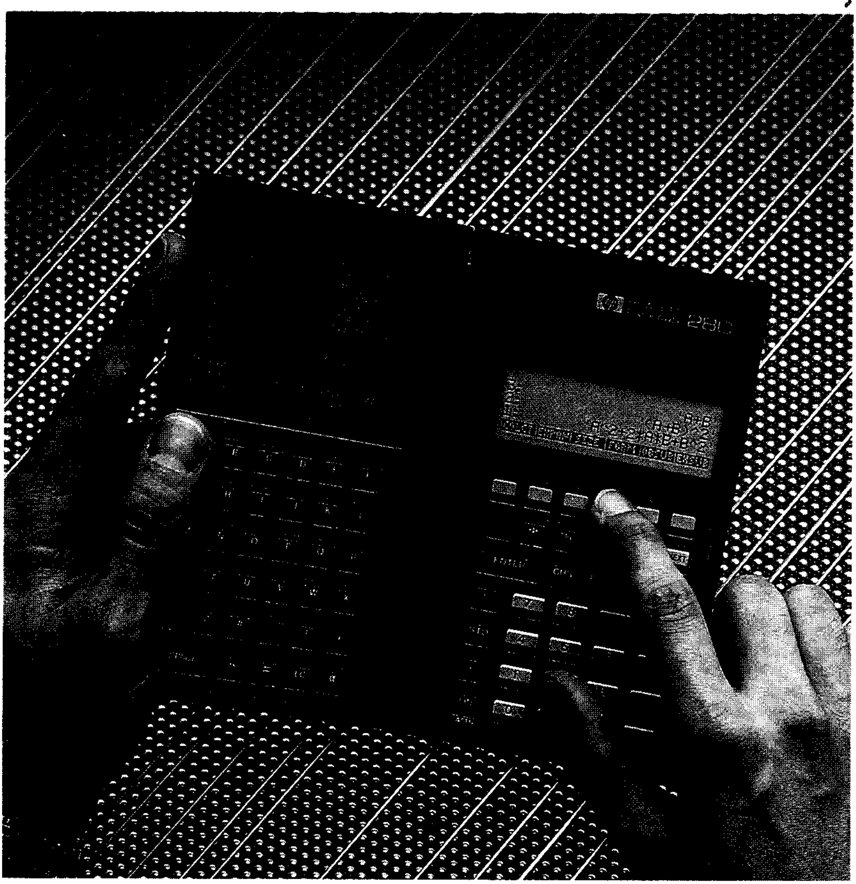
HEWLETT-PACKARD

HP-28C Getting Started Manual



HP-28C

Getting Started Manual

HEWLETT
PACKARD

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Notice

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Welcome to the HP-28C

Congratulations! With the HP-28C you can easily solve complicated problems, including problems you couldn't solve on a calculator before. The HP-28C combines powerful numerical computation with a new dimension—*symbolic computation*. You can formulate a problem symbolically, find a symbolic solution that shows the global behavior of the problem, and obtain numerical results from the symbolic solution.

The HP-28C offers the following features:

- Algebraic manipulation. You can expand, collect, or rearrange terms in an expression, and you can symbolically solve an equation for a variable.
- Calculus. You can calculate derivatives, indefinite integrals, and definite integrals.
- Numerical solutions. Using the HP-28C Solver, you can solve an expression or equation for any variable. You can also solve a system of linear equations. With multiple data types, you can use complex numbers, vectors, and matrices as easily as real numbers.
- Plotting. You can plot expressions, equations, and statistical data.
- Unit conversion. You can convert between any equivalent combinations of the 120 built-in units. You can also define your own units.
- Statistics. You can calculate single-sample statistics, paired-sample statistics, and probabilities.
- Binary number bases. You can calculate with binary, octal, and hexadecimal numbers and perform bit manipulations.
- Direct entry for algebraic formulas, plus RPN logic for interactive calculations.

The *HP-28C Getting Started Manual* (this manual) introduces your calculator and leads you through a sampling of examples.

The *HP-28C Reference Manual* gives specific information about commands and how the calculator works. The first two chapters explain the fundamentals and basic operations. The third chapter is a dictionary of menus, describing the concepts and commands for each menu.

We recommend that you first work through the examples in Getting Started to get comfortable with the calculator. When you want to know more about a particular command, you can look up the command in the Reference Manual. When you're familiar with the commands and want a broader understanding of the calculator's operation, you can read the theoretical discussions in the Reference Manual.

These manuals show you how to use the HP-28C to do math, but they don't teach math. We assume that you're already familiar with the relevant mathematical principles. For example, to use the calculus features of the HP-28C effectively, you should know elementary calculus.

On the other hand, you don't need to understand all the math topics in the HP-28C to use those parts of interest to you. For example, you don't need to understand calculus to use the statistical capabilities.

Contents

Appendixes and Index

How To Use This Manual

If you have the time and inclination, you can read this manual from front to back, working every example. If not, we recommend that you first read chapters 1 through 5 to get comfortable with the calculator. Then, if you're interested in a topic covered in a later chapter, you can skip ahead and try the examples in that chapter. Eventually you'll want to work through chapters 6, 7, and 8, to learn how to use the calculator more efficiently.

Each chapter contains examples that demonstrate, step by step, how to use the calculator. The first step in each chapter is "step 0." This step prepares your calculator to match the illustrations in the examples that follow.

What's in This Manual

Chapter 1, "A First Look," gives you a tour of the HP-28C, pointing out some of the calculator's features. This chapter gives you background information you'll need to use the calculator.

Chapters 2, 3, and 4 show you how to calculate on the HP-28C, including an easy way you can repeat a calculation without programming. Chapter 2, "Doing Arithmetic," shows how to make simple arithmetic calculations. Chapter 3, "Using Variables," shows how to store a number in a variable and then refer to the number by name. Chapter 4, "Repeating a Calculation," shows how to enter a calculation once, using variables instead of numbers, and then repeat the calculation for various values of the variables.

Chapter 5, "More Numerical Functions," describes additional functions including trigonometric, logarithmic, exponential, and hyperbolic functions, and introduces complex numbers on the HP-28C.

Chapters 6 and 7 give more information about calculator features you've already used. Chapter 6, "More About the Command Line," gives details about entering and editing information. Chapter 7, "More About the Stack," describes additional commands to manipulate the information you've entered.

Chapter 8, "Programs," shows how to write a program and compares programs with expressions.

Chapters 9 through 16 describe applications built into the HP-28C. Chapter 9, "Plotting Expressions," plots the graph of an expression and estimates a zero and a minimum for the expression. Chapter 10, "The Solver," finds more accurate values for the zero and minimum estimated in chapter 9. Chapter 11, "Symbolic Solutions," solves a quadratic equation and isolates variables in equations. Chapter 12, "Calculus," differentiates an expression and calculates indefinite and definite integrals. Chapter 13, "Vectors and Matrices," calculates with arrays, including solving a system of linear equations. Chapter 14, "Statistics," calculates single-sample and paired-sample statistics. Chapter 15, "Binary Arithmetic," performs arithmetic with binary integers. Chapter 16, "Unit Conversions," converts a number from one system of units to another.

Chapter 17, "Printing," shows how to use the HP-28C with the HP 82240A printer.

For More Information

As you work the examples in this manual, you may have questions about the features demonstrated or mentioned in the examples. Both this manual and the Reference Manual contain additional information.

- If you have problems, see "Answers to Common Questions" on page 199.
- For a brief description of what each key does, see appendix D, "Key Index," on page 241.
- For a brief description of the commands in each menu, see appendix C, "Menu Map," on page 219.
- For detailed information about a menu, look in the Reference Manual. All menus (plus some additional topics) appear alphabetically in chapter 3, "Dictionary." The contents of the dictionary are listed on the back cover of the Reference Manual.
- For detailed information about a particular command, look in the "Operation Index" at the back of the Reference Manual. There you'll find a reference to a dictionary entry (usually a menu) and a page reference to the particular command.

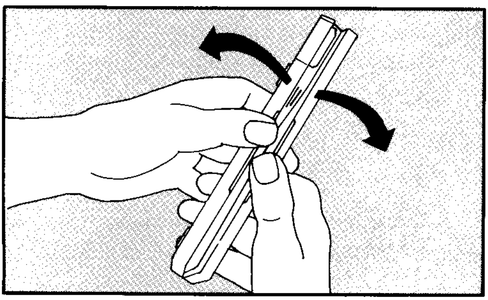
1

A First Look

This chapter gives an overview of the HP-28C. First described are the calculator's external features. Next, a simple example demonstrates basic calculator operation and concepts. Finally, a keyboard illustration highlights the major features of the keyboard and display, followed by a discussion of these features.

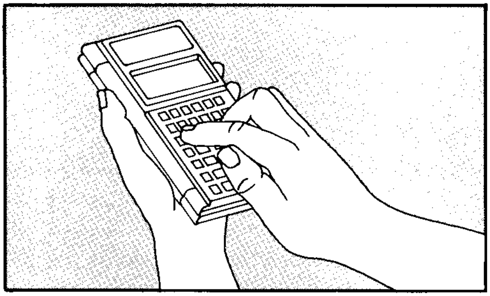
Opening and Closing the Case

The calculator forms its own case, opening and closing like a book. To open the calculator, hold it with the hinge away from you and open it with your thumbs.



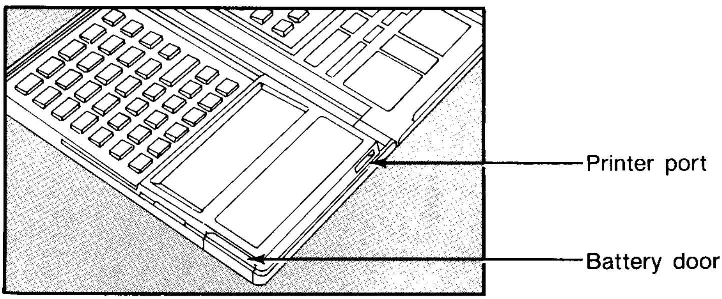
To close the calculator, fold the two sides together and press until you hear a click.

You can fold back the left-hand side of the calculator until it is back-to-back with the right-hand keyboard. This is handy for field work—when you want to hold the calculator in one hand and operate it with the other—or to save space on a desk.



Locating the Battery Door and Printer Port

With the calculator open, note the location of the battery door and the printer port.



The HP-28C is powered by three N-cell alkaline batteries. Batteries are included with the calculator. If the batteries are not already installed, follow the instructions that start on page 213.

When you use the HP-28C with a printer, the calculator sends information to the printer via an infra-red signal. This signal is emitted from the printer port and received by the printer. Printer operations are described in chapter 17.

Turning the HP-28C On and Off

Press [ON] to turn on the calculator. The HP-28C has *Continuous Memory*, so all data in the calculator, including the contents of the display, are unchanged from the last time you used the calculator.

While the calculator is on, [ON] acts as the ATTN (*attention*) key, as printed in white below the key. Pressing [ON] clears any text you've typed in and stops programs.

Press ■[OFF] to turn off the calculator. ("Press ■[OFF]" means "press the shift key ■, then press the key with OFF printed above it.")

If the calculator is inactive for about 10 minutes, it automatically turns off to conserve energy. Press [ON] to turn it on again.

Clearing All Memory (Memory Reset)

You can restore the calculator to its initial state by resetting memory. All information in the calculator is lost. Any modes you've changed (number display format, choice of radix mark, angle mode, and so on) are restored to their *default* settings.

To reset memory:

1. Press and hold [ON].
2. Press and hold [INS] (in the upper-left corner of the right-hand keyboard).
3. Press and release [▶] (in the upper-right corner of the right-hand keyboard).
4. Release [INS].
5. Release [ON].

The calculator beeps and displays `Memory Lost`. The message automatically disappears when you next press a key.

If you begin to reset memory but change your mind, *continue holding down* [ON] while you press [DEL] (next to [INS]), and then release [ON]. Pressing [DEL] cancels the reset sequence.

Adjusting the Display Contrast

You can adjust the contrast of the display to compensate for various viewing angles and light intensities.

To adjust the contrast:

1. Press and hold [ON].
2. Press [+] one or more times to darken the display, or press [-] one or more times to lighten the display.
3. Release [ON].

An Overview of the Calculator

This section gives an overview of how the calculator works. It demonstrates a simple calculation and then identifies some major features and concepts.

A Simple Calculation

For the first example, calculate the following:

$$(15 + 23) \times \sin 30^\circ$$

The basic steps are the same as using paper and pencil. First calculate 15 + 23, which produces an intermediate result. Then calculate sin 30°, which produces the other intermediate result. Finally, combine the intermediate results for the answer.

If you make a mistake while keying in a number, press [◆] (in the right-most column of the right-hand keyboard) to erase the digit you just keyed in.

0. Prepare your calculator to match the illustrations.

a. Reset memory, using the steps on page 18.

b. Press [ON] to clear the message from the display. The display shows the *stack*, which is your work area. Currently the stack is empty.

```
4:
3:
2:
1:
```

1. Calculate 15 + 23.

a. Press [1] [5] to write the number 15 in the *command line*. Note that the stack moves up to make room for the command line, so only three stack levels are displayed.

```
3:
2:
1:
15□
```

b. Press [ENTER] to put 15 on the stack. The number goes in *stack level 1*, as indicated by 1: to the left. Note that the command line disappears, so four stack levels are displayed again.

```
4:
3:
2:
1:                    15
```

c. Press [2] [3] to write the number 23 in the command line.

```
3:
2:
1:                    15
23□
```

d. Press [ENTER] to put 23 in level 1. The number 15, which was in level 1, is lifted to level 2.

```
4:
3:
2:                    15
1:                    23
```

(In practice, you don't need to press [ENTER] a second time, but the step is included here to demonstrate how the stack works.)

e. Press [+] to add 15 and 23. The numbers 15 and 23 are removed from the stack, and their sum, 38, is returned to level 1.

```
4:
3:
2:
1:                    38
```

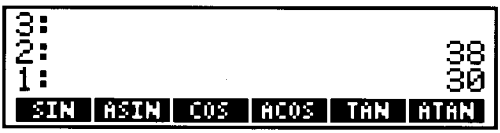
You'll leave this intermediate result on the stack while you calculate the second intermediate result.

2. Calculate sin 30°.

a. Press [TRIG] to select the trigonometry menu. The bottom line of the display shows six commands in the TRIG menu. The six *menu labels* (SIN through ATAN) define the six *menu keys* (the keys immediately below the display).

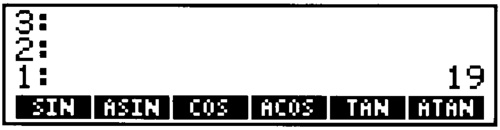
b. Press [3] [0] to write the number 30 in the command line.

c. Press [ENTER] to put 30 in level 1. The previous result, 15 + 23 = 38, is lifted to level 2.



d. Press SIN to calculate sin 30°. The number 30 is removed from level 1, and its sine, .5, is returned to level 1. The previous result, 38, remains in level 2.

3. Press [×] to calculate 38 × .5. The numbers 38 and .5 are removed from levels 1 and 2, and their product, 19, is returned to level 1.



This completes the calculation:

$$(15 + 23) \times \sin 30° = 19.$$

To summarize, here's a general model of the calculation you just completed.

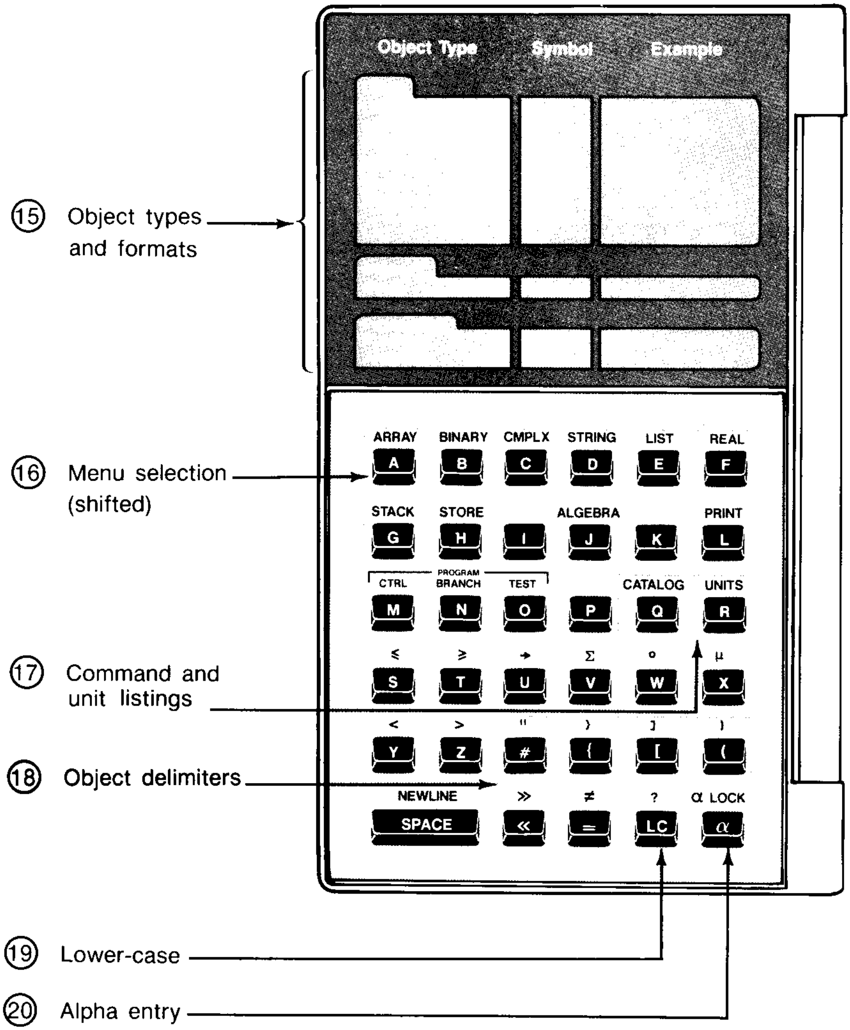
1. Key a number into the *command line*.
2. Press [ENTER] to put a number on the *stack*.
3. When the appropriate number or numbers are on the stack, press the key to execute the command. (If the command isn't printed on the keyboard, select the *menu* that contains the command, and press the *menu key* below the appropriate *menu label*.)

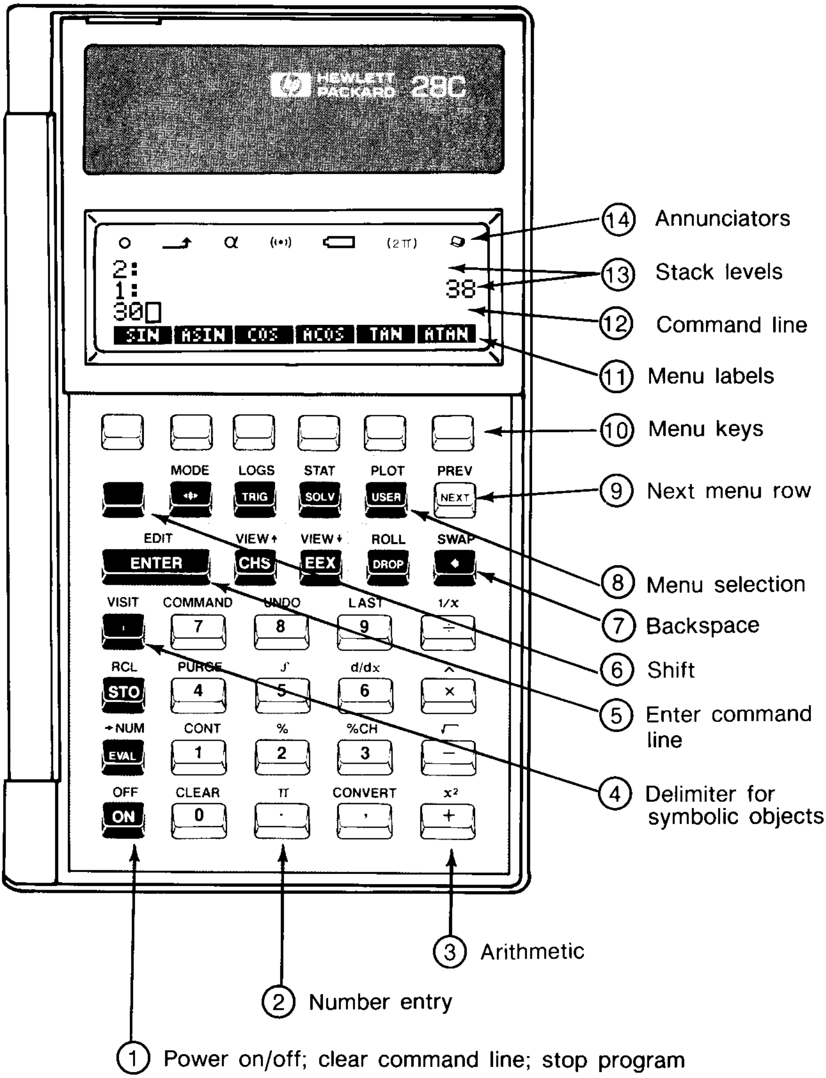
The style of calculation illustrated above, in which you enter numbers onto the stack before you perform mathematical operations, is called RPN (*Reverse Polish Notation*) or stack logic. Nearly all HP-28C commands, not just calculations, use stack logic. The inputs required by a command, called its *arguments*, must be on the stack before the command is executed.

You can also calculate by entering an expression in algebraic form, as it might appear written in a book. In the next chapter you'll perform the same calculation as above, using an expression.

Major Features and Concepts

The illustrations on pages 24 and 25 show the calculator keyboard and display, with important features identified. The numbers in the following descriptions correspond to the numbers in the illustrations.


Object Type
Symbol
Example
⑮ Object types and formats
⑯ Menu selection (shifted)
⑰ Command and unit listings
⑱ Object delimiters
⑲ Lower-case
⑳ Alpha entry
ARRAY
BINARY
CMPLX
STRING
LIST
REAL
STACK
STORE
ALGEBRA
PRINT
PROGRAM
CTRL
BRANCH
TEST
CATALOG
UNITS
NEWLINE
SPACE
α LOCK
LC


HEWLETT PACKARD 28C
(14) Annunciators
(13) Stack levels
(12) Command line
(11) Menu labels
(10) Menu keys
(9) Next menu row
(8) Menu selection
(7) Backspace
(6) Shift
(5) Enter command line
(4) Delimiter for symbolic objects
(3) Arithmetic
(2) Number entry
(1) Power on/off; clear command line; stop program
SIN ASIN COS ACOS TAN ATAN
MODE LOGS STAT PLOT PREV
TRIG SOLV USER NEXT
EDIT VIEW↑ VIEW↓ ROLL SWAP
ENTER CHS EEX DROP
VISIT COMMAND UNDO LAST 1/x
7 8 9 ÷
RCL PURGE ∫ d/dx ^
STO 4 5 6 ×
→NUM CONT % %CH √
EVAL 1 2 3 −
OFF CLEAR π CONVERT x²
ON 0 . , +

1. Power on/off, clear command line, stop program. To turn on the calculator, press [ON]; to turn it off, press ■[OFF] . (OFF is printed on the keyboard above [ON]. "Press ■[OFF]" means press the shift key ■, which is item 6 in the diagram and below, and then press [ON].)

While the calculator is on, [ON] also acts as the ATTN (*attention*) key to clear text in the command line or stop a running program. (ATTN is printed on the keyboard below [ON].)

2. Number entry. To key in numbers, use the digit keys [0] through [9], [CHS] (*change sign*), and [EEX] (*enter exponent*). Depending on your choice of *radix mark* (page 34), use either [·] or [,] to separate integer part from fractional part. Number entry is described on page 33.

3. Arithmetic. The arithmetic functions are described in "One-Number Functions" on page 39 and "Two-Number Functions" on page 40.

4. Delimiter for symbolic objects. Delimiters are punctuation that identify types of objects; symbolic objects are names and algebraics. To key in a symbolic object, press ['] at the beginning and (when necessary) the end of the object.

Real numbers require no delimiters. The delimiters for other object types are on the left-hand keyboard. (See item 15, "Object types and formats," and item 18, "Object delimiters," below.)

5. Enter command line. Press [ENTER] to process the text in the command line.

6. Shift. Press the colored shift key ■ to execute a command printed in color above a key.

7. Backspace. Press [◀] to erase the last character you typed in.

8. Menu selection. Use the menu selection keys to assign commands to the menu keys. For example, press [TRIG] to select the TRIG menu. To select a different menu, press another menu selection key.

When no menu labels are visible, the *cursor menu* is active. The operations in the cursor menu ([INS] through [▶]) are printed in white above the menu keys. When menu labels are visible, press [◂▴▾▸] to select the cursor menu. To restore the previous menu, press [◂▴▾▸] a second time.

There are additional menu selection keys on the left-hand keyboard (see item 16). For an alphabetical listing of all menus, including a brief description of the commands in each menu, refer to appendix C, "Menu Map."

9. Next menu row. Press [NEXT] to display the next row of the current menu (A menu can contain up to four rows, with up to six commands in each row.) Press ■[PREV] to display the previous row.

10. Menu keys. The menu keys are defined by the menu labels. If no labels are visible, these keys execute the cursor menu operations labeled in white above the keys.

11. Menu labels. The menu labels show the current definitions of the menu keys.

12. Command line. The text you key in goes in the command line.

13. Stack levels. The stack shows the objects you're currently working with. Each numbered stack level (level 1, level 2, and so on) holds one object.

The numbers you used in the calculation are one type of object, but there are several other types. See item 15, "Object types and formats."

14. Annunciators. The annunciators indicate the status of the calculator. When an annunciator is visible, it indicates the following:

Annunciator	Meaning
○	Suspended program.
↗	Shift key ■ was pressed.
α	Alpha entry mode.
((•))	Busy, not ready for input.
▭	Low battery.
(2π)	Radians mode.
🖨	Sending data to printer.

15. Object types and formats. This table shows the correct delimiters and examples for the 10 basic types of object. An "object" is any of the individual items you work with on the calculator. The 10 basic object types are grouped into three classes: *data* objects, which have fixed values, *name* objects, which can refer to other objects, and *procedure* objects, which contain commands. The 10 basic object types are:

- Real numbers, such as 5 or -4.3×10^{15}.
- Complex numbers, which are a pair of real numbers representing a complex number $x + iy$ or a point in a plane.
- Binary integers, which are unsigned integers used in computer science.
- Strings, which contain arbitrary sequences of characters.
- Vectors, which are one-dimensional arrays used in linear algebra.
- Matrices, which are two-dimensional arrays used in linear algebra.
- Lists, which contain arbitrary sequences of objects.

- Names, which enable you to name and store other objects and to perform symbolic calculations.
- Programs, which enable you to create your own commands.
- Algebraics, which represent mathematical expressions and equations.

16. Menu selection (shifted). Use the menu selection keys to assign commands to the menu keys. For example, press ■[ARRAY] to select the ARRAY menu. To select a different menu, press another menu selection key.

There are additional menu selection keys on the right-hand keyboard (see item 8).

17. Command and unit listings. Press ■[CATALOG] for a listing of all HP-28C commands and their required arguments (page 86). Press ■[UNITS] for a listing of the units recognized in unit conversion (page 187).

18. Object delimiters. These symbols identify the different object types. (See item 15, "Object types and formats," above.) For example, [#] identifies binary integers, while [«] and ■[»] identify programs.

Real numbers require no delimiters. Symbolic objects (names and algebraics) require the ['] delimiter, located on the right-hand keyboard (see item 4 above).

19. Lower-case. Press [LC] to key in lower-case letters. Lower-case mode continues until you press [LC] a second time, press [ENTER] to process the command line, or press [ON] to clear the command line.

20. Alpha entry. Press [α] to accumulate commands in the command line rather than immediately executing them. Alpha entry mode continues until you press [α] a second time, press [ENTER] to process the command line, or press [ON] to clear the command line.

2

Doing Arithmetic

There are two ways to do arithmetic on the HP-28C. You can do arithmetic using the stack, as you did in the previous chapter, or you can enter an *expression* representing the calculation. In the previous chapter you calculated:

$$(15 + 23) \times \sin 30°$$

Here's how to make the same calculation using an expression.

0. Prepare the calculator to match the illustrations.

a. Press ■[CLEAR] to clear the stack.

b. Press [TRIG] to select the TRIG menu. The display should look like this:

1. Put the expression on the stack.

a. Press ['] to start the expression. The cursor changes, indicating *algebraic entry mode*. You'll see the effects of this entry mode as you key in the expression.

b. Press [(] [1] [5] [+] [2] [3] ■[)] to enter the first part of the expression. Because of algebraic entry mode, pressing [+] wrote the character + in the command line rather than executing the command.

```
2:
1:
'(15+23)▤
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

c. Press [×] SIN . Because of algebraic entry mode, pressing [×] wrote * in the command line, and pressing SIN wrote SIN(in the command line, rather than executing the commands.

```
2:
1:
'(15+23)*SIN(▤
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

d. Press [3] [0] [ENTER] to complete the expression and put it on the stack. The closing parenthesis) and the closing delimiter ' are added for you.

```
3:
2:
1:      '(15+23)*SIN(30)'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

2. Press [EVAL] (*evaluate*) to evaluate the expression. The expression is removed from the stack, and the result, 19, is returned to level 1.

This completes the calculation:

$$(15 + 23) \times \sin 30° = 19.$$

To perform a calculation that's already written as an expression, such as in a textbook, it's easier to key in the expression and evaluate it. Alternatively, to see the intermediate results of your calculation, or to perform an on-going calculation, it's easier to calculate on the stack. The results are the same.

The relationship between stack calculations and expressions is demonstrated in chapter 4, "Repeating a Calculation." In that chapter you calculate on the stack, using variables instead of numbers, to produce an expression.

Entering and Displaying Numbers

There are modes that affect how numbers are displayed. To demonstrate the choices, put the number ⅔ on the stack.

1. Press [2] [ENTER] to put the number 2 in level 1 of the stack.

2. Press [3] [ENTER] to put the number 3 in level 1. The number 2 is lifted to level 2 of the stack.

3. Press [÷]. The number in level 2 is divided by the number in level 1, and the result, ⅔, is returned to level 1.

This result is the decimal approximation to ⅔, as displayed by the default choices for radix mode and number display. Now look at the other choices.

Selecting the Radix Mark

You can choose whether a period or a comma is the current *radix mark*—the punctuation that separates the integer part of a number from the fractional part. This choice affects how you enter numbers and how they're displayed.

4. Press ■ [MODE] to select the MODE menu. The first row of the MODE menu appears.

5. Press [NEXT] twice to display the third row of the MODE menu. There are two menu labels for selecting the radix mark, RDX. and RDX,. The label for RDX. appears in black letters, indicating that the current radix mark is the period (the default choice).

6. Press RDX, to select comma as the radix mark. The period radix marks (also called *decimal points*) are replaced by comma radix marks, and the label for RDX, now appears in black letters, indicating that the current radix mark is the comma.

7. Press RDX. to return to the period radix mark.

Selecting Number Display Mode

You can choose how many decimal places are displayed.

8. Press [NEXT] to return to the first row of the MODE menu. (The last row of MODE menu was displayed, so pressing [NEXT] cycles back to the first row. You could also press ■[MODE] to display the first row.)

There are four basic choices: STD (standard), FIX (fixed), SCI (scientific), and ENG (engineering) number display formats. The label for STD appears in black characters, indicating that STD is the current choice. (STD is the default choice.) In STD mode the number of decimal places depends on the value. For an integer, no decimal places are shown; for the example displayed above, the maximum of 12 decimal places are shown.

The other display formats show a given number of decimal places—from 1 through 11—regardless of the number being displayed. We'll demonstrate each of the other display formats with two decimal places. Only the displays of the numbers are rounded—internally, the numbers are unchanged.

9. Press [2] FIX (*fixed*) to display numbers rounded to two decimal places.

```
3:
2:                   19.00
1:                    0.67
 STD [FIX] SCI  ENG [DEG] RAD
```

10. Press [2] SCI (*scientific*) to display numbers as a *mantissa* and an *exponent*. The value of the number is the product of the mantissa and 10 raised to the power of the exponent. The mantissa is always between 1 and 9.99999999999. In this case, the mantissa is rounded to two decimal places.

```
3:
2:                  1.90E1
1:                 6.67E-1
 STD  FIX [SCI] ENG [DEG] RAD
```

11. Press [2] **ENG** (*engineering*) to display numbers as a mantissa and an exponent, like SCI display mode, but adjusting the mantissa to make the exponent a multiple of 3.

```
3:
2:                 19.0E0
1:                667.E-3
 STD  FIX  SCI [ENG ][DEG ] RAD
```

12. Press **STD** (*standard*) to return to standard number display mode.

```
3:
2:                     19
1:          .666666666667
[STD ] FIX  SCI  ENG [DEG ] RAD
```

Keying In Numbers With Exponents

You can enter numbers that are quite large or small by using scientific notation. A number can be represented by a *mantissa* and an *exponent*, where the value of the number is the product of the mantissa and 10 raised to the power of the exponent.

For example, key in the number -4.2×10^{-12}.

1. Press [4] [·] [2] for the mantissa.

```
2:                     19
1:          .666666666667
4.2□
[STD ] FIX  SCI  ENG [DEG ] RAD
```

(If you make a mistake, press [◆] to erase the mistake and then key in the correct digits.)

2. Press [CHS] (*change sign*) to make the mantissa negative.

```
2:                      19
1:          .666666666667
-4.2□
[STD ] FIX  SCI  ENG [DEG ] RAD
```

(Pressing [CHS] a second time would make the mantissa positive again.)

3. Press [EEX] (*enter exponent*) to begin the exponent. An E appears in the command line.

```
2:                      19
1:          .666666666667
-4.2E□
[STD ] FIX  SCI  ENG [DEG ] RAD
```

(If you press [EEX] by mistake for a number without an exponent, you can erase the E by pressing [◆].)

4. Press [1] [2] for the exponent.

```
2:                      19
1:          .666666666667
-4.2E12□
[STD ] FIX  SCI  ENG [DEG ] RAD
```

5. Press [CHS] to make the exponent negative.

```
2:                      19
1:          .666666666667
-4.2E-12□
[STD ] FIX  SCI  ENG [DEG ] RAD
```

6. Press [ENTER] to put the number on the stack.

```
3:                    19
2:        .666666666667
1:             -4.2E-12
[STD] FIX  SCI  ENG [DEG] RAD
```

One-Number Functions

Functions that act on a single number—for example, negating a number or taking a square root—are called one-number functions. All act on the number in level 1. There are four one-number functions on the keyboard:

- Press [CHS] to negate the number.
- Press ■[1/x] to take the inverse (reciprocal) of the number.
- Press ■[√] to take the square root of the number.
- Press ■[x^2] to square the number.

If you're keying in a number, it's not necessary to press [ENTER] before executing the one-number function—pressing the function key automatically performs ENTER for you. For example, you can calculate ⅛ as follows:

1. Press [8].

```
2:        .666666666667
1:             -4.2E-12
8□
[STD] FIX  SCI  ENG [DEG] RAD
```

2. Press ■[1/x] to put the decimal equivalent of ⅛ in level 1.

```
3:        .666666666667
2:              -4.2E-12
1:                  .125
[STD] FIX  SCI  ENG [DEG] RAD
```

Whether you press [ENTER] or let ■[1/x] execute ENTER for you, the rule for one-number functions is: put the number on the stack and execute the function.

Two-Number Functions

Functions that act on two numbers—such as addition—are called two-number functions. All act on the numbers in levels 1 and 2.

When you divided 2 by 3, you put both numbers on the stack before you pressed the [÷] key. In practice you don't need to press [ENTER] to put the second number on the stack, because pressing [÷] automatically executes the second ENTER operation for you. Whether you press [ENTER] or you let [÷] execute ENTER for you, the rule for two-number functions is: put the numbers on the stack and execute the function. In the following examples we'll let the function execute ENTER for us.

Addition and Subtraction

To calculate 36 + 17:

1. Press [3] [6] [ENTER] to put 36 in level 1.
2. Press [1] [7] [+] to return the result (53) to level 1.

For addition the order of the numbers doesn't matter. However, the order is important for subtraction.

To calculate 91 − 27:

3. Press [9] [1] [ENTER] to put 91 in level 1.
4. Press [2] [7] [−] to return the result (64) to level 1.

Multiplication and Division

To calculate 13 × 6:

5. Press [1] [3] [ENTER] to put 13 in level 1.

6. Press [6] [×] to return the result (78) to level 1.

```
3:                         53
2:                         64
1:                         78
[STD] FIX  SCI  ENG [DEG] RAD
```

For multiplication the order of the numbers doesn't matter. However, the order is important for division.

To calculate 182/14:

7. Press [1] [8] [2] [ENTER] to put 182 in level 1.

8. Press [1] [4] [÷] to return the result (13) to level 1.

```
3:                         64
2:                         78
1:                         13
[STD] FIX  SCI  ENG [DEG] RAD
```

Powers and Roots

The order of the numbers is important for both powers and roots.

To calculate 5^3:

9. Press [5] [ENTER] to put 5 in level 1.

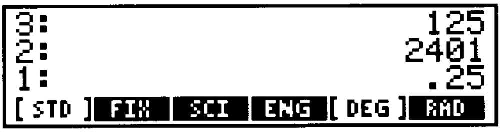
10. Press [3] ■ [^] to return the result (125) to level 1.

```
3:                         78
2:                         13
1:                        125
[STD] FIX  SCI  ENG [DEG] RAD
```

To calculate $\sqrt[4]{2401}$:

11. Press [2] [4] [0] [1] [ENTER] to put 2401 in level 1.

12. Press [4] ■[1/x] to put ¼ in level 1. The number 2401 is lifted to level 2.



13. Press ■[^] to return the result (7) to level 1.

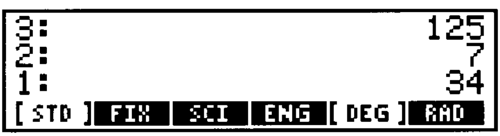
Percentages

You can calculate a given percentage of a number, and you can find the difference between two numbers expressed as a percentage of the first number.

To calculate 40% of 85:

14. Press [8] [5] [ENTER] to put 85 in level 1.

15. Press [4] [0] ■[%] to return the result (34) to level 1.



For percent the order of the numbers doesn't matter. However, the order is important for percent change.

To calculate the percent change from 60 to 75:

16. Press [6] [0] [ENTER] to put 60 in level 1.

17. Press [7] [5] ■[%CH] (*percent change*) to return the result (25) to level 1. (The positive result means that 75 is 25% more than 60.)

```
3:                          7
2:                         34
1:                         25
[STD] FIX  SCI  ENG [DEG] RAD
```

Swapping Levels 1 and 2

For all the functions where the order of the numbers is important—subtraction, division, powers, roots, and percent change—you can switch the order of the numbers by pressing ■[SWAP]. For example, you currently have 25 on the stack; suppose you want to calculate 30 − 25.

18. Press [3] [0] [ENTER] to put 30 on the stack.

19. Press ■[SWAP] to change the order of the numbers.

```
3:                         34
2:                         30
1:                         25
[STD] FIX  SCI  ENG [DEG] RAD
```

20. Press [−] to return the result (5) to level 1.

```
3:                          7
2:                         34
1:                          5
[STD] FIX  SCI  ENG [DEG] RAD
```

Clearing Objects from the Stack

As you worked these examples, you accumulated quite a few numbers on the stack. The stack grows without limit as you put more objects on the stack, and those objects remain until you use them in an operation or until you clear them.

21. Press [DROP] to clear the object in level 1. Objects in higher levels move down one level each.

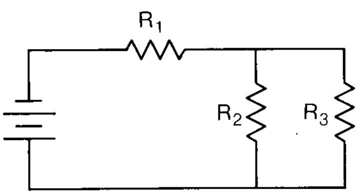
```
3:                 125
2:                   7
1:                  34
[STD ] FIX  SCI  ENG [DEG ] RAD
```

22. Press ■[CLEAR] to clear all objects from the stack.

```
3:
2:
1:
[STD ] FIX  SCI  ENG [DEG ] RAD
```

Chain Calculations

When you perform complicated calculations, the stack acts as temporary storage to hold intermediate results. This temporary storage acts automatically. For example, suppose you want to calculate the total resistance of the following circuit:



The formula for total resistance in this circuit is:

$$R_{total} = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3}}$$

If R_1, R_2, and R_3 have resistances of 8, 6, and 3 ohms respectively, calculate the following:

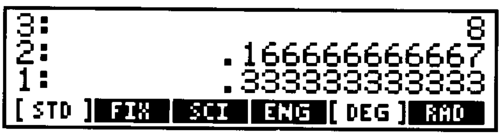
$$R_{total} = 8 + \frac{1}{\frac{1}{6} + \frac{1}{3}}$$

Calculate as follows:

1. Press [8] [ENTER] to put 8 in level 1. Leave 8 on the stack until it's time to add it to the rest of the calculation.

2. Press [6] ■ [1/x] to put the ⅙ on the stack. The number 8 is now in level 2.

3. Press [3] ■ [1/x] to put ⅓ on the stack. The number 8 is now in level 3.



4. Press [+] to add the reciprocals of 6 and 3. The number 8 drops to level 2.

```
3:
2:                    8
1:                   .5
[STD] FIX SCI ENG [DEG] RAD
```

5. Press ■[1/x] to take the reciprocal of the sum. The number 8 is still in level 2.

```
3:
2:                    8
1:                    2
[STD] FIX SCI ENG [DEG] RAD
```

6. Press [+] to add 8 and the reciprocal, completing the calculation of R_{total}. The display shows the result (10 ohms) in level 1.

```
3:
2:
1:                   10
[STD] FIX SCI ENG [DEG] RAD
```

If You Execute the Wrong Function

The HP-28C includes recovery features to help you "backtrack" when you mistakenly execute a function. The following steps reverse the effects of a function, whether a one-number or two-number function.

1. Press ■[UNDO] to recover the previous contents of the stack.
2. If a number was in the command line when you made the mistake, press ■[COMMAND] to recover the previous contents of the command line.
3. Continue the calculation.

3

Using Variables

You can store a number (or any object) by creating a variable. A variable is the combination of a name object and any other object. The name object defines the name of the variable; the other object defines the contents of the variable. You can then use the variable's name to refer to the variable's contents.

Variables are stored in *user memory*, a part of the calculator's memory distinct from the stack. The stack is designed for temporary storage of the objects you're currently working with, such as the numbers you're using in a calculation. User memory is designed for long-term storage of variables, such as numbers that you use repeatedly.

This chapter describes how to use numerical variables, but variables are useful for all types of objects. For example, a program object has no intrinsic name. You name the program by storing it in a variable, and you can then run the program by referring to the variable's name. For details, refer to chapter 8, "Programs."

Creating a Variable: [STO]

Suppose you repeatedly use a volume measurement of 133 in your calculations. Create a variable named VOL (for "volume") as follows:

0. Prepare the calculator to match the illustrations.

a. Press ■[CLEAR] to clear the stack.

b. If a menu is displayed, press [◂◆▸] to select the cursor menu.

1. Press [1] [3] [3] [ENTER] to put the number in level 1.

```
4:
3:
2:
1:                    133
```

2. Press ['] [V] [O] [L] [ENTER] to put the name 'VOL' in level 1. Note that the closing ' is added for you. The number 133 is lifted to level 2.

```
4:
3:
2:                    133
1:                  'VOL'
```

3. Press [STO] (*store*). The number and the name are removed from the stack, creating a variable named VOL with a value of 133.

Evaluating a Variable

Evaluating a variable means using the variable's name to refer to the variable's contents. When the variable contains a number, evaluating the variable returns the number to the stack.

(More generally, when a variable contains a data object or algebraic object, evaluating the variable returns the object to the stack. When a variable contains a name or a program, evaluating the variable causes the name or program to be evaluated.)

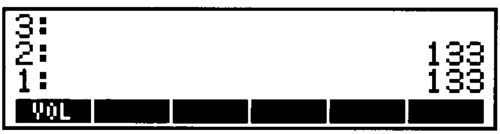
Now that you've created the variable VOL, evaluate it.

4. Press [USER] to select the USER menu. The left-most menu label is VOL, the name of the variable you just created. The USER menu shows the names of all variables in user memory.

5. Press VOL to return the value of VOL to the stack.

You can also evaluate VOL by typing in its name *without quotes*.

6. Press [V] [O] [L] [ENTER] to return another copy of VOL's value to the stack.



7. Press [DROP] [DROP] to clear the stack.

Changing the Value of a Variable

Now change the value of the variable VOL to 151.

8. Press [1] [5] [1] [ENTER] to put the new value in level 1.

9. Key in the variable's name.

a. Press ['] to begin the variable's name. The cursor changes, indicating algebraic entry mode.

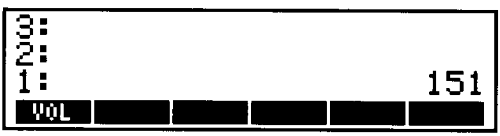
At the beginning of chapter 2 you saw that, in algebraic entry mode, pressing a function key such as [+] wrote the character + rather than executing the command. Similarly, pressing a USER menu key writes the variable's name rather than evaluating the variable.

b. Press VOL to write the variable's name in the command line.

10. Press [STO] to change the value of the variable VOL to 151. Like the arithmetic functions, the STO command automatically executes ENTER. The number and name are removed from the stack.

Now evaluate VOL to return the new value.

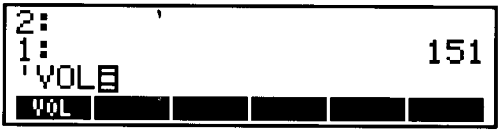
11. Press VOL to return 151 to the stack.



Purging a Variable: ■[PURGE]

When you finish with the variable VOL, purge it from user memory.

12. Press ['] VOL to write the variable name in the command line. (The quote ['] is necessary to avoid evaluating the variable.)



13. Press ■[PURGE] to purge the variable VOL from user memory. Its label disappears from the USER menu, and the permanent row of the USER menu appears.

The USER menu contains one permanent row of commands in addition to the variables you've created. The row of commands is always the last menu row: if any variables exist in user memory, pressing [USER] displays a row of variable names; if there are more than six variables, pressing [NEXT] displays another row of variable names; and so on. Eventually, pressing [NEXT] displays the permanent row of commands.

This section shows how to use the CLUSR (*clear USER*) command in the USER menu. All commands in the USER menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "USER" in the Reference Manual.

14. Press CLUSR to write CLUSR in the command line. Because this command is so drastic and its effect can't be reversed, pressing CLUSR *never* executes the command immediately.

15. Press [ENTER] to execute CLUSR, purging all variables from user memory. (If you change your mind and don't want to clear all variables, press [ON] to clear CLUSR from the command line.)

Quoted and Unquoted Names

In the examples above you used variable names in two ways, quoted and unquoted. The quotes ['] are important: they distinguish the *name* of a variable from the *contents* of a variable. Here's a summary of the differences between quoted and unquoted names.

A quoted name is an object. It goes on the stack, and it can be an argument to a command. For example, you used quoted names as arguments to [STO] and ■[PURGE] when you created, changed, and purged the variable VOL.

An unquoted name is like a command to evaluate the variable with that name. The unquoted name doesn't go on the stack—instead, the object stored in the variable goes on the stack. (If this object is a name or a program, it is also evaluated.)

If you type in an unquoted name that isn't associated with a variable, the quoted form of the name goes on the stack.

4

Repeating a Calculation

At the beginning of chapter 2, you made a calculation by keying in an expression and then evaluating the expression. In chapter 3, you created a numerical variable by storing a number in user memory. In this chapter you'll create an expression containing variables.

An expression that contains variables makes it easy to repeat a calculation. Each time you evaluate the expression, the calculation is made with the current values of the variables. If you change the value of one or more variables, you can simply evaluate the expression again to recalculate with the new values.

This chapter first shows how to create an expression by calculating on the stack, using variables as symbolic arguments. It then introduces a calculator feature called the Solver. Using the Solver is an easy way to store values in the variables and evaluate the expression.

The Solver also has sophisticated capabilities to find zeros of expressions, roots of equations, and maxima and minima. These capabilities are discussed in chapter 10, "The Solver." For a detailed description of the Solver, refer to "SOLVE" in the Reference Manual.

Creating an Expression

We'll repeat the resistance calculation from "Chain Calculations" in chapter 2, only this time we'll use variables, rather than numbers, as arguments. Recall that the formula for the circuit is:

$$R_{total} = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3}}$$

To create an expression for this formula:

0. Prepare the calculator to match the illustrations.

   a. Press ■ [CLEAR] to clear the stack.

   b. If a menu is displayed, press [◂◆▸] to select the cursor menu.

1. Press ['] [R] [1] [ENTER] to put the name 'R1' on the stack. Note that the closing ' is added for you. You'll leave R1 on the stack until it's time to add it to the rest of the calculation.

```
4:
3:
2:
1:                        'R1'
```

2. Put the reciprocal of R2 on the stack.

   a. Press ['] [R] [2] [ENTER] to put the name 'R2' on the stack.

   b. Press ■ [1/x] to return the reciprocal of R2.

```
4:
3:
2:                        'R1'
1:                   'INV(R2)'
```

3. Put the reciprocal of R3 on the stack.

   a. Press ['] [R] [3] [ENTER] to put the name 'R3' on the stack.

   b. Press ■[1/x] to return the reciprocal of R3.

```
4:
3:                'R1'
2:           'INV(R2)'
1:           'INV(R3)'
```

4. Press [+] to add the reciprocals of R2 and R3.

```
4:
3:
2:                'R1'
1:   'INV(R2)+INV(R3)'
```

5. Press [1/x] to take the reciprocal of the sum.

```
3:
2:                'R1'
1: 'INV(INV(R2)+INV(R3)
   )'
```

6. Press [+] to add R1 and the reciprocal. The resulting expression represents R_{total}.

```
3:
2:
1: 'R1+INV(INV(R2)+INV(
   R3))'
```

You could key in this expression directly, taking care to add parentheses where necessary. Every expression is equivalent to a stack calculation, so you can choose the method that is easier for you.

You'll use this expression again in chapter 10, "The Solver," so now create a variable RTOT that contains the expression. (Remember that you can store any object type—not just numbers—in a variable.)

7. Press [ENTER] to make a copy of the expression. (When no command line is present, pressing [ENTER] executes the command named DUP (*duplicate*)).

```
3:
2:  'R1+INV(INV(R2)+INV…
1:  'R1+INV(INV(R2)+INV(
    R3))'
```

8. Press ['] [R] [T] [O] [T] to write the variable name in the command line.

```
2:  'R1+INV(INV(R2)+INV…
1:  'R1+INV(INV(R2)+INV(
    R3))'
'RTOT
```

9. Press [STO] to create the variable RTOT. The expression and the name are removed from the stack.

```
3:
2:
1:  'R1+INV(INV(R2)+INV(
    R3))'
```

Using the Solver To Repeat a Calculation

10. Press [SOLV] to select the SOLVE menu. This section discusses STEQ (*store EQ*) and SOLVR (the Solver). All commands in the SOLVE menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "SOLVE" in the Reference Manual.

11. Press STEQ (*store EQ*) to store the expression as the *current equation*—a normal variable with the special name EQ. The expression is taken from the stack and stored in a variable named EQ, just as if you had created EQ by pressing ['] [E] [Q] [STO].

12. Press SOLVR to display the Solver menu. The variables in the current equation appear in the Solver menu. (If the equation contains more than six variables, pressing [NEXT] displays additional rows of variables.)

13. Assign values to the variables R1, R2, and R3.

a. Press [8] R1 to store the number 8 in the variable R1. (In the Solver menu, pressing R1 is equivalent to putting 'R1' on the stack and pressing [STO].) The top line of the display shows the variable name and the value.

b. Press [6] R2 to store the number 6 in the variable R2.

c. Press [3] R3 to store the number 3 in the variable R3.

14. Press EXPR= to evaluate the expression EQ. The value (10) is returned to level 1, and it appears in inverse characters in the top line of the display.

15. Now assign a different value to a variable and recompute the value of the expression. For example, what if R3 is 12?

a. Press [1] [2] R3 to store the number 12 in the variable R3.

b. Press EXPR= to evaluate the expression EQ. The new value (12) is returned to level 1, and it appears in inverse characters in the top line of the display.

5

More Numerical Functions

This chapter introduces the TRIG, LOGS, REAL, and COMPLEX menus. The TRIG menu contains trigonometric functions and commands dealing with angular measurement. The LOGS menu contains logarithmic, exponential, and hyperbolic functions.

Most functions in the TRIG and LOGS menu apply to both real and complex numbers. The REAL menu contains additional commands primarily for real numbers. The COMPLEX menu contains additional commands primarily for complex numbers and two-dimensional coordinates.

This chapter shows you how to use one or more commands in each menu. All commands in these menus are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "TRIG," "LOGS," "REAL," and "COMPLEX" in the Reference Manual.

Trigonometric Functions

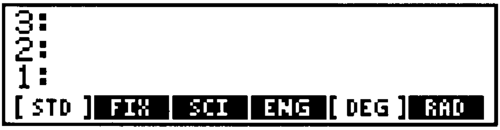
This section shows how to select the current angle mode, calculate with π, and convert angular measure.

Selecting Angle Mode

The calculator can interpret angular arguments and results as degrees ($1/360$ of a circle) or as radians ($1/2\pi$ of a circle). The default choice is degrees angle mode. For the examples in this section, switch to radians angle mode.

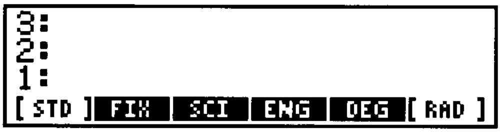
0. Press ■[CLEAR] to clear the stack. This prepares your calculator to match the illustrations.

1. Press ■[MODE] to select the MODE menu. All commands in the MODE menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "MODE" in the Reference Manual.



The two right-most menu labels, DEG (*degrees*) and RAD (*radians*), represent your choices of angle mode. Note that DEG appears in black characters, indicating that the current angle mode is degrees.

2. Press RAD to select radians angle mode. The radians annunciator **(2π)** appears and the menu labels change. (Most illustrations in this manual don't show the annunciators. To locate the **(2π)** annunciator, see the illustration on page 25.)



3. Press [TRIG] to display the first row of the TRIG menu.

These are one-number functions, acting on the number in level 1. For real numbers, the angle mode affects how SIN (*sine*), COS (*cosine*), and TAN (*tangent*) interpret their arguments, and how ASIN (*arc sine*), ACOS (*arc cosine*), and ATAN (*arc tangent*) express their results.

You'll use the SIN function in the discussion of π that comes next.

Using π

The transcendental number π can't be represented exactly by a real number on the HP-28C. In general, the 12-digit approximation (3.14159265359) yields results accurate to 12 digits, which is sufficient for most applications.

The HP-28C also offers a symbolic constant π that represents π exactly. In radians angle mode, the functions SIN, COS, and TAN recognize the symbolic constant π and produce an exact result. The functions SIN and COS also recognize π/2.

For other functions, the symbolic constant π produces an expression containing π. If you force a real-number result, the calculator uses the 12-digit approximation.

To demonstrate the difference between 3.14159265359 and π, calculate the sine of each.

4. Calculate the sine of 3.14159265359.

a. Press ■[π] [ENTER] to put 'π' in level 1. Although this object looks like a name, it's actually an expression with a single term, the symbolic constant π.

b. Press ■[→NUM] (*to number*) to force a real-number result. The 12-digit approximation to π (3.14159265359) is returned to level 1.

c. Press SIN to calculate the sine of the approximation to π. The result ($-2.06761537357 \times 10^{-13}$) isn't exactly 0 because the argument (3.14159265359) isn't exactly π.

```
3:
2:
1:     -2.06761537357E-13
 SIN | ASIN | COS | ACOS | TAN | ATAN
```

5. Press ■[π] SIN to calculate the sine of π. The SIN function recognizes the symbolic constant π and returns the exact result (0).

```
3:
2:     -2.06761537357E-13
1:                      0
 SIN | ASIN | COS | ACOS | TAN | ATAN
```

6. Press ■[CLEAR] to clear the stack.

Converting Angular Measure

The TRIG menu contains commands that convert an angle from one system of measurement to another. These commands are on the third row of the TRIG menu. Take a quick look at the second row before continuing to the third.

7. Press [NEXT] to display the second row of the TRIG menu.

```
3:
2:
1:
 P→R | R→P | R→C | C→R | ARG |
```

These commands deal with complex numbers and are duplicated in the COMPLEX menu. Complex numbers are introduced in "Using Complex Numbers" on page 69. The functions P→R (*polar-to-rectangular*) and R→P (*rectangular-to-polar*), which convert two-dimensional coordinates between polar and rectangular notation, are discussed in "Converting Polar and Rectangular Coordinates" on page 70.

8. Press [NEXT] to display the third row of the TRIG menu.

You'll use the commands HMS→ and D→R to convert an angle expressed in degrees, minutes, and seconds to an angle expressed in radians.

The four HMS (*hours-minutes-seconds*) commands enable you to calculate with numbers whose fractional parts are expressed as minutes and seconds. Such numbers must have the following special format, called the HMS format:

h.MMSSs

where *h* represents hours (or degrees), *MM* represents minutes, *SS* represents seconds, and *s* represents decimal fraction of seconds. *MM* and *SS* each represent two digits; *h* and *s* each represent any number of digits.

The commands →HMS (*decimal-to-HMS*) and HMS→ (*HMS-to-decimal*) convert a real number between the normal decimal format and the special HMS format. The commands HMS+ (*HMS plus*) and HMS− (*HMS minus*) add and subtract numbers in HMS format, with the result also in HMS format.

For example, convert 141° 26′ 15″ to decimal degrees.

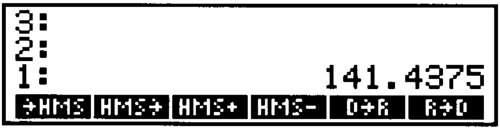
9. Enter the number in HMS format.

  a. Press [1] [4] [1] [.] to key in the degrees.

  b. Press [2] [6] to key in the minutes.

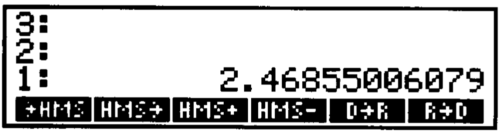
  c. Press [1] [5] to key in the seconds.

10. Press HMS→ to convert the number from HMS format to decimal degrees.



The other two functions on this menu row, D→R (*degrees-to-radians*) and R→D (*radians-to-degrees*) convert a real number between degrees angular measure and radians angular measure.

11. Press D→R to convert the number in level 1 from degrees to radians.



Altogether, you've calculated:

141° 26′ 15″ = 141.4375° = 2.46855006079 radians

Logarithmic, Exponential, and Hyperbolic Functions

The LOGS menu contains logarithmic and exponential functions, both common and natural, and hyperbolic functions. For a detailed description of these functions, refer to "LOGS" in the Reference Manual.

12. Press ■[LOGS] to display the first row of the LOGS menu.

```
3:
2:
1:            2.46855006079
 LOG | ALOG |  LN  | EXP  | LNP1 | EXPM
```

The functions LOG (*common logarithm*) and ALOG (*common antilogarithm*) compute logarithms and exponentials to base 10. The functions LN (*natural logarithm*) and EXP (*natural exponential*) calculate logarithms and exponentials to base *e*. (*e* is a transcendental number approximately equal to 2.71828182846.)

For an argument x, the function LNP1 (*ln plus 1*) computes ln $(x + 1)$, and the function EXPM (*exp minus 1*) computes (exp x) $-$ 1. For arguments close to 0, each of these functions provides greater accuracy than the corresponding sequence of functions. (An example using LNP1 appears in "Time Value of Money" on page 128.)

13. Press [NEXT] to display the second row of the LOGS menu.

```
3:
2:
1:            2.46855006079
 SINH | ASINH | COSH | ACOSH | TANH | ATANH
```

These are the hyperbolic functions and their inverses: SINH (*hyperbolic sine*) and ASINH (*inverse hyperbolic sine*), COSH (*hyperbolic cosine*) and ACOSH (*inverse hyperbolic cosine*), and TANH (*hyperbolic tangent*) and ATANH (*inverse hyperbolic tangent*). These functions are derived from e^x, the natural exponential function. All are one-number functions that act on the number in level 1.

Other Real Functions

The REAL menu contains functions that apply primarily to real numbers.

14. Press ■[REAL] to select the REAL menu.

This section describes the commands in the first row. All commands in the REAL menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "REAL" in the Reference Manual.

The function NEG (*negate*) returns $-x$ for an argument x. The function FACT (*factorial*) returns $n!$ for a positive integer n or the gamma function $\Gamma(x + 1)$ for a non-integer argument x. The command RAND (*random number*) returns a random number calculated from a seed specified by RDZ (*randomize*).

The functions MAXR (*maximum real*) and MINR (*minimum real*) return symbolic constants for the largest and smallest positive real numbers representable on the HP-28C. (To force a numerical result for a symbolic constant, see "Using π" on page 63.)

This section shows you how to use the function NEG. For convenience, you can execute NEG by pressing [CHS] (*change sign*) if no command line is present. To enter the NEG command in the command line—for example, when you're keying in a program—press NEG or [N] [E] [G].

Now negate the number in level 1 twice, once by pressing [CHS] and once by pressing NEG.

15. Press [CHS] to negate the number in level 1.

```
3:
2:
1:          -2.46855006079
 NEG | FACT | RAND | RDZ | MAXR | MINR
```

16. Press NEG to negate the number a second time.

```
3:
2:
1:           2.46855006079
 NEG | FACT | RAND | RDZ | MAXR | MINR
```

Using Complex Numbers

The HP-28C includes an object type that represents complex numbers. For example, the complex number $z = 3 + 4i$ is represented by the object (3,4). Because each complex number is a single object, you can calculate with complex numbers as easily as real numbers.

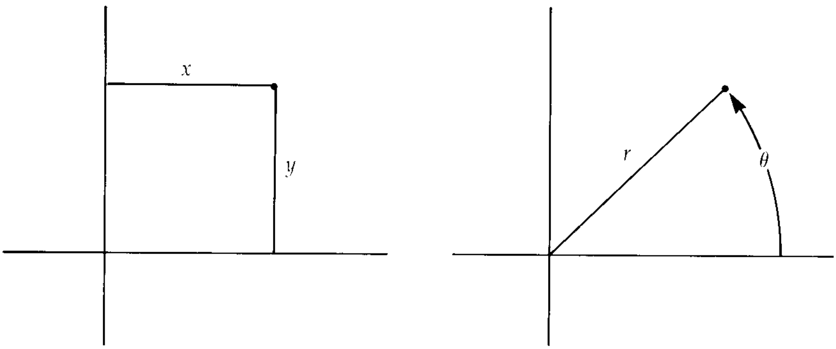
Most real-number functions also work with complex numbers. For example, you add complex numbers just as you do real numbers—put the numbers on the stack and press [+].

For certain functions, a real-number argument can produce a complex result. For example, taking the square root of the negative real number -4 produces the complex result $0 + 2i$, displayed as (0,2).

The HP-28C also uses complex-number objects to represent pairs of coordinates. In the next section you'll use complex numbers to convert polar and rectangular coordinates.

Converting Polar and Rectangular Coordinates

A point in a plane can be described by two different coordinate systems. The illustration below shows one point described two ways, in rectangular notation (x, y) and in polar notation (r, θ).



In this section you'll take a point (x_1, y_1) in rectangular coordinates, rotate it 10° in a counter-clockwise direction, and express the result (x_2, y_2) in rectangular coordinates. The basic steps are:

- Convert (x_1, y_1) to (r_1, θ_1).
- Add (r_1, θ_1) and (0, 10) to calculate (r_2, θ_2).
- Convert (r_2, θ_2) to (x_2, y_2).

Before starting the calculation, select degrees angle mode (to express θ in degrees) and FIX 2 number display mode (to make the complex numbers easy to read).

0. Prepare your calculator to match the illustrations.

- **a.** Press ■[CLEAR] to clear the stack.
- **b.** Press ■[MODE] DEG to select degrees angle mode.
- **c.** Press [2] FIX to select FIX 2 number display mode.

Now begin the calculation, letting $(x_1, y_1) = (18.1, 44.2)$. Use the COMPLEX menu to enter (18.1, 44.2).

1. Press ■ [CMPLX] to select the COMPLEX menu.

All commands in the COMPLEX menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "COMPLEX" in the Reference Manual.

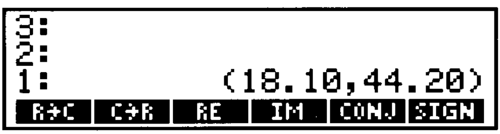
The R→C (*real-to-complex*) command converts two real numbers x and y to one complex number (x, y); C→R (*complex-to-real*) does the opposite. For a complex argument (x, y), RE (*real part*) returns x, IM (*imaginary part*) returns y, CONJ (*conjugate*) returns $(x, -y)$, and SIGN returns the complex sign of (x, y).

2. Put (x_1, y_1) on the stack.

a. Press [1] [8] [.] [1] [ENTER] to put x_1 on the stack.

b. Press [4] [4] [.] [2] [ENTER] to put y_1 on the stack.

c. Press [R→C] to combine x_1 and y_1 into (x_1, y_1).



You can also key in a complex number all at once, as shown in step 5 below.

3. Press [NEXT] to display the second row of the COMPLEX menu.

```
3:
2:
1:               (18.10,44.20)
 R→P   P→R   ABS   NEG   ARG
```

The functions R→P (*rectangular-to-polar*) and P→R (*polar-to-rectangular*) convert a complex number between rectangular notation (x, y) and polar notation (r, θ). For a complex argument (x, y), the function ABS (*absolute value*) returns r, the function NEG returns $(-x, -y)$, and the function ARG returns θ.

4. Press R→P to convert (x_1, y_1) to (r_1, θ_1). The angle θ is expressed in degrees because you selected degrees angle mode.

```
3:
2:
1:               (47.76,67.73)
 R→P   P→R   ABS   NEG   ARG
```

5. Press [(] [0] [,] [1] [0] [ENTER] to put (0, 10) on the stack. The closing parenthesis) is added for you.

```
3:
2:               (47.76,67.73)
1:                (0.00,10.00)
 R→P   P→R   ABS   NEG   ARG
```

6. Press [+] to calculate (r_2, θ_2).

```
3:
2:
1:              (47.76,77.73)
 R→P | P→R | ABS | NEG | ARG |
```

7. Press P→R to convert (r_2, θ_2) to (x_2, y_2).

```
3:
2:
1:              (10.15,46.67)
 R→P | P→R | ABS | NEG | ARG |
```

This completes the calculation. In rectangular coordinates, (18.1, 44.2) rotated 10° counter-clockwise equals (10.15, 46.67).

6

More About the Command Line

This chapter discusses how the command line works and how to edit text in the command line. For more information about the command line, refer to chapter 2, "Basic Operations," in the Reference Manual.

Entry Modes

The HP-28C has three entry modes, each optimized for keying in certain types of objects.

- *Immediate entry mode,* which is the default mode, enables you to key in data objects and immediately act on them.
- *Algebraic entry mode* makes it easy to key in algebraic objects (expressions and equations) and then act on them.
- *Alpha entry mode* is used to key in programs.

This section demonstrates these entry modes by repeating a calculation three times, once in each mode.

0. Prepare the calculator to match the illustrations.

  a. Press ■ [CLEAR] to clear the stack.

  b. Press ■ [MODE] STD to select STD number display mode.

  c. Press [◂⬍▸] to select the cursor menu.

Immediate Entry Mode

This is the entry mode you're familiar with. In this example you'll see that you can enter more than one number on the command line.

1. Press [1] [SPACE] [2] to write the numbers 1 and 2 in the command line.

```
3:
2:
1:
1 2□
```

2. Press [+] to add the two numbers. In immediate entry mode, pressing [+] executes ENTER (putting both numbers on the stack) and then executes the + function.

```
4:
3:
2:
1:                    3
```

Algebraic Entry Mode

You saw this entry mode when you keyed in an expression (page 31) or a name (page 49).

3. Press ['] to begin the expression. The cursor changes, indicating algebraic entry mode.

```
3:
2:
1:                    3
'▤
```

4. Press [1] [+] [2] to write the expression in the command line. In algebraic entry mode, pressing [+] writes + in the command line rather than executing ENTER and the + function.

```
3:
2:
1:                          3
'1+2█
```

5. Press [EVAL] to evaluate the expression. In algebraic entry mode, pressing [EVAL] executes ENTER (putting the expression on the stack) and then executes the EVAL command.

```
4:
3:
2:                          3
1:                          3
```

Why did pressing [EVAL] cause execution when pressing [+] didn't? The reason is that [+] is a *function* and [EVAL] is a *command*.

- Functions are mathematical operations. They are allowed in algebraic objects (expressions and equations), so in algebraic entry mode their names are written in the command line. Other examples of functions are SIN, LN, NEG, and R→P.
- Commands are generally stack and user-memory operations. They aren't allowed in algebraic objects, so they execute in algebraic entry mode just as they do in immediate entry mode. Other examples of commands are DROP, SWAP, STO, and PURGE.

Next is an entry mode where functions *and* commands write their names in the command line.

Alpha Entry Mode

This entry mode is automatically selected when you begin to key in a program. This example uses [α] (*alpha entry*), rather than a program, to select alpha entry mode.

6. Press ['] to begin the expression. The cursor changes, indicating algebraic entry mode.

```
3:
2:                             3
1:                             3
'▤
```

7. Press [α] to select alpha entry mode. The cursor changes again, indicating alpha entry mode. In addition, the **α** annunciator appears at the top of the display. (Most illustrations in this manual don't show the annunciators. For the location of the annunciators, see page 25.)

```
3:
2:                             3
1:                             3
'█
```

8. Press [1] [+] [2] ['] to key the expression into the command line. This time the expression won't be the last object in the command line, so you must add the closing ' yourself.

```
3:
2:                             3
1:                             3
'1+2'█
```

9. Press [EVAL] to write EVAL in the command line. Because EVAL is a command, spaces are automatically added before and after its name.

```
3:
2:                         3
1:                         3
'1+2' EVAL █
```

10. Press [ENTER] to process the contents of the command line. The alpha annunciator α disappears.

```
4:
3:                         3
2:                         3
1:                         3
```

Why did pressing [ENTER] cause execution when pressing [+] and [EVAL] didn't? The reason is that [ENTER] isn't a function or a command.

Operations that aren't functions or commands are simply called operations. They execute in all entry modes, so they're not programmable. Other examples of operations are [ON], [◄], and the menu selection keys.

Summary of Function, Command, and Operation Keys

To be precise, the entry mode affects only the key specifically identified with a function, command, or operation. For example, you can spell out the command [S] [T] [O] in any entry mode, because the rules for entry modes apply only to the [STO] key.

Here's a summary.

- Function keys execute only in immediate entry mode.
- Command keys execute in immediate or algebraic entry mode.
- Operation keys execute in all entry modes.

Editing Objects

Next you'll edit an object in the command line. In chapter 4 you created an expression for a resistance calculation, and you stored the expression in a variable named RTOT. Now create a new expression that is similar to RTOT but includes a fourth resistor. You'll return a copy of RTOT to the stack, return that copy to the command line, and edit the copy to create the modified expression. The original expression RTOT won't change.

0. Press ■ [CLEAR] to clear the stack, preparing the calculator to match the illustrations.

Returning Objects to the Command Line

1. Return the expression stored in RTOT to the stack.

  a. Press [USER] to select the USER menu.

b. Press **RTOT** to return the expression stored in RTOT to level 1.

```
2:
1:  'R1+INV(INV(R2)+INV(
    R3))'
 R3 | R2 | R1 | EQ | RTOT |
```

2. Press ■ EDIT to return the expression to the command line.

```
1:  'R1+INV(INV(R2)+INV(
    R3))'
'R1+INV(INV(R2)+INV(
R3))'
```

The expression in level 1 appears in inverse characters to warn you that it will be replaced by the contents of the command line. The alpha annunciator α appears, indicating that alpha entry mode is active.

Now modify the expression to represent the formula:

$$R_{total} = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$$

Moving the Cursor

3. Move the cursor to the desired position.

The operations for moving the cursor are on the *cursor menu*—the labels printed in white just above the menu keys. The cursor menu is active whenever the command line exists and no menu is displayed. (You can turn the cursor menu on and off by pressing [◄♦►]. Pressing ■[EDIT] automatically turns on the cursor menu.)

a. Press [▼] to move the cursor to the lower row of the command line.

```
1:  'R1+INV(INV(R2)+INV(
    R3))'
'R1+INV(INV(R2)+INV(
█3))'
```

b. Press [▶] three times to move the cursor just past the term for R3.

```
1:  'R1+INV(INV(R2)+INV(
    R3))'
'R1+INV(INV(R2)+INV(
R3)█'
```

You can hold down [▲], [▼], [◄], or [▶] for repeated motion in the indicated direction, or you can press ■[▲], ■[▼], ■[◄], or ■[▶] to move the cursor as far as possible in the indicated direction.

Selecting Insert or Replace Mode

4. Press [INS] to select insert mode. The shape of the cursor changes to an arrow, indicating that text will be inserted to the left of the character at the cursor position.

   (Pressing [INS] a second time returns to replace mode, where text replaces the character at the cursor position.)

5. Press [+] ■[1/x] [(] [R] [4] to key in the term for R4.

```
1:  'R1+INV(INV(R2)+INV(
    R3))'
'R1+INV(INV(R2)+INV(
R3)+ INV (R4◂'
```

6. Press [ENTER] to replace the expression in level 1 by the edited expression in the command line.

```
2:
1:  'R1+INV(INV(R2)+INV(
    R3)+INV(R4))'
 R3 | R2 | R1 | EQ | RTOT |
```

Canceling an Edit

If you change your mind about editing the object in level 1—if you decide that you wanted to keep the original—don't press [ENTER]. Instead, press [ON] to cancel the edit. The command line is cleared, and the original object remains in level 1. Sometimes, if you make mistakes editing an object, it's easier to cancel the edit and start over.

Editing a Variable

In the preceding example you created a modified copy of RTOT, but you didn't change RTOT itself. You could change RTOT by using ■[VISIT] instead of ■[EDIT], as follows:

1. Press ['] [R] [T] [O] [T] ■[VISIT] to return the contents of RTOT to the command line.
2. Edit the expression.
3. Press [ENTER] to replace the previous contents of the variable RTOT by the expression in the command line. (To cancel the edit, press [ON] instead of [ENTER].)

7

More About the Stack

Now that you've used the stack for a variety of operations, here's a summary of its basic features.

- The stack is a sequence of objects, each object occupying one numbered stack level.
- The objects you key into the command line are put on the stack when you execute ENTER. Each object is put in level 1, lifting other objects to the next higher stack level. The first object in the command line is the first object put on the stack.
- The stack can contain any number of objects.
- Most commands take their arguments from the stack and return their results to the stack.

This chapter first discusses ■[CATALOG], which shows the arguments that must be on the stack for each command, and ■[LAST], which returns copies of the arguments used by the most recent command. Also described are ■[VIEW↑] and ■[VIEW↓], which enable you to view any objects on the stack.

Next discussed are commands for copying and rearranging the objects on the stack. These sections shows you how to use some of the commands in the STACK menu. All commands in the STACK menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "STACK" in the Reference Manual.

The Catalog of Commands

The HP-28C contains a catalog of all commands, listed alphabetically. For each command the catalog shows its usage—that is, the arguments required by the command. The following example checks the usage of STO and +.

For a complete description of the catalog, refer to "CATALOG" in the Reference Manual. For a description of any command listed in the catalog, refer to "Operation Index" in the back of the Reference Manual.

1. Press ■ [CATALOG] to start the catalog. The first command is ABORT.

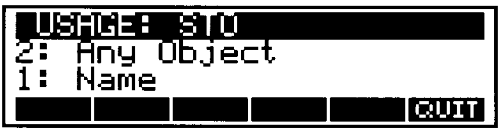
Normal calculator operation is suspended while the catalog is active. The NEXT, PREV, and SCAN operations move the catalog to other commands. The USE operation displays the arguments required by the current command. The FETCH and QUIT operations terminate the catalog, restoring normal calculator operation.

2. Press [S] to move the catalog to SAME. (Pressing any letter key moves the catalog to the first command that starts with that letter.)

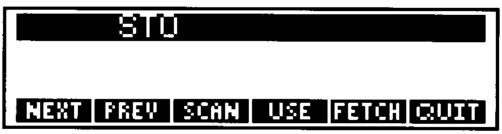
3. Press **SCAN** to start the catalog moving automatically through the alphabetical listing of commands. The **SCAN** menu label changes to **STOP**. When you see STO displayed, press **STOP** to stop scanning.

4. Probably the catalog scanned past STO before you could press **STOP**. Press **PREV** repeatedly until STO is displayed. (You can repeatedly execute **NEXT** or **PREV** by holding down the menu key.)

5. Press **USE** to show the usage for STO. The USAGE display shows that STO takes any object in level 2 and a name in level 1.

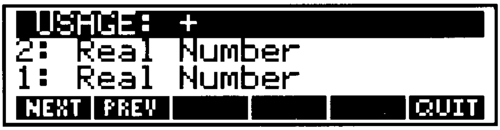


6. Press **QUIT** to return to the main catalog.



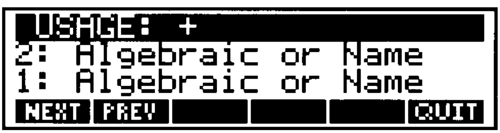
7. Press [#] to move the catalog to +. (Pressing any non-alphabetical key on the left-hand keyboard whose character doesn't begin a command moves the catalog to +, the first non-alphabetical command.)

8. Press USE to show the usage for +. The display shows that + takes real numbers in levels 2 and 1.



For commands such as + that can take more than one combination of arguments, you can press NEXT or PREV to display other options.

9. Press NEXT 14 times to view the complete usage for +. The 14th possible combination of arguments is a symbolic object (an algebraic object or a name) with another symbolic object.



10. Press QUIT to return to the main catalog.

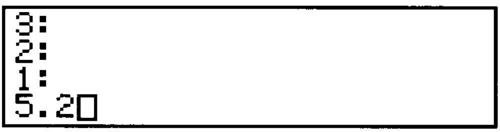
11. Press QUIT to exit the catalog and return to normal calculator operation. (Alternatively, you can exit the catalog by pressing FETCH, which also writes the name of the current command in the command line.)

Recovering Last Arguments

Whenever a command takes arguments from the stack, it saves a copy of its arguments and discards the arguments saved from the previous command. You can recover the arguments from the last command by pressing ■[LAST]. This feature is useful when you use a number in two consecutive calculations.

For example, calculate (ln x)/x for $x = 5.2$.

0. Prepare the calculator to match the illustrations.
   - a. Press ■[CLEAR] to clear the stack.
   - b. Press ■[MODE] STD to select STD number display mode.
   - c. Press [◂▴▸] to select the cursor menu.
1. Press [5] [·] [2] to write 5.2 in the command line.



2. Press ■[LOGS] LN to calculate ln 5.2.

3. Press ■[LAST] to return 5.2 to level 1.

```
3:
2:              1.64865862559
1:                        5.2
 LOG  ALOG  LN  EXP  LNP1 EXPM
```

4. Press [÷] to calculate (ln 5.2)/5.2.

```
3:
2:
1:               .31704973569
 LOG  ALOG  LN  EXP  LNP1 EXPM
```

Viewing Stack Objects

You can check the contents of the stack without moving any objects by executing ■[VIEW↑] and ■[VIEW↓]. Viewing has no effect on the contents of the stack or the action of commands.

To observe the effect of the commands in the remainder of this chapter, clear the stack and key in a few names.

0. Press ■[CLEAR] to clear the stack.
1. Press [◄▲▼►] to select the cursor menu.
2. Press ['] [A] [ENTER] ['] [B] [ENTER] ['] [C] [ENTER] ['] [D] [ENTER] ['] [E] [ENTER] ['] [F] [ENTER] to put six names on the stack.

```
4:                        'C'
3:                        'D'
2:                        'E'
1:                        'F'
```

3. Press ■ [VIEW↑] twice to show higher levels of the stack.

```
6:                                   'A'
5:                                   'B'
4:                                   'C'
3:                                   'D'
```

4. Press ■ [VIEW↓] twice to show lower levels of the stack.

```
4:                                   'C'
3:                                   'D'
2:                                   'E'
1:                                   'F'
```

Copying Stack Objects

When you make a copy of an object on the stack, the copy is returned to level 1, and the other objects on the stack (including the original object) are pushed to a higher level.

The next commands make copies of the object in level 1, level 2, any level, or both levels 1 and 2.

5. Press ■ [STACK] to display the STACK menu.

```
3:                                   'D'
2:                                   'E'
1:                                   'F'
 DUP  OVER  DUP2  DROP2  ROT  LIST→
```

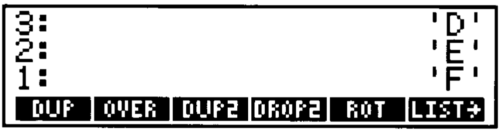
The remainder of this chapter discusses most of the commands in the STACK menu. All commands are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "STACK" in the Reference Manual.

6. Make a copy of the object in level 1, then drop it from the stack.

   a. Press DUP (*duplicate*) to make a copy of the object in level 1.

   (When no command line is present, you can execute DUP by pressing [ENTER]. To enter DUP in the command line—for example, when you're keying in a program—press DUP or [D] [U] [P].)

   b. Press [DROP] to drop the copy from the stack.



7. Make a copy of the object in level 2, then drop it from the stack.

   a. Press OVER to make a copy of the object in level 2.

   b. Press [DROP] to drop the copy from the stack.

8. Make a copy of the object in level 3, then drop it from the stack.

a. Press [NEXT] to show the second row of the STACK menu.

b. Press [3] PICK to make a copy of the object in level 3.

This command uses a number to specify a stack level. Note that [1] PICK is equivalent to DUP, and [2] PICK is equivalent to OVER.

c. Press [DROP] to drop the copy from the stack.

9. Make copies of the objects in levels 1 and 2.

   a. Press [NEXT] to return to the first row of the STACK menu.

   b. Press DUP2 to make copies of the objects in levels 1 and 2.

   c. Press DROP2 to drop the copies from the stack.

Rearranging Stack Objects

In general, objects on the stack are rearranged by rotating a block of objects. The rotation occurs in one of two directions. In one direction, the object in level 1 moves to the highest level in the block, and the other objects in the block move down to lower levels. In the other direction, the object in the highest level in the block moves to level 1, and the other objects in the block move up to higher levels.

The next commands rotate blocks of two, three, or four objects.

10. Rotate the objects in levels 1 and 2.

a. Press ■ [SWAP] to exchange the objects in levels 1 and 2.

b. Press ■ [SWAP] again to restore the original order.

11. Rotate the objects in levels 1, 2, and 3.

a. Press ROT to move the object in level 3 to level 1.

b. Press ROT twice more to restore the original order.

12. Rotate the objects in levels 1, 2, 3, and 4.

a. Press [4] ■[ROLL] to move the object in level 4 to level 1.

```
3:                              'E'
2:                              'F'
1:                              'C'
 DUP | OVER | DUP2 |DROP2| ROT |LIST→
```

Note that [1] ■[ROLL] has no effect, [2] ■[ROLL] is equivalent to ■[SWAP], and [3] ■[ROLL] is equivalent to ROT.

b. Press [NEXT] to show the second row of the STACK menu.

c. Press [4] ROLLD to restore the original order.

```
3:                              'D'
2:                              'E'
1:                              'F'
ROLLD| PICK |DUPN |DROPN|DEPTH|→LIST
```

8

Programs

This chapter shows how to write and use simple programs. For general information about programs, refer to "Programs" in the Reference Manual. For information about the commands used primarily in programs, refer to "PROGRAM BRANCH," "PROGRAM CONTROL," and "PROGRAM TEST" in the Reference Manual.

This chapter also compares expressions with programs. This discussion is based on the use of expressions in chapter 4.

Creating Programs

A program is a sequence of objects and commands contained in a single object. When you evaluate the program, the objects are put on the stack and the commands are executed.

In chapter 6 you learned about alpha entry mode, in which pressing a command key writes the command name in the command line rather than executing the command. Only when you finally pressed [ENTER] were the commands executed. A program is effectively an object that contains an entire command line. Evaluating the program has the same effect as returning its contents to the command line and pressing [ENTER].

Programs are most useful when stored in a variable. The unquoted name of a program variable acts as a command. You can run the program (that is, evaluate it) by pressing a key in the USER menu, or you can call the program as a subroutine (that is, evaluate it) by including its unquoted name in another program.

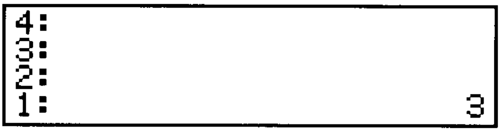
In this section you'll calculate the area of a disk in three ways, the third way being a program. Next you'll store the program in a variable DISK, then use DISK within a program that calculates the volume of a cylinder.

0. Prepare your calculator to match the illustrations.

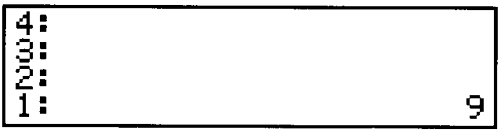
- **a.** Press ■[CLEAR] to clear the stack.
- **b.** Press ■[MODE] [STD] to select STD number display mode.
- **c.** Press [◂✦▸] to select the cursor menu.

1. Calculate πr^2 for $r = 3$, using [ENTER] to put objects on the stack.

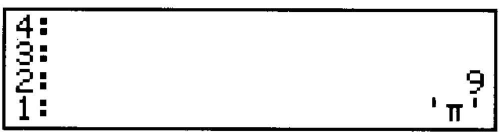
- **a.** Press [3] [ENTER] to put 3 on the stack.



- **b.** Press ■[x^2] to compute r^2.



- **c.** Press ■[π] [ENTER] to put π on the stack.



d. Press [×] to compute πr^2.

```
4:
3:
2:
1:                    '9*π'
```

e. Press ■[→NUM] to force a real-number result.

```
4:
3:
2:
1:          28.2743338823
```

2. Repeat the calculation, using [ENTER] to put 3 on the stack and using alpha entry mode to accumulate the commands.

a. Press [3] [ENTER] to put 3 on the stack.

```
4:
3:
2:          28.2743338823
1:                      3
```

b. Press [α] to select alpha entry mode. The **α** annunciator appears. (Most illustrations in this manual don't show the annunciatiors. For the location of the annunciators, see page 25.)

c. Press ■[x^2] to write SQ (*square*) in the command line. The cursor indicates alpha entry mode.

```
3:
2:          28.2743338823
1:                      3
SQ █
```

d. Press ■ [π] to write π in the command line.

```
3:
2:          28.274333882З
1:                      3
SQ π█
```

e. Press [SPACE] to write a space after π.

```
3:
2:          28.2743338823
1:                      3
SQ π █
```

f. Press [×] to write * in the command line.

```
3:
2:          28.2743338823
1:                      3
SQ π *█
```

g. Press ■ [→NUM] to write →NUM in the command line.

```
3:
2:          28.2743338823
1:                      3
SQ π * →NUM █
```

h. Press [ENTER] to execute the commands in the command line.

```
4:
3:
2:          28.2743338823
1:          28.2743338823
```

Executing the commands all at once produces the same result as executing them one at a time, but you don't see the intermediate results.

3. Repeat the calculation, using [ENTER] to put 3 on the stack and creating a program that contains the commands.

a. Press [3] [ENTER] to put 3 on the stack.

```
4:
3:          28.274338823
2:          28.274338823
1:                     3
```

b. Press [«] to begin the program. The cursor changes, indicating alpha entry mode, and the **α** annunciator appears. (Pressing [«] automatically selects alpha entry mode, just as pressing ['] automatically selects algebraic entry mode.)

```
3:          28.274338823
2:          28.274338823
1:                     3
«█
```

c. Press ■[x²] ■[π] [SPACE] [×] ■[→NUM] to write `SQ π * →NUM` in the command line.

```
3:          28.274338823
2:          28.274338823
1:                     3
« SQ π * →NUM █
```

d. Press [ENTER] to put the program in level 1. The closing » is added for you.

```
4:        28.2743338823
3:        28.2743338823
2:                    3
1:     « SQ π * →NUM »
```

e. Press [EVAL] to evaluate the program in level 1. Evaluating a program that contains the commands is equivalent to accumulating the commands in the command line and then executing them all at once.

```
4:
3:        28.2743338823
2:        28.2743338823
1:        28.2743338823
```

f. Press ■[CLEAR] to clear the stack.

4. Store the program in a variable named DISK.

a. Press ■[COMMAND] to recover the previous contents of the command line.

```
3:
2:
1:
▒ SQ π * →NUM
```

b. Press [ENTER] to put the program on the stack.

```
4:
3:
2:
1:     « SQ π * →NUM »
```

c. Press ['] [D] [I] [S] [K] to enter the name in the command line.

```
3:
2:
1:      « SQ π * →NUM »
'DISK█
```

d. Press [STO] to create the program variable DISK. The program and name are removed from the stack.

```
4:
3:
2:
1:
```

5. Calculate πr^2 for $r = 3$, using the USER menu to run DISK.

a. Press [USER] to select the USER menu. The program variable DISK appears at the left-hand end of the first row because it is the most recently created variable. (Your display will be different from the illustration if you created different variables.)

```
3:
2:
1:
DISK | R3 | R2 | R1 | EQ | RTOT
```

b. Press [3] DISK to calculate $\pi \times 3^2$.

```
3:
2:
1:          28.2743338823
DISK | R3 | R2 | R1 | EQ | RTOT
```

c. Press [DROP] to clear the stack.

Programs That Call Programs

You can now use the name DISK like a command in other programs. For example, you'll create a program CYL that calculates the volume of a cylinder. The program CYL uses DISK to calculate the area of the cylinder's base, and is said to *call* DISK.

Before writing the program CYL, calculate the volume of a cylinder step-by-step using the stack.

6. Calculate $\pi r^2 h$ for $r = 3$ and $h = 4$, using the USER menu to run DISK.

a. Press [3] DISK to calculate $\pi \times 3^2$.

b. Press [4] [×] to calculate $\pi \times 3^2 \times 4$.

```
3:
2:
1:              113.097335529
DISK | R3 | R2 | R1 | EQ | RTOT
```

7. Now write a program that takes r and h from the stack and returns $\pi r^2 h$. (Assume that r is in level 2 and h is in level 1.)

a. Press [«] to begin the program. The cursor changes, indicating alpha entry mode, and the α annunciator appears.

b. Press ■ [SWAP] to write SWAP in the command line. When executed, SWAP will move r to level 1.

```
2:
1:              113.097335529
« SWAP █
DISK | R3 | R2 | R1 | EQ | RTOT
```

c. Press DISK to write DISK in the command line. When executed, DISK will return πr^2.

```
2:
1:            113.097335529
« SWAP DISK █
DISK | R3 | R2 | R1 | EQ | RTOT
```

d. Press [×] to write * in the command line. When executed, * will return $\pi r^2 h$.

```
2:
1:            113.097335529
« SWAP DISK *█
DISK | R3 | R2 | R1 | EQ | RTOT
```

e. Press [ENTER] to put the program in level 1. The closing » is added for you.

```
3:
2:            113.097335529
1:        « SWAP DISK * »
DISK | R3 | R2 | R1 | EQ | RTOT
```

8. Press ['] [C] [Y] [L] [STO] to store the program in a variable named CYL. The label for CYL is added to the USER menu.

```
3:
2:
1:            113.097335529
CYL | DISK | R3 | R2 | R1 | EQ
```

9. Calculate $\pi r^2 h$ for $r = 3$ and $h = 4$, using the USER menu to run CYL.

a. Press [3] [ENTER] to put 3 on the stack.

```
3:
2:          113.097335529
1:                      3
 CYL  DISK  R3   R2   R1   EQ
```

b. Press [4] CYL to calculate $\pi r^2 h$.

```
3:
2:          113.097335529
1:          113.097335529
 CYL  DISK  R3   R2   R1   EQ
```

Comparing Programs With Expressions

Programs and expressions are called *procedure* objects. A procedure contains commands that are executed when the procedure is evaluated.

An expression represents a mathematical calculation in a form similar to written mathematical notation. It contains one or more functions and the functions' arguments, which can be numbers, variables, or subexpressions. When evaluated, an expression takes no arguments from the stack and returns a single result to the stack. Every expression is equivalent to some program. (The converse is not true.)

In chapter 4 you created an expression RTOT by performing a calculation using variables, rather than numbers, as arguments. In this sense you can think of an expression as the symbolic result of a calculation.

At the same time, expressions are like programs. When you evaluate an expression, the functions in the expression are executed. In chapter 4 you used the Solver to assign values to the variables in RTOT, and you evaluated RTOT when you pressed EXPR= .

There are two major differences between programs and expressions. The first difference involves what kinds of commands can be included in them. Programs can include any commands, including stack commands such as SWAP and DROP, and user-memory commands such as STO and PURGE. Expressions can't include stack commands or user-memory commands. The commands that you can include in expressions, such as + and SIN, are called *functions*.

The second major difference concerns programs and expressions stored in variables. Suppose the USER menu shows a program named CYL and an expression named RTOT. In immediate entry mode, pressing CYL causes the program CYL to be evaluated. Pressing RTOT *doesn't* cause the expression RTOT to be evaluated—instead, the expression is returned to level 1.

The calculator "delays" evaluating expressions so you can use them as symbolic arguments. When you created the expression RTOT, for example, you first entered names, then used those names as symbolic arguments to produce expressions, and then combined those expressions into larger expressions.

When you do want to evaluate an expression, you must execute an explicit command. For example, in chapter 2 you pressed [EVAL] to evaluate the expression in level 1, and in chapter 2 you pressed EXPR= to evaluate the current equation.

Refer to "ALGEBRA" in the Reference Manual for a more detailed explanation of algebraic objects.

9

Plotting Expressions

This chapter introduces plotting on the HP-28C. Plotting is helpful in itself, giving a visual understanding of how an expression behaves. In addition, plotting makes it easy to estimate the roots, maxima, or minima of an expression. The next chapter, "The Solver," shows how to use the Solver to turn estimates into precise numbers.

In this chapter you'll learn how to use some of the commands in the PLOT menu. All commands in the PLOT menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "PLOT" in the Reference Manual.

0. Prepare the calculator to match the illustrations.

- **a.** Press ■[CLEAR] to clear the stack.
- **b.** Press ■[MODE] RAD to select radians angle mode. The (2π) annunciator appears.
- **c.** Press STD to select STD number display mode.
- **d.** Press [◄♦►] to select the cursor menu.

1. Plotting uses a variable named PPAR to store a list of plotting parameters. Purge any existing PPAR to ensure that the next plot uses the default plotting parameters.

a. Press ■[PLOT] to select the PLOT menu.

```
3:
2:
1:
STEQ RCEQ PMIN PMAX INDEP DRAW
```

b. Press [NEXT] to display the second row of the PLOT menu.

```
3:
2:
1:
PPAR RES AXES CENTR *W *H
```

c. Press ['] PPAR ■[PURGE] to purge any existing PPAR.

For the first example, plot sin *x*.

2. Put the expression in level 1.

a. Press [TRIG] to select the TRIG menu.

b. Press ['] SIN [X] [ENTER] to put the expression in level 1.

```
3:
2:
1:                'SIN(X)'
SIN ASIN COS ACOS TAN ATAN
```

3. Store the expression as the *current equation*—a normal variable with the special name EQ.

   a. Press ■[PLOT] to select the PLOT menu.

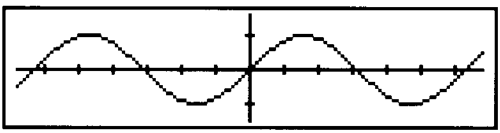
```
3:
2:
1:                'SIN(X)'
STEQ RCEQ PMIN PMAX INDEP DRAW
```

   b. Press STEQ to store the expression in a variable named EQ. Pressing STEQ is equivalent to pressing ['] [E] [Q] [STO].

   (The Solver also uses the variable EQ. In chapter 4, you stored a copy of the expression RTOT in EQ. When you executed STEQ just now, you replaced the copy of RTOT with the expression 'SIN(X)'.)

```
3:
2:
1:
STEQ RCEQ PMIN PMAX INDEP DRAW
```

4. Press DRAW. The calculator plots the expression.



The horizontal line is the axis for the independent variable (x in this example), and the vertical line is the axis for the dependent variable (the value of the expression sin x). The ticks on both axes mark intervals of length 1.

5. Wait for the ((•)) annunciator to disappear, indicating that the plot is complete.

6. Press [ON] to restore the normal display of the stack.

Changing the Scale of the Plot

In general, plotting an expression doesn't produce such tidy results the first time. When you're plotting an unfamiliar expression you may need to adjust the plotting region—defined by the plotting parameters—to show the relevant characteristics of the expression.

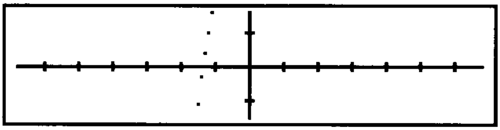
If you know beforehand the region that you want to plot, you can directly change the plotting parameters in PPAR. (PPAR is described in detail in "PLOT" in the Reference Manual.) More often you need to experiment to find the desired plotting region. This manual shows you how to use commands in the PLOT menu to "home in" on the desired plot.

For the second example, plot the expression $x^3 - x^2 - x + 3$.

7. Press ['] [X] ■ [^] [3] [-] [X] ■ [^] [2] [-] [X] [+] [3] [ENTER] to put the expression in level 1.

8. Press STEQ to store the expression as the current equation.

9. Press DRAW. The calculator plots the expression.



The horizontal line is the axis for x, and the vertical line is the axis for $x^3 - x^2 - x + 3$.

This plot shows a *zero* of the expression—a value of X for which the value of the expression is zero. The zero is located where the graph of the expression crosses the X axis. In the next chapter we'll use the Solver to find a precise number for this zero.

To show more of the graph, expand the vertical scale and plot again.

10. Wait for the ((•)) annunciator to disappear, indicating that the plot is complete.

11. Press [ON] to restore the normal display of the stack.

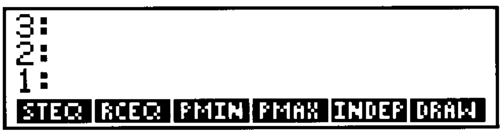
12. Expand the height by a scaling factor of 2.

a. Press [NEXT] to display the second row of the PLOT menu.

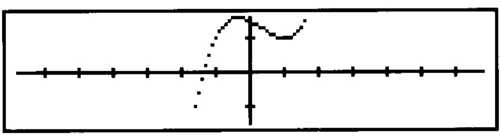
b. Press [2] *H (*times height*) to double the vertical scale.

13. Plot again with the new plot parameters.

a. Press ■[PREV]. The first row of the PLOT menu reappears.



b. Press DRAW. The new plot looks like this:

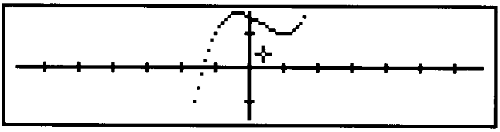


The ticks on the horizontal axis still mark off intervals of length 1, but now the tick marks on the vertical axis mark off intervals of length 2.

Now translate the plot, moving the interesting part to the center of the display.

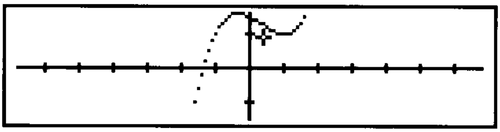
Translating the Plot

With the plot still displayed, press [▶] four times, then press [▲] four times. You'll see cross hairs in the display.



You can use the cross hairs to *digitize* any point on the display, returning the coordinates of the point (according to the current scale) to the stack. We'll digitize the point we want to be the center of the next plot and use it to adjust the plotting parameters.

14. Move the cross hairs to the approximate position shown below. Use [▲], [▼], [◀], and [▶] to move the cross hairs.



15. Press [INS] to digitize the point.

16. Press [ON] to return to the stack display. The coordinates of the digitized point, represented by a complex number, are in level 1. (Your coordinates may differ slightly from the illustration.)

17. Redefine the center of the plot.

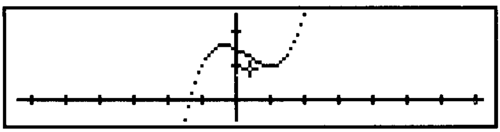
a. Press [NEXT] to display the second row of the PLOT menu.

b. Press CENTR. The coordinates are taken from the stack and used to adjust the plot parameters. Unlike *H, the CENTR command doesn't change the scale.

18. Try another plot.

a. Press ■[PREV] to display the first row of the PLOT menu.

b. Press DRAW.



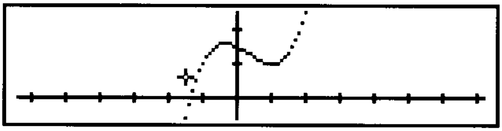
Now zoom in on an interesting part of the plot. You could use *H again, using a *fractional* scaling factor. (For example, a scaling factor of .5 would return the vertical scale to its original value.) But there's a more flexible way to zoom in on a plot.

Redefining the Corners of the Plot

We'll digitize two points this time, one for the lower-left corner of the new plot and one for the upper-right corner, to zoom in on the local maximum and minimum.

19. Digitize the desired lower-left corner.

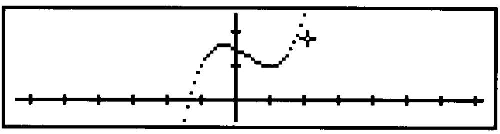
a. Move the cross hairs to the approximate position shown below. Use [▲], [▼], [◀], and [▶] to move the cross hairs.



b. Press [INS] to digitize the point.

20. Digitize the desired upper-right corner.

a. Move the cross hairs to the approximate position shown below.



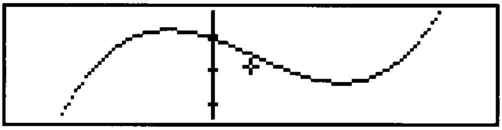
b. Press [INS] to digitize the point.

21. Press [ON] to return to the stack display. The coordinates of the lower-left corner, represented by a complex number, are in level 2. The coordinates of the upper-right corner are in level 1. (Your coordinates may differ slightly from the illustration.)

22. Press PMAX (*plot maxima*) to redefine the upper-right corner of the plot. The coordinates are taken from the stack and used to adjust the plotting parameters.

23. Press PMIN (*plot minima*) to redefine the lower-left corner of the plot.

24. Press DRAW. The new plot appears.



Since you changed the height and width of the plot, both the vertical and horizontal scales are changed.

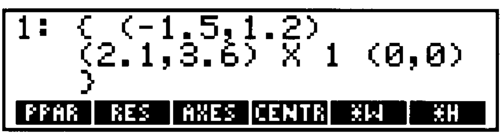
The plot shows two *extremes* in the expression's graph—a local maximum and a local minimum. In the next chapter we'll use the Solver to find a precise value for the minimum. To avoid repeating all these steps to generate our current plotting parameters, store the current value of PPAR in a variable with a different name. To recreate this plot in the next chapter, you'll restore PPAR to its current value.

25. Press [ON] to return to the stack display.

26. Put the current contents of PPAR in level 1.

   a. Press [NEXT] to display the second row of the PLOT menu.

   b. Press PPAR to return the list containing the current plotting parameters to level 1. For information about the plotting parameters and for details about plotting in general, see "PLOT" in the Reference Manual.



27. Create a variable PPAR1 that contains the current plotting parameters.

a. Press ['] PPAR [1].

```
1: { (-1.5,1.2)
   (2.1,3.6) X 1 (0,0)
'PPAR1
PPAR  RES  AXES  CENTR  *W  *H
```

b. Press [STO] to create PPAR1.

Now you're ready to use the Solver to find precise numbers for the zero, local minimum, and local maximum of the expression.

10

The Solver

This chapter describes how to find a zero and a minimum of the expression you plotted in the previous chapter. You'll need some of the results from that chapter, so work through the steps in the previous chapter if you haven't done so already.

For a complete description of the Solver, refer to "SOLVE" in the Reference Manual.

0. Prepare the calculator to match the illustrations.

   a. Press ■ [CLEAR] to clear the stack.

   b. Press ■ [MODE] RAD to select radians angle mode. The (2π) annunciator appears.

   c. Press [2] FIX to select FIX 2 number display mode.

Finding a Zero of an Expression

The following example assumes that the expression $x^3 - x^2 - x + 3$ is still the current equation and that you've created the variable PPAR1, as described in the previous chapter. You'll plot the expression again, digitize an estimate for a zero of the expression, and then use the Solver to find a more accurate value for the zero.

1. Plot the expression $x^3 - x^2 - x + 3$ again, using the default values for PPAR.

First, purge the existing PPAR to ensure that the next plot uses the default plotting parameters.

a. Press ■ [PLOT] to select the PLOT menu.

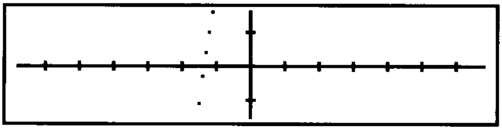
b. Press [NEXT] to display the second row of the PLOT menu.

c. Press ['] PPAR ■ [PURGE] to purge any existing PPAR.

Now plot the expression.

d. Press ■ [PREV] to return to the first row of the PLOT menu.

e. Press DRAW. The calculator plots the expression.

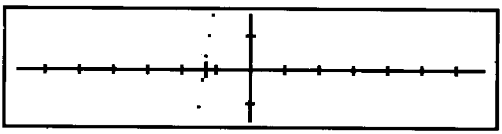


f. Wait for the ((•)) annunciator to disappear, indicating that the plot is complete.

This plot shows a *zero* of the expression—a value of X for which the value of the expression is zero. The zero is located where the graph of the expression crosses the horizontal axis.

2. Digitize an estimate for the zero.

a. Move the cross hairs to the approximate intersection of the graph and the horizontal axis. (Use [▲], [▼], [◀], and [▶] to move the cross hairs.)



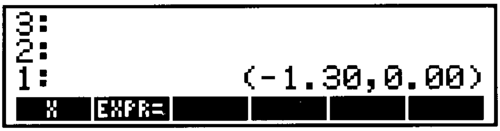
b. Press [INS] to digitize the point. You'll use this point as an estimate for finding the exact zero of the expression. (In case the expression has more than one root, the estimate indicates which one you want.)

c. Press [ON] to return to the stack display. The coordinates of the digitized point, represented by a complex number, are in level 1. (Your coordinates may differ slightly from the illustration.)

3. Use the Solver to find a more accurate estimate.

a. Press [SOLV] to display the SOLVE menu.

b. Press SOLVR. The Solver menu shows all the variables in the current equation (only X in this example).



c. Press X. The digitized point is taken from level 1 and stored in the variable X as an initial estimate.

(Although the digitized point contains two coordinates, the Solver will use only the first coordinate as an estimate.)

d. Press ■ X to solve for X. The Solver indicates that it's solving for X and then returns the result to level 1.

```
X: -1.36
Sign Reversal
1:                    -1.36
  X  EXPR=
```

The message `Sign Reversal` indicates that the Solver found an approximate solution, correct to 12 digits. If the Solver found an exact solution, it would display the message `Zero`. These messages, called *qualifying messages,* are discussed in "SOLVE" in the Reference Manual.

e. Press [ON] to return to the normal stack display.

Finding a Minimum

Next use the Solver to find the expression's local minimum. You'll plot the expression, using the plotting parameters stored in the variable PPAR1, then digitize three points to estimate the minimum, and then use the Solver to find a more accurate minimum.

4. Plot the expression, using the plotting parameters stored in the variable PPAR1.

First, restore the variable PPAR to the values stored in PPAR1.

a. Press [USER] to display the USER menu. If PPAR1 isn't displayed at first, press [NEXT] to display more variables.

b. Press PPAR1 to return the list of plotting parameters to level 1.

```
1: { (-1.50,1.20)
   (2.10,3.60) X 1.00
   (0.00,0.00) }
  X  PPAR PPAR1 CYL DISK R3
```

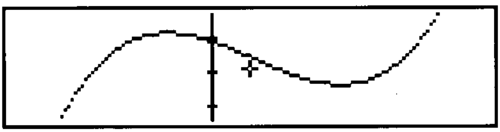
c. Press ['] PPAR. (If PPAR isn't currently displayed, press [NEXT] to display more variables.)

d. Press [STO] to store the plotting parameters from PPAR1 into PPAR.

Now plot the expression.

e. Press ■[PLOT] to display the PLOT menu.

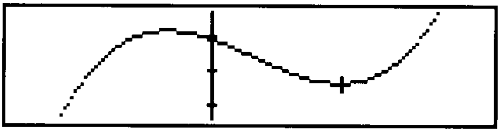
f. Press DRAW. The calculator plots the expression.



g. Wait for the ((•)) annunciator to disappear, indicating that the plot is complete.

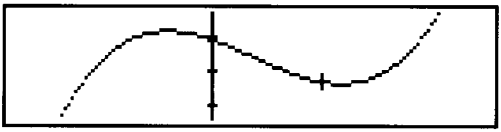
5. Digitize three points to estimate the minimum.

a. Move the cross hairs to the approximate minimum.



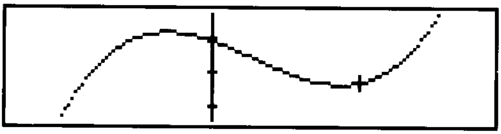
b. Press [INS] to digitize the point.

c. Move the cross hairs just to the left of the minimum.



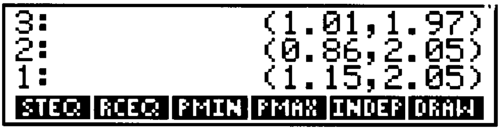
d. Press [INS] to digitize the point.

e. Move the cross hairs just to the right of the minimum.



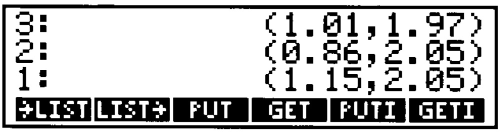
f. Press [INS] to digitize the point.

g. Press [ON] to return to the stack display. The three points are in levels 1, 2, and 3. (Your points may differ slightly from the illustration.)



Now combine the three estimates in a list. By doing so, you can handle the three estimates as a single object. This is a typical use for lists—combining several objects into one.

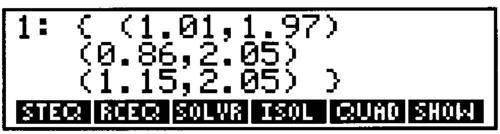
h. Press ■[LIST] to display the LIST menu.



i. Press [3] →LIST to combine the three points in a list.

6. Use the Solver to find a more accurate estimate for the minimum.

a. Press [SOLV] to display the SOLVE menu.



b. Press SOLVR. The Solver menu shows all the variables in the current equation (only X in this example).

```
1: { (1.01,1.97)
   (0.86,2.05)
   (1.15,2.05) }
  X  EXPR=
```

c. Press X. The list of points is taken from the stack and stored in the variable X as initial estimates.

d. Press ■ X to solve for X. The Solver indicates that it's solving for X and then returns the result, 1.00, to level 1.

```
X: 1.00
Extremum
1:                  1.00
  X  EXPR=
```

The message `Extremum` indicates that the Solver found an extreme point of the expression.

e. Press [ON] to return to the normal stack display.

Time Value of Money

This section shows how to use the Solver with time value of money (TVM) calculations. For n number of periods, i% interest per period, $\$pmt$ payment, $\$pv$ present value, and $\$fv$ future value, the formula for TVM is:

$$(1 - sppv) \times pmt \times (100/i) + pv = -fv \times sppv$$

where

$$sppv\ (single\ payment\ present\ value) = (1 + i/100)^{-n}$$

$$= \exp(-\mathrm{n} \times \ln(1 + i/100)).$$

This formula assumes that payments are made at the end of each period.

First you'll key in the expression for *sppv* and store it in a variable SPPV. Next you'll key in the equation and store it in a variable TVM. After making TVM the current equation, you'll use the Solver to calculate any of the five variables *n*, *i*, *pmt*, *pv*, or *fv*, for given values of the other four variables.

0. Prepare the calculator to match the illustrations.

- **a.** Press ■ [CLEAR] to clear the stack.
- **b.** Press ■ [MODE] [2] FIX to select FIX 2 number display mode.

1. Key in the expression for *sppv*.

- **a.** Press ['] to begin the expression.
- **b.** Press ■ [LOGS] to select the LOGS menu.

c. Press **EXP** [−] [N] [×] **LNP1** [I] [÷] [1] [0] [0] [ENTER] to put the expression on the stack. This expression takes advantage of the greater accuracy of LNP1 to calculate ln (1 + *i/100*).

```
2:
1:  'EXP(-N*LNP1(I/100))
 LOG | ALOG | LN | EXP | LNP1 | EXPM
```

2. Press ['] [S] [P] [P] [V] [STO] to create the variable SPPV.

3. Key in the equation for TVM.

a. Press ['] [(] [1] [−] to begin the equation.

```
2:
1:
'(1-█
 LOG | ALOG | LN | EXP | LNP1 | EXPM
```

b. Press [USER] to select the USER menu. The variable SPPV is the left-most label on the first row because it's the most recently created variable.

```
2:
1:
'(1-█
 SPPV | X | PPAR | PPAR1 | CYL | DISK
```

c. Press **SPPV** [■] [)] [×] [P] [M] [T] [×] [1] [0] [0] [÷] [I] [+] [P] [V] [=] [−] [F] [V] [×] **SPPV** [ENTER] to put the expression in level 1.

```
2:
1:  '(1-SPPV)*PMT*100/I+
   PV=-FV*SPPV'
 SPPV | X | PPAR | PPAR1 | CYL | DISK
```

4. Press ['] [T] [V] [M] [STO] to create the variable TVM. The USER menu shows a new label for TVM.

```
3:
2:
1:
 TVM  SPPV   X   PPAR PPAR1  CYL
```

5. Make TVM the current equation.

   a. Press **TVM** to return TVM to the stack.

```
2:
1:  '(1-SPPV)*PMT*100/I+
   PV=-FV*SPPV'
 TVM  SPPV   X   PPAR PPAR1  CYL
```

   b. Press [SOLV] to select the SOLVE menu.

```
2:
1:  '(1-SPPV)*PMT*100/I+
   PV=-FV*SPPV'
 STEQ  RCEQ  SOLVR  ISOL  QUAD  SHOW
```

   c. Press **STEQ** to store the expression in the variable EQ.

6. Press **SOLVR** to display the Solver menu. All the variables in TVM and SPPV appear in the menu. (The variables in SPPV appear because the current equation, TVM, contains SPPV.)

```
3:
2:
1:
  N     I    PMT   PV    FV   LEFT=
```

7. Given values N = 30 × 12, I = 11.5/12, PMT = −630, and FV = 0, calculate PV. (PMT has a negative value because money paid out is a negative number, while money received is a positive number.)

a. Press [3] [0] [ENTER] [1] [2] [×] to assign the value to N.

```
N: 360.00
2:
1:
 N  |  I  | PMT | PV  | FV  |LEFT=
```

b. Press [1] [1] [·] [5] [ENTER] [1] [2] [÷] to assign the value to I.

```
I: 0.96
2:
1:
 N  |  I  | PMT | PV  | FV  |LEFT=
```

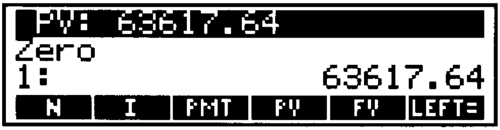
c. Press [6] [3] [0] [CHS] to assign the value to PMT.

```
PMT: -630.00
2:
1:
 N  |  I  | PMT | PV  | FV  |LEFT=
```

d. Press [0] to assign the value to FV.

```
FV: 0.00
2:
1:
 N  |  I  | PMT | PV  | FV  |LEFT=
```

e. Press ■ PV to solve for PV. The calculator indicates that it's solving for PV and then returns the value $63,617.64.



The message `Zero` indicates that the returned value exactly satisfies the current equation.

11

Symbolic Solutions

This chapter describes two methods for finding symbolic solutions. There is a simple method for solving a quadratic expression by calculating the linear expression that represents both zeros. There is also a more versatile method that provides a symbolic solution for a variable in more general equations.

Each method works with both expressions and equations. The *zero* of an expression $f(x)$ is the same as the *root* of the equation $f(x) = 0$, and the *root* of the equation $f(x) = g(x)$ is the same as the *zero* of the expression $f(x) - g(x)$.

0. Prepare your calculator to match the illustrations.

- **a.** Press ■ [CLEAR] to clear the stack.
- **b.** Press ■ [MODE] [STD] to select STD number display mode.
- **c.** Press [◂▸] to select the cursor menu.

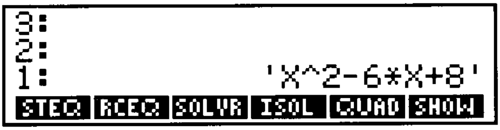
Finding the Zeros of a Quadratic Expression

You can find both zeros of a quadratic expression without plotting or making estimates. The following example solves $x^2 - 6x + 8$.

1. Press ['] [X] ■ [^] [2] [-] [6] [×] [X] [+] [8] [ENTER] to put the expression in level 1.

```
4:
3:
2:
1:              'X^2-6*X+8'
```

2. Press [SOLV] to select the SOLVE menu.



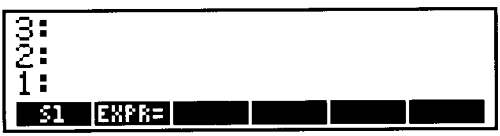
3. Press ['] [X] [ENTER] to put the name X on the stack, indicating the variable for which you're solving.

4. Press QUAD (*quadratic*). An expression representing both solutions is returned to level 1.

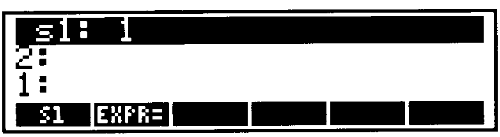
The variable s1 represents an arbitrary sign, either +1 or −1. Each value of s1 corresponds to a zero of the expression.

5. Press STEQ to store the expression as the current equation.

6. Press SOLVR to display the Solver menu. s1 is the only variable in the current equation.

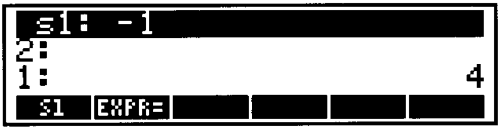


7. Press [1] S1 to make s1 a positive sign.



8. Press **EXPR=** to return one of the solutions to level 1.

9. Press [1] [CHS] **s1** to make s1 a negative sign.



10. Press **EXPR=** to return the second solution to level 1.

The two roots of $x^2 - 6x + 8$ are $x = 4$ and $x = 2$.

11. Press ['] [S1] ■[PURGE] to purge the variable s1. (Otherwise, when you next execute QUAD, s1 would be replaced by its value and wouldn't appear in the expression.)

Isolating a Variable

The HP-28C can isolate a single occurrence of a variable in an equation, returning an expression representing the symbolic solution of the equation. In other words, if x is the variable for which the equation is solved, and a, b, and c are the other variables in the equation, isolating x produces an expression in a, b, and c such that the equation is satisfied when x has the value of the expression.

For the first example, isolate *x* in the equation

$$a(x + 3) - b = c.$$

This example is simple because there is only one occurrence of *x*. Later examples show how to manipulate the equation to produce a single occurrence of *x*.

0. Press ■ [CLEAR] to clear the stack.

1. Press [SOLV] to display the SOLVE menu.

```
3:
2:
1:
 STEQ  RCEQ  SOLVR  ISOL  QUAD  SHOW
```

2. Press ['] [A] [×] [(] [X] [+] [3] ■ [)] [−] [B] [=] [C] [ENTER] to put the equation on the stack.

```
3:
2:
1:              'A*(X+3)-B=C'
 STEQ  RCEQ  SOLVR  ISOL  QUAD  SHOW
```

3. Press ['] [X] to specify the variable you want to isolate.

```
2:
1:              'A*(X+3)-B=C'
'X█
 STEQ  RCEQ  SOLVR  ISOL  QUAD  SHOW
```

4. Press **ISOL** to isolate *x*.

```
3:
2:
1:              '(C+B)/A-3'
STEQ RCEQ SOLVR ISOL QUAD SHOW
```

The expression returned represents a symbolic solution of the equation for *x*—that is, the equation

$$a(x + 3) - b = c$$

is satisfied when $x = (c + b)/a - 3$.

Expanding and Collecting

If *x* occurs more than once, you must manipulate the equation to eliminate all but one occurrence of *x*. The next example shows how to isolate *x* in the equation

$$2(a + x) = 3(b - x) + c.$$

The strategy is to expand the equation, subtract one side's *x*-term from both sides, collect the equation to cancel the *x*-term on one side and produce a single *x*-term on the other side, and then isolate.

5. Press ['] [2] [×] [(] [A] [+] [X] ■ [)] [=] [3] [×] [(] [B] [−] [X] ■ [)] [+] [C] [ENTER] to put the equation on the stack.

```
3:
2:              '(C+B)/A-3'
1:   '2*(A+X)=3*(B-X)+C'
STEQ RCEQ SOLVR ISOL QUAD SHOW
```

6. Press ■ [ALGEBRA] to select the ALGEBRA menu.

```
3:
2:              '(C+B)/A-3'
1:   '2*(A+X)=3*(B-X)+C'
COLCT EXPAN SIZE FORM OBSUB EXSUB
```

In this example you'll use EXPAN (*expand*) and COLCT (*collect*) to manipulate the equation. In the next example you'll use FORM (*form algebraic expression*) to manipulate an equation. All commands in the ALGEBRA menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "ALGEBRA" in the Reference Manual. In addition, FORM, a powerful algebraic editor, has its own section "ALGEBRA (FORM)" in the Reference Manual.

7. Press EXPAN to expand both sides of the equation.

```
3:
2:               '(C+B)/A-3'
1:   '2*A+2*X=3*B-3*X+C'
COLCT EXPAN SIZE FORM OBSUB EXSUB
```

8. Subtract the left side's *x*-term (2*x*) from both sides of the equation.

a. Press ['] [2] [×] [X] [ENTER] to put the left side's *x*-term on the stack.

```
3:               '(C+B)/A-3'
2:   '2*A+2*X=3*B-3*X+C'
1:                    '2*X'
COLCT EXPAN SIZE FORM OBSUB EXSUB
```

b. Press [−] to subtract 2*x* from both sides.

```
2:               '(C+B)/A-3'
1:  '2*A+2*X-2*X=3*B-3*X
    +C-2*X'
COLCT EXPAN SIZE FORM OBSUB EXSUB
```

9. Press COLCT to collect the equation. Each side is collected independently, and the x-terms cancel on the left side.

```
3:
2:               '(C+B)/A-3'
1:          '2*A=3*B+C-5*X'
COLCT EXPAN SIZE FORM OBSUB EXSUB
```

10. Isolate x in the equation.

a. Press [NEXT] to display the second row of the ALGEBRA menu. The command ISOL appears in this menu as well as the SOLVE menu.

```
3:
2:               '(C+B)/A-3'
1:          '2*A=3*B+C-5*X'
TAYLR ISOL QUAD SHOW OBGET EXGET
```

b. Press ['] [X] ISOL to isolate x.

```
3:
2:               '(C+B)/A-3'
1:          '(3*B+C-2*A)/5'
TAYLR ISOL QUAD SHOW OBGET EXGET
```

The expression returned represents a symbolic solution of the equation for x—that is, the equation

$$2(a + x) = 3(b - x) + c$$

is satisfied when $x = (3b + c - 2a)/5$.

Using FORM

If there are multiple occurrences of x, and if any occurrence has a symbolic coefficient, the command COLCT won't combine the coefficients. The next example isolates x in the equation

$$a(x + b) + 2x = c,$$

where x occurs more than once and has a symbolic coefficient a. The strategy is to expand the equation, use FORM to collect coefficients of x, and then isolate x.

11. Press ['] [A] [×] [(] [X] [+] [B] [■] [)] [+] [2] [×] [X] [=] [C] [ENTER] to put the equation on the stack.

```
3:             '(C+B)/A-3'
2:         '(3*B+C-2*A)/5'
1:         'A*(X+B)+2*X=C'
TAYLR ISOL QUAD SHOW OBGET EXGET
```

12. Expand the equation.

a. Press [NEXT] to return to the first row of the ALGEBRA menu.

```
3:             '(C+B)/A-3'
2:         '(3*B+C-2*A)/5'
1:         'A*(X+B)+2*X=C'
COLCT EXPAN SIZE FORM OBSUB EXSUB
```

b. Press EXPAN to expand the equation.

```
3:             '(C+B)/A-3'
2:         '(3*B+C-2*A)/5'
1:         'A*X+A*B+2*X=C'
COLCT EXPAN SIZE FORM OBSUB EXSUB
```

Now use FORM to collect the coefficients of x.

13. Press FORM to start FORM. Normal calculator operation is suspended while FORM is active. The FORM display shows the equation with all subexpressions delimited by parentheses. You'll use FORM to manipulate subexpressions within the equation.

```
((((A*X)+(A*B))+(2*X))=
C)
COLCT EXPAN LEVEL EXGET  [←]   [→]
```

The goal is to combine (A*X) and (2*X) in a single term ((A+2)*X). There are three steps required, shown below as you might write them on paper. The current form of the equation is:

$$(ax + ab) + 2x = c$$

The first step is to commute ax and ab, giving:

$$(ab + ax) + 2x = c$$

The second step is to associate ax and $2x$, giving:

$$ab + (ax + 2x) = c$$

The third step is to merge ax and $2x$, giving:

$$ab + (a + 2)\, x = c$$

14. Commute *ax* and *ab*.

a. Press [illegible] three times to move the cursor (the inverse character or characters) to +. The position of the cursor determines which subexpression you're acting on. Here you want to act on the subexpression `((A*X)+(A*B))` to commute the arguments to +.

```
((((A*X)+(A*B))+(2*X))=
C)
COLCT EXPAN LEVEL EXGET [←] [→]
```

b. Press [NEXT] to display the first row of manipulations for +. (The manipulations that appear when you press [NEXT] are specific to the function or variable indicated by the cursor.)

```
((((A*X)+(A*B))+(2*X))=
C)
 -()   ←→   ←M   M→   ←A   A→
```

c. Press [illegible] (*commute*) to commute the arguments to +.

```
((((A*B)+(A*X))+(2*X))=
C)
 -()   ←→   ←M   M→   ←A   A→
```

d. Press [ENTER] to return to the main FORM menu.

```
((((A*B)+(A*X))+(2*X))=
C)
COLCT EXPAN LEVEL EXGET [←] [→]
```

15. Associate *ax* and 2*x*.

a. Press [→] four times to move the cursor to the second +. Here you want to act on the subexpression (((A*B)+(A*X))+(2*X)) to associate the terms (A*X) and (2*X) in a single subexpression.

```
((((A*B)+(A*X))+(2*X))=
C)
COLCT EXPAN LEVEL EXGET  [←]  [→]
```

b. Press NEXT to display the first row of manipulations for +. (These are the same manipulations as before because the cursor again indicated an additive subexpression.)

```
((((A*B)+(A*X))+(2*X))=
C)
 -()   ←→   ←M   M→   ←A   A→
```

c. Press A→ (*associate right*) to associate the terms (A*X) and (2*X) in the subexpression ((A*X)+(2*X)).

```
(((A*B)+((A*X)+(2*X)))=
C)
 -()   ←→   ←M   M→   ←A   A→
```

d. Press ENTER to return to the main FORM menu.

```
(((A*B)+((A*X)+(2*X)))=
C)
COLCT EXPAN LEVEL EXGET  [←]  [→]
```

16. Merge *ax* and 2*x*.

a. Press [→] four times to move the cursor to the second +. Here you want to act on the subexpression `((A*X)+(2*X))` to combine the coefficients of `X`.

```
(((A*B)+((A*X)+(2*X)))=
C)
COLCT EXPAN LEVEL EXGET  [←]   [→]
```

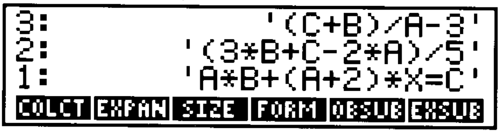
b. Press NEXT to display the first row of manipulations for +.

```
(((A*B)+((A*X)+(2*X)))=
C)
 -()   ←→   ←M    M→    ←A    A→
```

c. Press M→ (*merge right*) to combine the coefficients of `X`. This accomplishes the goal of combining `(A*X)` and `(2*X)` in a single term `((A+2)*X)`.

```
(((A*B)+((A+2)*X))=C)
 1/()  ←→   ←D    D→    ←A    A→
```

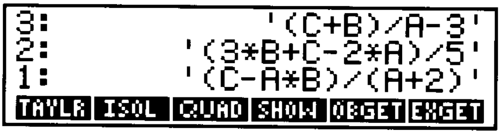
17. Press [ON] to exit FORM and return the modified equation to the stack.



18. Now that *x* occurs only once in the equation, you can isolate *x*.

a. Press [NEXT] to display the second row of the ALGEBRA menu.

b. Press ['] [X] **ISOL** to isolate *x*.



The expression returned represents a symbolic solution of the equation for *x*—that is, the equation

$$a(x + b) + 2x = c$$

is satisfied when $x = (c - ab)/(a + 2)$.

12

Calculus

You can differentiate and integrate many expressions on the HP-28C. For a polynomial expression you can find the derivative and the indefinite integral. For expressions including only arithmetic, trigonometric, logarithmic, exponential, and hyperbolic functions, you can find the derivative. For any expression you can find definite integrals.

This chapter contains simple examples of finding derivatives, indefinite integrals, and definite integrals for expressions. For more information about doing calculus on the HP-28C, refer to "Calculus" in the Reference Manual.

0. Prepare your calculator to match the illustrations.

- **a.** Press ■ [CLEAR] to clear the stack.
- **b.** Press ■ [MODE] [RAD] to select radians angle mode. The (2π) annunciator appears.
- **c.** Press [STD] to select STD number display mode.
- **d.** Press [◂▴▸] to select the cursor menu.
- **e.** Press ['] [X] ■ [PURGE] to purge the variable X (if it exists).

Differentiating an Expression

You can differentiate an expression step-by-step, observing how the calculator applies the rules of differentiation, or you can differentiate an expression all at once. The final results are identical. You'll differentiate an expression twice, first step-by-step and then all at once.

Step-by-Step Differentiation

To differentiate step-by-step, key in the derivative as a expression. Suppose you want to find:

$$\frac{d}{dx} \tan (x^2 + 1)$$

1. Key in the derivative.

a. Press ['] ■ [d/dx] [X] [(]. The command line shows:

```
3:
2:
1:
'∂X(▯
```

This part of the expression indicates that you're differentiating with respect to X.

b. Press [TRIG] [TAN]. The command line shows:

```
2:
1:
'∂X(TAN(▯
 SIN | ASIN | COS | ACOS | TAN | ATAN
```

c. Press [X] ■ [^] [2] [+] [1]. The command line shows:

```
2:
1:
'∂X(TAN(X^2+1▯
 SIN | ASIN | COS | ACOS | TAN | ATAN
```

d. Press [ENTER]. The expression is now in level 1.

2. Press [EVAL]. The display shows:

```
2:
1:  '(1+SQ(TAN(X^2+1)))*
    ∂X(X^2+1)'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

The result reflects the chain rule of differentiation:

$$\frac{d}{dx} \tan (x^2 + 1) = \frac{d}{d(x^2 + 1)} \tan (x^2 + 1) \times \frac{d}{dx} (x^2 + 1)$$

The derivative of tan has been evaluated. Next you'll evaluate the derivative of $x^2 + 1$.

3. Press [EVAL]. The display shows:

```
2:
1:  '(1+SQ(TAN(X^2+1)))*
    ∂X(X^2)'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

The result reflects the derivative of a sum:

$$\frac{d}{dx} (x^2 + 1) = \frac{d}{dx} x^2 + \frac{d}{dx} 1$$

The derivative of 1 is 0, so that term disappears. Next you'll evaluate the derivative of x^2.

4. Press [EVAL]. The display shows:

```
2:
1:  '(1+SQ(TAN(X^2+1)))*
    (∂X(X)*2*X^(2-1))'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

The result again reflects the chain rule:

$$\frac{d}{dx}\,x^2 = \frac{d}{dx}\,x^2 \times \frac{d}{dx}\,x$$

The derivative of x^2 has been evaluated. Finally, evaluate the derivative of x itself.

5. Press [EVAL]. The display shows:

```
2:
1:  '(1+SQ(TAN(X^2+1)))*
    (2*X)'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

Here is the fully evaluated derivative.

Complete Differentiation

To differentiate an expression all at once, perform differentiation as a stack operation. Again, suppose you want to find:

$$\frac{d}{dx}\,\tan\,(x^2 + 1)$$

1. Press ['] TAN [X] ■[^] [2] [+] [1] [ENTER]. The expression is in level 1.

```
3:
2:  '(1+SQ(TAN(X^2+1)))…
1:          'TAN(X^2+1)'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

2. Press ['] [X] [ENTER]. The name indicates that you're differentiating with respect to X. The variable of differentiation is in level 1, and the expression is in level 2.

```
3:  '(1+SQ(TAN(X^2+1)))…
2:          'TAN(X^2+1)'
1:                   'X'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

3. Press ■[d/dx]. The fully evaluated derivative is returned to level 1.

```
2:  '(1+SQ(TAN(X^2+1)))…
1:  '(1+SQ(TAN(X^2+1)))*
    (2*X)'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

Integrating an Expression

The HP-28C calculates the indefinite integral of an expression by *symbolic integration,* which returns an expression as a result. This method returns an exact result only for polynomial expressions. (For other expressions, the HP-28C integrates a Taylor series approximation to the expression. See "Calculus" in the Reference Manual for details.) The first example below demonstrates symbolic integration.

In contrast, definite integrals are calculated by *numerical integration,* which returns numerical results. This method works for any expression that is "well-behaved" in the mathematical sense. The second example below demonstrates numerical integration.

Symbolic Integration of Polynomials

In this example you'll symbolically integrate the polynomial

$$8x^3 + 9x^2 + 2x + 5.$$

0. Press ■[CLEAR] to clear the stack.

1. Press ['] [8] [×] [X] ■[^] [3] [+] [9] [×] [X] ■[^] [2] [+] [2] [×] [X] [+] [5]. The command line shows:

```
2:
1:
'8*X^3+9*X^2+2*X+5█
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

2. Press [ENTER] to put the expression in level 1.

3. Press ['] [X] [ENTER]. The name indicates that you're integrating with respect to x. The variable of integration is in level 1, and the expression is in level 2.

```
3:
2:   '8*X^3+9*X^2+2*X+5'
1:                  'X'
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

4. Press [3] [ENTER]. This number indicates that you're integrating a third-degree polynomial. The degree is in level 1, the variable of integration is in level 2, and the expression is in level 3.

```
3:   '8*X^3+9*X^2+2*X+5'
2:                  'X'
1:                    3
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

5. Press ■[∫] to begin integration. Wait for the ((•)) annunciator to disappear, indicating that integration is completed. The integral is returned to level 1.

```
2:
1:  '5*X+X^2+3*X^3+2*X^4
 SIN  ASIN  COS  ACOS  TAN  ATAN
```

Numerical Integration of Expressions

In this example you'll find a numerical value for the integral.

$$\int_0^1 \exp\,(x^3 + 2x^2 - x + 4)\,dx$$

0. Press ■[CLEAR] to clear the stack.
1. Key in the expression.
   a. Press ■[LOGS] to display the LOGS menu.

```
3:
2:
1:
 LOG  ALOG  LN  EXP  LNP1  EXPM
```

   b. Press ['] EXP. The command line shows:

```
2:
1:
'EXP(
 LOG  ALOG  LN  EXP  LNP1  EXPM
```

c. Press [X] ■[^] [3] [+] [2] [×] [X] ■[^] [2] [−] [X] [+] [4]. The command line shows:

```
2:
1:
'EXP(X^3+2*X^2-X+4█
 LOG  ALOG  LN  EXP  LNP1 EXPM
```

d. Press [ENTER]. The expression is now in level 1.

2. Key in the variable and limits of integration. You'll enter them as objects within a list object. (This is a typical use of a list—combining several objects so you can handle them as a single object.)

a. Press [{]. The brace begins the list object that will contain the variable and limits of integration.

b. Press [X] [SPACE] to enter the variable of integration as the first object in the list.

```
2:
1:  'EXP(X^3+2*X^2-X+4)'
{X □
 LOG  ALOG  LN  EXP  LNP1 EXPM
```

c. Press [0] [SPACE] [1] to enter the limits of integration as the second and third objects in the list.

```
2:
1:  'EXP(X^3+2*X^2-X+4)'
{X 0 1□
 LOG  ALOG  LN  EXP  LNP1 EXPM
```

d. Press [ENTER]. The list is now in level 1, and the expression is in level 2.

```
3:
2:  'EXP(X^3+2*X^2-X+4)'
1:               { X 0 1 }
 LOG  ALOG  LN   EXP  LNP1 EXPM
```

3. Key in the accuracy you require.

If the expression included constants derived from empirical data, specify the accuracy of the constants. For example, if the constants are accurate to three decimal places, specify an accuracy of .001.

In this example you're integrating an expression without empirical constants, so you could specify 12-digit accuracy. However, the iterative process of numerical integration takes longer for greater accuracy, so specify an accuracy of .00001.

a. Press [EEX] [CHS] [5]. The command line shows:

```
2:  'EXP(X^3+2*X^2-X+4)'
1:               { X 0 1 }
1E-5□
 LOG  ALOG  LN   EXP  LNP1 EXPM
```

b. Press [ENTER]. The accuracy is in level 1, the variable and limits of integration in level 2, and the expression in level 3.

```
3:  'EXP(X^3+2*X^2-X+4)'
2:               { X 0 1 }
1:                  .00001
 LOG  ALOG  LN   EXP  LNP1 EXPM
```

4. Press ■[∫]. The busy annunciator ((•)) is displayed while the calculator estimates the definite integral. The estimated integral is returned to level 2, and an error bound is returned to level 1.

```
3:
2:        103.117678153
1:     1.03086911923E-3
 LOG  ALOG  LN  EXP  LNP1 EXPM
```

The value of the integral is 103.118 ± .001. Note that the error bound returned is approximately the product of the estimated integral and the accuracy you specified.

13

Vectors and Matrices

Linear algebra deals with two types of arrays: *vectors*, which are one-dimensional arrays, and *matrices*, which are two-dimensional arrays. The HP-28C allows you to enter vectors and matrices as individual objects, called *array objects*, and calculate with them as easily as with numbers.

This chapter shows basic array calculations using real arrays—vectors and matrices whose elements are real numbers. You can also calculate with arrays whose elements are complex numbers.

All commands in the ARRAY menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "ARRAY" in the Reference Manual.

0. Prepare your calculator to match the illustrations.

- **a.** Press ■ [CLEAR] to clear the stack.
- **b.** Press ■ [MODE] STD to select STD number display mode.
- **c.** Press [◆] to select the cursor menu.

Vectors

This section demonstrates vector arithmetic, the cross product, and the dot product.

Keying In a Vector

1. Press [[] to start the vector.
2. Press [2] to enter the first element. The command line shows:

```
3:
2:
1:
[2□
```

3. Press [SPACE] [3] to enter the second element.
4. Press [SPACE] [4] to enter the third element. The command line shows:

```
3:
2:
1:
[2 3 4□
```

5. Press [ENTER]. The vector is in level 1.

```
4:
3:
2:
1:                  [ 2 3 4 ]
```

Multiplying a Vector and a Number

Multiply the vector in level 1 by 15. (The order of the arguments makes no difference, just as it makes no difference when you multiply two numbers.)

6. Press `1` `5` `×`. The result is returned to level 1.

```
4:
3:
2:
1:              [ 30 45 60 ]
```

Adding and Subtracting Vectors

You can add and subtract vectors just as you add and subtract numbers, provided that the vectors have the same number of elements. For subtraction, the order of the arguments is important, just as it's important when you subtract one number from another.

For this example, subtract the vector [−10 20 30] from the vector in level 1.

7. Press `[` `1` `0` `CHS` `SPACE` `2` `0` `SPACE` `3` `0`. The command line shows:

```
3:
2:
1:              [ 30 45 60 ]
[-10 20 30□
```

8. Press `−`. The result is returned to level 1.

```
4:
3:
2:
1:              [ 40 25 30 ]
```

Finding the Cross Product

Find the cross product of the vector in level 1 with the vector [2 −2 1]. (The cross product is defined only for three-element vectors.)

9. Press [[] [2] [SPACE] [2] [CHS] [SPACE] [1]. The command line shows:

```
3:
2:
1:               [ 40 25 30 ]
[2 -2 1□
```

10. Execute the CROSS command.

a. Press ■[ARRAY] to display the ARRAY menu.

```
2:
1:               [ 40 25 30 ]
[2 -2 1□
→ARRY ARRY→ PUT GET PUTI GETI
```

b. Press [NEXT] twice to display the third row of the ARRAY menu.

```
2:
1:               [ 40 25 30 ]
[2 -2 1□
CROSS DOT DET ABS RNRM CNRM
```

c. Press CROSS to return the cross product to level 1.

```
3:
2:
1:           [ 85 20 -130 ]
CROSS DOT DET ABS RNRM CNRM
```

Finding the Dot Product

Find the dot product of the vector currently in level 1 with the vector [5 7 2]. (The two vectors must have the same number of elements.)

11. Press [[] [5] [SPACE] [7] [SPACE] [2]. The command line shows:

12. Press DOT to return the dot product to level 1.

13. Press [DROP] to clear the stack.

Matrices

This section describes how to invert a matrix and how to find the determinant of a matrix. Both of these calculations are restricted to a *square* matrix—one with the same number of rows as columns.

The calculations you performed on vectors also apply to matrices (with the exception of the dot and cross products). You can multiply a matrix and a number in the same way that you multiplied a vector and a number. Also, you can add or subtract two matrices, provided that the matrices have the same dimensions.

Keying In a Matrix

To key in the matrix:

$$\begin{bmatrix} 1 & 2 & 3 \\ 1 & 3 & 3 \\ 1 & 2 & 4 \end{bmatrix}$$

1. Press [[] to start the matrix.
2. Press [[] [1] [SPACE] [2] [SPACE] [3] to enter the first row of the matrix. The command line shows:

```
2:
1:
[[1 2 3□
CROSS  DOT  DET  ABS  RNRM  CNRM
```

3. Press [[] [1] [SPACE] [3] [SPACE] [3] to enter the second row of the matrix. The command line shows:

```
2:
1:
[[1 2 3[1 3 3□
CROSS  DOT  DET  ABS  RNRM  CNRM
```

4. Press [[] [1] [SPACE] [2] [SPACE] [4] to enter the third row of the matrix. The command line shows:

```
2:
1:
[[1 2 3[1 3 3[1 2 4□
CROSS  DOT  DET  ABS  RNRM  CNRM
```

5. Press [ENTER] to put the matrix in level 1.

```
1: [[ 1 2 3 ]
    [ 1 3 3 ]
    [ 1 2 4 ]]
CROSS DOT DET ABS RNRM CNRM
```

Viewing a Large Matrix

When a matrix has many elements or non-integer elements, you may not see the entire matrix at once. To view a large matrix, use ■[EDIT] (if the matrix is in level 1) or ■[VISIT] to return the matrix to the command line. You can then use the cursor menu keys to display any part of the matrix. For details, refer to "Editing Objects" on page 80.

Inverting a Matrix

Because the matrix in level 1 is square, you can find its inverse.

6. Press ■[1/x]. The inverse matrix is returned to level 1.

```
1: [[ 6 -2 -3 ]
    [ -1 1 0 ]
    [ -1 0 1 ]]
CROSS DOT DET ABS RNRM CNRM
```

Finding the Determinant

Because the matrix in level 1 is square, you can find its determinant.

7. Press DET. The determinant is returned to level 1.

8. Press [DROP] to clear the stack.

Multiplying Two Arrays

You can use the [×] function to multiply two matrices or a matrix and a vector. (Use CROSS or DOT to multiply two vectors, as described above.)

Multiplying Two Matrices

The order of the arguments is important when multiplying two matrices. The number of *columns* in the matrix in level 2 must equal the number of *rows* in the matrix in level 1. For example, you can calculate the following matrix product.

$$\begin{bmatrix} 2 & 2 \\ 4 & 1 \\ 2 & 3 \end{bmatrix} \begin{bmatrix} 2 & 2 & 1 & 4 \\ 3 & 4 & 2 & 1 \end{bmatrix}$$

To calculate this matrix product:

1. Enter the first matrix.

   a. Press [[] to begin the first matrix.

   b. Press [[] [2] [SPACE] [2] to enter the first row. The command line shows:

```
2:
1:
[[2 2□
CROSS DOT DET ABS RNRM CNRM
```

   c. Press [[] [4] [SPACE] [1] to enter the second row. The command line shows:

```
2:
1:
[[2 2[4 1□
CROSS DOT DET ABS RNRM CNRM
```

   d. Press [[] [2] [SPACE] [3] to enter the third row. The command line shows:

```
2:
1:
[[2 2[4 1[2 3□
CROSS DOT DET ABS RNRM CNRM
```

   e. Press [ENTER]. The first matrix is now in level 1.

```
1:  [[ 2 2 ]
     [ 4 1 ]
     [ 2 3 ]]
CROSS DOT DET ABS RNRM CNRM
```

2. Key in the second matrix.

a. Press [[] to begin the second matrix.

b. Press [[] [2] [SPACE] [2] [SPACE] [1] [SPACE] [4] to enter the first row. The command line shows:

```
1:  [[ 2 2 ]
      [ 4 1 ]
[[2 2 1 4
CROSS DOT DET ABS RNRM CNRM
```

c. Press [[] [3] [SPACE] [4] [SPACE] [2] [SPACE] [1] [ENTER]. The second matrix is now in level 1, and the first matrix is in level 2.

```
2:  [[ 2 2 ]  [ 4 1 ]  ...
1:  [[ 2 2 1 4 ]
      [ 3 4 2 1 ]]
CROSS DOT DET ABS RNRM CNRM
```

3. Press [×]. The product is returned to level 1.

```
1:  [[ 10 12 6 10 ]
      [ 11 12 6 17 ]
      [ 13 16 8 11 ]]
CROSS DOT DET ABS RNRM CNRM
```

Multiplying a Matrix and a Vector

The order of the arguments is important when multiplying a matrix and a vector. The matrix must be in level 2, and the vector must be in level 1. The number of *columns* in the matrix must equal the number of *elements* in the vector.

To multiply the matrix currently in level 1 by the vector [3 1 1 2]:

4. Key in the vector.

   a. Press [[] to start the vector.

   b. Press [3] [SPACE] [1] [SPACE] [1] [SPACE] [2]. The command line shows:

```
1:  [[ 10 12 6 10 ]
     [ 11 12 6 17 ]
[3 1 1 2□
CROSS DOT DET ABS RNRM CNRM
```

5. Press [×]. The product is returned to level 1.

```
3:
2:
1:             [ 68 85 85 ]
CROSS DOT DET ABS RNRM CNRM
```

6. Press [DROP] to clear the stack.

Solving a System of Linear Equations

To solve a system of n linear equations with n variables, use an n-element *constant* vector, an $n \times n$ *coefficient* matrix, and division ([÷]). The constant vector contains the constant values of the equations. The coefficient matrix contains the coefficients of the variables.

The next example shows how to solve a system of three linearly independent equations in three variables. Suppose the equations are

$$\begin{aligned} 3x + y + 2z &= 13 \\ x + y - 8z &= -1 \\ -x + 2y + 5z &= 13 \end{aligned}$$

1. Key in the constant vector.

a. Press [[ ] to begin the constant vector.

b. Press [1] [3] [SPACE] [1] [CHS] [SPACE] [1] [3]. The command line shows:

```
2:
1:
[13 -1 13□
CROSS  DOT  DET  ABS  RNRM  CNRM
```

c. Press [ENTER]. The constant vector is now in level 1.

```
3:
2:
1:              [ 13 -1 13 ]
CROSS  DOT  DET  ABS  RNRM  CNRM
```

2. Key in the coefficient matrix.

   a. Press [[] to begin the coefficient matrix.

   b. Press [[] [3] [SPACE] [1] [SPACE] [2] to enter the first row. The command line shows:

```
2:
1:              [ 13 -1 13 ]
[[3 1 2□
CROSS  DOT  DET  ABS  RNRM  CNRM
```

   c. Press [[] [1] [SPACE] [1] [SPACE] [8] [CHS] to enter the second row. The command line shows:

```
2:
1:              [ 13 -1 13 ]
[[3 1 2[1 1 -8□
CROSS  DOT  DET  ABS  RNRM  CNRM
```

   d. Press [[] [1] [CHS] [SPACE] [2] [SPACE] [5] to enter the third row. The command line shows:

```
2:
1:              [ 13 -1 13 ]
[[3 1 2[1 1 -8[-1 2 5□
CROSS  DOT  DET  ABS  RNRM  CNRM
```

3. Press [÷]. The solution vector is returned to level 1.

```
3:
2:
1:                    [ 2 5 1 ]
CROSS  DOT  DET  ABS  RNRM  CNRM
```

The values in the solution vector are the values of the variables that satisfy the equations:

$$x = 2, \quad y = 5, \quad z = 1$$

To solve under-determined, over-determined, or near-singular systems of equations, refer to "ARRAY" in the Reference Manual.

14

Statistics

This chapter describes how to enter statistical data and how to calculate single-sample and paired-sample statistics, using commands in the STAT menu. All commands in the STAT menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "STAT" in the Reference Manual.

0. Prepare your calculator to match the illustrations.

a. Press ■[CLEAR] to clear the stack.

b. Press ■[MODE] [2] FIX to select FIX 2 number display mode.

The following table lists the consumer price index change (CPI), the producer price index change (PPI), and the unemployment rate (UR), all in percentages, for the United States over a 5-year period. Enter these data and calculate statistics from them.

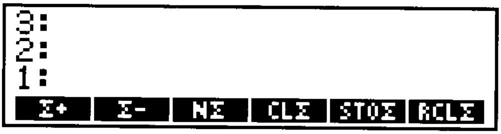
Data for Statistical Example

Year	CPI	PPI	UR
1975	9.1	9.2	8.5
1976	5.8	4.6	7.7
1977	6.5	6.1	7.0
1978	7.6	7.8	6.0
1979	11.5	19.3	5.8

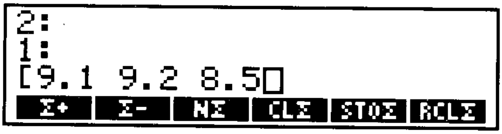
Entering Data

Statistical data are stored in a statistics matrix named ΣDAT—an ordinary matrix with a special name. Each row of the matrix contains one data point, which in this example comprises the values of CPI, PPI, and UR for one year.

1. Press ■[STAT] to display the STAT menu.



2. Press [illegible] to clear any previous statistical data. (Any existing ΣDAT is purged.)
3. Press [[] [9] [.] [1] [SPACE] [9] [.] [2] [SPACE] [8] [.] [5] to enter the data point for 1975. The command line shows:



4. Press [illegible]. The data point is added to ΣDAT. (Because you purged ΣDAT in step 2, a new matrix named ΣDAT is automatically created.) The data point for 1975 is the first row of ΣDAT.
5. Press [[] [5] [.] [8] [SPACE] [4] [.] [6] [SPACE] [7] [.] [7] [illegible]. The data point for 1976 is added to ΣDAT, forming the second row of the statistics matrix.
6. Press [[] [6] [.] [5] [SPACE] [6] [.] [1] [SPACE] [7] [illegible]. The data point for 1977 is added to ΣDAT, forming the third row of the statistics matrix.

Editing Data

If you make a mistake while keying in data, and you realize your mistake before pressing Σ+, you can simply edit the command line. But suppose you believe that you made a mistake entering the data point for 1976. You can return data points to the stack, edit those that contain mistakes, and restore the data points to ΣDAT.

7. Press Σ-. The data point for 1977 (the last row in ΣDAT) is removed from ΣDAT and returned to the stack.

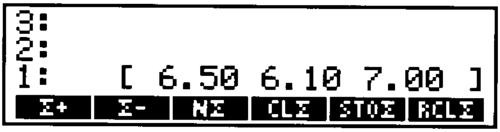
```
3:
2:
1:     [ 6.50 6.10 7.00 ]
 Σ+  | Σ-  | NΣ  | CLΣ | STOΣ| RCLΣ
```

8. Press Σ- a second time. The data point for 1976 is removed from ΣDAT and returned to the stack.

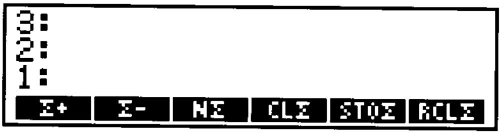
```
3:
2:     [ 6.50 6.10 7.00 ]
1:     [ 5.80 4.60 7.70 ]
 Σ+  | Σ-  | NΣ  | CLΣ | STOΣ| RCLΣ
```

9. If you find you did make a mistake in this data point, press ■ [EDIT] to return the data point to the command line, edit the data point, and press [ENTER] to put the corrected data point back on the stack. (Refer to "Editing Objects" on page 80.)

10. Press [Σ+]. The corrected data point for 1976 is added to ΣDAT, again forming the second row of the statistics matrix.



11. Press [Σ+] a second time. The data point for 1977 is added to ΣDAT, again forming the third row of the statistics matrix.



Now enter the rest of the data.

12. Press [[] [7] [·] [6] [SPACE] [7] [·] [8] [SPACE] [6] [Σ+] to add the data point for 1978.

13. Press [[] [1] [1] [·] [5] [SPACE] [1] [9] [·] [3] [SPACE] [5] [·] [8] [Σ+] to add the data point for 1979.

Check that you entered all five data points.

14. Press NΣ to return the number of data points.

15. Press DROP to clear the stack.

Single-Sample Statistics

In this section you'll find the mean, standard deviation, and variance of CPI, PPI, and UR. The data for CPI are contained in the first column of ΣDAT, the data for PPI in the second column, and the data for UR in the third column.

1. Press NEXT to display the second row of the STAT menu.

Here are the commands for mean, standard deviation, and variance.

Finding the Mean

2. Press MEAN. A vector containing the means for CPI, PPI, and UR is returned to level 1.

```
3:
2:
1:    [ 8.10 9.40 7.00 ]
 TOT  MEAN SDEV  VAR  MAXΣ MINΣ
```

The mean for CPI is 8.1, for PPI is 9.4, and for UR is 7.

Finding the Standard Deviation

3. Press SDEV. A vector containing the sample standard deviations for CPI, PPI, and UR is returned to level 1.

```
3:
2:    [ 8.10 9.40 7.00 ]
1:    [ 2.27 5.80 1.14 ]
 TOT  MEAN SDEV  VAR  MAXΣ MINΣ
```

The sample standard deviation for CPI is 2.27, for PPI is 5.8, and for UR is 1.14.

Finding the Variance

4. Press **VAR**. A vector containing the sample variances for CPI, PPI, and UR is returned to level 1.

```
3:     [ 8.10 9.40 7.00 ]
2:     [ 2.27 5.80 1.14 ]
1:   [ 5.17 33.64 1.30 ]
 TOT  MEAN  SDEV  VAR  MAXΣ  MINΣ
```

The sample variance for CPI is 5.17, for PPI is 33.64, and for UR is 1.3.

5. Press ■ [CLEAR] to clear the stack.

Paired-Sample Statistics

In this section you'll find the correlation and covariance of CPI and PPI, then use a linear regression model to predict values of PPI from values of CPI.

1. Press [NEXT] to display the third row of the STAT menu.

```
3:
2:
1:
 COLΣ  CORR  COV  LR  PREDV
```

Here are the commands for correlation, covariance, linear regression, and predicted value.

Specifying a Pair of Columns

Before performing paired-sample statistics, specify which columns of the statistics matrix ΣDAT contain the independent and dependent data. In this example you want CPI (in column 1) to be the independent data and PPI (in column 2) to be the dependent data.

2. Press [1] [SPACE] [2] COLΣ . The numbers 1 and 2 are stored in a list named ΣPAR, which is an ordinary list with a special name. The commands that perform paired-sample statistics refer to ΣPAR.

If you don't specify the columns containing the independent and dependent data, the calculator uses columns 1 and 2. In this example you didn't need to specify the columns, but remember to execute COLΣ if your independent and dependent data aren't contained in columns 1 and 2.

Finding the Correlation

3. Press CORR . The correlation of CPI and PPI is returned to level 1.

Finding the Covariance

4. Press **COV**. The sample covariance of CPI and PPI is returned to level 1.

```
3:
2:                    0.96
1:                   12.65
 COLΣ  CORR  COV   LR   PREDV
```

Finding the Linear Regression

5. Press **LR**. The calculator finds the straight line that best fits the data for CPI and PPI, returning the intercept to level 2 and the slope to level 1.

```
3:                   12.65
2:                  -10.43
1:                    2.45
 COLΣ  CORR  COV   LR   PREDV
```

The intercept (−10.43) and slope (2.45) are also stored in the list ΣPAR.

Finding Predicted Values

Suppose you want to find the predicted values for PPI when CPI has values of 6 and 7.

6. Press [6] PREDV. The predicted value is returned to level 1.

The predicted value is calculated from the slope and intercept stored in ΣPAR.

7. Press [7] PREDV. The predicted value is returned to level 1.

15

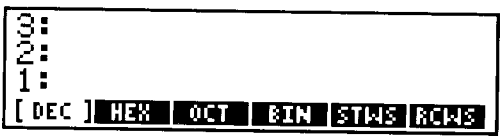
Binary Arithmetic

This chapter describes how to perform arithmetic with binary integers. Each binary integer contains from 1 to 64 bits and represents an unsigned binary number. For ease in entering binary numbers and reading the results, you can choose decimal, hexadecimal, octal or binary base. However, this choice doesn't affect the internal representation of binary integers, and commands act on binary integers bit-by-bit.

All commands in the BINARY menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "BINARY" in the Reference Manual.

0. Press ■ [CLEAR] to clear the stack.

1. Press ■ [BINARY] to display the BINARY menu.



Selecting the Wordsize

The current wordsize affects the length of binary integers returned by commands and the display of binary integers on the stack. The current wordsize can range from 1 through 64 bits, with a default wordsize of 64 bits. Suppose you want a wordsize of 16.

2. Press [1] [6] STWS . The current wordsize is now 16. If you key in a binary integer longer than 16 bits, only the 16 least significant bits are displayed.

Selecting the Base

The current base affects the value of binary integers you key in and the display of binary integers on the stack. The choices for the base are decimal, hexadecimal, octal, and binary, with a default choice of decimal base. Suppose you want hexadecimal base.

3. Press HEX. The display shows:

```
3:
2:
1:
 DEC [ HEX ] OCT  BIN  STWS RCWS
```

The label for HEX now appears as black letters on a white background, indicating that the current base is HEX.

Entering Binary Integers

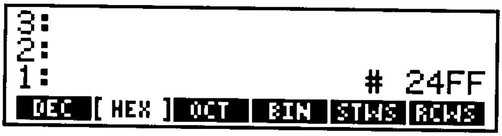
Key in the address $24FF_{16}$.

4. Press [#] [2] [4] [F] [F]. The command line shows:

```
2:
1:
#24FF□
 DEC [ HEX ] OCT  BIN  STWS RCWS
```

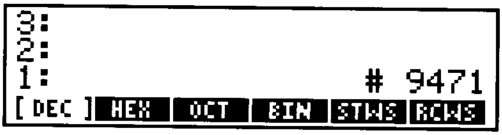
If you hadn't already selected HEX base, you would have to do so now. You can select the current base at any time before you press [ENTER].

5. Press [ENTER]. The binary integer is now in level 1.

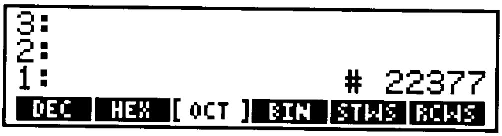


Let's see how this binary integer is represented in other bases. You don't need to change the binary integer, only the current mode.

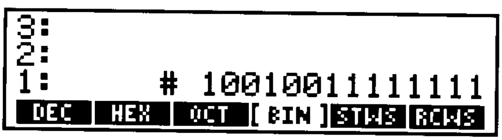
6. Press DEC. The binary integer is displayed in decimal base.



7. Press OCT. The binary integer is displayed in octal base.



8. Press BIN. The binary integer is displayed in binary base.



9. Press HEX. The binary integer is displayed in hexadecimal base.

```
3:
2:
1:                 # 24FF
 DEC [ HEX ] OCT  BIN  STWS RCWS
```

Calculating With Binary Integers

Calculate the address $1F0_{16}$ less than the given address.

10. Press [#] [1] [F] [0]. The command line shows:

```
2:
1:                 # 24FF
#1F0□
 DEC [ HEX ] OCT  BIN  STWS RCWS
```

11. Press [−]. The difference is returned to level 1.

```
3:
2:
1:                 # 230F
 DEC [ HEX ] OCT  BIN  STWS RCWS
```

You can mix binary integers and real numbers in your calculations. A normal real integer (entered without the # delimiter) is interpreted in base 10 regardless of the current binary integer base.

For example, to calculate the address 27_{10} less than the given address, simply key in 27 and subtract.

12. Press [2] [7] [-]. The difference, expressed as a binary integer, is returned to level 1.

16

Unit Conversion

This chapter contains examples of unit conversion—converting the numerical value of a physical measurement from one system of units to another. For detailed information, refer to "UNITS" in the Reference Manual.

0. Prepare your calculator to match the illustrations.

   a. Press ■[CLEAR] to clear the stack.

   b. Press ■[MODE] STD to select STD number display mode.

   c. Press [◄◆►] to select the cursor menu.

The UNITS Catalog

The UNITS catalog lists alphabetically all units built into the HP-28C.

1. Press ■[UNITS]. The first unit is "are", abbreviated "a". This is a unit of area equivalent to 100 meter^2.

2. Press SCAN. The catalog scans through the units in alphabetical order. Note that the SCAN menu label changes to STOP. If you press STOP to stop scanning or if you reach the end of the catalog, the label changes back to SCAN.

3. Press [S]. The catalog shows the entry for "second."

This entry shows that the correct abbreviation is "s," the full name is "second," and the value is 1 second.

Be sure to use the abbreviations exactly as they appear in the UNITS catalog. For example, the HP-28C recognizes lower-case "s" as seconds, but not upper-case "S".

"Second" is defined in terms of itself because it is a fundamental unit.

4. Press [D]. The catalog shows the entry for "day."

This entry shows that the correct abbreviation is "d," the full name is "day," and the value is 86,400 seconds.

Next look for the "foot" unit.

5. Press [F]. The catalog shows the entry for "farad."

6. Press NEXT seven times. The catalog shows the entry for "international foot."

```
ft  int'l foot
.3048
m
NEXT PREV SCAN      FETCH QUIT
```

(There are two versions of "foot" in the catalog; the next unit is "survey foot.") You can write the abbreviation for "international foot" to the command line.

7. Press FETCH. The normal display returns, and the command line shows:

```
3:
2:
1:
ft  □
```

The following examples show you how to key in units directly, but you can use ■ [UNITS] and FETCH if you prefer.

8. Press [ON] to clear the command line.

Converting Units

First convert 15 °C to degrees Fahrenheit.

1. Press [1] [5] [ENTER]. The numerical value is in level 1.

```
4:
3:
2:
1:                              15
```

2. Press ■[°] [C] [ENTER]. The unit abbreviation is converted to a name and put in level 1, and the numerical value is lifted to level 2.

3. Press ■[°] [F] [ENTER]. The new unit is in level 1, the old unit in level 2, and the numerical value in level 3.

4. Press ■[CONVERT]. The converted numerical value is returned to level 2, and the new unit is returned to level 1.

The result shows that 15 °C converts to 59 °F.

For the next example, convert 40 inches to millimeters. This time you'll let ■ [CONVERT] automatically execute ENTER for you.

5. Press ■ [CLEAR] to clear the stack.
6. Press [4] [0] [ENTER]. The numerical value is in level 1.

```
4:
3:
2:
1:                     40
```

7. Press [LC] [I] [N] [ENTER]. The numerical value is in level 2, and the old unit is in level 1.

```
4:
3:
2:                     40
1:                   'in'
```

Next key in mm for "millimeter." You won't find "millimeter" in the UNITS catalog. It's considered a *prefixed* unit—the unit m (for meter) prefixed by m (for milli, or one-thousandth). Similarly, km is a prefixed unit for kilometer, and ms is a prefixed unit for millisecond. A complete list of prefixes appears in "UNITS" in the Reference Manual.

8. Press [LC] [M] [M] ■ [CONVERT]. The converted numerical value is returned to level 2, and the new unit is returned to level 1.

```
4:
3:
2:                   1016
1:                   'mm'
```

The result shows that 40 inches converts to 1016 millimeters.

Converting Unit Strings

Strings are objects that contain characters. You can use *unit strings* to define more complicated units than those used so far.

A unit string can represent a unit raised to a power, such as "ft^2", or the product of units, such as "ft*lb", or any combination of unit powers and products.

A unit string can also represent a quotient of units, such as "m/sec". However, the / symbol can't appear more than once. Be sure to group all direct units *before* the / symbol and all inverse units *after* the / symbol. For example, "feet per second per second" is represented by "ft/s^2".

For the next example, convert 1 mile per hour to feet per second.

1. Press ■[CLEAR] to clear the stack.
2. Press [1] [ENTER]. The numerical value is in level 1.

```
4:
3:
2:
1:                               1
```

3. Press [LC] [M] [P] [H] [ENTER]. The old unit is in level 1, and the numerical value is in level 2.

```
4:
3:
2:                               1
1:                           'mph'
```

4. Press ■["] to start the unit string. Note that the alpha annunciator *α* appears, indicating that alpha entry mode is active. Pressing ■[CONVERT] won't automatically execute ENTER in alpha entry mode, so you'll need to press [ENTER] after keying in the unit string.
5. Press [LC] [F] [T] [÷] [S] [ENTER]. The new unit is in level 1, the old unit in level 2, and the numerical value in level 3.

```
4:
3:                  1
2:              'mph'
1:             "ft/s"
```

6. Press ■[CONVERT]. The converted numerical value is returned to level 2, and the new unit is returned to level 1.

```
4:
3:
2:       1.46666666667
1:             "ft/s"
```

The result shows that 1 mile per hour converts to 1.46666666667 feet per second.

Next convert 10 cubic feet to gallons.

7. Press ■[CLEAR] to clear the stack.
8. Press [1] [0] [ENTER]. The numerical value is in level 1.

```
4:
3:
2:
1:                 10
```

9. Press ■["] [LC] [F] [T] ■[^] [3] [ENTER]. The old unit is in level 1, and the numerical value is in level 2.

```
4:
3:
2:                    10
1:                "ft^3"
```

10. Press [LC] [G] [A] [L] ■[CONVERT]. The converted numerical value is returned to level 2, and the new unit is returned to level 1.

```
4:
3:
2:        74.8051948052
1:                'gal'
```

The result shows that 10 cubic feet converts to 74.8051948052 gallons.

Checking for the Correct Units

Using incorrect units can lead to unexpected numerical results or to an `Inconsistent Units` error. The solution in either case is to check the UNITS catalog or the "UNITS" section of the Reference Manual.

Unexpected numerical results can occur if you use a unit with the correct dimensions but an incorrect numerical value. For example, if you convert one acre to "ft^2", the result is greater than 43,560. This occurs because there are two "foot" units, "ft" (international foot) and "ftUS" (survey foot). Converting one acre to "ftUS^2" returns exactly 43,560.

An `Inconsistent Units` error occurs if you use a unit with incorrect dimensions. For example, this occurs if you use "lb" (pound) as a unit of force. The correct unit for force is "lbf" (pound-force).

17

Printing

This chapter describes some basic commands for using your HP-28C with an HP 82240A printer. Refer to the printer manual for instructions about how to position the printer relative to the HP-28C and how to turn on the printer.

All commands in the PRINT menu are described briefly in appendix C, "Menu Map." For complete descriptions, refer to "PRINT" in the Reference Manual.

0. Press ■ [CLEAR] to clear the stack.

Printing a Running Record

To print a running record of your calculations, select trace printing mode.

1. Press ■ [PRINT] to select the PRINT menu.

The two right-most menu labels, TRACE and NORM, control whether trace printing mode is active. The label for NORM appears in black letters, indicating that the calculator is in normal (non-trace) printing mode. Normal printing mode is the default mode.

2. Press TRACE to select trace printing mode. The menu labels change, indicating trace printing mode.

Now see what happens when you add two numbers—for example, 44 and 72.

3. Press [4] [4] [ENTER]. Your input and the result are printed.

```
44 ENTER
1: 44
```

4. Press [7] [2] [+]. Again your input and the result are printed.

```
72 +
1: 116
```

5. Press NORM to turn off trace printing mode.

Printing Level 1

6. Press PR1 to print the object in level 1. In this example, the printer prints:

```
116
```

The object remains in level 1, unchanged.

You can print a message by putting a string in level 1 and executing PR1.

7. Print the message "OK."

   a. Press ■ ["] [O] [K] [ENTER] to put the message string in level 1. (Pressing ■ ["] automatically selects alpha entry mode, so you need to press [ENTER] to put the string on the stack.)

   b. Press PR1 to print the message. The printer prints:

```
OK
```

Only the contents of the string are printed, not the quotation marks.

Printing the Stack

8. Press PRST to print the objects on the stack. In this example, the printer prints:

```
2: 116
1: "OK"
```

The contents of the stack are unchanged.

Printing a Variable

You can print the contents of a variable without recalling the variable to the stack. To demonstrate, store the string "OK" in a variable named "A", then print the contents of A.

9. Press ['] [A] [STO] to create the variable A with value "OK".
10. Press ['] [A] [PRVAR] to print the name and value of the variable.

```
A
"OK"
```

The name of the variable is dropped from the stack.

A

Support, Warranty, and Service

This appendix contains information to help you when you have problems with your calculator. If you have problems understanding how to use the calculator, and you can't find an appropriate topic in the Table of Contents (page 5) or the Subject Index (page 247), see "Answers to Common Questions" below. If you don't find an answer to your question, you can contact our Calculator Technical Support department, using the address or phone number listed on the inside back cover.

If your calculator doesn't seem to work properly, see "Determining If the Calculator Requires Service" on page 204. If the calculator does require service, see "Limited One-Year Warranty" on page 207 and "Obtaining Service" on page 209.

Answers to Common Questions

Q: *The calculator doesn't turn on when I press* [ON]. *What is wrong?*

A: There may be a simple problem that you can solve immediately, or the calculator may require service. See "Determining If the Calculator Requires Service" on page 204.

Q: *How can I verify that the calculator is operating properly?*

A: Perform the calculator self-test, as described on page 206.

Q: *How do I clear everything from the calculator's memory?*

A: Press and hold [ON] [INS] [▶], then release, as described in "Clearing All Memory (Memory Reset)" on page 18.

Q: *How do I change the number of decimal places in the display?*

A: See "Selecting Number Display Mode" on page 35.

Q: *My numbers are displayed with commas instead of decimal points. How do I change to decimal points?*

A: Press ■ [MODE] [NEXT] [NEXT] RDX,, as described in "Selecting the Radix Mark" on page 34.

Q: *What are the symbols at the top of the display?*

A: These symbols, called *annunciators*, indicate the status of the calculator. See page 28 for a table showing the meaning of each annunciator.

Q: *What does "object" mean?*

A: "Object" is a general term for almost everything you work with. Numbers, expressions, arrays, programs, and so on, are all types of objects. See "Major Features and Concepts" on page 23 for a brief description of object types. See chapter 1, "Fundamentals," in the Reference Manual for a detailed discussion of object types.

Q: *The calculator beeps and displays* `Bad Argument Type`. *What is wrong?*

A: The objects on the stack aren't the correct type for the command you're attempting. For example, executing [STO] without a name in level 1 causes this error. Use CATALOG to check the correct arguments for the command, as described in "The Catalog of Commands" on page 86.

Q: *The calculator beeps and displays* `Too Few Arguments`. *What is wrong?*

A: There are fewer objects on the stack than required by the command you're attempting. For example, executing [+] with only one number on the stack causes this error. Use CATALOG to check the correct arguments for the command, as described in "The Catalog of Commands" on page 86.

Q: *The calculator beeps and displays an error message different from the two listed above. How do I find out what's wrong?*

A: See appendix A, "Messages," in the Reference Manual.

Q: *How do I enter* π*?*

A: Press ■ [π] [ENTER] to put the symbolic constant π on the stack. If you want the numerical approximation, put π on the stack and press ■ [→NUM].

Q: *Why did the cursor change its appearance?*

A: The cursor indicates the current entry mode. The entry modes are immediate (empty cursor), algebraic (partly filled cursor), or alpha (filled cursor), as described in "Entry Modes" on page 75. The shape of the cursor indicates replace mode (box cursor) or insert mode (arrow cursor), as described in "Selecting Insert or Replace Mode" on page 83.

Q: *I keyed in a name (or pressed a USER menu key), but the name didn't go on the stack. Why not?*

A: You entered an *unquoted* name, which refers to the *contents* of a variable. To put a name on the stack, press ['] first. (See "Quoted and Unquoted Names" on page 54.)

Q: *What do three dots (...) mean at the right end of a display line?*

A: The three dots, called an *ellipsis,* indicate that the displayed object is too long to display on one line.

Q: *How do I display all of an object?*

A: Use ■[EDIT] or ■[VISIT] to return the object to the command line, as described in "Editing Objects" on page 80. You can then use the cursor keys to display any part of the object. To cancel the edit, press [ON].

Q: *How do I change menus?*

A: To display another row of the same menu, press [NEXT] or ■[PREV] one or more times. To display the first row of a different menu, press the menu selection key for that menu.

Q: *How do I turn off the menu display?*

A: Press [◂▴▾▸] to select the cursor menu, which is labeled in white letters above the menu keys. (For a complete description, see "The Cursor Menu: [◂▴▾▸]" in the Reference Manual.) Pressing [◂▴▾▸] a second time restores the previously displayed menu.

Q: *What is the difference between STO and STORE?*

A: The STO command assigns a specified value to a variable. The STORE menu contains commands that perform *storage arithmetic,* using the value of a variable as an argument and assigning the resulting value to the variable.

Q: *What should I do when I run out of memory?*

A: Purge all unneeded objects and variables and, if necessary, disable one or more recovery features. See "Recovery" and "Low Memory" in the Reference Manual.

Q: *I typed in an expression, using variables I've already defined. How do I get a numerical result?*

A: Press [EVAL] to *evaluate* the expression. (If any variables contain other expressions, press ■[→NUM] to evaluate repeatedly to a numerical result.)

Q: *I expected a symbolic result, but I got a numerical result. Why?*

A: There are values assigned to one or more variables. Purge the contents of the variables (see "Purging a Variable: ■[PURGE]" on page 53) and then try again.

Q: *When I press* DRAW*, the display clears, the ((•)) annunciator blinks and then stops, but I don't see any points plotted on the display. Why not?*

A: The calculated values are outside the current plot range. See "Changing the Scale of the Plot" on page 112.

Q: *I evaluated a variable or an expression, and now the calculator doesn't respond. Pressing [ON] has no effect. What happened?*

A: You defined a variable in terms of itself, creating a circular definition, and now the calculator is executing an "endless loop." To terminate the loop, perform a System Halt as follows:

1. Press and hold [ON].
2. Press [▲].
3. Release [ON].

Then redefine the variable to remove the circular definition.

Q: *The calculator displays horizontal lines, vertical lines, annunciators, and occasionally beeps. What is happening?*

A: You started one of the self-tests. To quit the self-test, perform a System Halt (described in the answer above).

Q: *The calculator is slower than usual, and the ⌂ annunciator is blinking. What is happening?*

A: The calculator is in Trace printing mode. Press ■ [PRINT] NORM to turn off Trace printing mode.

Q: *The printer prints several lines quickly, then slows down. Why?*

A: The calculator quickly transmits a certain amount of data to the printer, then slows its transmission rate to make sure the printer can keep up.

Q: *The printer drops characters or prints ■ characters. What is wrong?*

A: The distance or angle between the printer and the calculator may be too large, or there may be an obstruction blocking the transmission. See the printer manual for details about positioning the printer and calculator.

If you don't find an answer to your question, you can contact our Calculator Technical Support department, using the address or phone number listed on the inside back cover.

Determining If the Calculator Requires Service

Use these guidelines to determine whether the calculator is functioning properly. If the calculator does require service, see "Limited One-Year Warranty" on page 207 and "Obtaining Service" on page 209.

If nothing appears in the display when you press [ON]:

1. Check the display contrast.
   a. Press and hold [ON].
   b. Press [+] several times.
   c. Release [ON].
   d. If the display remains blank, press [ON] and repeat steps a, b, and c.
2. Change the batteries, as described on page 213.
3. If steps 1 and 2 don't restore the calculator, it requires service. See "Limited One-Year Warranty" on page 207 and "Obtaining Service" on page 209.

If the display is visible, but nothing happens when you press keys:

1. Perform a System Halt.
   a. Press and hold [ON].
   b. Press [▲].
   c. Release [ON].
2. Perform a Memory Reset.
   a. Press and hold [ON].
   b. Press and hold [INS] and [▶].
   c. Release [INS] and [▶].
   d. Release [ON].
3. If steps 1 and 2 fail to restore the calculator, it requires service. See "Limited One-Year Warranty" on page 207 and "Obtaining Service" on page 209.

The Calculator Self-Test

If the calculator works, but you think it's not working properly:

1. If you have a printer, turn it on.
2. Start the self-test.
   a. Press and hold [ON].
   b. Press [◀].
   c. Release [ON].

   The self-test proceeds automatically. (If the self-test doesn't proceed, you probably pressed [ON][▼] by mistake. This starts another self-test, used at the factory, that requires input from the keyboard. Quit this self-test by executing a System Halt, described in step 4 below, and then start the correct self-test.)
3. Watch for the self-test message. The self-test shows horizontal and vertical lines, a blank display, a random pattern, and then it displays the result of the self-test.
   - The message `OK-28C` indicates that the calculator passed the self-test.
   - A message such as `1 FAIL` indicates that the calculator failed the self-test. The number indicates the nature of the failure. When you send the calculator for service, include the failure number.

     If you interrupt the self-test by pressing a key, the self-test returns a failure message because it didn't expect any keystrokes. *Such a failure message doesn't indicate a problem with the calculator.*
4. Halt the self-test by performing a System Halt.
   a. Press and hold [ON].
   b. Press [▲].
   c. Release [ON].
5. If the self-test returns a failure message, *and you didn't cause the failure by interrupting the self-test,* the calculator requires service. See "Limited One-Year Warranty" below and "Obtaining Service" on page 209.

Limited One-Year Warranty

What We Will Do

The HP-28C (except for the batteries, or damage caused by the batteries) is warranted by Hewlett-Packard against defects in materials and workmanship for one year from the date of original purchase. If you sell your unit or give it as a gift, the warranty is automatically transferred to the new owner and remains in effect for the original one-year period. During the warranty period, we will repair or, at our option, replace at no charge a product that proves to be defective, provided you return the product, shipping prepaid, to a Hewlett-Packard service center.

What Is Not Covered

Batteries, and damage caused by the batteries, are not covered by the Hewlett-Packard warranty. Check with the battery manufacturer about battery and battery leakage warranties.

This warranty does not apply if the product has been damaged by accident or misuse or as the result of service or modification by other than an authorized Hewlett-Packard service center.

No other express warranty is given. The repair or replacement of a product is your exclusive remedy. **ANY OTHER IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS IS LIMITED TO THE ONE-YEAR DURATION OF THIS WRITTEN WARRANTY.** Some states, provinces, or countries do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you. **IN NO EVENT SHALL HEWLETT-PACKARD COMPANY BE LIABLE FOR CONSEQUENTIAL DAMAGES.** Some states, provinces, or countries do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

This warranty gives you specific legal rights, and you may also have other rights which vary from state to state, province to province, or country to country.

Warranty for Consumer Transactions in the United Kingdom

This warranty shall not apply to consumer transactions and shall not affect the statutory rights of a consumer. In relation to such transactions, the rights and obligations of Seller and Buyer shall be determined by statute.

Obligation to Make Changes

Products are sold on the basis of specifications applicable at the time of manufacture. Hewlett-Packard shall have no obligation to modify or update products once sold.

Warranty Information

If you have any questions concerning this warranty, please contact an authorized Hewlett-Packard dealer or a Hewlett-Packard sales and service office. Should you be unable to contact them, please contact:

- In the United States: The Calculator Service Center. The address and phone number are listed on the inside back cover.
- In Europe:

  Hewlett-Packard S.A.
  150, route du Nant-d'Avril
  P.O. Box CH-1217 Meyrin 2
  Geneva, Switzerland
  Telephone: (022) 82 81 11

  Note: Do *not* send calculators to this address for repair.
- In other countries:

  Hewlett-Packard International
  3495 Deer Creek Rd.
  Palo Alto, California 94304
  U.S.A.
  Telephone: (415) 857-1501

  Note: Do *not* send calculators to this address for repair.

Obtaining Service

Hewlett-Packard maintains service centers in most major countries throughout the world. You may have your calculator serviced at a Hewlett-Packard service center any time it malfunctions, whether the unit is under warranty or not. There is a charge for service after the one-year warranty period. Calculators normally are serviced and reshipped within five (5) working days of receipt at any service center. This is an average time and could possibly vary depending upon the time of year and work load at the service center. The total time you are without your calculator will depend largely on the shipping time.

Obtaining Service in the United States

The address and phone number of the Calculator Service Center are listed on the inside back cover.

Obtaining Service in Europe

Contact one of the following Hewlett-Packard entities for the location of the service center nearest you. (Do *not* ship your calculator to a service center without first contacting one of these entities.)

Austria
Hewlett-Packard GmbH
Kleinrechner-Service
Wagramerstr, Liebigasse
A-1220 Vienna
Telephone: (222) 23 65 11

Belgium
Hewlett-Packard Belgium SA/NV
Boulevard de la Woluwe 100
Woluwelaan
B-1200 Brussels
Telephone: (2) 762 32 00

Denmark
Hewlett-Packard A/S
Datavej 52
DK-3460 Birkerod (Copenhagen)
Telephone: (02) 81 66 40

Eastern Europe
Refer to the address listed under Austria

Finland
Hewlett-Packard OY
Revontulentie 7
SF-02100 Espoo 10 (Helsinki)
Telephone: (90) 455 02 11

France
Please contact your distributor or the nearest Hewlett-Packard sales office.

Germany
Hewlett-Packard GmbH
Reparaturzentrum Frankfurt
Berner Str. 117
D-6000 Frankfurt 56
Telephone: (611) 500001-0

Italy
Hewlett-Packard Italiana S.P.A.
Casella postale 3645 (Milano)
Via G. Di Vittorio, 9
I-20063 Cernusco Sul Naviglio (Milan)
Telephone: (2) 90 36 91

Netherlands
Hewlett-Packard B.V.
Van Heuven Goedhartlaan 121
N-1181 KK Amsteveen (Amsterdam)
P.O. Box 667
Telephone: (020) 472021

Norway
Hewlett-Packard Norge A/S
P.O. Box 34
Oesterndalen 18
N-1345 Oesteraas (Oslo)
Telephone: (2) 17 11 80

Spain
Hewlett-Packard Espanola S.A.
Calle Jerez 3
E-Madrid 16
Telephone: (1) 458 2600

Sweden
Hewlett-Packard Sverige AB
Skalholtsgatan 9 Kista
Box 19
S 163 93 SPÅNGA (Stockholm)
Telephone: (8) 750 20 00

Switzerland
Hewlett-Packard (Schweiz) AG
Kleinrechner-Service
Allmend 2
CH-8967 Widen
Telephone: (057) 50111

United Kingdom
Hewlett-Packard Ltd
King Street Lane
GB-Winnersh, Wokingham
Berkshire RG11 5AR
Telephone: (0734) 784 774

International Service Information

Not all Hewlett-Packard service centers offer service for all models of HP calculators. However, if you bought your calculator from an authorized HP dealer, you can be sure that service is available in the country where you bought it.

If you are outside the country where you bought your calculator, you can contact one of the entities listed on the previous page, or the local HP service center, to see if service is available for it. If service is unavailable, please ship the unit to the United States Calculator Service Center. The address is listed on the inside back cover. A list of service centers for other countries can be obtained by writing to that address.

All shipping, reimportation arrangements, and customs costs are your responsibility.

Shipping Instructions

If your calculator requires service, ship it to the nearest Hewlett-Packard service center or designated collection point. Along with the calculator, you should include:

- Your return address and description of the problem. If a Service Card was included in the box with your calculator, you can use it to provide the service center with this information.
- If the one-year warranty has not expired, include a sales receipt or other documentary proof of purchase date.

The calculator and accompanying information should be packaged in the original shipping box or other adequate protective packaging to prevent in-transit damage. Such damage is not covered by the one-year limited warranty; Hewlett-Packard suggests that you insure the shipment to the service center. If necessary, contact your dealer for assistance.

Whether or not the unit is under warranty, it is your responsibility to pay shipping charges for delivery to the Hewlett-Packard service center. If the unit is under warranty, the serviced calculator is returned to you with postage prepaid. For out-of-warranty service in the United States and some countries, the unit is returned C.O.D. (covering shipping costs and the service charge).

Service Agreements

A service support agreement is available for your product. Refer to the literature included in the box. For additional information, please contact the Calculator Service Center; the address and phone number are listed on the inside back cover.

Service Charge

There is a standard charge for out-of-warranty service that includes labor and materials. In the United States, the full charge is subject to the customer's local sales tax. In European countries, the full charge is subject to Value Added Tax (VAT) and similar taxes wherever applicable. All such taxes will appear as separate items on invoiced amounts.

Calculator products damaged by accident or misuse are not covered by the fixed service charges. In these situations, service charges will be individually determined based on time and material.

Warranty on Service

Any out-of-warranty service is warranted against defects in materials and workmanship for a period of 90 days from the date of service.

B

Maintenance and Safety

Batteries

The HP-28C is powered by three alkaline batteries. A fresh set of batteries typically will provide approximately six months to one year of use. However, expected battery life depends on how the calculator is used.

Use only fresh N-cell alkaline batteries. Do not use rechargeable batteries.

Low Power Indicator

When the low battery annunciator (▭) comes on, the HP-28C can continue operating for at least 40 hours. If the calculator is turned off, Continuous Memory will be preserved for approximately one month.

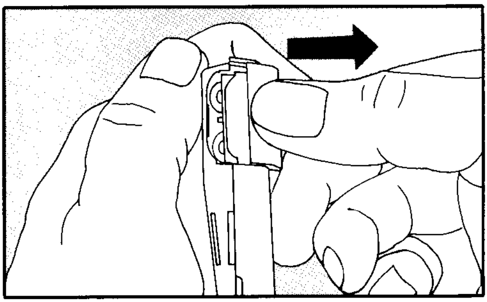
Installing Batteries

If you have just purchased the HP-28C and are installing the batteries for the first time, you can take as long as you'd like to complete these procedures.

However, if you are replacing batteries, you should keep in mind that there is a time limit for completing these procedures if you want to preserve the information you have stored inside the calculator (Continuous Memory). Once the battery compartment is open, you must replace the batteries and close the compartment within one minute to prevent loss of Continuous Memory. Therefore, you should have the new batteries readily at hand before opening the battery compartment. Also, you must make sure the calculator is off during the entire process of changing batteries.

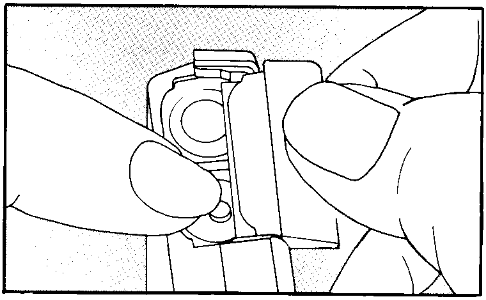
To install batteries:

1. Have three fresh N-cell batteries readily at hand.
2. Open the calculator to expose the keyboard and display. If you are replacing batteries, make sure the calculator is off. *Do not press* [ON] *until the entire procedure for changing batteries is completed. Changing batteries with the calculator on could erase the contents of Continuous Memory.*
3. Hold the calculator with the battery compartment door facing up. To remove the battery compartment door, slide it towards the back of the calculator (away from the product label).

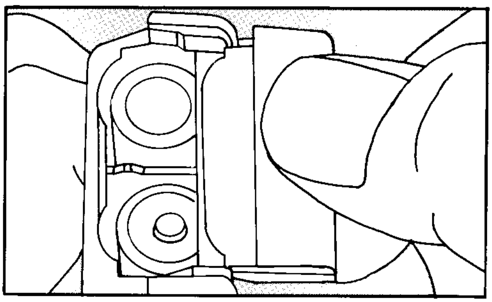


4. Tip the calculator to remove the old batteries.
5. Insert three new batteries. Orient the batteries as shown on the diagram on the back of the calculator. Be certain to observe the polarities (+ and −) as shown.

6. Press the batteries into the compartment using the portion of the battery door that extends beyond the metal contact plate. Press down until the contact plate is lined up with the grooves on the calculator case.



7. Slide the contact plate into the grooves. If necessary, use your finger to push the single battery into the compartment so that the door can slide over it. Slide the door until it latches into place.



Calculator Maintenance

To clean the display, use a cloth slightly moistened with water. Avoid getting the calculator wet.

Do not lubricate the hinge.

Environmental Limits

In order to maintain product reliability, you should observe the following temperature and humidity limits of the HP-28C:

- 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.

Safety and Regulatory Information

For your protection, the HP-28C has been tested to various national and international regulatory standards. This regulatory testing includes electrical/mechanical safely, radio interference, ergonomics, acoustics, and hazardous materials. Where required, approvals obtained from third-party test agencies are shown on the product label. In addition, various regulatory bodies require some of the information under the following headings:

U.S.A. Radio Frequency Interference

The HP-28C generates and uses radio frequency energy and may cause interference to radio and television reception. Although the HP-28C has been tested and found to comply with the limits for a Class B computing device in accordance with the specifications in Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference in a residential installation, there is no guarantee that interference will not occur in a particular installation. In the unlikely event that there is interference to radio or television reception (which can be determined by turning the HP-28C off and on or by removing the batteries), you are encouraged to correct the interference by one or more of the following measures:

- Reorient the receiving antenna.
- Relocate the product with respect to the receiver.

If necessary, you should consult your dealer or an experienced radio/television technician for additional suggestions. You may find the following booklet, prepared by the Federal Communications Commission, helpful: *How to Identify and Resolve Radio-TV Interference Problems*. This booklet is available from the U.S. Government Printing Office, Washington, D.C. 20402, Stock Number 004-000-00345-4. At the first printing of this manual, the telephone number was (202) 783-3238.

South Africa Radio Frequency Interference

The HP-28C has been certified to comply with the RFI requirement published in the Government Gazette, dated December, 1979 (number 6794) in notice R2862 and subsequent amendments.

Germany Radio Frequency Interference

The HP-28C has been tested together with its Hewlett-Packard printer and complies with VFG 1046/84, VDE 0871B, and similar non-interference standards.

Should you use equipment that is not manufactured or recommended by Hewlett-Packard, that system configuration has to comply with the requirements of Paragraph 2 of the German Federal Gazette, Order (VFG) 1046/84, dated December 14, 1984.

Air Safety Notice (U.S.A.)

The HP-28C and its printer have been tested to the requirements of RTCA (Radio Technical Commission for Aeronautics) Docket 160B, Section 21 and found to comply with those limits. Many airlines permit the use of calculators in flight based on such a qualification. However, before boarding a flight, check with an airline representative on the carrier's policy regarding use of calculators in flight.

C

Menu Map

This appendix shows the commands in each HP-28C menu. The menus are listed in alphabetical order, from ALGEBRA to USER. For detailed information about a menu, refer to chapter 3, "Dictionary," in the Reference Manual. The Dictionary describes all menus, listed in alphabetical order. For detailed information about a particular command, refer to the Operation Index at the back of the Reference Manual. The Operation Index lists all commands in alphabetical order and gives a page reference to the command's description in the Dictionary.

This appendix doesn't include the menus of the interactive operations offered by CATALOG, FORM, the Solver, and UNITS.

- CATALOG is described in "The Catalog of Commands" on page 86. For details, see "CATALOG" in the Reference Manual.
- FORM is described in "Using FORM" on page 140. For details, see "ALGEBRA (FORM)" in the Reference Manual.
- The Solver is described in chapter 10, "The Solver," on page 119. For details, see "SOLVE" in the Reference Manual.
- UNITS is described in "The UNITS Catalog" on page 187. For details, see "UNITS" in the Reference Manual.

For each menu in this appendix, the commands are grouped by rows that appear in the display at one time. Pressing [NEXT] moves to the next row, and pressing ■[PREV] moves to the previous row.

The column labeled "Command" is the name that appears in the display. The column labeled "Description" is a short description of the command or its entire name. The column labeled "Page" refers to an example, description, or mention of the command in this manual. For commands without page references, see the Operation Index in the Reference Manual.

ALGEBRA

	Command	Description	Page
Row 1	COLCT	Collect terms	137
	EXPAN	Expand products	137
	SIZE	Size	*
	FORM	Form algebraic expression	140
	OBSUB	Object substitute	*
	EXSUB	Expression substitute	*
NEXT			
Row 2	TAYLR	Taylor series	*
	ISOL	Isolate	135
	QUAD	Quadratic form	133
	SHOW	Show variable	*
	OBGET	Object get	*
	EXGET	Expression get	*

* See the Operation Index at the back of the Reference Manual.

ARRAY

	Command	Description	Page
Row 1	→ARRY	Stack-to-array	*
	ARRY→	Array-to-stack	*
	PUT	Put element	*
	GET	Get element	*
	PUTI	Put and increment index	*
	GETI	Get and increment index	*
NEXT			
Row 2	SIZE	Size	*
	RDM	Redimension	*
	TRN	Transpose	*
	CON	Constant array	*
	IDN	Identity matrix	*
	RSD	Residual	*
NEXT			
Row 3	CROSS	Cross product	160
	DOT	Dot product	161
	DET	Determinant	164
	ABS	Absolute value	*
	RNRM	Row norm	*
	CNRM	Column norm	*
NEXT			
Row 4	R→C	Real-to-complex	*
	C→R	Complex-to-real	*
	RE	Real part	*
	IM	Imaginary part	*
	CONJ	Conjugate	*
	NEG	Negate	*

* See the Operation Index at the back of the Reference Manual.

BINARY

	Command	Description	Page
Row 1	DEC	Decimal mode	183
	HEX	Hexadecimal mode	182
	OCT	Octal mode	183
	BIN	Binary mode	183
	STWS	Store wordsize	181
	RCWS	Recall wordsize	*
NEXT			
Row 2	RL	Rotate left	*
	RR	Rotate right	*
	RLB	Rotate left byte	*
	RRB	Rotate right byte	*
	R→B	Real-to-binary	*
	B→R	Binary-to-real	*
NEXT			
Row 3	SL	Shift left	*
	SR	Shift right	*
	SLB	Shift left byte	*
	SRB	Shift right byte	*
	ASR	Arithmetic shift right	*
NEXT			
Row 4	AND	And	*
	OR	Or	*
	XOR	Exclusive or	*
	NOT	Not	*

* See the Operation Index at the back of the Reference Manual.

COMPLEX

	Command	Description	Page
Row 1	R→C	Real-to-complex	71
	C→R	Complex-to-real	71
	RE	Real part	71
	IM	Imaginary part	71
	CONJ	Conjugate	71
	SIGN	Sign	71
NEXT			
Row 2	R→P	Rectangular-to-polar	72
	P→R	Polar-to-rectangular	73
	ABS	Absolute value	72
	NEG	Negate	72
	ARG	Argument	72

LIST

	Command	Description	Page
Row 1	→LIST	Stack-to-list	126
	LIST→	List-to-stack	*
	PUT	Put element	*
	GET	Get element	*
	PUTI	Put and increment index	*
	GETI	Get and increment index	*
NEXT			
Row 2	SUB	Subset	*
	SIZE	Size	*

* See the Operation Index at the back of the Reference Manual.

LOGS

	Command	Description	Page
Row 1	LOG	Common logarithm	67
	ALOG	Common antilogarithm	67
	LN	Natural logarithm	67
	EXP	Exponential	67
	LNP1	Natural log of 1 + x	67
	EXPM	Exponential minus 1	67
NEXT			
Row 2	SINH	Hyperbolic sine	68
	ASINH	Inverse hyperbolic sine	68
	COSH	Hyperbolic cosine	68
	ACOSH	Inverse hyperbolic cosine	68
	TANH	Hyperbolic tangent	68
	ATANH	Inverse hyperbolic tangent	68

MODE

	Command	Description	Page
Row 1	STD	Standard	37
	FIX	Fix	36
	SCI	Scientific	36
	ENG	Engineering	37
	DEG	Degrees	62
	RAD	Radians	62
NEXT			
Row 2	+CMD	Enables COMMAND	*
	-CMD	Disables COMMAND	*
	+LAST	Enables LAST	*
	-LAST	Disables LAST	*
	+UND	Enables UNDO	*
	-UND	Disables UNDO	*
NEXT			
Row 3	+ML	Enables multi-line	*
	-ML	Disables multi-line	*
	RDX.	Sets radix "."	35
	RDX,	Sets radix ","	35
	PRMD	Print/display modes	*

* See the Operation Index at the back of the Reference Manual.

PLOT

	Command	Description	Page
Row 1	STEQ	Store equation	111
	RCEQ	Recall equation	*
	PMIN	Plot minima	117
	PMAX	Plot maxima	117
	INDEP	Independent	*
	DRAW	Draw	111
NEXT			
Row 2	PPAR	Recall plot parameters	117
	RES	Resolution	*
	AXES	Axes	*
	CENTR	Center	115
	*W	Multiply width	*
	*H	Multiply height	113
NEXT			
Row 3	STOΣ	Store sigma	*
	RCLΣ	Recall sigma	*
	COLΣ	Sigma columns	*
	SCLΣ	Scale sigma	*
	DRWΣ	Draw sigma	*
NEXT			
Row 4	CLLCD	Clear LCD	*
	DISP	Display	*
	PIXEL	Pixel	*
	DRAX	Draw axes	*
	CLMF	Clear message flag	*
	PRLCD	Print LCD	*

* See the Operation Index at the back of the Reference Manual.

PRINT

	Command	Description	Page
Row 1	PR1	Print level 1	196
	PRST	Print stack	197
	PRVAR	Print variable	198
	PRLCD	Print LCD	*
	TRACE	Enable trace mode	195
	NORM	Disable trace mode	195
NEXT			
Row 2	PRSTC	Print stack (compact)	*
	PRUSR	Print user variables	*
	PRMD	Print modes	*
	CR	Carriage right	*

* See the Operation Index at the back of the Reference Manual.

PROGRAM BRANCH

	Command	Description	Page
	IF	Begin IF clause	*
	IFERR	Begin IF ERROR clause	*
Row 1	THEN	Being THEN clause	*
	ELSE	Begin ELSE clause	*
	END	End program structure	*
NEXT			
	START	Begin definite loop	*
	FOR	Begin definite loop	*
Row 2	NEXT	End definite loop	*
	STEP	End definite loop	*
	IFT	If-Then command	*
	IFTE	If-Then-Else function	*
NEXT			
	DO	Define indefinite loop	*
	UNTIL	Define indefinite loop	*
Row 3	END	End program structure	*
	WHILE	Define indefinite loop	*
	REPEA	Define indefinite loop	*
	END	End program structure	*

* See the Operation Index at the back of the Reference Manual.

PROGRAM CONTROL

	Command	Description	Page
Row 1	SST	Single step	*
	HALT	Suspend program	*
	ABORT	Abort program	*
	KILL	Abort suspended programs	*
	WAIT	Pause program	*
	KEY	Return key string	*
NEXT			
Row 2	BEEP	Beep	*
	CLLCD	Clear LCD	*
	DISP	Display	*
	CLMF	Clear message flag	*
	ERRN	Error number	*
	ERRM	Error message	*

* See the Operation Index at the back of the Reference Manual.

PROGRAM TEST

	Command	Description	Page
Row 1	SF	Set flag	*
	CF	Clear flag	*
	FS?	Flag set?	*
	FC?	Flag clear?	*
	FS?C	Flag set? Clear	*
	FC?C	Flag clear? Clear	*
NEXT			
Row 2	AND	And	*
	OR	Or	*
	XOR	Exclusive or	*
	NOT	Not	*
	SAME	Same	*
	==	Equal	*
NEXT			
Row 3	STOF	Store flags	*
	RCLF	Recall flags	*
	TYPE	Type	*

* See the Operation Index at the back of the Reference Manual.

REAL

	Command	Description	Page
Row 1	NEG	Negate	69
	FACT	Factorial (gamma)	68
	RAND	Random number	68
	RDZ	Randomize	68
	MAXR	Maximum real	68
	MINR	Minimum real	68
NEXT			
Row 2	ABS	Absolute value	*
	SIGN	Sign	*
	MANT	Mantissa	*
	XPON	Exponent	*
NEXT			
Row 3	IP	Integer part	*
	FP	Fractional part	*
	FLOOR	Floor	*
	CEIL	Ceiling	*
	RND	Round	*
NEXT			
Row 4	MAX	Maximum	*
	MIN	Minimum	*
	MOD	Modulo	*
	%T	Percent of total	*

* See the Operation Index at the back of the Reference Manual.

SOLVE

	Command	Description	Page
Row 1	STEQ	Store equation	59
	RCEQ	Recall equation	*
	SOLVR	Solver variables menu	59
	ISOL	Isolate	135
	QUAD	Quadratic form	133
	SHOW	Show variable	*
NEXT			
Row 2	ROOT	Rootfinder	*

* See the Operation Index at the back of the Reference Manual.

STACK

	Command	Description	Page
Row 1	DUP	Duplicate	92
	OVER	Over	92
	DUP2	Duplicate two objects	94
	DROP2	Drop two objects	94
	ROT	Rotate	95
	LIST→	List-to-stack	*
NEXT			
Row 2	ROLLD	Roll down	96
	PICK	Pick	93
	DUPN	Duplicate *n* objects	*
	DROPN	Drop *n* objects	*
	DEPTH	Depth	*
	→LIST	Stack-to-list	*

* See the Operation Index at the back of the Reference Manual.

STAT

	Command	Description	Page
Row 1	Σ+	Sigma plus	172
	Σ-	Sigma minus	173
	NΣ	Sigma N	175
	CLΣ	Clear sigma	172
	STOΣ	Store sigma	*
	RCLΣ	Recall sigma	*
NEXT			
Row 2	TOT	Total	*
	MEAN	Mean	176
	SDEV	Standard deviation	176
	VAR	Variance	177
	MAXΣ	Maximum sigma	*
	MINΣ	Minimum sigma	*
NEXT			
Row 3	COLΣ	Sigma columns	178
	CORR	Correlation	178
	COV	Covariance	179
	LR	Linear regression	179
	PREDV	Predicted value	180
NEXT			
Row 4	UTPC	Upper chi-square distribution	*
	UTPF	Upper Snedecor's f distribution	*
	UTPN	Upper normal distribution	*
	UTPT	Upper Student's t distribution	*

* See the Operation Index at the back of the Reference Manual.

STORE

	Command	Description	Page
Row 1	STO+	Store plus	*
	STO-	Store minus	*
	STO*	Store times	*
	STO/	Store divide	*
	SNEG	Store negate	*
	SINV	Store invert	*
NEXT			
Row 2	SCONJ	Store conjugate	*

* See the Operation Index at the back of the Reference Manual.

STRING

	Command	Description	Page
Row 1	→STR	Object-to-string	*
	STR→	String-to-object	*
	CHR	Character	*
	NUM	Character number	*
	POS	Position	*
	DISP	Display	*
NEXT			
Row 2	SUB	Subset	*
	SIZE	Size	*

* See the Operation Index at the back of the Reference Manual.

TRIG

	Command	Description	Page
Row 1	SIN	Sine	62
	ASIN	Arc sine	62
	COS	Cosine	62
	ACOS	Arc cosine	62
	TAN	Tangent	62
	ATAN	Arc tangent	62
[NEXT]			
Row 2	P→R	Polar-to-rectangular	65
	R→P	Rectangular-to-polar	65
	R→C	Real-to-complex	*
	C→R	Complex-to-real	*
	ARG	Argument	*
[NEXT]			
Row 3	→HMS	Decimal to hours-minutes-seconds	65
	HMS→	Hours-minutes-seconds to decimal	65
	HMS+	Hours-minutes-seconds plus	65
	HMS-	Hours-minutes-seconds minus	65
	D→R	Degrees-to-radians	66
	R→D	Radians-to-degrees	66

* See the Operation Index at the back of the Reference Manual.

USER

	Command	Description	Page
Row 1	ORDER	Order	*
	CLUSR	Clear user memory	53
	MEM	Memory	*

* See the Operation Index at the back of the Reference Manual.

D

Key Index

This index describes the actions of the keys on the calculator keyboard. First is an alphabetical index of the keys on the left-hand keyboard, followed by an alphabetical index of the keys on the right-hand keyboard. Last is an index of the keys on the cursor menu (the white labels above the top row of the right-hand keyboard).

This index includes shifted keys such as ■[ARRAY] and ■[OFF]. It doesn't include character keys such as [A] through [Z] and [0] through [9], which always write a character in the command line. (Other character keys include delimiters such as [(], operators such as [=], and symbolic constants such as ■[π]. These characters have special meaning to the calculator, but their keys are simply character keys.) If you don't find a key listed in this index, it is a character key.

For each key, there is a brief description of its action and a page reference. If the key isn't mentioned in this manual, an asterisk (*) appears for the page reference. For information about such a key, or for additional information about any key, look in the Operation Index at the back of the Reference Manual.

Left-hand Keyboard

Key	Description	Page
■ [ALGEBRA]	Selects the ALGEBRA menu.	137
■ [ARRAY]	Selects the ARRAY menu.	160
■ [BINARY]	Selects the BINARY menu.	181
■ [BRANCH]	Selects the PROGRAM BRANCH menu.	*
■ [CATALOG]	Starts the command catalog.	86
■ [CMPLX]	Selects the COMPLEX menu.	71
■ [CTRL]	Selects the PROGRAM CONTROL menu.	*
[LC]	Switches lower-case mode on or off.	29
■ [LIST]	Selects the LIST menu.	126
■ [PRINT]	Selects the PRINT menu.	195
■ [REAL]	Selects the REAL menu.	68
■ [STACK]	Selects the STACK menu.	91
■ [STORE]	Selects the STORE menu.	*
■ [STRING]	Selects the STRING menu.	*
■ [TEST]	Selects the PROGRAM TEST menu.	*
■ [UNITS]	Selects the UNITS catalog.	187
[α]	Switches alpha mode on or off.	78
■ [α LOCK]	Locks alpha mode on.	*

* See the Operation Index at the back of the Reference Manual.

Right-hand Keyboard

Key	Description	Page
[ATTN] ([ON])	Aborts program execution; clears the command line; exits catalogs, FORM, plot displays.	17
[CHS]	Changes the sign of a number in the command line or executes NEG.	38
■[CLEAR]	Clears the stack.	45
■[COMMAND]	Moves an entry from the command stack to the command line.	47
■[CONT]	Continues a halted program.	*
■[CONVERT]	Performs a unit conversion.	189
■[d/dx]	Derivative.	147
[DROP]	Drops one object from the stack.	45
■[EDIT]	Copies the object in level 1 to the command line for editing.	80
[EEX]	Enters exponent in command line.	38
[ENTER]	Parses and evaluates the command line.	26
[EVAL]	Evaluates an object.	33
■[LAST]	Returns last arguments.	89
■[LOGS]	Selects the LOGS menu.	67
■[MODE]	Selects the MODE menu.	34
[NEXT]	Displays the next row of menu labels.	27
[ON] ([ATTN])	Turns the calculator on; aborts program execution; clears the command line; exits catalogs, FORM, plot displays.	17
■[OFF]	Turns the calculator off.	17
■[PLOT]	Selects the PLOT menu.	110
■[PREV]	Displays the previous row of menu labels.	27

* See the Operation Index at the back of the Reference Manual.

Key	Description	Page
■ [PURGE]	Purges one or more variables.	53
■ [RCL]	Recalls the contents of a variable, unevaluated.	*
■ [ROLL]	Moves the level $n+1$ object to level 1.	96
[SOLV]	Selects the SOLVE menu.	59
■ [STAT]	Selects the STAT menu.	172
[STO]	Stores an object in a variable.	49
■ [SWAP]	Swaps the objects in levels 1 and 2.	44
[TRIG]	Selects the TRIG menu.	62
■ [UNDO]	Replaces the stack contents.	47
[USER]	Selects the USER menu.	51
■ [VIEW↑]	Moves the display window up one line.	90
■ [VIEW↓]	Moves the display window down one line.	90
■ [VISIT]	Copies an object to the command line for editing.	84
■ [x^2]	Squares a number or matrix.	39
■ [1/x]	Inverse (reciprocal).	39
[+]	Adds two objects.	41
[−]	Subtracts two objects.	41
[×]	Multiplies two objects.	41
[÷]	Divides two objects.	42
■ [%]	Percent.	43
■ [%CH]	Percent change.	44
■ [^]	Raises a number to a power.	42
■ [√]	Takes the square root.	39
■ [∫]	Definite or indefinite integral.	151
■	Shift key.	26
[◂⬍▸]	Selects cursor menu or restores last menu.	82
[◀]	Backspace.	26
■ [→NUM]	Forces a numerical result.	63

* See the Operation Index at the back of the Reference Manual.

Cursor Menu

The cursor menu is labeled in white above the menu keys (the top row of the right-hand keyboard). The cursor menu is active when the command line is present and no menu labels are displayed. To select the cursor menu when menu labels are displayed, press [◂✦▸]. To restore the previous menu, press [◂✦▸] a second time.

Key	Description	Page
[INS]	Switches between replace and insert modes.	83
■ [INS]	Deletes all characters to the left of the cursor.	*
[DEL]	Deletes character at cursor.	*
■ [DEL]	Deletes character at cursor and all characters to the right.	*
[▲]	Moves cursor up.	82
■ [▲]	Moves cursor up all the way.	82
[▼]	Moves cursor down.	82
■ [▼]	Moves cursor down all the way.	82
[◀]	Moves cursor left.	82
■ [◀]	Moves cursor left all the way.	82
[▶]	Moves cursor right.	82
■ [▶]	Moves cursor right all the way.	82

* See the Operation Index at the back of the Reference Manual.

Subject Index

For index entries with multiple references, page numbers in **bold** type indicate primary references.

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Notes

Comments on the HP-28C *Getting Started Manual* and *Reference Manual*

We welcome your evaluation of these manuals. Your comments and suggestions help us improve our publications.

HP-28C Getting Started Manual* and *Reference Manual

Printing date (from either title page) ____________________

Please circle a response for each of the statements below.

1=Strongly Agree 2=Agree 3=Neutral
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