Sparcom

QUICK GUIDE

To the HP 48 Super Calculator

By Thomas Dick, Ph.D.

Sparcom

QUICK GUIDE to the **HP-48** *super calculator*

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Preface

The HP-48 is not just another graphing calculator, but a true "computer in your hand." Besides its graphing capabilities (including function, parametric, polar, conic, truth, and statistical plotting), the HP-48 comes equipped with a remarkably powerful symbolic algebra system, a fast and robust numerical equation solver, a spreadsheet-like matrix environment, and a wide variety of other mathematical tools.

Every HP-48 includes a serial port for file exchange via cable connection to either IBM or Macintosh computers (using the KERMIT protocol), and a two-way infrared communications system for *wireless* transfer of information from calculator to calculator or calculator. The expandable version of the HP-48 (the SX) also includes two RAM/ROM expansion slots for expanding memory and/or for running special software.

Obviously, this little manual cannot deliver all of the information contained in the HP-48 owner's manual (for example, we don't discuss the statistics package in the HP-48). However, I hope that you can use it to learn about the HP-48 quickly, and for easy and fast reference in the future. For those who desire more information about the HP-48, particularly programming, I recommend the definitive reference: *HP-48 Insights, Parts I and II*, by William C. Wickes (Larken Publications).

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Thomas Dick
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TABLE OF CONTENTS

About this manual

In this little manual, a box containing Helvetica font indicates a labelled key on the HP-48 keyboard.

Examples: [MTH] or [ENTER] or [SIN]

A boxed expression in the HP-48's font indicates one of the six white keys directly below the screen. The label for the key appears along the bottom of the screen once the appropriate menu is activated.

Example: [STEQ] is found under the [PLOT] menu.

In this guide, we will generally not indicate the shift key presses except for special emphasis or for characters not labelled on the keyboard.

A pointing hand appears to bring your attention to helpful hints, shortcuts, or other important notes.

1. BASIC INFORMATION

In this opening section, we'll take a brief tour of the HP-48, including the keyboard, screen, and ports.

The [ON] key

What better place to start? The [ON] key (lower left corner of the keyboard) not only powers up your calculator, but also serves as an "ATTENTION!" key (note the **ATTN** label).

Whenever you find yourself in an unfamiliar situation, pressing [ON] once or twice will almost always bring you back to the "stack," the main work area for the HP-48.

If you leave your calculator on for a few minutes without pressing any keys, then it will automatically shut off to save battery power. When you press [ON] again, the screen should look just like you left it. The memory of the calculator is continuously maintained, even when the calculator is off.

Batteries

The HP-48 takes three AAA batteries, and they are located in the lower compartment in the back of the calculator. You should get several months use out of a set of batteries.

Even when you take the batteries out, the calculator's memory will be maintained for a few minutes, giving you the chance to change the batteries without a loss of stored information.

Ports

The upper compartment on the back of the HP-48 contains its doors to the outside world. You can see a 4-prong serial port for connecting your calculator to a Macintosh or PC-compatible computer. Under the cover are two infrared "eyes" —one for input, one for output. These allow for wireless communication between your HP-48 and another calculator or printer (the cover does not need to be off for infrared communication). If you examine the top front edge of your calculator, you should see a small arrow to aid you in lining up the infrared beam.

If you have the HP-48SX calculator, then you can slide off this plastic cover and see the two glass infrared eyes. You can also see the two card ports. These allow you to plug in extra memory cards, special software, or even the interface to an overhead projection device.

Contrast control

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

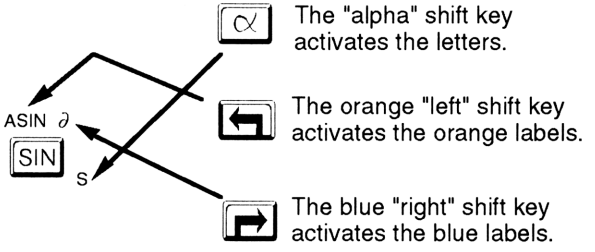
Screen messages

At the top of your screen is an area where messages about the calculator's status and modes are displayed. For example, if your calculator reads RAD and {HOME } at the top of the screen, then the calculator is in radian mode (for angle measure) and you are in the HOME directory of the memory.

Whenever the little hourglass is on at the top of the screen, the calculator is "busy" with a calculation. Pressing ON while this *annunciator* is on will abort the computation and return you to the stack. The annunciator ((·)) tells you your batteries are getting low, and you should change them within a few days. (The calculator will also give you a "Low Battery" message when you first turn it on.)

Shift Keys:

Right above the [ON] key are three shift keys:



When one of the shift keys has been pressed, its label is displayed at the top of the screen.

[↱] and [↰] toggle on and off. Pressing [α] twice in a row locks the calculator in alpha mode; a third press unlocks it.

Helpful Hint: When typing several letters in a row, it's better to simply hold the [α] down as you type, rather than lock the calculator into alpha mode.

Lower case letters are activated with [α] [↰]; Greek letters are activated with [α] [↱]; other special symbols (like ≥) may be accessed with one or the other of these shift combinations.

Menus

There are far more functions and operations on the HP-48 than one could ever hope to fit on the keyboard, even with multiple shift keys. The HP-48 arranges these additional items into menus, and they are accessed by the six white keys on the top row, just below the screen. These *soft* keys refer to whatever menu labels you have displayed across the bottom of the screen at the time.

If you press **MTH** , you'll see that the menu labels have little folder tabs, each indicating another menu. For example, HYP reveals a menu of the hyperbolic functions. To get back to the top level of the MTH menu, just press **MTH** again.

When a menu has more than six labels, you can "turn the pages" back and forth using **NXT** (next) and **PREV** (previous). The menu pages are arranged like a desktop address directory—pressing **NXT** repeatedly will eventually bring you back to the first page of the menu. Try these keys out on the MODES menu to see the various options available.

2. THE STACK

The stack is the primary work area for the calculator. It is arranged in levels (hence the name). When you type, the characters appear on the *command line* until you press [ENTER] or an operation key that forces automatic entry.

a. Enter 2:

2 [ENTER] 1: 2

b. Enter 2.5×10^{38}:

2.5 [EEX] **38** [ENTER] 1: 2.5E38

Deleting characters and objects

On the same row of keys as [ENTER] is a "backarrow" key. It acts as a *backspace* and will delete the last character you typed on the command line. (If nothing is on the command line, then this key drops the last entry off the stack.)

[DROP] drops the last entry off the stack.

[CLR] clears all the entries off the stack (but does not clear anything stored in memory).

Editing objects on the stack

To edit an object on the stack, simply press the EDIT key. This places the contents of level 1 in an editor, and you will see a flashing insertion arrow (cursor). To make changes, use the directional arrow keys to move the cursor where you want it. Any characters you type will be inserted where the cursor is pointing. Pressing the backspace key will delete the character immediately to the left of the cursor. Pressing DEL will delete the character underneath the flashing cursor.

After you have made the changes you want, simply press ENTER . If you have made some mistakes in editing, and you would prefer starting over again with the original entry, just press ON to abort the editing process. Then you can press EDIT again to start over. Along the menu you'll see some additional soft keys: the SKIP→ key will skip the cursor to the extreme right; the DEL→ key *deletes* everything to the right (be careful!). Similarly, you can skip or delete to the extreme left. If you toggle the INS key *off* (so the white square does not appear on the label), then the calculator will type over characters rather than inserting them.

Moving objects on the stack

There are a variety of ways to change the position of the entries on the stack. For example, the [SWAP] key interchanges the objects on levels 1 and 2 of the stack:

2[ENTER] 3[ENTER] [SWAP]

```
2:  3
1:  2
```

You are not limited to the four levels you see on the screen. Press [CLR] and try this:

3 [ENTER] 1 [ENTER] 7 [ENTER] 8 [ENTER] 5 [ENTER]

The first number you entered is now out of view, but it is still on the stack. To move up the stack to see it, press [▲] to activate the stack cursor. Now you can move up and down the stack using the [▲] and [▼] arrow keys. Your calculator will beep at you when you hit the top or bottom of the stack.

Now, let's discuss the menu soft keys that appear here. Move your cursor down to level 1 and then back up to level 3 (containing the number 7).

Press [VIEW] and the contents of this level go to the editor. Now you can edit this entry without disturbing any other entries on the stack. Press [ENTER] to lock in the change (or [ON] *not* to) and you're back to the stack cursor environment.

Now, press [PICK] and this entry will be duplicated on level 1 of the stack, while all the other entries will shift up a level (now we have *six* entries on the stack).

Press [ROLL] and the entry is rolled down to level 1, and the entries below it shift up one level.

Press [ROLLD] and the entry rolls down one level, with the contents of level 1 taking its place in the stack.

The [ECHO] key allows you to "echo" the contents of a stack level to the command line.

NOTE: The [↑STK] menu key from the [EDIT] menu also gets you into the stack cursor environment so that you can ECHO objects onto the editing line.

When you are finished working with the stack cursor, simply press [ON] to get back to the normal stack.

3. MODES

The [MODES] menu controls how the HP-48 displays objects to you.

Numeric display modes

Press [MODES] . The standard numeric display mode of the HP-48 is 12 significant digits (15 digits are carried internally during computation). Your calculator is in standard mode if a white box is lit on the first menu key [STD] .

Try this: [π] [→ NUM]

Now watch the display as you press these keys:

[MODES] 4 [FIX] 3 [SCI] 5 [ENG] [STD]

4 [FIX] fixes the numeric display to 4 decimal places. **3** [SCI] puts the numeric display in scientific notation with three decimal places. **5** [ENG] displays numbers in engineering notation with five decimal places. [STD] returns to the default setting of 12 digits of precision.

The different numerical display modes do *not* affect the internal precision (12 digits) of the number being displayed.

The current display mode is indicated by a small white box on the menu key.

Symbolic mode

In a later section we'll talk about symbolic arithmetic on the HP-48. For this, you need to have the [SYM] key toggled on.

Beeper

The "BEEP" that you hear when you have pressed an invalid operation key can be turned on and off by pressing the [BEEP] key in the [MODES] menu.

The clock and [TIME] menu

Turn to the second page of the [MODES] menu by pressing [NXT]. The last key of this menu controls whether or not the date and time are displayed at the top of your calculator's screen.

To set the date and time on your HP-48, press [TIME] (the orange shift of [4]). The [SET] folder shows you the following menu:

[→DAT] [→TIM] [A/PM] [12/24] [M/D]

The first two keys on this menu allow you to set the date and time respectively. The following two examples will illustrate how to use these keys.

a. To set the date to July 4, 1993

7.041993 [→DAT]

b. To set the time to 3:45

3.45 [→TIM]

[A/PM] toggles between AM and PM.

[12/24] toggles between a 12-hour and 24-hour clock.

[M/D] toggles between the month/day/year date format and the European day.month.year format.

Press [**TIME**] [ADJ] to see a menu that allows you to adjust the hour, minute and second display on your clock.

More modes

Press [**MODES**] [**NXT**] to go to the second page of the modes menu. Generally, you will want most of these soft keys toggled on.

For example, having [STK] on will allow you to "undo" a mistake if you press the wrong key. [CNCT] (the "T" is covered when this key is on) is for connected mode of function graphs. The [ML] mode will allow you to see multiple lines of level one of the stack, if needed.

Angle and coordinate modes

Press [MODES] [NXT] [NXT] to see the third page of the [MODES] menu. Here you have the options to choose degrees, radians, or grads for angle measure. Press [GRAD] and then [RAD] and note that these modes are indicated at the top of your calculator screen, but [DEG] is *not* displayed when you are in degree mode.

Similarly, you can choose rectangular [XYZ], cylindrical [R∠Z], or spherical [R∠∠] modes for displays of three coordinates. Cylindrical and spherical coordinate modes are indicated at the top of the screen, but rectangular mode is not.

Either [R∠Z] or [R∠∠] corresponds to polar mode for two coordinates.

You can also use [RAD] (orange shift of the [1] key) to toggle between radian mode and degree mode. [POLAR] (blue shift of the [1] key) toggles between rectangular and polar forms for coordinate displays.

Try this: [( )] 0,1 [ENTER]

Now press [POLAR] [RAD] [POLAR] and note the different ways the coordinates are displayed.

4. RPN ARITHMETIC

Like most HP calculators, the HP-48 uses *Reverse Polish Notation* (RPN): first you enter the objects, and then you apply the operation. The answers shown for the following examples are for the standard (STD) numeric display.

a. To add: 26 + 82

26 ENTER **82** + 1: 108

b. To subtract: 86 – 32

86 ENTER **32** – 1: 54

c. To change sign or enter a negative number:

2 +/– ENTER 1: -2

Note that pressing – makes the calculator attempt to perform subtraction.

d. To multiply: $62 \cdot 45$

62 [ENTER] **45** [×] 1: 2790

e. To divide: $85 \div 20$

85 [ENTER] **20** [÷] 1: 4.25

f. To raise to a power: $(42)^5$

42 [ENTER] **5** [y^x] 1: 130691232

g. To take a square root: $\sqrt{20}$

20 [$\sqrt{x}$] 1: 4.472135955

h. To square: $(25)^2$

25 [x^2] 1: 625

i. To find a reciprocal: $\frac{1}{85}$

85 [$1/x$] 1: 1.17647058824 E-2

(which is equivalent to 0.0117647058824)

Combinations of arithmetic operations:

Reverse Polish Notation can seem strange at first, but if you give it a chance, you'll find that it's very efficient. Here's a few examples to illustrate.

a. $(5+2)^3$

5 ENTER **2** + **3** y^x 1: 343

b. $5+2^3$

5 ENTER **2** ENTER **3** y^x + 1: 13

c. $6\sqrt{10}$

6 ENTER **10** $\sqrt{x}$ × 1: 18.973665961

d. $(25+7)^{4/5}$

25 ENTER **7** + **4** ENTER **5** ENTER ÷ y^x

1: 16

Notice that no parentheses are needed in calculating any of these results on the HP-48. On an *algebraic* entry calculator, you often need to decide ahead of time where you will need parentheses.

Trigonometric and inverse trigonometric functions

Set your HP-48 in *radian* mode and try these:

a. sin 2

2 [SIN] 1: .909297426826

b. arctan 1

1 [ATAN] 1: .785398163397

Logarithms and exponentials

a. log 2 (common logarithm base 10)

2 [LOG] 1: .301029995664

b. e^{10}

10 [e^x] 1: 22026.4657948

c. ln(3) (natural logarithm base e)

3 [LN] 1: 1.09861228867

5. UNDOING AN OPERATION—THE LAST KEYS

Here are some keys that you will undoubtedly find valuable: the LAST keys are the orange and blue shifts of the number [2] and [3] keys. Press [CLR] and we'll illustrate with some examples.

LAST [STACK] returns the stack to its status immediately before the last operation. In other words, it acts like an "UNDO" key.

2 [ENTER] 3 [ENTER] [×] [STACK]	2:	2
	1:	3

LAST [ARG] keeps your last result on the stack, but returns the last arguments used by the HP-48.

[+] [ARG]	3:	5
	2:	2
	1:	3

LAST [CMD] returns you to the last *command line* on your calculator, while LAST [MENU] returns you to the last menu that appeared on your calculator screen.

Each of the LAST operations require that the corresponding mode be on under the [MODES] menu.

6. USING UNITS

One of the truly unique capabilities of the HP-48 is its management of units. Units of measurement can be attached to numerical quantities by selecting the appropriate unit from the UNITS menu. Unit management is automatically taken care of by the HP-48.

2 UNITS LENG FT 3 IN	2:	2_ ft
	1:	3_ in
+	1:	27_ in

Notice that the HP-48 converts to the second argument's units for addition and subtraction. To simply convert from one unit to another, press the orange shift key and then the desired unit.

↰ YD	1:	.75_ yd

Addition and subtraction require like attribute units, while multiplication and division can be performed with any mix of units.

.5 UNITS TIME S	1:	.5_s
÷	1:	1.5_yd/s

Note that compound units are formed automatically. Finally, to convert this last result to miles per hour:

UNITS SPEED ↰ MPH	1:	3.06818181818_mph

7. SYMBOLIC ARITHMETIC

Another of the HP-48's unique features is its ability to do arithmetic with symbolic expressions, much like computer algebra systems on desktop and mainframe computers. To perform purely symbolic arithmetic, we'll need to make sure the calculator is in symbolic mode: press [MODES] and check that [SYM] has a square lit up on it. (If not, press it to toggle on symbolic mode.)

The ['] key is used to denote symbolic expressions. It is called the "tick" key and is located as the left-most key in the third row from the top. Enclosing an expression in "ticks" essentially tells the HP-48 to suppress immediate evaluation of the result. The [EVAL] key is used to *evaluate* a symbolic expression.

a. Evaluate $'2 + 3'$

['] 2 [+] 3 [ENTER]	1:	'2+3'
[EVAL]	1:	5

Press [( )] to obtain a set of parentheses when you need them. When you are finished typing the contents, just press [▶] to move along to the rest of your expression.

b. Evaluate $'7 * (4 + 9) - 15'$

['] 7 [×] [( )] 4 [+] 9 [▶] [−] 15 [ENTER]

1: '7*(4+9)-15'

[EVAL] 1: 76

Note that you need to indicate multiplication explicitly when typing in a symbolic expression.

Special constants

Special constants such as π and e are displayed in symbolic form when the calculator is in symbolic mode.

[π] [EVAL] 1: 'π'

Use [→ NUM] (blue shift of [EVAL]) to express a decimal approximation of π:

[→ NUM] 1: 3.14159265359

To express e in decimal form to 12 digits of precision:

[α] [↰] [E] [ENTER] 1: 'e'

[→ NUM] 1: 2.71828182846

Fractions

The [→ Q] key (orange shift of [EVAL]) converts decimal numbers to their closest rational number equivalent.

2.5 [ENTER] [→ Q]	1:	'5/2'

Pressing [EVAL] will calculate the decimal form of a fraction in symbolic form:

['] 58 [÷] 3 [ENTER]	1:	'58/3'
[EVAL]	1:	19.3333333333

The [→ Q] and [EVAL] keys can be used to perform fraction arithmetic.

To add 3/4 and 2/3 as fractions:

['] 3 [÷] 4 [ENTER]		
['] 2 [÷] 3 [ENTER]	2:	'3/4'
	1:	'2/3'
[+]	1:	'3/4+2/3'
[EVAL]	1:	1.41666666667
[→ Q]	1:	'17/12'

Use [FIX] under the [MODES] menu to control the number of digits used in the numerator and denominator of the rational form.

If the HP-48 is in standard numeric display mode (so that [STD] is lit up under the [MODES] menu):

[π] [→NUM] [→Q] 1: '1146408/364913'

Now, press **2** [FIX] and try again:

[π] [→NUM] [→Q] 1: '22/7'

The [→Qπ] key

Press [ALGEBRA] [NXT] to find the [→Qπ] key, which converts a decimal number to either a rational multiple of π or a rational number, whichever is closest. For example, make sure the HP-48 is in radian mode, and express $\arcsin(.5)$ as a rational multiple of π:

.5 [ENTER] [ASIN] 1: .523598775598

[ALGEBRA] [NXT] [→Qπ] 1: '1/6*π'

Real and complex roots

The HP-48 handles complex number arithmetic quite easily, so you should take some care when working with roots of real numbers. The following two examples show an important distinction between the exponentiation and root keys in finding a cube root of -8.

a. **8** [+/−] **ENTER** ['] **1** [÷] **3** **ENTER** [y^x]

```
1:          '(-8)^(1/3)'
```

EVAL

```
1:    (1,1.73205080757)
```

This is the ordered pair notation for the complex number approximating $1 + i\sqrt{3}$. Press **3** [y^x] and note that the result is approximately $(-8, 0)$.

b. In contrast, using the [$\sqrt[x]{y}$] key will yield the negative real cube root rather than a complex root:

8 [+/−] **ENTER** **3** [$\sqrt[x]{y}$]

```
1:                    -2
```

Symbols and names for operations

When you use the tick marks to form a symbolic expression, the operation keys produce a corresponding symbol or name for that operation. Here are some examples (press **EVAL** after any of these to evaluate the expression).

a. ' $\sqrt[x]{y}$ 3 , 8 **ENTER** 1: 'XROOT(3,8)'

b. ' $1/x$ 2 **ENTER** 1: 'INV(2)'

c. ' x^2 3 **ENTER** 1: 'SQ(3)'

d. ' 10^x 100 **ENTER** 1: 'ALOG(100)'

e. ' e^x 1 **ENTER** 1: 'EXP(1)'

The trigonometric, inverse trigonometric, and logarithmic keys all provide their names and a matching set of parentheses when pressed between tick marks.

8. SYMBOLIC ALGEBRA

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

Make sure the calculator is in symbolic mode by checking that SYM is lit up under the MODES menu.

Two important keys to remember here are the "tick" key (for symbolic expressions), and the α key (to obtain the letters). Here's how to enter the symbolic expression $A + B$:

' A + B ENTER 1: 'A+B'

Now, let's raise it to the second power:

2 y^x 1: '(A+B)^2

The ALGEBRA menu has the EXPA key for expanding symbolic expressions:

ALGEBRA EXPA 1: 'A^2+2*A*B+ B^2'

There is also a [COLCT] key for collecting like terms, cancelling like factors in rational expressions, and other simplifications. Let's illustrate with an example:

Enter $3X^2$:

['] 3 [×] X [y^x] 2 [ENTER] 1: '3*X^2'

Divide by $6X$:

['] 6 [×] X [ENTER] [÷] 1: '3*X^2/(6*X)'

Add $2X$:

['] 2 [×] X [ENTER] [+] 1: '3*X^2/(6*X)+2*X'

Now use the [COLCT] key twice:

[COLCT] 1: '.5*X+2*X'

[COLCT] 1: '2.5*X'

For complicated expressions, you may find that you need to use a combination of the [EXPA] and [COLCT] keys to obtain the "best" simplification that the HP-48 can do.

Equation Writer

The Equation Writer uses the screen as a "blackboard" to write expressions in usual textbook format. It is helpful for entering a complicated expression when you want to visually match the notation with that in a book or your notes.

An important key to remember while using the Equation Writer application is the [▶] key. Use it whenever you want to proceed to the next "component" of an expression. For example, you press [▶] whenever you wish to leave a denominator or get "outside" a radical sign.

Suppose we want to enter the expression

$$\frac{X+1}{\sqrt{X^2-1}} + 3X.$$

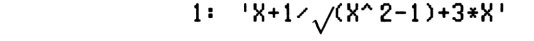
To enter the Equation Writer, we press [EQUATION]. The stack disappears (but not the menu key labels). Watch your screen as you enter the following keystrokes:

[()] X [+] 1 [▶] [÷] [$\sqrt{x}$] X [y^x] 2 [▶] [−] 1 [▶] [▶] 3 [×] X

Note that a multiplication dot is used in the Equation Writer instead of an asterisk. Press [ENTER] to send the expression to the stack.

Typesetting an expression on the stack

Now, let's edit the expression. Press [EDIT] and remove the parentheses around $X+1$ using the cursor and the [DEL] key. When you are done, press [ENTER].



To simply typeset this expression that is already on the stack, press the [▼] key. This will take several moments, for the HP-48 needs to recalculate the sizes of the fonts, fraction bars, and radical signs:

$$X + \frac{1}{\sqrt{X^2 - 1}} + 3 \cdot X$$

9. CREATING VARIABLES AND FUNCTIONS

To store any object under a variable name, enter the contents on the stack, then type the name of the variable and press [STO] to store it. For example,

3 [ENTER] W [STO] stores 3 under the variable name W.

To recall the value, simply type the name and enter it:

W [ENTER] 1: 3

If a symbolic expression contains W, then [EVAL] will substitute the value:

['] W [y^x] 4 [ENTER] 1: 'W^4'

[EVAL] 1: 81

The [VAR] menu

Items created and stored in the HP-48 appear by name under the [VAR] menu. Press [VAR] now and you should see a menu key labelled [W]. Pressing [W] will also return its contents to the stack.

[VAR] [W] 1: 3

Purging stored information from memory

[VAR] ['] [W] [PURGE] makes W disappear from the [VAR] menu.

Defining your own functions

Expressions can be stored under variable names. For example, suppose we stored the formula for $\sec(X)$ under the name SEC:

['] 1 [÷] [COS] X [ENTER] SEC [STO] stores $1/\cos(X)$ under the variable name SEC.

Pressing [VAR] [SEC] simply returns the expression $1/\cos(X)$ to the stack.

In contrast, we can actually *define* a secant function key that will operate just like the other trigonometric function keys. To do this, we enter the formula as an equation:

['] SEC [()] X [blacktrianglerlight] [=] 1 [÷] [COS] X [ENTER]

```
1:    'SEC(X)=1/COS(X)'
```

Now we press the [DEF] key to define the function.

Try out your new [SEC] key in radian mode

0 [ENTER] [VAR] [SEC] 1: 1

or degree mode:

[RAD] 60 [ENTER] [VAR] [SEC] 1: 2

This is an example of a *user-defined function*. It actually operates like a small program—pressing [SEC] executes the program to take a value X off the stack and return the value of $1/\cos(X)$.

To see what the program looks like internally, first enter the name of the program on the stack:

['] [VAR] [SEC] [ENTER] 1: 'SEC'

Now recall its contents using the [RCL] key (blue shift of STO):

[RCL] 1: ≪→ X '1/COS(X)' ≫

The delimiters ≪ and ≫ denote a program on the HP-48. In this case, our program takes a value off the stack (indicated by the arrow), calls it X, and finally evaluates $1/\cos(X)$.

Define the other two trigonometric functions by entering

'CSC(X)=1/SIN(X)' [DEF]

and

'CTN(X)=COS(X)/SIN(X)' [DEF]

Now you have all six trigonometric function keys for your HP-48.

10. THE SOLVER

The [SOLVE] application allows you to work with expressions and equations numerically. We'll work through an example that illustrates the power of this application.

Press [SOLVE] to bring up this menu:

[SOLVR] [ROOT] [NEW] [EDEQ] [STEQ] [CAT]

EQ is the special name that the HP-48 reserves for the expressions or equations that it works with in the SOLVE or PLOT applications. The key [STEQ] is short for "STORE under the name EQ."

Let's store the expression $X^2 - 3$ under the name EQ for now:

['] X [y^x] 2 [–] 3 [STEQ]

Evaluating the EQ expression

Once a variable expression has been stored in EQ, you should see it displayed at the top of the screen under "Current equation:"

Press [SOLVR] and you should see a white menu key for the variable [X] and a black menu key labelled [EXPR=] . You can use these to evaluate EQ quickly for any number of variable values.

To evaluate EQ at $X = 15$:

15 [X] [EXPR=] 1: EXPR: 222

To evaluate EQ at $X = 3$:

3 [X] [EXPR=] 1: EXPR: 6

The label "EXPR:" is for your convenience, and is not recognized by the calculator for computation purposes. For example, you could press [+] to obtain the sum 228. You could even press [X] again to feed this value in as the next value of X.

If you press the orange shift key [↰] and then [X], the HP-48 will use the current X value as an initial seed to find a root of the expression. You should see a message saying "Solving for X" at the top of the screen, and then a labelled X: value appears on the stack.

[↰] [X] 1: X: 1.73205080757

A message also appears at the top of the screen informing you of the quality of the answer:

"Zero" indicates that the displayed value X is a root (making EQ equal to 0 to 12 digits);

"Sign Reversal" indicates that EQ can reverse sign (from positive to negative or vice-versa) by a change in the last digit of the displayed value X (for continuous functions, this means the displayed value is within one digit of a root);

"Extremum" generally indicates that the displayed value X minimizes the absolute value of EQ.

Different roots may be found by changing the seed value X:

5 [+/−] [X] [↰] [X] 1: X: -1.73205080757

Now we have found both roots of $X^2 - 3$.

Changing the expression in EQ

Press [SOLVE] to bring up the main menu. To change the expression in EQ, we could enter a new expression and press [STEQ], or we can edit the current EQ by pressing [EDEQ] (short for "EDIT the expression in EQ"). [EDEQ] places the expression on the editing line where you can make changes. Pressing [ENTER] locks in the changes to EQ, while pressing [ON] leaves the old EQ intact.

The old expression in EQ is lost whenever you make a change using [STEQ] or [EDEQ].

If you want to save the old EQ expression before making any changes, press [↱] (blue) [STEQ] to return the contents of EQ to the stack:

1: 'X^2-3'

Now we can enter a name in tick marks and store the expression:

['] Y1 [STO] will store the expression under the name Y1, which can now be found in your [VAR] menu.

Analyzing equations in the SOLVER

Let's try another example.

Type ['] **A** [y^x] **3** [−] **2** [×] **B = C** [y^x] **2 + 6** **ENTER**

```
1:    'A^3-2*B=C^2+6'
```

Now press **SOLVE** **STEQ** **SOLVR** .

Note that there is a white key for each of the three variables in the equation. We'll enter the values $A = 3$, $B = 4$, and $C = -5$, and check *both* sides of the equation:

3 [A] **4** [B] **5** [+/−] [C] **EXPR=**

```
2:          LEFT:  19
1:         RIGHT:  31
```

We can see that the two sides of the equation do not match. We can pick any of the variables, say B, and solve for it given the values already stored for A and C:

[↰] **B**

```
1:    B: -2.00000000001
```

The original value stored in B was used as a seed for the HP-48's numerical root finder (you can see the effects of round-off precision). Press **EXPR=** to see that both sides of the equation now equal 31.

Reviewing EQ and variable values

While in the SOLVER, you can press [REVIEW] to see a display of the expression stored in EQ and the current values of all the variables involved. When you are done reviewing this data, just press [ON].

Using [NEW] to save an expression

Let's enter $X^3 - 3 * X$ using the Equation Writer:

[EQUATION] X [y^x] 3 [▶] [−] 3 [×] X [ENTER]

```
1:                    'X^3-3*X'
```

To name the expression and load it into EQ at the same time:

[SOLVE] [NEW] Y2 [ENTER]

```
Current equation:
Y2:                   'X^3-3*X'
```

When using [NEW] to name a new equation or a function, the calculator is automatically in alpha mode.

Now the roots of this new expression can be found using [SOLVR] Under the [VAR] menu you'll find soft keys for all the variables (X, A, B, and C) as well as for all the expressions (Y2, Y1, and EQ). As usual, you can purge any or all of these using the [PURGE] key.

11. THE PLOTTER

Press [PLOT] and you should see a plot type listed at the top of the screen followed by the current EQ expression (or "No Current Equation" if there is none). This menu should appear:

[PLOTR] [PTYPE] [NEW] [EDEQ] [STEQ] [CAT]

Press [PLOTR] to bring up the basic command menu as well as the plotting parameter screen, showing you the current equation, independent (and possibly dependent) variables, and the x (horizontal) and y (vertical) ranges of the viewing window. To return to the main PLOT menu, press [PLOT] again.

[PTYPE] displays the menu of graph types you can select. Press [FUNC] (for function). After you have made a choice of plot type, you are returned automatically to the main [PLOT] menu.

The other four keys you see here are identical to those under the main [SOLVE] menu. [NEW] stores a new expression with a name of your choosing. If you do not choose a name, then the expression is automatically given the name EQ. [EDEQ] puts the current EQ expression on the command line for editing. After editing is complete, [ENTER] replaces the old expression with the new one. To abort the editing process, press [ON]. [STEQ] stores an expression under the name EQ.

Using the CATALOG

[CAT] displays a catalog of stored expressions from which any may be selected for use in either the SOLVER or PLOTTER. If you just finished the section on the SOLVER, then press [CAT] to see the catalog:

```
Y2:          'X^3-3*X'
EQ:              'Y2'
Y1:          'X^2-3'
```

The directional arrow keys are active and the following menu is displayed:

[PLOTR] [SOLVR] [EQ+] [EDIT] [→STK] [VIEW]

Use your arrow keys to point to an expression. If you press [PLOTR] or [SOLVR], then the expression is stored in EQ and you are transferred directly to either the PLOTTER or the SOLVER application.

To remove functions from the catalog, move the cursor to indicate the function to be removed and press [PURGE].

[EQ+] lets you build a list of expressions or equations, each of which would be plotted one after the other in the PLOTTER.

[EDIT] allows you to edit a chosen entry in the catalog, [→STK] sends a copy of the entry to the stack, and [VIEW] lets you view the entry (in case it is large, like a program).

Basic Function Plotting

This section leads you through some function plotting examples that should familiarize you with most of the basic features of the HP-48 plotter.

Let's start out by making sure that the HP-48 is in radian mode (check for the letters RAD at the top of the screen). Press [RAD] if necessary to switch to radian mode.

Setting the Plotting Parameters

To set up graphing with the default (usual) parameters, i.e., with the center of the screen at the origin, with coordinate axes shown, with each axis mark representing one unit, and each pixel valued at 0.1 unit, press [PLOT] [PLOTR] [NXT] [RESET]. The default viewing window is $[-6.5, 6.5] \times [-3.1, 3.2]$ (x range by y range).

Now, let's enter the sine function for graphing:

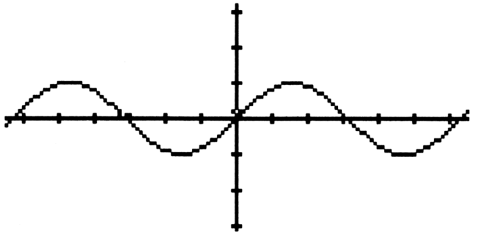
['] [SIN] [X] [ENTER] 1: 'SIN(X)'

Press [PLOT] [STEQ] to store the function in EQ. Your screen should read as follows:

```
Plot type: FUNCTION
EQ: 'SIN(X)'
Indep: 'X'
```

```
x:          -6.5  6.5
y:          -3.1  3.2
```

ERASE DRAW displays the graph of $y = \sin x$.



ERASE clears the graphics screen; otherwise, the new graph will be plotted over whatever was on the graphics screen previously.

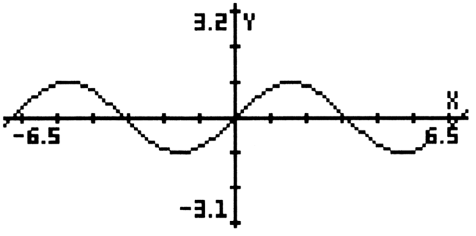
Interactive graphing features

The directional arrow keys now move a small crosshairs around the screen.

Press COORD or + and the coordinates of the crosshairs are displayed in the lower left corner of the screen (the menu labels also have disappeared). Pressing COORD or + again toggles the coordinates off and the menu labels back on.

[–] toggles the menu labels on and off without coordinates displayed. Press the arrow keys several times while the coordinates are displayed. (The crosshairs move much faster when the coordinates are not displayed.)

[LABEL] displays left-right and top-bottom endpoints on any axes that happen to be in the viewing window. If the menu keys are toggled off, then the labels should appear as follows on our graph of the sine function:



The labels cannot be removed unless you redraw the graph.

Press [ON] until you leave the graphics screen. Then press [ERASE] [DRAW] to redraw the graph without labels.

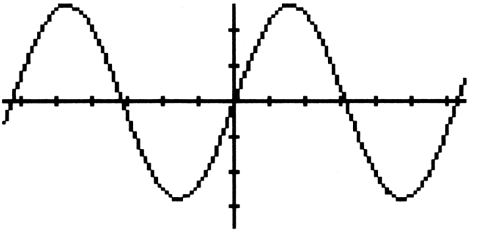
To return back to the stack, press [ON]. To return to the graphics screen from the stack without redrawing, press [GRAPH].

Rescaling the function graph

Using the same function example as before (EQ: SIN(X) at default plotting parameters), we'll illustrate several ways to rescale a function graph, both from inside and outside the graphics screen environment.

Press **PLOT** PLOTR AUTO .

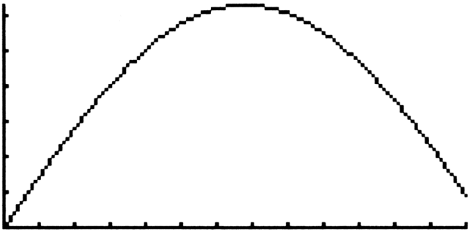
This computes a sample of the values of the expression for the x range and then sets the y range automatically to include the extreme y values.



Press **ON** to return to the stack and **PLOTR** menu. The XRNG and YRNG keys allow you to set a new horizontal and vertical ranges. To set the new viewing window to $[0, 3] \times [0, 1]$:

0 **SPC** **3** XRNG **0** **SPC** **1** YRNG

Now press ERASE DRAW to see the resulting graph.

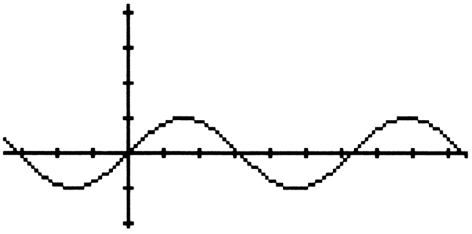


Interactive zooming features

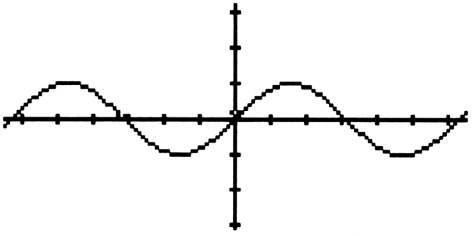
Press [ON] to return to the stack and [NXT] [RESET] to reset the plotting parameters. Now press [PREV] to return to the front page of the [PLOTR] menu and redraw the graph with [ERASE] [DRAW].

Once you've drawn a graph, you have an interactive menu available.

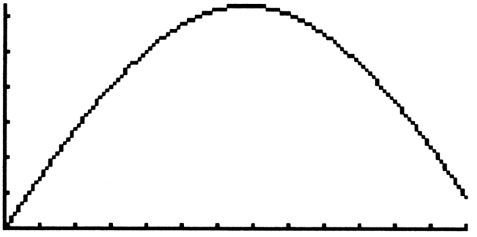
[CENT] allows you to recenter the screen with the same relative dimensions. Move your crosshairs to the point $(3, 1)$ and then press the [CENT] menu key.



Let's go back to our original picture by leaving the graph (press ON) and use RESET ERASE and DRAW from the PLOTR menu.



The ZBOX key allows you to set two opposite corners of your viewing window (the order is unimportant). Press ZBOX once and you'll see a small mark at the origin. Now, move the crosshairs over to the point $(3, 1)$ and press ZBOX again.



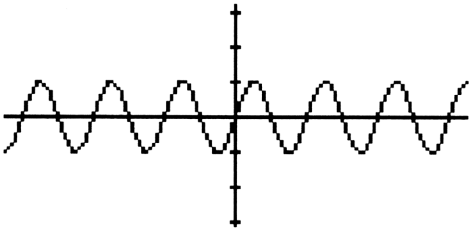
Look familiar? We effectively set the viewing window to $[0, 3] \times [0, 1]$ again, but this time without leaving the graph.

Notice that [ZBOX] can only zoom in on a smaller window, while [XRNG] and [YRNG] allow you to set any window size.

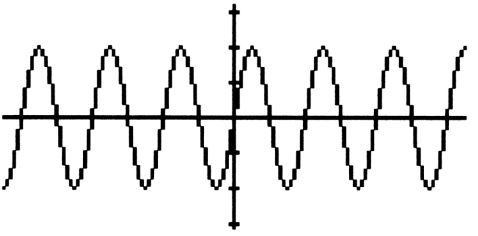
The [ZOOM] folder key brings up a zooming feature submenu which provides for selective zooming in or out by factors on one or both axes.

[XAUTO] selects x-axis zoom factor with automatic y-axis scaling (like [AUTO] from the [PLOTR] menu).

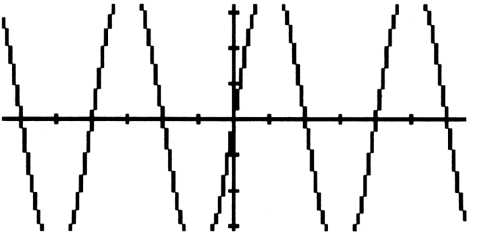
[X] selects a horizontal zoom factor with no change in the y range. Let's try it. Press [X] and type in 3.14 [ENTER] . This will effectively zoom out horizontally by a factor approximately equal to π.



Go back into the [ZOOM] folder. [Y] selects a y-axis zoom factor with no change in x range. Press [Y] .5 [ENTER] to zoom in vertically by a factor of 2.



Back to ZOOM again. The XY selects a common zoom factor for both the x and y ranges. Press XY .5 ENTER to zoom in by a factor of 2 both horizontally and vertically.



Anytime you're in the ZOOM folder and you change your mind, you can press EXIT to go back to the top level of the interactive graphics menu.

Connected mode

If you press [MODES] [NXT] you will find the soft key for *connected* mode. When this key is toggled off (so that the label reads [CNCT]), at most one pixel per column will be lit on a function plot. When this key is toggled on (so that the label reads [CNC] with a white box covering the T), then additional pixels are lit to give the graph a continuous appearance. To contrast the two modes, try this example.

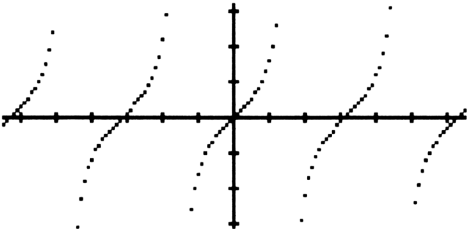
Store the tangent function in EQ:

['] [TAN] X [ENTER] 1: 'TAN(X)'

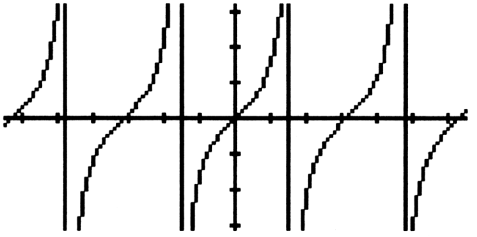
[PLOT] [STEQ]

Now, make sure that radian mode is on (RAD should appear at the top of the screen) and that connected mode is *off* ([CNCT] should appear under [MODES] [NXT]).

Now graph the tangent function by pressing [PLOT] [PLOTR] [ERASE] [DRAW].



To "fill in" the gaps, press [ON] [MODES] [NXT] and toggle connect mode *on*. Now graph the tangent function again by pressing [PLOT] [PLOTR] [DRAW].



Notice how it appears that "vertical asymptotes" have been drawn in. This is not really the case— the calculator has simply connected the graph across the asymptotes.

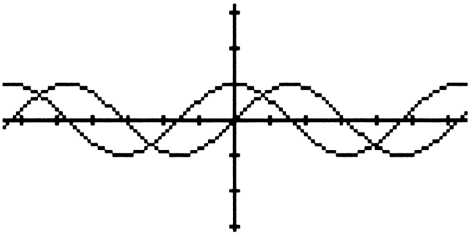
Plotting two functions simultaneously

To graph two functions simultaneously, enter them as the two sides of an equation. For example, to plot both the sine and cosine functions at the default plotting parameters, you should enter 'SIN(X)=COS(X)' on the stack:

['] [SIN] X [▶] [=] [COS] X [ENTER]

```
1:      'SIN(X)=COS(X)'
```

Then press [PLOT] [STEQ] [PLOTR] [NXT] [RESET] [ERASE] [DRAW] to see the simultaneous plot.



Plotting two or more functions sequentially

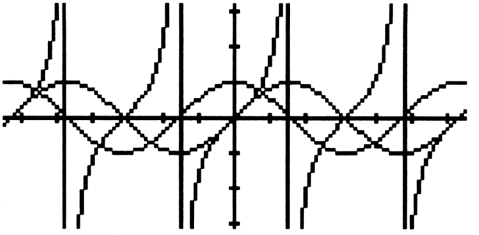
To graph two or more functions sequentially, enter them within a set of *list* braces.

For example, to plot the sine, cosine, and tangent functions sequentially at the default plotting parameters, you should enter

[{ }] ['] [SIN] X [▶] [SPC] ['] [COS] X [▶] [SPC] ['] [TAN] X [ENTER]

1:{ 'SIN(X)' 'COS(X)' 'TAN(X)'}

Then press [PLOT] [STEQ] [PLOTR] [NXT] [RESET] [ERASE] [DRAW] to see the sequential plot.



12. TOOLS FOR ALGEBRA AND CALCULUS

For each of the following examples, make sure you first purge [X] from the calculator's memory:

['] X [PURGE]

There should be no [X] under the [VAR] menu.

Solving linear equations

To solve $3x - 1 = 0$:

3 [×] X [−] 1 [ENTER] ['] X [ENTER]

```
                    2:          '3*X-1'
                    1:              'X'
```

[ALGEBRA] [ISOL]

```
                    1:  'X=.333333333333'
```

[→ Q]

```
                    1:             'X=1/3'
```

To solve $\sin x = 0$:

[SIN] X [▶] [=] 0 [ENTER] ['] X [ENTER]

```
                    2:        'SIN(X)=0'
                    1:              'X'
```

[ALGEBRA] [ISOL]

```
                    1:          'X=π*n1'
```

The $n1$ is a parameter representing an arbitrary integer. In other words, any integer multiple of π is a solution to this equation.

The ISOL button generally works successfully when the variable being solved for only appears in one term of the equation.

Solving quadratic equations

To solve $x^2 - x - 6 = 0$:

' X y^x 2 − X − 6 ENTER X ENTER

```
2:              'X^ 2-X-6'
1:                    'X'
```

ALGEBRA QUAD

```
1:        'X=(1+s1*5)/2'
```

The $s1$ is a parameter representing ± 1.

Use SOLVE STEQ to store the expression under the name EQ. Now you can substitute 1 and -1 for $s1$ using the SOLVR menu to find the solutions $x = 3$ and $x = -2$.

Now, try solving $x^2 + x = -1$, first with the ISOL key, and then with the QUAD key. Note that ISOL fails, but QUAD successfully returns the two complex solutions.

Derivatives

To see differentiation take place step-by-step, we enter the derivative as a symbolic expression, and then evaluate it with [EVAL] . (Reminder: Purge X from the [VAR] menu.)

To take the derivative of $sin(x^2)$ with respect to x, first purge any value stored in X: 'X [PURGE]

['] [SIN] [( )] X [y^x] 2 [ENTER]

['] X [ENTER]

```
2:          'SIN(X^2)'
1:                 'X'
```

Now press the differentiation key [∂] to obtain

```
1:    'COS(X^2)*(2*X)'
```

Step-by-step differentiation

To see the same result unfold step-by-step, enter the derivative expression

['] [∂] X [( )] [SIN] [( )] X [y^x] 2 [ENTER]

```
1:      '∂X(SIN(X^2))'
```

Now press [EVAL] once to see

```
1: 'COS(X^2)*∂X(X^2)'
```

Press [EVAL] twice more to obtain the final result

```
1:      'COS(X^2)*(2*X)'
```

Partial differentiation

In the Equation Writer, enter $\frac{\partial}{\partial y}(x^5 + 3xy^2 - 15)$:

[∂] Y [▶] X [y^x] 5 [▶] [+] 3 X [×] Y [y^x] 2 [▶] [−] 15 [ENTER]

```
1: '∂Y(X^5+3*X*Y^2-15)'
```

The final display shows how this expression could have been entered directly in "tick" marks on the stack.

Notice that in the Equation Writer, the calculator assumed that typing X immediately after the 3 meant multiplication. However, we explicitly needed [×] between X and Y to tell the calculator that we meant multiplication, and *not* a single variabley named XY. The multiplication key must be used whenever it is intended when typing an expression in tick marks on the stack.

Press [EVAL] to observe the result

```
1:          '3*X*(2*Y)'
```

You can press [ALGEBRA] [COLCT] to simplify the expression.

Integration

The Equation Writer is particularly nice for entering an integral. For example, to type in $\int_0^1 \frac{1}{1+t^2}\,dt$

EQUATION ∫ 0 ▶ 1 ▶ 1 ÷ 1 + T y^x 2 ▶ ▶ ▶ T

Press ENTER to obtain '∫(0,1,1/(1+T^2),T)' on the stack. The display shows how the integral could have been entered directly on the stack as a symbolic expression.

Press ENTER to duplicate the integral on the stack. Now press EVAL EVAL :

```
                                1:          .785398163397
ALGEBRA NXT →Qπ                 1:               '1/4 * π'
```

Now let's evaluate the integral $\int_0^x \frac{1}{1+t^2}\,dt$

SWAP EDIT gets our definite integral back onto an editing line. Move the cursor so that it is flashing over the upper limit 1. Press DEL (delete) and type X in its place. Finally, press ENTER . To check the integral in the Equation Writer, press ▼ . Press ON to return to the stack. Now press EVAL EVAL :

```
                                1:             'ATAN(X)'
```

Numerical integration

Using [EVAL] to compute a definite integral $\int_a^b f(x)\,dx$ essentially tells the HP-48 to look for an *antiderivative* F (such that $dF/dx = f$) and compute

$$F(b) - F(a).$$

If the calculator returns the original integral to you when you press [EVAL], it means that it was unable to find an antiderivative for the integrand. Here is an example of an integral for which there is no nice closed form antiderivative for the integrand:

$$\int_0^1 e^{-x^2}\,dx.$$

Let's enter this integral in the Equation Writer:

[EQUATION] [$\int$] 0 [▶] 1 [▶] [e^x] [−] X [y^x] 2 [▶] [▶] [▶] X

Press [ENTER] [EVAL] and note that the integral expression is simply returned back to us. To use a numerical integration technique on the definite integral, press [→NUM] instead of [EVAL].

```
1:                .746824132812
```

The accuracy of the computation is governed by the numeric display. For example, if you press [MODES] 2 [FIX] to fix two decimal

places, then using [→NUM] to evaluate a definite integral will invoke an error factor of .01. Whenever [→NUM] is used for numerical integration, a variable [IERR] appears under the [VAR] menu. The number stored in [IERR] number represents a likely bound on the maximum error in the computed result of the definite integral. For example, when we computed $\int_0^1 e^{-x^2}\,dx$ with [STD] display mode, the likely maximum error recorded in [IERR] is $7.46827971619E-12$.

Taylor polynomials

To compute a Taylor polynomial about 0 for a function, you'll need three arguments on the stack: the function, the variable of differentiation, and the degree of the desired polynomial.

For example, to compute the fifth degree Taylor polynomial of $\sin x$:

['] [SIN] [X] [ENTER] ['] [X] [ENTER] [5] [ENTER]

```
3:          'SIN(X)'
2:              'X'
1:                5
```

Make sure you are in *radian* mode. Now, press [ALGEBRA] [TAYLR] to obtain the Taylor polynomial. Press [▼] to view it in the Equation Writer environment

Make sure you are in *radian* mode. Now, press **ALGEBRA** **TAYLR** to obtain the Taylor polynomial. Press **▼** to view it in the Equation Writer environment

$$X - \frac{1}{3!}X^3 + \frac{1}{5!}X^5$$

Press **ON** to return to the stack.

To calculate the Taylor polynomial of $f(x)$ about a point $x = a$, you can first calculate the Taylor polynomial of $f(z + a)$ about $z = 0$, and then simply replace z by $x - a$. Here's an example illustrating how you can use the calculator to compute Taylor polynomials about points other than 0.

Compute the fourth degree Taylor polynomial of $\ln x$ about $x = 1$.

' **LN** **Z** **+** **1** **ENTER** **'** **Z** **ENTER** **4** **ENTER**

```
3:          'LN(Z+1)'
2:                'Z'
1:                  1
```

Now press **ALGEBRA** **TAYLR** . You can replace Z by $X - 1$ by

' **X** **−** **1** **ENTER** **'** **Z** **STO**

Then press **EVAL**. Use **→Q** to change the decimals to fractions view the final result in the Equation Writer by pressing **▼**:

$$X - 1 - \frac{1}{2} \cdot (X-1)^2 + \frac{1}{3} \cdot (X-1)^3 - \frac{1}{4} \cdot (X-1)^4$$

When an expression is too large to be viewed on a single screen of the Equation Writer, press GRAPH to remove the menu labels and allow the directional arrows to scroll the screen. Press ON once to return the menu labels and ON again to return to the stack.

Summations

A summation can be entered much like an integral in the Equation Writer. For example, to enter

$$\sum_{N=1}^{100} \frac{1}{N}$$

press

EQUATION **∑** **N** **=** **1** **▶** **100** **▶** **1** **÷** **N** **ENTER**

Then use **EVAL** to evaluate the summation.

```
1:          5.18737751761
```

13. FUNCTION GRAPH ANALYSIS

When you graph a function, a folder labelled FCN appears on the graphics menu. It contains several interactive tools for working with functions directly in the graphics environment. We'll illustrate the operation of these keys by means of an example.

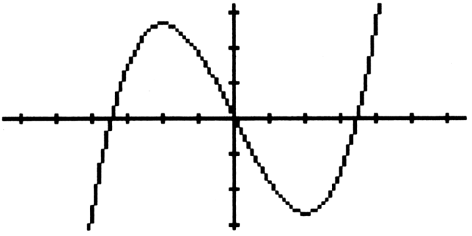
First, let's graph $X^3/6 - 2X$ at the default settings.

' X y^x 3 ÷ 6 − 2 × X ENTER

```
                                  1:          'X^3/6-2*X'
```

PLOT STEQ PLOTR NXT RESET

NXT NXT ERASE DRAW



Now, press FCN to obtain the Function Menu.

Place the crosshairs at $x = 3$. ROOT snaps the crosshairs to the nearest root, displays its value, and records it on the stack with the

see ROOT: 3.446410161514 at the bottom of the screen. Press [—] to get the menu labels back on screen.

If you have plotted two functions simultaneously, then [INTER] snaps the crosshairs to the nearest intersection point, displays its coordinates, and records it on the stack with the label "Isect:" . This key does not apply for our particular example.

Move the crosshairs back to the origin. [SLOPE] calculates the derivative of the function at the x-coordinate of the crosshairs location, displays it, and records it on the stack with the label "Slope:" . Press this key now and the calculator will compute the slope at $x = 0$. You should see SLOPE: -2 at the bottom of the screen. (Press [—] to obtain menu labels again.)

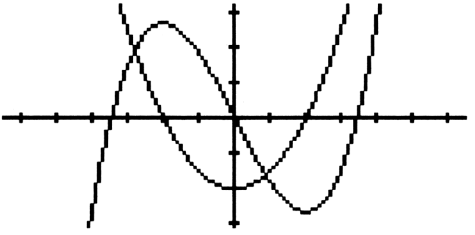
[AREA] first marks the lower limit of integration. Press this key now and you'll see a small mark at the origin. The second time it is pressed, it computes the definite integral (numerically) of the function from the first mark to the current crosshairs position, displays the value, and records it on the stack with the label "Area:" . Move the crosshairs back to $x = 3$ and press [AREA] again. You should see AREA: -5.625 at the bottom of the screen. (Press [—] to obtain menu labels again.)

The [AREA] key computes a definite integral, so integrating from right to left between two points will yield the opposite result from integrating from left to right.

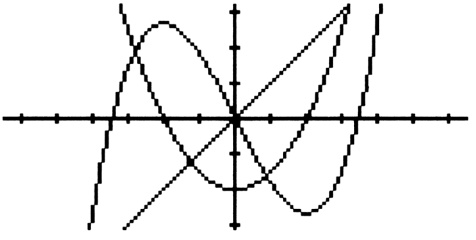
[EXTR] snaps the crosshairs to the nearest extremum, displays its coordinates, and records it on the stack with the label "Extrm:" . (The HP-48 is using its built-in root finder on the derivative of your function.) Move the crosshairs near the point (-2,-2) and press this key now. You should see EXTRM: (-2,2.66666666667) at the bottom of the screen. (Press [—] to obtain menu labels again.)

Pressing [NXT] shows [F(X)] , which computes the function's value at the crosshairs location, displays it, and records it on the stack with the label "F(x):" . Move the crosshairs to $x = -3$ and press the [F(X)] key. You should see F(X): 1.5 at the bottom of the screen. (Press [—] to obtain menu labels again.)

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



If you press [F'] again, then the second derivative is plotted, followed by the first derivative and the original function graph.



If more than one function is entered into EQ, then NXEQ allows you to cycle through the list. Press NXEQ repeatedly and you should see that our list of functions now includes the original function along with its two derivatives. The function displayed at the bottom of the screen is the currently "active" one for the purposes of the function folder.

Press NXT EXIT to leave the function folder and return to the main interactive graphics menu.

14. OTHER PLOT TYPES

In this section we briefly describe some other plot types available on the HP-48 by way of some simple examples. The [FCN] folder is inactive for these plot types, but the other interactive rescaling and zoom features all work. In all of these examples, the illustrations are for *connected* mode. (Press [MODES] [NXT]. If [CNCT] appears, press that menu key so that a white square covers the T.)

Conic sections

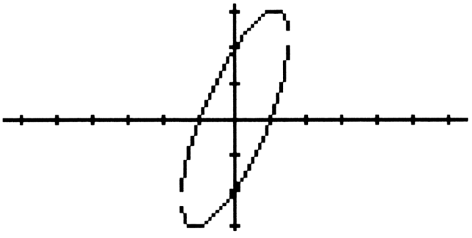
Press [PLOT] [PTYPE] [CONIC].

Through the Equation Writer, enter $4x^2-3x\cdot y+y^2-4=0$ (Note: there must be a multiplication sign between x and y to distinguish it from a single variable with the name xy.)

Now, let's plot the ellipse at the default plot parameter settings:

[STEQ] [PLOTR] [NXT] [RESET] [ERASE] [DRAW]

With the menu labels removed (press [—]), this graph should appear:



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

Parametric Plotting

Press [PLOT] [PTYPE] [PARA]

First, let's reset the plotting parameters at their default values using [RESET].

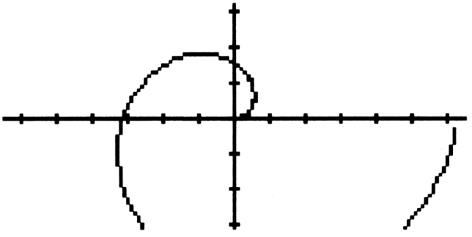
To plot $x(t) = t\cos t$ and $y(t) = t\sin t$ for $0 \leq t \leq 6.28$, we first enter the pair of coordinate functions in the *complex* form $x(t) + iy(t)$:

['] T [×] [COS] T [▶] [+] [α] ['] I [×] T [×] [SIN] T [STEQ]

Now, we enter the parameter T as the independent variable along with its starting and ending values:

{ T [SPC] 0 [SPC] 6.28 [ENTER] [INDEP]

Finally, erase the graphics screen and draw this spiral curve: ERASE DRAW . With the menu labels removed (press ▽), this graph should appear:



Polar Plotting

Press PLOT PTYPE POLAR

To plot $R = 3\sin(2.5\theta)$:

R = 3 × SIN 2.5 × α ↱ F ENTER

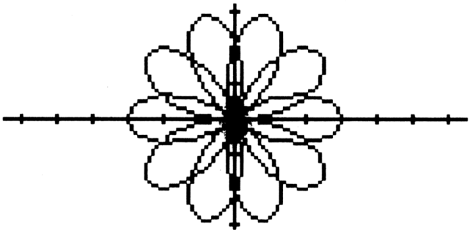
```
Plot type: POLAR
EQ:'R=SIN(2.5*θ)'
Indep: 'X'
x:          -6.5   6.5
y:          -3.1   3.2
```

Change the independent variable to θ and set its starting value at 0 and its ending value at 12.6 (approximately 4π).

◁ { } α ▷ F SPC 0 SPC 12.6 ENTER INDEP

To plot this polar flower, press ERASE DRAW .

With the menu labels removed (press ←), this graph should appear:



Inequality Plotting

Press PLOT PTYPE TRUTH

Enter $\sin(xy) < .5$ into EQ by pressing

SIN X × Y ▶ α ◁ 2 .5 ENTER STEQ

Set the plotting parameters at their default values with RESET and then press ERASE DRAW to see the shaded region. (This takes several minutes to plot completely.)

With the menu labels removed (press ←), this graph should appear:

For any plot type, you can hold down the REVIEW key in the graphics environment to see the settings for you screen. When you release the REVIEW key, you return to the graphics environment immediately.

15. MEMORY MANAGEMENT

The calculator's memory is organized in a tree structure consisting of directories, subdirectories, subsubdirectories, etc. Pressing [UP] (orange shift of the tick key) moves you up one level in the directory structure. Pressing [HOME] (blue shift of the tick key) moves you immediately to the top level of the directory.

Now let's create our own directory, which we'll call WORK. First, enter the name:

WORK [ENTER] 1: 'WORK'

Now press [MEMORY] (orange shift of [VAR]) and press the soft key [CRDIR] (for "create directory").

You should now find a folder called [WORK] under the [VAR] menu. If you press [WORK] , you'll find an empty menu, since there aren't objects stored away in this directory yet. Also notice that the *path* is shown in the message area at the top of your calculator screen ({ HOME WORK}). Press [UP] to move up the tree to your HOME directory. Press [WORK] again to return to your recently created directory.

The HP-48 always looks in the current directory for variable values, function definitions, EQ for plotting or solving, etc. If it does not

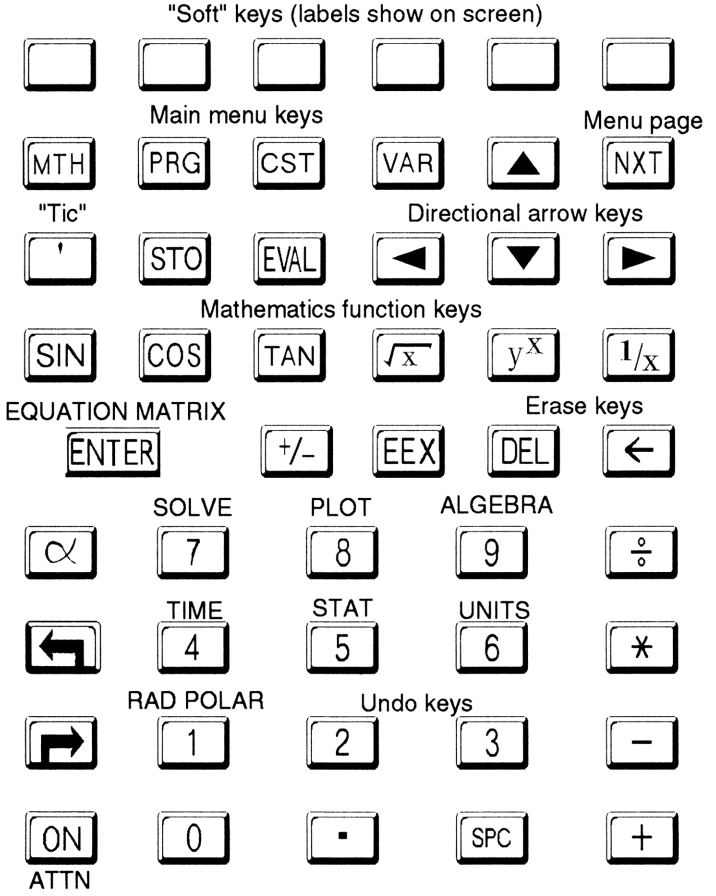
find what it is looking for, then it looks in the next higher directory (but never a lower directory).

This feature can be very useful. For example, if you define a function (like SEC) in the HOME directory, then this function is understood in *all* your subdirectories. It also allows you to have a different EQ expression in each directory. However, note that if you are taking a symbolic derivative in a subdirectory, then you must make sure that X (or whatever variable of differentiation you are using) is purged, not only in the subdirectory, but all directories *above* it.

Purging a directory

To purge an entire directory, you must be in the level immediately above it. Enter the name of the directory in tick marks on the stack. If the directory you want to purge is empty, then pressing **PURGE** erases it from the calculator's memory. If the directory has any contents, then press **PGDIR** (for "purge directory"), found in the third page of the **MEMORY** menu.

To clear all the memory in your calculator at once, press **ON** and the leftmost and rightmost soft keys simultaneously. (You'll get a "last chance" prompt to change your mind!)


"Soft" keys (labels show on screen)
Main menu keys
Menu page
MTH
PRG
CST
VAR
NXT
"Tic"
Directional arrow keys
'
STO
EVAL
Mathematics function keys
SIN
COS
TAN
EQUATION MATRIX
Erase keys
ENTER
+/-
EEX
DEL
SOLVE
PLOT
ALGEBRA
7
8
9
TIME
STAT
UNITS
4
5
6
RAD POLAR
Undo keys
1
2
3
ON
0
SPC
ATTN

16. KEYBOARD AND MENU INDEX

On the opposite page is a picture of your HP-48's keyboard. In this manual we've touched on many of the capabilities of the calculator (but by no means all!) Here's a tour of the keys starting at the top, with a brief mention of the purpose of each key.

The six white "soft" keys along the top row refer to whatever menu labels you have displayed across the bottom of the screen at the time.

[MTH] contains several submenus of mathematics functions.

[PRINT] contains commands for using an infrared printer.

[PRG] contains several submenus of programming commands.

[I/O] sets up your calculator to communicate with another calculator or computer.

[CST] allows you to make your own custom menus.

[MODES] controls how things are displayed on the calculator.

[VAR] contains objects you create and store in the calculator's memory.

[MEMORY] and [LIBRARY] allow you to organize your calculator's built-in and added memory.

[NXT] and [PREV] allow you to flip the pages of a menu.

The directional arrow keys [▲] [◀] [▼] [▶] move you around in different ways, depending on whether you are working on the stack, graphing, or editing and expression.

The "tick" key (single quote) is need for entering symbolic expressions. [UP] and [HOME] move you through the calculator's directory structure.

The [STO] key is used to store variables, expressions, programs, etc. in the calculator's memory. [RCL] recalls the contents of stored information and [DEF] is used to define your own functions.

[EVAL] evaluates symbolic expressions while [→NUM] and [→Q] are used to obtain decimal and rational forms of numbers.

[GRAPH] takes you to the graphics screen. [REVIEW] reviews the contents of the current menu. [SWAP] switches the position of two objects on the stack.

The third row of black keys are the basic mathematics function keys, including keys for derivatives, integrals, and summations.

The large [ENTER] key enters an object on the stack. [EQUATION] gains you access to the Equation Writer (a typesetting environment), while [MATRIX] gains you access to the Matrix Writer (a spreadsheet for entering and editing matrices).

[+/−] changes sign and toggles the crosshairs on a graph. [EDIT] and [VISIT] let you make changes to objects on the stack or stored in memory, respectively.

[EEX] is for exponential notation, and [2D] and [3D] let you build and dismantle two-dimensional and three-dimensional vectors.

The last two keys on the fourth row erase things. [DEL] and the backspace key delete characters while editing or typing, [PURGE] erases an item from memory, [DROP] drops an item from the stack, and [CLR] clears the entire stack.

The shift keys access the letters, orange labels, and blue labels on the other keys. The left (orange) shifts of the operation keys include a variety of delimiters (like parentheses, square brackets, program brackets, and set brackets).

The left (orange) shifts of the number keys gain access to a number of other menus and environments:

[SOLVE] is a numeric environment for evaluating and finding roots of expressions and equations.

[PLOT] is a graphic environment for plotting functions, conic sections, polar and parametric equations, inequalities, and statistical plots.

[ALGEBRA] is a menu of symbolic algebra tools, including menu keys for expanding and collecting terms, isolating variables, solving quadratic equations, and expanding Taylor polynomials.

[TIME] lets you set the HP-48's clock. [STAT] is an extensive data analysis environment. [UNITS] gives you a wide variey of units that you can append to numbers for arithmetic and conversions.

[RAD] toggles between radian and degree mode for angle measure. [POLAR] toggles between rectangular and polar coordinates.

LAST [STACK], [ARG], [CMD], and [MENU] recover the last stack, arguments, command line, and menu on your calculator.

That brings us back to where we started: the [ON] key, which also serves as the all-purpose ATTENTION getter for the calculator.

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