

Syntax: FOR *var* FROM *start* TO *finish* [*STEP increment*] DO *commands END;*

Sets variable *var* to *start*, and for as long as this variable is less than or equal to *finish*, executes the sequence of *commands*, and then adds *increment* to *var*.

Example 2: This program draws an interesting pattern on the screen.



```
EXPORT DRAWPATTERN()
BEGIN
LOCAL xincr,yincr,color;
STARTAPP("Function");
```

```
RECT();
xincr := (Xmax - Xmin)/318;
yincr := (Ymax - Ymin)/218;
FOR X FROM Xmin TO Xmax STEP xincr DO
FOR Y FROM Ymin TO Ymax STEP yincr DO
color := RGB(X^3 MOD 255,Y^3 MOD 255,
TAN(0.1*(X^3+Y^3)) MOD 255);
PIXON(X,Y,color);
END;
END;
WAIT;
END;
```

FOR DOWN

Syntax: `FOR` *var* `FROM` *start* `DOWNTO` *finish* `DO` *commands END;*

Sets variable *var* to *start*, and for as long as this variable is more than or equal to *finish*, executes the sequence of commands, and then subtracts 1 (decrement) from *var*.

FOR DOWN STEP

Syntax: `FOR` *var* `FROM` *start* `DOWNTO` *finish* [*STEP increment*] `DO` *commands END;*

Sets variable *var* to *start*, and for as long as this variable is more than or equal to *finish*, executes the sequence of commands, and then subtracts *increment* from *var*.

WHILE

Syntax: `WHILE` *test* `DO` *commands* `END;`

Evaluates `test`. If result is true (not 0), executes the *commands*, and repeats.

Example: A perfect number is one that is equal to the sum of all its proper divisors. For example, 6 is a perfect number because 6 = 1+2+3. The example below returns true when its argument is a perfect number.

```
EXPORT ISPERFECT(n)
BEGIN
 LOCAL d, sum;
 2 ▶d;
 1 ▶ sum;
WHILE sum <= n AND d < n DO
 IF irem(n,d)==0 THEN
  sum+d ▶ sum;
 END;
 d+1 ▶d;
 END;
 RETURN sum==n;
END;
```

The following program displays all the perfect numbers up to 1000:

```
EXPORT PERFECTNUMS()
BEGIN
LOCAL k;
FOR k FROM 2 TO 1000 DO
 IF ISPERFECT(k) THEN
 MSGBOX(k+" is perfect, press OK");
 END;
END;
END;
```

REPEAT Syntax: `REPEAT` *commands* `UNTIL` *test*;

Repeats the sequence of *commands* until *test* is true (not 0).

The example below prompts for a positive value for SIDES, modifying an earlier program in this chapter:

```
EXPORT SIDES;
EXPORT GETSIDES()
BEGIN
 REPEAT
 INPUT(SIDES,"Die Sides","N = ","Enter
num sides",2);
 UNTIL SIDES>0;
END;
```

BREAK Syntax: `BREAK(`*n*`)`

Exits from loops by breaking out of *n* loop levels. Execution picks up with the first statement after the loop. With no argument, exits from a single loop.

CONTINUE Syntax: `CONTINUE`

Transfers execution to the start of the next iteration of a loop.

Variable

These commands enable you to control the visibility of a user-defined variable.

LOCAL

Local.

Syntax: `LOCAL` *var1,var2,…varn;*

Makes the variables var1, var2, etc. local to the program in which they are found.

EXPORT

Syntax: `EXPORT var1, var2, …, varn;`

Exports the variables *var1*, *var2*, etc. so they are globally available and appear on the User menu when you press Vars and select User.

Function

These commands enable you to control the visibility of a user-defined function.

EXPORT

Export.

Syntax: `EXPORT FunctionName(Parameters)` or `Export Var{:=Val)` or `Export Var1[:=Val1], Var2[:=Val2], ...)`

In a program, declares the functions or variables to export globally. The exported functions appear in the Toolbox User menu and the exported variables appear in the Vars CAS, App, and User menus.

For an exported function, there are two uses of EXPORT.

Forward function declaration:

EXPORT function(params);

Normal function declaration:

EXPORT function[(params)]

BEGIN

//Function definition goes here

END;

Examples:

```
EXPORT X2M1(X);
```

```
EXPORT ratio:=0.15;
```

```
Export X2M1(X)

BEGIN

RETURN X^2-1;

END;
```

VIEW Syntax: `VIEW “text”, functionname();`

Replaces the View menu of the current app and adds an entry with `“text”`. If `“text”` is selected and the user presses OK or Enter, then `functionname()` is called.

KEY A prefix to a key name when creating a user keyboard. See “The User Keyboard: Customizing key presses” on page 256.

Commands under the Cmds menu

Strings

A string is a sequence of characters enclosed in double quotes (""). To put a double quote in a string, use two consecutive double quotes. The \ character starts an escape sequence, and the character(s) immediately following are interpreted specially. *n* inserts a new line and two backslashes insert a single backslash. To put a new line into the string, press Enter to wrap the text at that point.

ASC Syntax: `ASC`(*string*)

Returns a list containing the ASCII codes of *string*.

Example: `ASC(`*"AB"*) returns [65,66]

CHAR Syntax: `CHAR(vector)` or `CHAR(integer)`

Returns the string corresponding to the character codes in `vector`, or the single code of `integer`.

Examples: `CHAR(`*65*) returns "A"

`CHAR(`[82,77,72]) returns "RMH"

DIM Syntax: `DIM`(*str*ing)

Returns the number of characters in `string`.

Example: `DIM(`*"12345"*`)` returns 5, `DIM(`*""""*`)` and `DIM(`*"\n"*`)` return 1. (Notice the use of the two double quotes and the escape sequence.)

STRING Syntax: `STRING(`*object*`);`

Returns a string representation of *object*. The result varies depending on the type of *object*.

Examples:

String	**Result**
`string(`F1), when F1(X) = COS(X)	"COS(X)"
`STRING(`*2/3*`)`	`0.666666666667`
`string(`L1) when L1 = {1,2,3}	"{1,2,3}"
`string(`M1) when M1 = $\begin{bmatrix}1 & 2 & 3\\ 4 & 5 & 6\end{bmatrix}$	"[[1,2,3],[4,5,6]]"

INSTRING Syntax: `INSTRING(`*str1,str2*`)`

Returns the index of the first occurrence of *str2* in *str1*. Returns 0 if *str2* is not present in *str1*. Note that the first character in a string is position 1.

Examples:

`INSTRING(`*"vanilla","van"*`)` returns 1

`INSTRING` (*"banana","na"*) returns 3

`INSTRING(`*"ab","abc"*`)` returns 0

LEFT Syntax: `LEFT(`*str,n*`)`

Return the first *n* characters of string *str*. If *n* ≥ DIM(*str*) or *n* < 0, returns *str*. If *n* == 0 returns the string.

Example: `LEFT(`*"MOMOGUMBO",3*`)` returns "MOM"

RIGHT Syntax: RIGHT(*str,n*)

Returns the last n characters of string *str*. If *n* <= 0, returns empty string. If *n* > DIM*(str*), returns str

Example: `RIGHT(`"MOMOGUMBO",5) returns "GUMBO"

MID Syntax: `MID(`*str,pos,* [*n*])

Extracts *n* characters from string *str* starting at index *pos*. *n* is optional, if not specified, extracts all the remainder of the string.

Example: `MID(`*"MOMOGUMBO",3,5*) returns "MOGUM", `MID(`*"PUDGE",4*) returns "GE"

ROTATE Syntax: `ROTATE(`*str,n*)

Permutation of characters in string *str*. If 0 <=*n* < DIM*(str*), shifts *n* places to left. If –DIM*(str*) < *n* <= –1, shifts *n* spaces to right. If *n* > DIM*(str*) or *n* < –DIM*(str*), returns *str*.

Examples:

`ROTATE(`*"12345",2*) returns "34512"
`ROTATE(`*"12345",-1*) returns "51234"
`ROTATE(`*"12345",6*) returns "12345"

STRINGFROMID Syntax: STRINGFROMID(*integer*)

Returns, in the current language, the built-in string associated in the internal string table with the specified *integer*.

Examples:

STRINGFROMID(*56*) returns “Complex”

STRINGFROMID(*202*) returns “Real”

REPLACE Syntax: REPLACE(object$_1$, start, object$_2$)

Replaces part of object$_1$ with object$_2$ beginning at *start*. The objects can be matrices, vectors, or stings.

Example:

`REPLACE(`*"12345","3","99"*) returns "12995"

Drawing

There are 10 built-in graphics variables in the HP Prime, called *G0–G9*. *G0* is always the current screen graphic.

G1 to *G9* can be used to store temporary graphic objects (called *GROBs* for short) when programming applications that use graphics. They are temporary and thus cleared when the calculator turns off.

Twenty-six functions can be used to modify graphics variables. Thirteen of them work with Cartesian coordinates using the Cartesian plane defined in the current app by the variables *Xmin, Xmax, Ymin,* and *Ymax*.

The remaining thirteen work with pixel coordinates where the pixel `0,0` is the top left pixel of the *GROB*, and `320, 240` is the bottom right. Functions in this second set have a *_P* suffix to the function name.

C→PX Converts from Cartesian coordinates to screen coordinates.

Syntax: `C→PX(x,y)` or `C→PX({x,y})`

DRAWMENU Syntax: `DRAWMENU(string1, string2,… string6)`

Draws a six-button menu at the bottom of the display, with labels string1, string2, …, string6.

Example:

`DRAWMENU("ABC", "", "DEF")` creates a menu with the first and third buttons labelled ABC and DEF, respectively. The other four menu keys are blank.

FREEZE Syntax: `FREEZE`

Pauses program execution until a key is pressed. This prevents the screen from being redrawn after the end of the program execution, leaving the modified display on the screen for the user to see.

PX→C Converts from screen coordinates to Cartesian coordinates.

RGB Syntax: RGB(R, G, B, [A])

Returns an integer number that can be used as the color parameter for a drawing function, based on Red-, Green- and Blue-component values (each 0 to 255).

If Alpha is greater than 128, returns the color flagged as transparent. There is no alpha channel blending on Prime.

Examples:

`RGB(255,0,128)` returns `16711808`

`RECT(RGB(0,0,255))` makes a blue screen

`LINE(0,0,8,8,RGB(0,255,0))` draws a green line

Pixels and Cartesian

ARC_P

ARC Syntax; `ARC(`*G, x, y, r* [*, a1, a2, c*])

`ARC_P(`*G, x, y, r* [*, a1, a2, c*])

Draws an arc or circle on *G*, centered on point *x,y*, with radius *r* and color *c* starting at angle *a1* and ending on angle *a2*.

G can be any of the graphics variables and is optional. The default is *G0*

r is given in pixels.

c is optional and if not specified black is used. It should be specified in this way: #RRGGBB (in the same way as a color is specified in HTML).

a1 and *a2* follow the current angle mode and are optional. The default is a full circle.

Example:

`ARC(0,0,60,0,π,RGB(255,0,0))` draws a red semicircle with center at (0,0)—using the current Plot Setup window—and with a radius of 60 pixels. The semicircle is drawn counterclockwise from 0 to π.

BLIT_P

BLIT Syntax: `BLIT(`[*trgtGRB, dx1, dy1, dx2, dy2*], *srcGRB* [*,sx1, sy1, sx2, sy2, c*])

`BLIT_P` ([*trgtGRB, dx1, dy1, dx2, dy2*], *srcGRB* [*,sx1, sy1, sx2, sy2, c*])

Copies the region of *srcGRB* between point *sx1, sy1* and *sx2, sy2* into the region of *trgtGRB* between points *dx1, dy1* and *dx2, dy2*. Do not copy pixels from *srcGRB* that are color *c*.

trgtGRB can be any of the graphics variables and is optional. The default is G0.

srcGRB can be any of the graphics variables.

dx2, dy2 are optional and if not specified will be calculated so that the destination area is the same size as the source area.

sx2, sy2 are optional and if not specified will be the bottom right of the *srcGRB*.

sx1, sy1 are optional and if not specified will be the top left of *srcGRB*.

dx1, dy1 are optional and if not specified will be the top left of *trgtGRB*.

c can be any color specified as #RRGGBB. If it is not specified, all pixels from *srcGRB* will be copied.

Note Using the same variable for *trgtGRB* and *srcGRB* can be unpredictable when the source and destination overlap.

DIMGROB_P

DIMGROB

Syntax: `DIMGROB_P(G, w, h, [color])` or
`DIMGROB_P(G, w, h, list)`

`DIMGROB(G, w, h, [color])` or
`DIMGROB(G, w, h, list)`

Sets the dimensions of GROB *G* to *w* × *h*. Initializes the graphic *G* with *color* or with the graphic data provided in *list*. If the graphic is initialized using graphic data, then *list* is a list of integers. Each integer, as seen in base 16, describes one color every 16 bits.

Colors are in A1R5G5B5 format (that is,1 bit for the alpha channel, and 5 bits for R, G, and B).

FILLPOLY_P

FILLPOLY Syntax: `FILLPOLY_P(`[G],{(x_1, y_1), (x_2, y_2),...(x_n, y_n)}, Color, [Alpha]`)`

`FILLPOLY(`[G],{(x_1, y_1), (x_2, y_2),...(x_n, y_n)}, Color, [Alpha]`)`

For the polygon defined by the list of points, fills the polygon with the color defined by the RGB number Color. If Alpha is provided as an integer between 0 and 255 inclusive, the polygon is drawn with the corresponding transparency level. You can use a vector of points instead of a list; in this case, the points can be expressed as complex numbers.

Example:

`FILLPOLY_P({(20,20), (100, 20), (100, 100), (20, 100)}, #FF, 128)` draws a square, 80 pixels on a side, near the upper left of the display, using the color purple and transparency level 128.

GETPIX_P

GETPIX Syntax: `GETPIX(`[*G*], *x, y*)

`GETPIX_P(`[*G*], *x, y*)

Returns the color of the pixel *G* with coordinates *x,y*.

G can be any of the graphics variables and is optional. The default is *G0*, the current graphic.

GROBH_P

GROBH Syntax: `GROBH(`*G*)

`GROBH_P(`*G*)

Returns the height of *G*.

G can be any of the graphics variables and is optional. The default is *G0*.

GROBW_P

GROBW Syntax: `GROBW(`*G*`)`

`GROBW_P(`*G*`)`

Returns the width of *G*.

G can be any of the graphics variables and is optional. The default is *G0*.

INVERT_P

INVERT Syntax: `INVERT(`[*G, x1, y1, x2, y2*]`)`

`INVERT_P(`[*G, x1, y1, x2, y2*]`)`

Executes a reverse video of the selected region. *G* can be any of the graphics variables and is optional. The default is *G0*.

x2, y2 are optional and if not specified will be the bottom right of the graphic.

x1, y1 are optional and if not specified will be the top left of the graphic. If only one x,y pair is specified, it refers to the top left.

LINE_P

LINE Syntax: `LINE_P(`[G], x1, y1, x2, y2, [color]`)`

`LINE_P(`[G],points_definition, lines_definitions, otation_matrix or {rotation_matrix or -1, ["N"], [{eye_x, eye_y, eye_z} or -1], [{3Dxmin, 3Dxmax, 3Dymin, 3Dymax, 3Dzmin, 3Dzmax}]}, [zstring]`)`

`LINE_P(`[G],pre_rotated_points, line_definitions, [zstring]`)`

`LINE(`[G], x1, y1, x2, y2, [color]`)`

`LINE(`[G],points_definition, lines_definitions, otation_matrix or {rotation_matrix or -1, ["N"], [{eye_x, eye_y, eye_z} or -1], [{3Dxmin, 3Dxmax, 3Dymin, 3Dymax, 3Dzmin, 3Dzmax}]}, [zstring]`)`

`LINE(`[G],pre_rotated_points, line_definitions, [zstring]`)`

The basic form of LINE_P draws one line between specified pixel coordinates in the graphic using the specified color.

The advanced form of LINE_P allows the multiple lines to be rendered at the same time with a potential 3D transformation of the triangle's vertices.

This is mostly used if you have a set of vertices and lines and want to display them all at once (faster).

points_definition is either a list or a matrix of point definitions. Each point is defined by two to four numbers: x, y, z, and color. A valid point definition can have multiple forms. Here are some examples: [x, y, z, c], {x, y, z, c}, {x, y, #c}, {(x, y), c}, (x,y). You can use a vector of points instead of a list; in this case, the points can be expressed as complex numbers.

line_ definitions is either a list or a matrix of line definitions. Each line is defined by two to four numbers: p1, p2, color and alpha. p1 and p2 are the index in the points_definition of the two points that define the line. Color is used to override the per point color definition. If you need to provide an Alpha, but not a color, use -1 for the color.

Note that {Color, [Alpha], line_1, ..., line_n} is also a valid form to avoid respecifying the same color for each line.

rotation_matrix is a matrix between the sizes 2*2 to 3*4 that specifies the rotation and translation of the point using usual 3D or 4D geometry.

{eye_x, eye_y, eye_z} defines the eye position (projection).

{3Dxmin, 3Dxmax, 3Dymin, 3Dymax, 3Dzmin, 3Dzmax} is used to perform 3D clipping on the pretransformed objects.

Each point is rotated and translated through a multiplication by the rotation_matrix. It is then projected on the view plan using the eye position calculated by the following equation: x=eye_z/z*x-eye_x and y=eye_z/z*y-eye_y.

Each line is clipped in 3D, if 3D clipping data is provided.

If "N" is specified, the Z coordinates are normalized between 0 and 255 after rotation, providing easier zClipping.

If zstring is provided, per pixel z clipping happens using the z value string (see the following).

LINE_P returns a string that contains all the transformed points. If you plan to call TRIANGLE or LINE multiple times in a row using the same points and transformation, you can do so by replacing the points_definition with this string and omitting the transformation definition in subsequent calls to TRIANGLE and LINE.

About zstring:

TRIANGLE_P([G]) returns a string adapted for z clipping.

To use z clipping, call TRIANGLE_P to create a z clipping string (initialized at 255 for each pixels). You can then call LINE_P with appropriate z (0-255) values for each of the triangle vertices and LINE_P will not draw pixels farther than the already drawn pixels. ZString is automatically updated as appropriate.

PIXOFF_P

PIXOFF Syntax: `PIXOFF(`[*G*], *x, y*)

`PIXOFF_P(`[*G*], *x, y*)

Sets the color of the pixel *G* with coordinates *x,y* to white. *G* can be any of the graphics variables and is optional. The default is *G0*, the current graphic

PIXON_P

PIXON Syntax: `PIXON(`[*G*], *x, y* [,*color*])

`PIXON_P(`[*G*], *x, y* [,*color*])

Sets the color of the pixel *G* with coordinates *x,y* to *color*. *G* can be any of the graphics variables and is optional. The default is *G0*, the current graphic. *Color* can be any color specified as #RRGGBB. The default is black.

RECT_P

RECT Syntax: `RECT(`[*G, x1, y1, x2, y2, edgecolor, fillcolor*])

`RECT_P(`[*G, x1, y1, x2, y2, edgecolor, fillcolor*])

Draws a rectangle on G between points *x1,y1* and *x2,y2* using edgecolor for the perimeter and fillcolor for the inside.

G can be any of the graphics variables and is optional. The default is *G0*, the current graphic.

x1, y1 are optional. The default values represent the top left of the graphic.

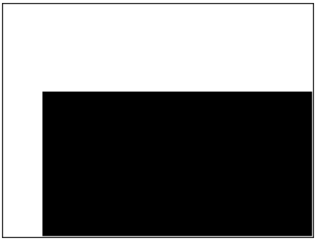
x2, y2 are optional. The default values represent the bottom right of the graphic.

edgecolor and *fillcolor* can be any color specified as #RRGGBB. Both are optional, and *fillcolor* defaults to *edgecolor* if not specified.

To erase a `GROB`, execute `RECT(`*G*`)`. To clear the screen execute `RECT()`.

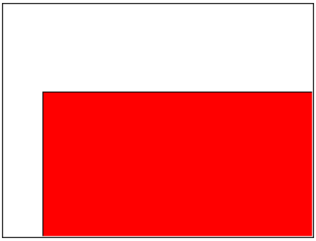
When optional arguments are provided in a command with multiple optional parameters (like `RECT`), the arguments provided correspond to the leftmost parameters first. For example, in the program below, the arguments `40` and `90` in the `RECT_P` command correspond to *x1* and *y1*. The argument `#000000` corresponds to *edgecolor*, since there is only the one additional argument. If there had been two additional arguments, they would have referred to *x2* and *y2* rather than *edgecolor* and *fillcolor*. The program produces a rectangle with a black edge and black fill.

```
EXPORT BOX()
BEGIN
RECT();
RECT_P(40,90,#0
00000);
WAIT;
END;
```



The program below also uses the `RECT_P` command. In this case, the pair of arguments `320` and `240` correspond to `x2` and `y2`. The program produces are rectangle with a black edge and a red fill.

```
EXPORT BOX()
BEGIN
RECT();
RECT_P(40,90,32
0,240,#000000,#
FF0000);
WAIT;
END;
```



SUBGROB_P

SUBGROB

Syntax: `SUBGROB(`*srcGRB* [,*x1, y1, x2, y2*], *trgtGRB*)

`SUBGROB_P(`*srcGRB* [,*x1, y1, x2, y2*], *trgtGRB*)

Sets *trgtGRB* to be a copy of the area of *srcGRB* between points *x1,y1* and *x2,y2*.

srcGRB can be any of the graphics variables and is optional. The default is *G0*.

trgtGRB can be any of the graphics variables except *G0*.

x2, y2 are optional and if not specified will be the bottom right of *srcGRB*.

x1, y1 are optional and if not specified will be the top left of *srcGRB*.

Example: `SUBGROB(`*G1, G4*) will copy G1 in G4.

TEXTOUT_P

TEXTOUT

Syntax: `TEXTOUT(`*text* [,*G*], *x, y* [,*font, c1, width, c2*])

`TEXTOUT_P(`*text* [,*G*], *x, y* [,*font, c1, width, c2*])

Draws text using color *c1* on graphic *G* at position *x, y* using *font*. Do not draw text more than *width* pixels wide and erase the background before drawing the text using color *c2*. *G* can be any of the graphics variables and is optional. The default is *G0*.

Font can be:

0: current font selected on the Homes Settings screen, *1*: small font *2*: large font. Font is optional and if not specified is the current font selected on the Homes Settings screen.

c1 can be any color specified as #RRGGBB. The default is black (#000000).

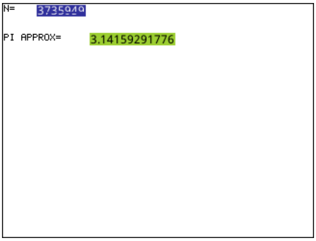
width is optional and if not specified, no clipping is performed.

c2 can be any color specified as #RRGGBB. *c2* is optional. If not specified the background is not erased.

Example:

The following program displays the successive approximations for π using the series for the arctangent(1). Note that a color for the text, and for background, has been specified (with the width of the text being limited to 100 pixels).

```
EXPORT PISERIES()
BEGIN
LOCAL sign;
K:=2;
A:=4;
sign:=-1;
RECT();
TEXTOUT_P("N=",0,0);
TEXTOUT_P("PI APPROX=",0,30);
REPEAT
A+sign*4/(2*K-1) ▶ A;
TEXTOUT_P(K ,35,0,2,#FFFFFF,
100,#333399);
TEXTOUT_P(A ,90,30,2,#000000,100,
#99CC33);
sign*-1 ▶ sign;
K+1 ▶ K;
UNTIL 0;
END;
END;
```



```
N=    3735949

PI APPROX=    3.14159291776
```

The program executes until the user presses On to terminate.

TRIANGLE_P

TRIANGLE

Syntax: `TRIANGLE_P(`[G], x1, y1, x2, y2, x3, y3, c1, [c2, c3], [Alpha], ["ZString", z1, z2, z3]`)`

`TRIANGLE_P(`[G], {x1, y1, [c1], [z1]}, {x2, y2, [c2], [z2]},{x3, y3, [c3], [z3]}, ["ZString"]`)`

`TRIANGLE_P(`[G],points_definition, triangle_definitions, rotation_matrix or {rotation_matrix or -1, ["N"], [{eye_x, eye_y, eye_z} or -1], [{3Dxmin, 3Dxmax, 3Dymin, 3Dymax, 3Dzmin, 3Dzmax}]}, [zstring]`)`

`TRIANGLE_P(`[G],pre_rotated_points, triangle_definitions, [zstring]`)`

`TRIANGLE_P(`[G]`)`

The basic form of TRIANGLE draws one triangle between the specified pixel coordinates in the graphic using the specified color and transparency (0 ≤ Alpha ≤ 255). If three colors are specified, it blends the colors in between the vertices.

The advanced form of TRIANGLE_P allows multiple triangles to be rendered at the same time with a potential 3D transformation of the triangles' vertices.

This is mostly used if you have a set of vertices and triangles and want to display them all at once (faster).

points_definition is either a list or a matrix of point definition. Each point is defined by two to four numbers: x, y, z, and color. A valid point definition can have multiple forms. Here are a couple of example: [x, y, z, c], {x, y, z, c}, {x, y, #c}, {(x, y), c}, (x,y)... You can use a vector of points instead of a list; in this case, the points can be expressed as complex numbers.

triangle_ definitions is either a list or a matrix of triangle definitions. Each triangle is defined by three to five numbers: p1, p2, p3, color and alpha. p1, p2 and p3 are the index in the points_definition of the 3 points that define the triangle. Color is used to override the per point color definition. If you need to provide an Alpha, but not a color, use -1 for the color.

Note that {Color, [Alpha], triangle_1, ..., triangle_n} is also a valid form to avoid respecifying the same color for each triangle.

rotation_matrix is a matrix between sizes 2*2 to 3*4 that specifies the rotation and translation of the point using usual 3D and 4D geometry.

{eye_x, eye_y, eye_z} defines the eye position (projection).

{3Dxmin, 3Dxmax, 3Dymin, 3Dymax, 3Dzmin, 3Dzmax} is used to perform 3D clipping on the pretransformed objects.

Each point is rotated and translated through a multiplication by the rotation_matrix. It is then projected on the view plan using the eye position calculated by the following equation: x=eye_z/z*x-eye_x and y=eye_z/ z*y-eye_y.

Each triangle is clipped in 3D, if 3D clipping data is provided.

If "N" is specified, the Z coordinates are normalized between 0 and 255 after rotation, providing easier zClipping.

If zstring is provided, per pixel z clipping happens using the z value string (see the following).

TRIANGLE_P returns a string which contains all the transformed points. If you plan to call TRIANGLE or LINE multiple times in a row using the same points and transformation, you can do so by replacing the points_definition with this string and omitting the transformation definition in subsequent calls to TRIANGLE and LINE.

About zstring:

TRIANGLE_P([G]) returns a string adapted for z clipping.

To use z clipping, call TRIANGLE_P to create a z clipping string (initialized at 255 for each pixels). You can then call TRIANGLE_P with appropriate z (0-255) values for each of the triangle vertices and TRIANGLE_P will not draw pixels farther than the already drawn pixels. ZString is automatically updated as appropriate.

Matrix

Some matrix commands take as their argument the matrix variable name on which the command is applied. Valid names are the global variables M0–M9 or a local variable that contains a matrix.

ADDCOL

Syntax: `ADDCOL(matrix, vector, column_number)`

Inserts the values in `vector` into a new column inserted before `column_number` in the specified matrix. The number of values in the vector must be the same as the number of rows in the matrix.

ADDROW

Syntax: `ADDROW(matrix, vector, row_number)`

Inserts the values in `vector` into a new row inserted before `row_number` in the specified matrix. The number of values in the vector must be the same as the number of columns in the matrix.

DELCOL

Syntax: `DELCOL (`*matrix,column_number*)

Deletes *column column_number* from the matrix.

DELROW

Syntax: `DELROW (`*matrix,row_number*)

Deletes row *row_number* from the matrix.

EDITMAT

Syntax: `EDITMAT (`*matrix*)

Starts the Matrix Editor and displays the specified matrix. If used in programming, returns to the program when user presses OK. Even though this command returns the matrix that was edited, `EDITMAT` cannot be used as an argument in other matrix commands.

REDIM

Syntax: `REDIM (`*matrix, size*)

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*). Existing values in the matrix are preserved. Fill values will be 0.

REPLACE

Syntax: `REPLACE (`*matrix, start, object*)

Replaces portion of a matrix or vector stored in *matrix* 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, graphics, and strings. For example, REPLACE("123456", 2, "GRM") -> "1GRM56"

SCALE Syntax: `SCALE`(*matrix, value, rownumber*)

Multiplies the specified *row_number* of the specified matrix by *value*.

SCALEADD Syntax: `SCALEADD`(*matrix, value, row1, row2*)

Multiplies the specified `row1` of the matrix by `value`, then adds this result to the second specified `row2` of the matrix and replaces `row1` with the result.

SUB Syntax: `SUB`(*matrix, start, end*)

Extracts a sub-object—a portion of a list, matrix, or graphic—and stores it in *matrix*. *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(M1{1,2},{2,2})`

SWAPCOL Syntax: `SWAPCOL`(*matrix, column1, column2*)

Swaps *column1* and *column2* of the specified matrix.

SWAPROW Syntax: `SWAPROW(`*matrix, row1, row2*)

Swaps *row1* and *row2* in the specified matrix.

App Functions

These commands allow you to launch any HP app, bring up any view of the current app, and change the options in the View menu.

STARTAPP Syntax: `STARTAPP(`*"name"*)

Starts the app with *name*. This will cause the app program's `START` function to be run, if it is present. The app's default view will be started. Note that the `START` function is always executed when the user taps Start in the Application Library. This also works for user-defined apps.

Example: `STARTAPP(`*"Function"*) launches the Function app.

STARTVIEW Syntax: `STARTVIEW(`*n* [,*draw?*])

Starts the *n*th view of the current app. If *draw?* is true (that is, not 0), it will force an immediate redrawing of the screen for that view.

The view numbers (*n*) are as follows:

```
Symbolic:0
Plot:1
Numeric:2
Symbolic Setup:3
Plot Setup:4
Numeric Setup:5
App Info: 6
View Menu:7
First special view (Split Screen Plot Detail):8
Second special view (Split Screen Plot Table):9
Third special view (Autoscale):10
Fourth special view (Decimal):11
Fifth special view (Integer):12
Sixth special view (Trig):13
```

The special views in parentheses refer to the Function app, and may differ in other apps. The number of a special view corresponds to its position in the View menu for that app. The first special view is launched by `STARTVIEW(8)`, the second with `STARTVIEW(9)`, and so on.

You can also launch views that are not specific to an app by specifying a value for *n* that is less than 0:

```
Home Screen:-1
Home Settings:-2
Memory Manager:-3
Applications Library:-4
Matrix Catalog:-5
List Catalog:-6
Program Catalog:-7
Notes Catalog:-8
```

VIEW Syntax: `VIEW ("string"[,program_name])`

```
BEGIN
Commands;
END;
```

Adds a custom option to the `View` menu. When `string` is selected, runs `program_name`. See “The

DiceSimulation program” on page 264.

Integer

BITAND Syntax: `BITAND(int1, int2, … intn)`

Returns the bitwise logical AND of the specified integers.

Example: `BITAND(20,13)` returns `4`.

BITNOT Syntax: `BITNOT(int)`

Returns the bitwise logical NOT of the specified integer.

Example: `BITNOT(47)` returns `549755813840`.

BITOR Syntax: `BITOR(int1, int2, … intn)`

Returns the bitwise logical OR of the specified integers.

Example: `BITOR(9,26)` returns `27`.

BITSL Syntax: `BITSL(int1 [,int2])`

Bitwise Shift Left. Takes one or two integers as input and returns the result of shifting the bits in the first integer to the left by the number places indicated by the second integer. If there is no second integer, the bits are shifted to the left by one place.

Examples:

`BITSL(28,2)` returns `112`

`BITSL(5)` returns `10`.

BITSR Syntax: `BITRL(int1 [,int2])`

Bitwise Shift Right. Takes one or two integers as input and returns the result of shifting the bits in the first integer to the right by the number places indicated by the second integer. If there is no second integer, the bits are shifted to the right by one place.

Examples:

`BITSR(112,2)` returns `28`

`BITSR(10)` returns `5`.

BITXOR Syntax: `BITXOR(int1, int2, … intn)`

Returns the bitwise logical exclusive OR of the specified integers.

Example: `BITXOR(9,26)` returns `19`.

B→R Syntax: `B→R(#integerm)`

Converts an integer in base *m* to a decimal integer (base 10). The base marker *m* can be *b* (for binary), *o* (for octal), or *h* (for hexadecimal).

Example: `B→R(#1101b)` returns `13`

GETBASE Syntax: `GETBASE(#integer[m])`

Returns the base for the specified integer (in whatever is the current default base): 0 = default, 1 = binary, 2 = octal, 3 = hexadecimal.

Examples: `GETBASE(#1101b)` returns `#1h` (if the default base is hexadecimal) while `GETBASE (#1101)` returns #0h.

GETBITS Syntax: `GETBITS(#integer)`

Returns the number of bits used by *integer*, expressed in the default base.

Example: `GETBITS(#22122)` returns `#20h` or `32`

R→B Syntax: `R→B(integer)`

Converts a decimal integer (base 10) to an integer in the default base.

Example: `R→B(13)` returns `#1101b` (if the default base is binary) or #Dh (if the default base is hexadecimal).

SETBITS Syntax: `SETBITS(#integer[m] [,bits])`

Sets the number of bits to represent *integer*. Valid values are in the range –64 to 65. If *m* or *bits* is omitted, the default value is used.

Example: `SETBITS(#1111b, 15)` returns `#1111:b15`

SETBASE Syntax: `SETBASE(#integer[m][c])`

Displays *integer* expressed in base *m* in whatever base is indicated by *c*, where *c* can be 1 (for binary), 2 (for octal), or 3 (for hexadecimal). Parameter m can be b (for binary), d (for decimal), o (for octal), or h (for hexadecimal). If *m* is omitted, the input is assumed to be in the default base. Likewise, if c is omitted, the output is displayed in the default base.

Examples: `SETBASE (#34o,1)` returns `#11100b` while `SETBASE (#1101)` returns #0h ((if the default base is hexadecimal).

I/O

I/O commands are used for inputting data into a program, and for outputting data from a program. They allow users to interact with programs.

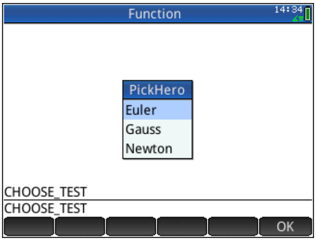
CHOOSE

Syntax: `CHOOSE(`*var, "title", "item1", "item2",…,"itemn"*)

Displays a choose box with the *title* and containing the choose items. If the user selects an object, the variable whose name is provided will be updated to contain the number of the selected object (an integer, 1, 2, 3, …) or 0 if the user taps Cancel.

Returns true (not zero) if the user selects an object; otherwise, returns false (0).

Example:



CHOOSE_TEST
CHOOSE_TEST

```
CHOOSE

(N,"PickHero",
"Euler","Gauss
","Newton");

IF N==1 THEN
PRINT("You
picked
Euler"); ELSE
IF N==2 THEN PRINT("You picked
Gauss");ELSE PRINT("You picked
Newton");

END;

END;
```

After execution of `CHOOSE`, the value of *N* will be updated to contain 0, 1, 2, or 3. The `IF THEN ELSE` command causes the name of the selected person to be printed to the terminal.

EDITLIST Syntax: `EDITLIST(`*listvar*`)`

Starts the List Editor loading *listvar* and displays the specified list. If used in programming, returns to the program when user taps OK.

Example: `EDITLIST(`*L1*`)` edits list L1.

EDITMAT Syntax: `EDITMAT(`*matrixvar*`)`

Starts the Matrix Editor and displays the specified matrix. If used in programming, returns to the program when user taps OK.

Example: `EDITMAT(`*M1*`)` edits matrix M1.

GETKEY Syntax: `GETKEY`

Returns the ID of the first key in the keyboard buffer, or –1 if no key was pressed since the last call to `GETKEY`. Key IDs are integers from 0 to 50, numbered from top left (key 0) to bottom right (key 50) as shown in figure 5-1.

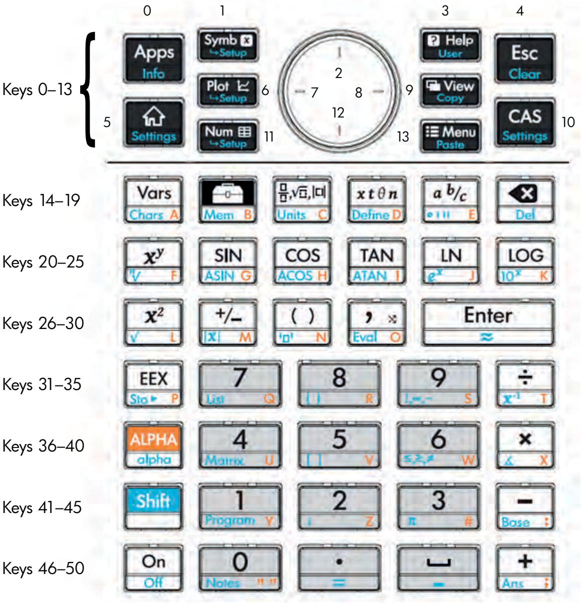


Figure 5-1: Numbers of the keys

INPUT Syntax: `INPUT(`var,[“title”], [“label”], [“help”], [reset_value][initial_value]`)`

`INPUT(`{vars},[“title”], [{“labels”}], [{“help”}], [{reset_values}], [{initial_values}]`)`

The simpler form of this command opens a dialog box with the given title and one field named label, displaying help at the bottom. The dialog box includes the CANCEL and OK menu keys. The user can enter a value in the labeled field. If the user presses the OK menu key, the variable var is updated with the entered value and 1 is returned. If the user presses the CANCEL menu key, the variable is not updated and 0 is returned.

In the more complex form of the command, lists are used to create a multi-field dialog box. If var is a list, each element can be either a variable name or a list using the following syntax.

- {var_name, real, [{pos}]} to create a check box control. If real is >1, this check box gets pooled with the next n -1 check boxes in a radio group (that is, only one of the n check boxes can be checked at any time)
- {var_name, [allowed_types_matrix] , [{pos}]} to create an edit field. [allowed_types_matrix] lists all the allowed types ([-1] stands for all types allowed). If the only allowed type is a string, the edition hides the double quotes.
- {var_name, {Choose items}, [{pos}]} to create a choose field.

If pos is specified, it is a list of the form {field start in screen %, field width in screen%, line(starts at 0)}. This allows you to control the precise position and size of your fields. Note that you have to specify pos for either none or all fields in the dialog box.

There is a maximum of seven lines of controls per page. Controls with more than seven lines are placed in subsequent pages. If more than one page is created, ["title"] can be a list of titles.

ISKEYDOWN

Syntax: `ISKEYDOWN(`*key_id*`);`

Returns true (non-zero) if the key whose *key_id* is provided is currently pressed, and false (0) if it is not.

MOUSE

Syntax: `MOUSE[(index)]`

Returns two lists describing the current location of each potential pointer (or empty lists if the pointers are not used). The output is {x , y, original z, original y, type} where *type* is 0 (for new), 1 (for completed), 2 (for drag), 3 (for stretch), 4 (for rotate), and 5 (for long click).

The optional parameter index is the *n*th element that would have been returned—x, y, original x, etc.—had the parameter been omitted (or –1 if no pointer activity had occurred).

MSGBOX

Syntax: `MSGBOX(`*expression or string* [,*ok_cancel?*]);

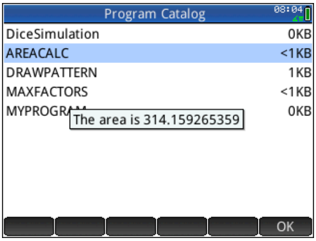
Displays a message box with the value of the given expression or *string*.

If *ok_cancel?* is true, displays the OK and Cancel buttons, otherwise only displays the OK button. Default value for *ok_cancel* is false.

Returns true (non-zero) if the user taps OK, false (0) if the user presses Cancel.

```
EXPORT AREACALC()
BEGIN
LOCAL radius;
INPUT(radius, "Radius of Circle","r =
","Enter radius",1);
MSGBOX("The area is " +π*radius^2);
END;
```

If the user enters 10 for the radius, the message box shows this:



Program Catalog

DiceSimulation	0KB
AREACALC	<1KB
DRAWPATTERN	1KB
MAXFACTORS	<1KB
MYPROGRAM	0KB

The area is 314.159265359

PRINT Syntax: `PRINT(`*expression* or *string*`);`

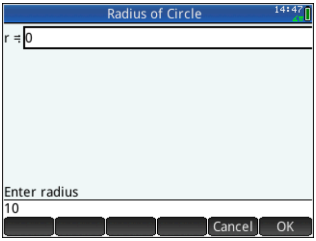
Prints the result of *expression* or *string* to the terminal.

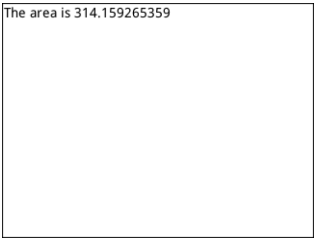
The terminal is a program text output viewing mechanism which is displayed only when `PRINT` commands are executed. When visible, you can press ▼ or ▲ to view the text, ⌫ Del to erase the text and any other key to hide the terminal. Pressing On Off stops the interaction with the terminal. `PRINT` with no argument clears the terminal.

There are also commands for outputting data in the Graphics section. In particular, the commands `TEXTOUT` and `TEXTOUT_P` can be used for text output.

This example prompts the user to enter a value for the radius of a circle, and prints the area of the circle on the terminal.

```
EXPORT AREACALC()
BEGIN
LOCAL radius;
INPUT(radius,
"Radius of
Circle","r =
","Enter
radius",1);

PRINT("The
area is "
+π*radius^2);
END;
```




The area is 314.159265359

Notice the use of the `LOCAL` variable for the radius, and the naming convention that uses lower case letters for the local variable. Adhering to such a convention will improve the readability of your programs.

WAIT Syntax: `WAIT(`*n*`);`

Pauses program execution for *n* seconds. With no argument or with *n* = 0, pauses program execution for one minute.

More

%CHANGE Syntax: `%CHANGE(x,y)`

The percentage change in going from *x* to *y*.

Example: `%CHANGE(20,50)` returns 150.

%TOTAL Syntax: `%TOTAL(x,y)`

The percentage of *x* that is *y*.

Example: `%TOTAL(20,50)` returns 250.

CAS Syntax: `CAS.function() or CAS.variable`

Executes the function or returns the variable using the CAS.

EVALLIST Syntax: `EVALLIST({list})`

Evaluates the content of each element in a list and returns an evaluated list.

EXECON Syntax: `EXECON(&expr, List1, [List2,…])`

Creates a new list based on the elements in one or more lists by iteratively modifying each element according to an expression that contains the ampersand character (&).

Examples:

`EXECON("&+1",{1,2,3})` returns `{2,3,4}`

Where the & is followed directly by a number, the position in the list is indicated. For example:

`EXECON("&2-&1",{1, 4, 3, 5}"` returns `{3, -1, 2}`

In the example above, &2 indicates the second element and &1 the first element in each pair of elements. The minus operator between them subtracts the first from the second in each pair until there are no more pairs. In this case (with just a single list), the numbers appended to & can only be from 1 to 9 inclusive.

EXECON can also operate on more than one list. For example:

`EXECON("&1+&2",{1,2,3},{4,5,6})` returns `{5,7,9}`

In the example above, &1 indicates an element in the first list and &2 indicates the corresponding element in the second list. The plus operator between them adds the two elements until there are no more pairs. With two lists, the numbers appended to & can have two digits; in this case, the first digit refers to the list number (in order from left to right) and the second digit can still only be from 1 to 9 inclusive.

EXECON can also begin operating on a specified element in a specified list. For example:

`EXECON("&23+&1",{1,5,16},{4,5,6,7})` returns `{7,12}`

In the example above, &23 indicates that operations are to begin on the second list and with the third element. To that element is added the first element in the first list. The process continues until there are no more pairs.

→HMS Syntax: `→HMS(value)`

Converts a decimal *value* to hexagesimal format; that is, in units subdivided into groups of 60. This includes degrees, minutes, and seconds as well as hours, minutes, and seconds.

Example: `→HMS(54.8763)` returns `54°52′34.68″`

HMS→ Syntax: `HMS→(value)`

Converts a *value* expressed in hexagesimal format to decimal format.

Example: `HMS→(54°52′34.68″)` returns `54.8763`

ITERATE Syntax: `ITERATE(expr, var, ivalue, #times)`

For `#times`, recursively evaluates `expr` in terms of `var` beginning with `var` = `ivalue`.

Example: `ITERATE(X^2, X, 2, 3)` returns `256`

TICKS Syntax: TICKS

Returns the internal clock value in milliseconds.

TIME Syntax: `TIME`(*program_name*)

Returns the time in milliseconds required to execute the program *program_name*. The results are stored in the variable `TIME`. The variable `TICKS` is similar. It contains the number of milliseconds since boot up.

TYPE Syntax: TYPE(object)

Returns the type of the object:

0: Real

1: Integer

2: String

3: Complex

4: Matrix

5: Error

6: List

8: Function

9: Unit

14.?: cas object. The fractional part is the cas type.

Variables and Programs

The HP Prime has four types of variables: Home variables, App variables, CAS variables, and User variables. You can retrieve these variables from the Variable menu (Vars).

The names of Home variables are reserved; that is, they cannot be deleted from the system and cannot be used to store objects of any other type than that for which they were designed. For example, A–Z and θ are reserved to store real numbers, Z0–Z9 are reserved to store complex numbers, and L0–L9 are reserved to store lists, etc. As a result, you cannot store a matrix in L8 or a list in Z.

Home variables keep the same value in Home and in apps; that is, they are global variables common to the system. They can be used in programs with that understanding.

App variable names are also reserved, though a number of apps may share the same app variable name. In any of these cases, the name of the app variable must be qualified if that variable is not from the current app. For example, if the current app is the Function app, `Xmin` will return the minimum x-value in the Plot view of the Function app. If you want the minimum value in the Plot view of the Polar app, then you must enter `Polar.Xmin`. App variables represent the definitions and settings you make when working with apps interactively. As you work through an app, the app functions may store results in app variables as well. In a program, app variables are used to edit an app's data to customize it and to retrieve results from the app's operation.

CAS variables are similar to the Home real variables A–Z, except that they are lowercase and designed to be used in CAS view and not Home view. Another difference is that Home and App variables always contain values, while CAS variables can be simply symbolic and not contain any particular value. The CAS variables are not typed like the Home and App variables. For example, the CAS variable *t* may contain a real number, a list, or a vector, etc. If a CAS variable has a value stored in it, calling it from Home view will return its contents.

User variables are variables created by the user, either directly or exported from a user program. They provide one of several mechanisms to allow programs to communicate with the rest of the calculator and with other programs. User variables created in a program may be either local to that program or global. Once a variable has been exported from a program, it will appear among the user variables in the `Variables` menu, next to the program that exported it. User variables may be multi-character, but must follow certain rules; see "Variables and visibility" on page 251 for details.

User variables, like CAS variables, are not typed and thus may contain objects of different types.

The following sections deal with using app variables in programs, providing descriptions of each app variable by name and its possible contents. For a list of all the Home and app variables, see chapter 4, "Variables", beginning on page 215. For user variables in programs, see "The HP Prime programming language", beginning on page 251.

App variables

Not all app variables are used in every app. S1Fit, for example, is only used in the Statistics 2Var app. However, many of the variables are common to the Function, Advanced Graphing, Parametric, Polar, Sequence, Solve, Statistics 1Var, and Statistics 2Var apps. If a variable is not available in all of these apps, or is available only in some of these apps (or some other app), then a list of the apps where the variable can be used appears under the variable name.

The following sections list the app variables by the view in which they are used. To see the variables listed by the categories in which they appear on the Variables menu see “App variables”, beginning on page 221.

Plot view variables

Axes

Turns axes on or off.

In Plot Setup view, check (or uncheck) `AXES`.

In a program, type:

`0 ▶ Axes`—to turn axes on.

`1 ▶ Axes`—to turn axes off.

Cursor

Sets the type of cursor. (Inverted or blinking is useful if the background is solid).

In Plot Setup view, choose `Cursor`.

In a program, type:

`0 ▶ Cursor`—for solid crosshairs (default)

`1 ▶ Cursor`—to invert the crosshairs

`2 ▶ Cursor`—for blinking crosshairs.

GridDots

Turns the background dot grid in Plot view on or off.

In Plot Setup view, check (or uncheck) `GRID DOTS`.

In a program, type:

`0 ▶ GridDots`—to turn the grid dots on (default).

`1 ▶ GridDots`—to turn the grid dots off.

GridLines

Turns the background line grid in Plot View on or off.

In Plot Setup view, check (or uncheck) `GRID LINES`.

In a program, type:

`0` ▶ `GridLines`—to turn the grid lines on (default).

`1` ▶ `GridLines`—to turn the grid lines off.

Hmin/Hmax
Statistics 1Var

Defines the minimum and maximum values for histogram bars.

In Plot Setup view for one-variable statistics, set values for `HRNG`.

In a program, type:

n_1 ▶ `Hmin`

n_2 ▶ `Hmax`

where $n_1 < n_2$

Hwidth
Statistics 1Var

Sets the width of histogram bars.

In Plot Setup view for one-variable statistics, set a value for `Hwidth`.

In a program, type:

n ▶ `Hwidth` where *n* > 0

Labels

Draws labels in Plot View showing X and Y ranges.

In Plot Setup View, check (or uncheck) `Labels`.

In a program, type:

`1` ▶ `Labels`—to turn labels on (default)

`0` ▶ `Labels`—to turn labels off.

Method
Function, Solve, Parametric, Polar, Statistics 2Var

Defines the graphing method: adaptive, fixed-step segments, or fixed-step dots.

In a program, type:

`0` ▶ `Method`—select adaptive

`1` ▶ `Method`—select fixed-step segments

`2` ▶ `Method`—select fixed-step dots

Nmin/Nmax
Sequence

Defines the minimum and maximum values for the independent variable.

Appears as the `N RNG` fields in the Plot Setup view. In Plot Setup view, enter values for `N Rng`.

In a program, type:

n_1 ▶ `Nmin`

n_2 ▶ `Nmax`

where $n_1 < n_2$

PixSize
Geometry

Sets the dimensions of each square pixel in the Geometry app. In Plot view, enter a positive value in `Pixel Size`.

Or enter `PixSize:=n`, where n>0.

Recenter

Recenters at the cursor when zooming.

From Plot-Zoom-Set Factors, check (or uncheck) `Recenter`.

In a program, type:

`0` ▶ `Recenter`— to turn recenter on (default).

`1` ▶ `Recenter`— to turn recenter off.

S1mark-S5mark
Statistics 2Var

Sets the mark to use for scatter plots.

In Plot Setup view for two-variable statistics, select one of `S1 Mark-S Mark`.

ScrollText
Geometry

Determines whether the current command in Plot view scrolls automatically or manually. In Plot view, select or clear Scroll Text.

You can also enter `ScrollText:=0` to scroll manually or `ScrollText:=1` to scroll automatically.

SeqPlot
Sequence

Enables you to choose between a Stairstep or a Cobweb plot.

In Plot Setup view, select `SeqPlot`, then choose `Stairstep` or `Cobweb`.

In a program, type:

`0` ▶ `SeqPlot`—for Stairstep.

`1` ▶ `SeqPlot`—for Cobweb.

θmin/θmax
Polar

Sets the minimum and maximum independent values.

In Plot Setup view enter values for θ Rng.

In a program, type:

n_1 ▶ θmin

n_2 ▶ θmax

where $n_1 < n_2$

θstep
Polar

Sets the step size for the independent variable.

In Plot Setup view, enter a value for θ Step.

In a program, type:

n ▶ θstep

where $n > 0$

Tmin/Tmax
Parametric

Sets the minimum and maximum independent variable values.

In Plot Setup view, enter values for T Rng.

In a program, type:

n_1 ▶ Tmin

n_2 ▶ Tmax

where $n_1 < n_2$

Tstep
Parametric

Sets the step size for the independent variable.

In Plot Setup view, enter a value for T Step.

In a program, type

n ▶ Tstep

where $n > 0$

Xtick

Sets the distance between tick marks for the horizontal axis.

In Plot Setup view, enter a value for X Tick.

In a program, type:

n ▶ Xtick where $n > 0$

Ytick

Sets the distance between tick marks on the vertical axis.

In Plot Setup view, enter a value for Y Tick.

In a program, type:

n ▶ Ytick where $n > 0$

Xmin/Xmax

Sets the minimum and maximum horizontal values of the plot screen.

In Plot Setup view, enter values for `X Rng`.

In a program, type:

n_1 ▶ `Xmin`

n_2 ▶ `Xmax`

where $n_1 < n_2$

Ymin/Ymax

Sets the minimum and maximum vertical values of the plot screen.

In Plot Setup view, enter the values for `Y Rng`.

In a program, type:

n_1 ▶ `Ymin`

n_2 ▶ `Ymax`

where $n_1 < n_2$

Xzoom

Sets the horizontal zoom factor.

In Plot View, press Menu then Zoom. Scroll to `Set Factors`, select it and tap OK. Enter the value for `X Zoom` and tap OK.

In a program, type:

n ▶ `Xzoom`

where $n > 0$

The default value is 4.

Yzoom

In Plot View, tap Menu then Zoom. Scroll to `Set Factors` and tap OK. Enter the value for `Y Zoom` and tap OK.

Or, in a program, type:

n ▶ `Yzoom` where $n > 0$

The default value is 4.

Symbolic view variables

AltHyp
Inference

Determines the alternative hypothesis used for hypothesis testing.

In Symbolic View, select an option for Alt Hypoth.

In a program, type:

0 ▶ AltHyp—for $\mu < \mu_0$

1 ▶ AltHyp—for $\mu > \mu_0$

2 ▶ AltHyp—for $\mu \neq \mu_0$

E0…E9
Solve

Contains an equation or expression. In Symbolic view, select one of E0 through E9 and enter an expression or equation. The independent variable is selected by highlighting it in Numeric view.

In a program, type (for example):

```
X+Y*X-2=Y ▶E1
```

F0…F9
Function

Contains an expression in X. In Symbolic View, select one of F0 through F9 and enter an expression.

In a program, type (for example):

```
SIN(X) ▶F1
```

H1…H5
Statistics 1Var

Contains a list of the dataset(s) that define a 1-variable statistical analysis. The first column in the list is the independent column and the second (if any) specifies the column used for the frequencies. For example, H1 by default returns {D1, ""}, where D1 is the default independent column and "" indicates that there is no column used for frequencies. In Symbolic view, select one of H1 through H5 and enter an independent column and an optional frequency column.

H1Type...H5Type

Statistics 1Var

Sets the type of plot used to graphically represent the statistical analyses H1 through H5. In Symbolic View, specify the type of plot in the field for Plot1, Plot2, etc.

Or in a program, store one of the following constant integers or names into the variables `H1Type, H2Type`, etc.

`1 Histogram` (default)

2 Box and Whisker

3 Normal Probability

4 Line

5 Bar

6 Pareto

Example:

```
2▶H3Type
```

Method

Inference

Determines whether the Inference app is set to calculate hypothesis test results or confidence intervals. In Symbolic view, make a selection for `Method`.

In a program, type:

`0 ▶ Method`—for `Hypothesis Test`

`1 ▶ Method`—for `Confidence Interval`

`2 ▶ Method`—for `Chi-Square`

`3 ▶ Method`—for `Regression`

R0...R9

Polar

Contains an expression in θ . In Symbolic view, select one of `R0` through `R9` and enter an expression.

In a program, type (for example):

```
SIN(θ) ▶ R1
```

S1...S5

Statistics 2Var

Contains a list that defines a 2-variable statistical analysis. Returns a list containing the independent column name, the dependent column name and the fit equation (if any).

S1Type...S5Type
Statistics 2Var

Sets the type of fit to be used by the `FIT` operation in drawing the regression line. From Symbolic view, specify the fit in the field for `Type1,Type2`, etc.

In a program, store one of the following constant integers into a variable `S1Type,S2Type,` etc.

1 Linear

2 Logarithmic

3 Exponential

4 Power

5 Exponent

6 Inverse

7 Logistic

8 Quadratic

9 Cubic

10 Quartic

11 User Defined

Example:

```
3 ▶ S2Type
```

InfType
Inference

Determines the type of hypothesis test or confidence interval. Depends upon the value of the variable `Method`. From Symbolic View, make a selection for `Type`.

Or, in a program, store the constant number from the list below into the variable Type. With `Method=0`, the constant values and their meanings are as follows:

0 Z-Test: 1 μ

1 Z-Test: $\mu_1 - \mu_2$

2 Z-Test: 1 π

3 Z-Test: $\pi_1 - \pi_2$

4 T-Test: 1 μ

5 T-Test: $\mu_1 - \mu_2$

With `Method=1`, the constants and their meanings are as follows:

0 Z-Int: 1 μ

1 Z-Int: $\mu_1 - \mu_2$

2 Z-Int: 1 π

3 Z-Int: $\pi_1 - \pi_2$

4 T-Int: 1 μ

5 T-Int: $\mu_1 - \mu_2$

With `Method=2`, the constants and their meanings are as follows:

0 Chi-square goodness of fit test

1 Chi-square two-way test

With `Method=3`, the constants and their meanings are as follows:

0 Linear t-test

1 Interval: Slope

2 Interval: Intercept

3 Interval: Mean Response

4 Prediction Interval

X0, Y0...X9,Y9
Parametric

Contains two expressions in `T`: `X(T)` and `Y(T)`. In Symbolic view, select any of `X0–Y0` through `X9–Y9` and enter expressions in T.

In a program, store expressions in T in Xn and Yn, where n is an integer from 0 to 9.

Example:

```
SIN(4*T)▶ Y1;2*SIN(6*T)▶ X1
```

U0...U9
Sequence

Contains an expression in `N`. In Symbolic view, select any of `U0` through `U9` and enter an expression in `N`, `Un(N−1)`, or `Un(N−2)`.

In a program, use the `RECURSE` command to store the expression in Un, where *n* is an integer from 0 to 9.

Example:

```
RECURSE (U,U(N−1)*N,1,2) ▶U1
```

Numeric view variables

C0...C9
Statistics 2Var

Contain lists of numerical data. In Numeric view, enter numerical data in `C0` through `C9`.

In a program, type:

```
LIST ▶ Cn
```

where $n = 0$, 1, 2, 3 ... 9 and `LIST` is either a list or the name of a list.

D0...D9
Statistics 1Var

Contain lists of numerical data. In Numeric view, enter numerical data in `D0` through `D9`.

In a program, type:

```
LIST ▶ Dn
```

where $n = 0$, 1, 2, 3 ... 9 and `LIST` is either a list or the name of a list.

NumIndep
Function
Parametric
Polar
Sequence
Advanced Graphing

Specifies the list of independent values (or two-value sets of independent values) to be used by `Build Your Own Table`. Enter your values one-by-one in the Numeric view.

In a program, type:

```
LIST ▶ NumIndep
```

`List` can be either a list itself or the name of a list. In the case of the Advanced Graphing app, the list will be a list of pairs (a list of 2-element vectors) rather than a list of numbers.

NumStart
Function
Parametric
Polar
Sequence

Sets the starting value for a table in Numeric view.

From Numeric Setup view, enter a value for `NUMSTART`.

In a program, type:

n ▶ `NumStart`

NumXStart
Advanced Graphing

Sets the starting number for the X-values in a table in Numeric view.

From Numeric Setup view, enter a value for `NUMXSTART`.

In a program, type:

n ▶ `NumXStart`

NumYStart
Advanced Graphing

Sets the starting value for the Y-values in a table in Numeric view.

From Numeric Setup view, enter a value for `NUMYSTART`.

In a program, type:

n ▶ `NumYStart`

NumStep
Function
Parametric
Polar
Sequence

Sets the step size (increment value) for the independent variable in Numeric view.

From Numeric Setup view, enter a value for `NUMSTEP`.

In a program, type:

n ▶ `NumStep`

where $n > 0$

NumXStep
Advanced Graphing

Sets the step size (increment value) for the independent X variable in Numeric view.

From Numeric Setup view, enter a value for `NUMXSTEP`.

In a program, type:

n ▶ `NumXStep`

where $n > 0$

NumYStep
Advanced Graphing

Sets the step size (increment value) for the independent Y variable in Numeric view.

From Numeric Setup view, enter a value for `NUMYSTEP`.

In a program, type:

n ▶ `NumYStep`

where $n > 0$

NumType
Function
Parametric
Polar
Sequence
Advanced Graphing

Sets the table format.

In Numeric Setup view, make a selection for `Num Type`.

In a program, type:

`0` ▶ `NumType`—for `Automatic` (default).

`1` ▶ `NumType`—for `BuildYourOwn`.

NumZoom
Function
Parametric
Polar
Sequence

Sets the zoom factor in the Numeric view.

From Numeric Setup view, type in a value for `NUMZOOM`.

In a program, type:

n ▶ `NumZoom`

where $n > 0$

NumXZoom
Advanced Graphing

Sets the zoom factor for the values in the X column in the Numeric view.

From Numeric Setup view, type in a value for `NUMXZOOM`.

In a program, type:

n ▶ `NumXZoom`

where $n > 0$

NumYZoom
Advanced Graphing

Sets the zoom factor for the values in the Y column in the Numeric view.

From Numeric Setup view, type in a value for `NUMYZOOM`.

In a program, type:

n ▶ `NumYZoom`

where $n > 0$

Inference app variables

The following variables are used by the Inference app. They correspond to fields in the Inference app Numeric view. The set of variables shown in this view depends on the hypothesis test or the confidence interval selected in the Symbolic view.

Alpha

Sets the alpha level for the hypothesis test. From the Numeric view, set the value of `Alpha`.

In a program, type:

n ▶ `Alpha`

where $0 < n < 1$

Conf

Sets the confidence level for the confidence interval. From Numeric view, set the value of `C`.

In a program, type:

n ▶ `Conf`

where $0 < n < 1$

ExpList

Contains the expected counts by category for the chi-square goodness of fit test. In the Symbolic view field Expected, select `Count`. Then, in Numeric view, enter the data in `ExpList`.

Mean_1 Sets the value of the mean of a sample for a 1-mean hypothesis test or confidence interval. For a 2-mean test or interval, sets the value of the mean of the first sample. From Numeric view, set the value of $\bar{x}$ or $\bar{x}_1$.

In a program, type:

n ▶ $\texttt{Mean}_1$

Mean_2 For a 2-mean test or interval, sets the value of the mean of the second sample. From Numeric view, set the value of $\bar{x}_2$.

In a program, type:

n ▶ $\texttt{Mean}_2$

μ_0 Sets the assumed value of the population mean for a hypothesis test. From the Numeric view, set the value of μ_0.

In a program, type:

n ▶ μ_0

where $0 < \mu_0 < 1$

n_1 Sets the size of the sample for a hypothesis test or confidence interval. For a test or interval involving the difference of two means or two proportions, sets the size of the first sample. From the Numeric view, set the value of $\texttt{n}_1$.

In a program, type:

n ▶ $\texttt{n}_1$

n_2 For a test or interval involving the difference of two means or two proportions, sets the size of the second sample. From the Numeric view, set the value of $\texttt{n}_2$.

In a program, type:

n ▶ $\texttt{n}_2$

ObsList Contains the observed count data for the chi-square goodness of fit test. In Numeric view, enter your data in `ObsList`.

ObsMat Contains the observed counts by category for the chi-square two-way test. In Numeric view, enter your data in `ObsMat`.

π_0

Sets the assumed proportion of successes for the One-proportion Z-test. From the Numeric view, set the value of π_0.

In a program, type:

n ▶ π_0

where $0 < \pi_0 < 1$

Pooled

Determine whether or not the samples are pooled for tests or intervals using the Student's T-distribution involving two means. From the Numeric view, set the value of `Pooled`.

In a program, type:

`0` ▶ `Pooled`—for not pooled (default).

`1` ▶ `Pooled`—for pooled.

ProbList

Contains the expected probabilities by category for the chi-square goodness of fit test. In the Symbolic view, in the Expected box, select `Probability`. Then, in Numeric view, enter the data in `ProbList`.

s_1

Sets the sample standard deviation for a hypothesis test or confidence interval. For a test or interval involving the difference of two means or two proportions, sets the sample standard deviation of the first sample. From the Numeric view, set the value of s_1.

In a program, type:

n ▶ s_1

s_2

For a test or interval involving the difference of two means or two proportions, sets the sample standard deviation of the second sample. From the Numeric view, set the value of s_2.

In a program, type:

n ▶ s_2

σ_1

Sets the population standard deviation for a hypothesis test or confidence interval. For a test or interval involving the difference of two means or two proportions, sets the population standard deviation of the first sample. From the Numeric view, set the value of σ_1.

In a program, type:

n ▶ σ_1

σ_2

For a test or interval involving the difference of two means or two proportions, sets the population standard deviation of the second sample. From the Numeric view, set the value of σ_2.

In a program, type:

n ▶ σ_2

x_1

Sets the number of successes for a one-proportion hypothesis test or confidence interval. For a test or interval involving the difference of two proportions, sets the number of successes of the first sample. From the Numeric view, set the value of x_1.

In a program, type:

n ▶ x_1

x_2

For a test or interval involving the difference of two proportions, sets the number of successes of the second sample. From the Numeric view, set the value of x_2.

In a program, type:

n ▶ x_2

Xlist

Contains the list of explanatory data (X) for the regression tests and intervals. In Numeric view, enter your data in `Xlist`.

Xval

For the confidence interval for the mean response and prediction interval for a future response, contains the value of the explanatory variable (X) under scrutiny. Enter a value when prompted by the wizard.

Ylist

Contains the list of response data (Y) for the regression tests and intervals. In Numeric view, enter your data in `Ylist`.

Finance app variables

The following variables are used by the Finance app. They correspond to the fields in the Finance app Numeric view.

CPYR

Compounding periods per year. Sets the number of compounding periods per year for a cash flow calculation. From the Numeric view of the Finance app, enter a value for `C/YR`.

In a program, type:

n ▶`CPYR`

where $n > 0$

BEG

Determines whether interest is compounded at the beginning or end of the compounding period. From the Numeric view of the Finance app, check or uncheck `End`.

In a program, type:

`1▶BEG`—for compounding at the end of the period (Default)

`0▶BEG`—for compounding at the beginning of the period

FV

Future value. Sets the future value of an investment. From the Numeric view of the Finance app, enter a value for `FV`.

In a program, type:

n ▶`FV`

Positive values represent return on an investment or loan.

IPYR

Interest per year. Sets the annual interest rate for a cash flow. From the Numeric view of the Finance app, enter a value for `I%YR`.

In a program, type:

n ▶`IPYR`

where $n > 0$

NbPmt

Number of payments. Sets the number of payments for a cash flow. From the Numeric view of the Finance app, enter a value for `N`.

In a program, type:

n ▶`NbPmt`

where $n > 0$

PMT

Payment value. Sets the value of each payment in a cash flow. From the Numeric view of the Finance app, enter a value for `PMT`.

In a program, type:

```
n▶PMT
```

Note that payment values are negative if you are making the payment and positive if you are receiving the payment.

PPYR

Payments per year. Sets the number of payments made per year for a cash flow calculation. From the Numeric view of the Finance app, enter a value for `P/YR`.

In a program, type:

```
n▶PPYR
```

where $n > 0$

PV

Present value. Sets the present value of an investment. From the Numeric view of the Finance app, enter a value for `PV`.

In a program, type:

```
n▶PV
```

Note: negative values represent an investment or loan.

GSize

Group size. Sets the size of each group for the amortization table. From the Numeric view of the Finance app, enter a value for `Group Size.`

In a program, type:

```
n▶GSize
```

Linear Solver app variables

The following variables are used by the Linear Solver app. They correspond to the fields in the app's Numeric view.

LSystem

Contains a 2x3 or 3x4 matrix which represents a 2x2 or 3x3 linear system. From the Numeric view of the Linear Solver app, enter the coefficients and constants of the linear system.

In a program, type:

```
matrix▶LSystem
```

where `matrix` is either a matrix or the name of one of the matrix variables M0-M9.

Triangle Solver app variables

The following variables are used by the Triangle Solver app. They correspond to the fields in the app's Numeric view.

SideA

The length of Side a. Sets the length of the side opposite the angle A. From the Triangle Solver Numeric view, enter a positive value for a.

In a program, type:

```
n ▶SideA
```

where $n > 0$

SideB

The length of Side b. Sets the length of the side opposite the angle B. From the Triangle Solver Numeric view, enter a positive value for b.

In a program, type:

```
n ▶SideB
```

where $n > 0$

SideC

The length of Side c. Sets the length of the side opposite the angle C. From the Triangle Solver Numeric view, enter a positive value for c.

In a program, type:

```
n ▶SideC
```

where $n > 0$

AngleA

The measure of angle A. Sets the measure of angle A. The value of this variable will be interpreted according to the angle mode setting (Degrees or Radians). From the Triangle Solver Numeric view, enter a positive value for angle A.

In a program, type:

```
n ▶AngleA
```

where $n > 0$

AngleB

The measure of angle B. Sets the measure of angle B.

The value of this variable will be interpreted according to the angle mode setting (Degrees or Radians). From the Triangle Solver Numeric view, enter a positive value for angle B.

In a program, type:

```
n ▶AngleB
```

where $n > 0$

AngleC

The measure of angle C. Sets the measure of angle C.

The value of this variable will be interpreted according to the angle mode setting (Degrees or Radians). From the Triangle Solver Numeric view, enter a positive value for angle C.

In a program, type:

```
n ▶AngleC
```

where $n > 0$

RECT

Corresponds to the status of ⊿ in the Numeric view of the Triangle Solver app. Determines whether a general triangle solver or a right triangle solver is used. From the Triangle Solver view, tap ⊿.

In a program, type:

`0▶RECT`—for the general Triangle Solver

`1▶RECT`—for the right Triangle Solver

Home Settings variables

The following variables (except Ans) are found in **Home Settings**. The first four can all be over-written in an app's Symbolic Setup view.

Ans

Contains the last result calculated in the Home view.

HAngle

Sets the angle format for the Home view. In **Home Settings**, choose `Degrees` or `Radians` for angle measure.

In a program, type:

`0 ▶ HAngle`—for Degrees.

`1 ▶ HAngle`—for Radians.

HDigits

Sets the number of digits for a number format other than Standard in the Home view. In **Home Settings**, enter a value in the second field of **Number Format**.

In a program, type:

n ▶ `HDigits`, where $0 < n < 11$.

HFormat

Sets the number display format used in the Home view. In **Home Settings**, choose `Standard`, `Fixed`, `Scientific`, or `Engineering` in the **Number Format** field.

In a program, store one of the following the constant numbers (or its name) into the variable `HFormat`:

0 Standard

1 Fixed

2 Scientific

3 Engineering

HComplex

Sets the complex number mode for the Home view. In **Home Settings**, check or uncheck the **Complex** field. Or, in a program, type:

`0` ▶ `HComplex`—for OFF.

`1` ▶ `HComplex`—for ON.

Date

Contains the system date. The format is `YYYY.MMDD`. This format is used irrespective of the format set on the **Home Settings** screen. On page 2 of **Home Settings**, enter values for `Date`.

In a program, type:

`YYYY.MMDD` ▶ `Date`, where `YYYY` are the four digits of the year, `MM` are the two digits of the month, and `DD` are the two digits of the day.

Time

Contains the system time. The format is `HH°MM′SS′′`, with the hours in 24-hour format. This format is used irrespective of the format set on the **Home Settings** screen. On page 2 of **Home Settings**, enter values for Time.

In a program, type:

`HH°MM′SS′′` ▶ `Time`, where `HH` are the two digits of the hour (0≤HH<24), `MM` are the two digits of the minutes, and `SS` are the two digits of the seconds.

Language

Contains an integer indicating the system language. From **Home Settings**, choose a language for the **Language** field.

In a program, store one of the following constant numbers into the variable Language:

1 ▶ `Language` (English)

2 ▶ `Language` (Chinese)

3 ▶ `Language` (French)

4 ▶ `Language` (German)

5 ▶ `Language` (Spanish)

6 ▶ `Language` (Dutch)

7 ▶ `Language` (Portuguese)

Entry

Contains an integer that indicates the entry mode. In **Home Settings**, select an option for **Entry**.

In a program, enter:

`0 ▶ Entry`—for Textbook

`1 ▶ Entry`—for Algebraic

`2 ▶ Entry`—for RPN

Integer

Base

Returns or sets the integer base. In **Home Settings**, select an option for the first field next to **Integers**. In a program, enter:

`0 ▶ Base`—for Binary

`1 ▶ Base`—for Octal

`2 ▶ Base`—for Decimal

`3 ▶ Base`—for Hexadecimal

Bits

Returns or sets the number of bits for representing integers. In **Home Settings**, enter a value for the second field next to **Integers**. In a program, enter:

n ▶ `Bits` where *n* is the number of bits.

Signed

Returns the status of, or sets a flag, indicating that the integer wordsize is signed or not. In **Home Settings**, check or uncheck the **±** field to the right of **Integers**. In a program, enter:

`0 ▶ Signed`—for unsigned

`1 ▶ Signed`—for signed

Symbolic Setup variables

The following variables are found in the Symbolic setup of an app. They can be used to overwrite the value of the corresponding variable in **Home Settings**.

AAngle

Sets the angle mode.

From Symbolic setup, choose `System`, `Degrees`, or `Radians` for angle measure. `System` (default) will force the angle measure to agree with that in **Home Settings**.

In a program, type:

`0 ▶ AAngle`—for System (default).

`1 ▶ AAngle`—for Radians.

`2 ▶ AAngle`—for Degrees.

AComplex

Sets the complex number mode.

From Symbolic setup, choose `System`, `ON`, or `OFF`. `System` (default) will force the complex number mode to agree with the corresponding setting in **Home Settings**.

In a program, type:

`0 ▶ AComplex`—for System (default).

`1 ▶ AComplex`—for ON.

`2 ▶ AComplex`—for OFF.

ADigits

Contains the number of decimal places to use for the Fixed, Scientific, or Engineering number formats in the app's Symbolic Setup.

From Symbolic setup, enter a value in the second field of `Number Format`.

In a program, type:

n ▶ `ADigits`

where $0 < n < 11$

AFormat

Defines the number display format used for number display in the Home view and to label axes in the Plot view.

From Symbolic setup, choose `Standard`, `Fixed`, `Scientific`, or `Engineering` in the Number Format field.

In a program, store the constant number into the variable `AFormat`.

0 System

1 Standard

2 Fixed

3 Scientific

4 Engineering

Example:

```
3 ▶ AFormat
```

Results variables

The Function, Statistics 1Var, Statistics 2Var, and Inference apps offer functions that generate results that can be re-used outside those apps (such as in a program). For example, the Function app can find a root of a function, and that root is written to a variable called `Root`. That variable can then be used elsewhere.

The results variables are listed with the apps that generate them. See “App variables” on page 221.

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