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TEXAS INSTRUMENTS

PROFESSIONAL

TEXAS INSTRUMENTS PROFESSIONAL TI-65

TI-65

GUIDEBOOK

Key Index This indexed keyboard provides a quick page reference to the description of each key.

	6-2 [DEC]	6-2 [HEX]	6-3 [OCT]					
	3-5 [CM]	3-5 [EXC]	8-5 [CP]	1-12 [FIX]	1-12 [ENG]	7-8 [π]	2-18 [%]	1-2 [ON]*
[3rd] 1-9	[STO] 3-3	[RCL] 3-5	[→] 2-12	[EE] 1-10	[(] 2-6	[)] 2-6	[y^x] 2-8	[CE/C]* 2-12
	1-10 ⟨D⟩	1-10 ⟨E⟩	1-10 ⟨F⟩	7-2 [in-cm]	7-3 [oz-g]	7-3 [gal-l]	7-4 [°F-°C]	
	4-11 [P⇌R]	4-3 [DRG]	4-4 [DRG▸]	1-15 [RND]	2-23 [ABS]	2-22 [INTG]	2-22 [FRAC]	
[2nd] 1-8	[SIN] 4-6	[COS] 4-6	[TAN] 4-6	[7] 1-10	[8] 1-10	[9] 1-10	[÷] 2-2	[OFF] 1-3
	1-10 ⟨A⟩	1-10 ⟨B⟩	1-10 ⟨C⟩	7-5 [psi-Pa]	7-6 [hp-kw]	7-6 [J-cal]	7-6 [lb-N]	2-16 [K]
	2-20 [LOG]	2-10 [x^2]	2-21 [x!]	10-8 [CORR]	10-8 [SLOPE]	10-8 [INTCP]	10-9 [FCST Y]	10-5 [CSR]
[INV] 1-9	[LN] 2-20	[$\sqrt{x}$] 2-10	[1/x] 2-10	[4] 1-10	[5] 1-10	[6] 1-10	[×] 2-2	

8-9 [DSZ]	8-8 [x<m]	8-8 [x=m]	8-8 [x>m]	10-4 [FRQ]	7-8 [c(ms^{-1})]	7-8 [g(ms^{-2})]	7-8 [me(kg)]	7-8 [e(C)]	
8-4 [LRN]	8-3 [PUM]	8-17 [DEL]	9-3 [∫dx]	10-4 [Σ−]	10-6 [MEAN]	10-6 [σ_{n-1}]	10-6 [σ_n]	10-9 [FCST X]	
[RST] 8-5	[BST] 8-17	[SST] 8-17	[x⇌y] 2-14	[Σ+] 10-4	[1] 1-10	[2] 1-10	[3] 1-10	[−] 2-2	[=]
8-16 [LIST]				5-6 [TUp▲]	7-8 [h(Js)]	7-8 [k(JK^{-1})]	7-8 [NA(mol^{-1})]	7-8 [R($Jmol^{-1}K^{-1}$)]	
8-5 [PAUSE]	8-7 [RTN]	8-6 [LBL]	8-6 [GTO]	5-6 [TDn▼]	4-18 [D.d]	4-18 [H:M:S]	4-18 [D:M.m]	4-18 [D:M:S]	
[R/S] 8-5	[SBR] 8-7	[F1] 8-6	[F2] 8-6	[:] 4-14	[0] 1-10	[.] 1-10	[+/−] 1-10	[+] 2-2	2-2

* [ON] and [CE/C] are physically the same key. This guidebook uses [ON] for references to turning the calculator on and [CE/C] for references to clearing operations.

Alternate Function Keys Some calculator keys have alternate functions, which are accessed by pressing the [INV], [2nd], or [3rd] key just prior to the function key. Each key is described in the appropriate section of this manual.

TEXAS INSTRUMENTS

TI-65

TECHNICAL ANALYST™ GUIDEBOOK

Important

Record the serial number and the date you purchased the calculator in the spaces below. The serial number is on the bottom case. Always refer to this information in correspondence regarding this product.

TI-65		
Model	Serial No.	Purchase Date

Important

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The TI-65 Technical Analyst™ Calculator

The TI-65 Technical Analyst™ calculator is designed to perform many advanced operations that are useful in mathematics and science. It can serve as a valuable tool both in school and in your career. This guidebook explains the many features of the TI-65 calculator.

Programmability The calculator includes memory space for up to 100 program steps, enabling you to enter simple or sophisticated programs. In the "learn" mode, you teach the calculator to perform operations simply by pressing the appropriate key sequences.

Arithmetic Operations The calculator can perform common arithmetic operations involving powers, roots, reciprocals, constant calculations, percentages, logarithms, factorials, number portions, and absolute value.

Trigonometric Operations The calculator can perform a wide range of operations involving trigonometric functions. It can perform operations in three types of angle units (degrees, radians, and grads), four angle display formats (decimal degrees, degrees/decimal minutes, degrees/minutes/seconds, and hours/minutes/seconds), and two coordinate systems (polar and rectangular).

Statistical Operations You can use special keys to perform a variety of useful statistical operations, including mean, standard deviation, correlation, intercept, slope, and predicted value.

Number-System Modes In addition to the decimal number-system mode, the calculator enables you to perform integer operations in the hexadecimal and the octal modes.

Measurement Conversions The calculator features keys that enable you to conveniently convert values between metric and English systems of measurement.

Timer Features "Time up" and "time down" enable the calculator to function as a stopwatch or a "countdown" timer. You can enter timer values and perform operations in four timer display formats.

Physical Constants Nine physical constants with up to 13 digits of precision are built into the calculator.

Dual-Purpose Memory You can use the 16 user memories to store frequently used numbers or variable values needed in a program. To create space for a program, you can convert user memories into as many as 100 program steps. To prevent user memories from accidentally being converted into program steps, you can protect some or all of the user memories.

13-Digit Calculations Although the display of the TI-65 shows only 10 digits, the calculator uses 13-digit values internally, increasing the accuracy of the results.

Display Formats In addition to "standard" floating-decimal or fixed-decimal notation, the calculator also can display results in scientific or engineering notation.

Alternate Function Keys To maximize the capabilities of the TI-65, most of its keys perform additional functions when used in conjunction with the [2nd], [3rd], and/or [INV] keys.

AOS™ Algebraic Operating System The AOS™ Algebraic Operating System enables you to enter combined operations in a straightforward sequence and prioritizes the operations according to rules of algebraic hierarchy.

Constant Memory™ Feature When you turn off the calculator, the Constant Memory™ feature retains many of the values that you have entered, so that they are available when you turn the calculator on again.

APD™ Automatic Power Down Feature To extend the life of the batteries, the APD™ Automatic Power Down feature automatically turns the calculator off after about 15 to 25 minutes (the time may vary) if you do not press a key.

Chapter 1: Getting Started

This chapter introduces the fundamental features that enable you to begin using your TI-65 Programmable Scientific calculator, including turning the calculator on and off, clearing the calculator, understanding the display, using alternate functions, entering numbers in standard or scientific notation, and display formats.

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Turning the Calculator On and Off

The [ON] and [OFF] keys turn the calculator on and off. If you don't turn the calculator off, the APD™ Automatic Power Down feature turns it off for you. The Constant Memory™ feature retains some values even when you turn off the calculator.

Turning the Calculator On

To turn the calculator on, press the [ON] key. After you press [ON], the digit **0** and the **DEG** (degree) indicator should appear in the display. The calculator is in the decimal number-system mode using floating-decimal notation.

The **STAT** indicator also may appear in the display. If so, the calculator was in the statistics mode when you last turned the calculator off.

Note: The [ON] key and the [CE/C] key are physically the same key. Although "ON" is printed on the top part of the [CE/C] key, it is not a second function. If the calculator is off, pressing this key turns it on; if the calculator is already on, this key operates as a clear entry/clear key. This guidebook uses [ON] for references to turning the calculator on and [CE/C] for references to clearing operations.

See "Clearing the Calculator" for additional information about clearing values that are retained by the calculator's Constant Memory™ feature.

Turning the Calculator Off

To turn the calculator off, press [OFF]. The display and any pending operations are cleared when you turn the calculator off.

When you turn the calculator off, the Constant Memory feature retains:

- The values in the user memories and statistical registers
- The program steps in the program memory
- The value of the timer
- The number of user memories that are protected, if any

When you turn the calculator back on, the retained values are still available and the user memory protection setting is unchanged.

The APD Feature

To conserve power, the Automatic Power Down™ feature automatically turns the calculator off if you do not press a key for about 15 to 25 minutes (the time may vary). The effect is the same as if you had pressed [OFF].

The APD feature does not turn the calculator off while a program or the timer is running.

Clearing the Calculator

The [CE/C] key clears the calculator without affecting any memory areas. The [2nd] [CM] key sequence clears the user memories, the [2nd] [CP] key sequence clears the program memory, and the [2nd] [CSR] key sequence clears the statistical registers.

Clearing the Display and Pending Operations

Press the [CE/C] key to clear incorrect entries, error conditions, the display, or pending operations. [CE/C] does not affect the user memories, the program memory, the statistical registers, the angle or number-system mode, or the display format (except scientific notation).

- To clear an incorrect numerical entry, press [CE/C] once. (Refer to "Correcting Entry Errors" in Chapter 2 for more information.)
- To clear an error condition, indicated by **Error** and an error number in the display, press [CE/C] once. (Refer to Appendix A for more information on error conditions.)
- To clear the display and all pending operations, press [CE/C] twice.
- To clear the display and all pending operations and return the calculator to the decimal number-system and degree modes and to floating-decimal notation, press [OFF] and then press [ON].

In the examples in this guidebook, the [OFF] [ON] key sequence is used to clear the calculator before starting each example, so that the calculator returns to its default conditions. However, in most instances you can instead press [CE/C] twice to clear the display and all pending operations if you prefer.

Clearing the User Memories

To clear all the user memories, press [2nd] and then press [CM]. To clear only one user memory, store a zero in that memory.

Clearing the Program Memory

To clear the program memory, press [2nd] [CP] while the calculator is outside the learn mode. The program memory is cleared; all 16 user memories are available. Refer to "The User Memories" in Chapter 3 and "Arrangement of the Program Steps and User Memories" in Chapter 9 for more information.

Clearing the Statistical Registers

If **STAT** is displayed, the calculator is in the statistics mode, and user memories 1 through 6 are being used as statistical registers. Press [2nd] [CSR] to clear the statistical registers and leave the statistics mode. **STAT** is erased from the display, user memories 1-6 become available again, and the calculator is ready for general operation. If you press [2nd] [CSR] when the calculator is not in the statistics mode, an error occurs.

Clearing All the Memories and Registers

You can use a special key sequence to clear all values and operations from the calculator at the same time. This key sequence is unusual in that it is the only key sequence that involves holding down more than one key at the same time.

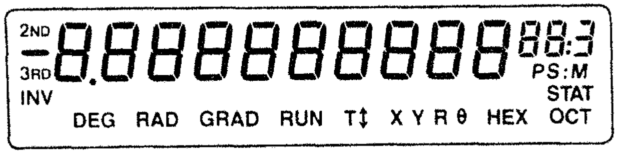
First, press [OFF] to turn off the calculator. Then hold down the [R/S] key; while you are holding down [R/S], press [ON], then release both keys. The display then shows **0** and **DEG**, and the calculator is completely cleared.

This key sequence clears values otherwise retained by the Constant Memory feature, including the user memories, the program memory, the statistical registers, and the timer; it also resets the user memory protection to zero. You must use this key sequence when you install new batteries; you also may find it to be useful if you experience difficulties that you are unable to resolve in other ways.

The Display

The display shows entries and results with a maximum of 10 significant digits, although the calculator's internal display register retains a maximum of 13 digits. To present additional information about the calculator, special indicators may also appear in the display.

Display Indicators



Note: The T↕ indicator is a compound indicator that is never displayed in its entirety. Rather, it is partially displayed as either T↑ or T↓.

Indicator	Meaning
2nd	The calculator will access the second function of the next key pressed. This indicator appears when you press [2nd].
3rd	The calculator will access the third function of the next key pressed. This indicator appears when you press [3rd].
INV	The calculator will access the inverse function of the next key (or key sequence) pressed. This indicator appears when you press [INV].
DEG	The calculator is in the degree mode. All angles are interpreted as degrees.
RAD	The calculator is in the radian mode. All angles are interpreted as radians.
GRAD	The calculator is in the grad mode. All angles are interpreted as grads.

Display Indicators (Continued)

Indicator	Meaning
RUN	A program (or integration) is running.
T↑	The "time up" feature is running.
T↓	The "time down" feature is running.
X	The displayed number is the x coordinate in a pair of rectangular coordinates.
Y	The displayed number is the y coordinate in a pair of rectangular coordinates.
R	The displayed number is the length (r) coordinate in a pair of polar coordinates.
θ	The displayed number is the angle (θ) coordinate in a pair of polar coordinates.
HEX	The calculator is in the hexadecimal mode. You can perform arithmetic calculations with hexadecimal numbers.
OCT	The calculator is in the octal mode. You can perform arithmetic calculations with octal numbers.
STAT	The calculator is in the statistics mode. You can enter statistical data and perform statistical calculations.
PS:M	The numbers above this indicator represent the highest program step number and available user memory number.

Alternate Function Keys

The calculator provides a wide variety of mathematical operations without crowding the keyboard. The primary function of each key is marked on the lower area of the key. Most of the keys, however, can perform more than one function. The [2nd], [3rd], and [INV] keys give you access to these alternate functions.

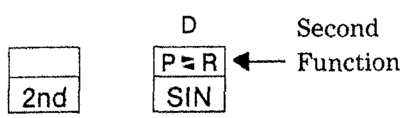
Interpreting Key Symbols

This guidebook uses key symbols that correspond to the function you are performing, as listed below.

Type of Function	Shown in Guidebook	Positioned on Keyboard	Example
Primary	In a box	Lower half of a key	[R/S]
Second	After [2nd] in brackets	Upper half of a key	[2nd] [PAUSE]
Third	After [3rd] in brackets	Above a key	[3rd] [LIST]

[2nd] Second Function

The [2nd] key enables you to perform the "second" functions that are marked in the top half of a key and are "color coded" to the [2nd] key.



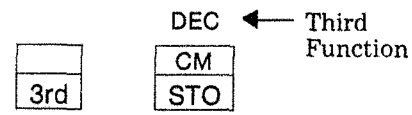
To perform a second function, press [2nd] and then press the appropriate function key.

When you press [2nd], **2nd** appears in the display until you press another key. If you press [2nd] by accident, press [2nd] again to cancel its effect.

Note: The [ON] key is not a second function even though it is located in the upper half of the [CE/C] key. Instead, it is available as a first function when the calculator is off.

[3rd] Third Function

The [3rd] key enables you to perform the "third" functions that are marked above a key and are "color coded" to the [3rd] key. To perform a third function, press [3rd] and then press the appropriate function key.



When you press [3rd], **3rd** appears in the display until you press another key. If you press [3rd] by accident, press [3rd] again to cancel its effect. If you press [3rd] and then a key that does not have a third function, the key performs its normal function.

Note: The digits A–F are not third functions. Instead, they are first functions as memory addresses, label names, or hexadecimal digits.

[INV] Inverse Function

The [INV] key enables you to perform "inverse" (opposite) operations (as listed in Appendix A). To perform an inverse function, press [INV] and then the appropriate function key.

When you press [INV], **INV** appears in the display until you press another key. If you press [INV] by accident, press [INV] again to cancel its effect. If you press [INV] and then a key that does not have an inverse function, the key performs its normal function.

You can use the [INV] key in combination with the [2nd] or [3rd] key. For example, to convert from centimeters to inches, you can press either [INV] [3rd] [in-cm] or [3rd] [INV] [in-cm].

Entering Numbers

The numeric entry keys enable you to enter the data needed to perform calculations.

[0]-[9], <A>-<F>
Digits

In the decimal mode, the digit keys enter the digits 0-9 into the display. In the hexadecimal mode, you can enter the digits 0-9 and the hexadecimal digits A-F. In the octal mode you can enter only the digits 0-7.

You can enter a maximum of 10 digits in any mode.

[•]
Decimal Point

In the decimal mode, the [•] key enters a decimal point. (The decimal point is not displayed until you enter an additional digit.) For numbers less than 1 and greater than − 1, a zero automatically precedes the decimal point.

[+/−]
Change Sign

The [+/−] key changes the sign of the number in the display. (In the hexadecimal and octal modes, the [+/−] key displays the two's complement of a number.) To enter a negative number, first enter the number as a positive value and then press [+/−].

[EE]
Scientific Notation Entry

In scientific notation, a number is expressed as a base value (mantissa) times 10 raised to a power (exponent). For example, in scientific notation the number 93,000,000 is expressed 9.3 07.

9.3 07 means $9.3 \times 10^7 = 93000000$
mantissa (9.3)
exponent (07)

Enter a number in scientific notation as follows.

1. Enter the mantissa. If it is negative, press [+/−].
2. Press [EE]. 00 appears at the right of the display.
3. Enter the exponent. If it is negative, press [+/−]. If you press an incorrect digit, simply re-enter the correct digits.

[EE]
Scientific Notation Entry (Continued)

When you press an operation key after a scientific notation entry, the calculator "normalizes" the number. This means that the calculator adjusts the exponent and the location of the decimal point in the mantissa so that one digit of the mantissa precedes the decimal point.

Using scientific notation, you can enter any number within the range of the calculator (from $\pm 1 \times 10^{-99}$ to $\pm 9.999999999 \times 10^{99}$). You can enter a mantissa with a maximum of 10 digits and a decimal point, and an exponent with one or two digits.

Scientific notation is an option only in the decimal number-system mode. You cannot enter a number in scientific notation if the calculator is in the hexadecimal or the octal mode.

Note: You can also use [EE] to convert the display format to scientific notation, as explained later in this chapter.

Example

Enter 60.23×10^{23}, but accidentally enter the wrong exponent.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter a value and an incorrect exponent	60.23 [EE] 56	60.23 56
Correct the exponent	23	60.23 23
Normalize the result	[=]	6.023 24

Display Formats

The calculator normally displays results in floating-decimal notation. You can set the number of decimal places displayed in the result, and you can choose to display results in scientific or engineering notation. All results are displayed in that format until you select another format or turn the calculator off.

Floating-Decimal Notation

The calculator normally displays numbers in floating-decimal notation, in which numbers are displayed in the range −9999999999 to −0.000000001, 0, or 0.000000001 to 9999999999. (Any results outside of this range are displayed in scientific notation.)

The display format is always set to floating-decimal notation when you turn the calculator on. By changing the display format, you can convert a number from one format to another.

[2nd] [FIX] n Fixed-Decimal

The [2nd] [FIX] n key sequence enables you to set the number of decimal places displayed in a result. To set the number of decimal places, press [2nd] [FIX] and then press a digit key ([0] through [9]). To remove the fixed-decimal setting and restore floating-decimal notation, press [INV] [2nd] [FIX].

If a result has more than the fixed number of decimal places (or if the fixed number of decimal places does not fit in the display), the displayed number is rounded. If a result has fewer than the fixed number of decimal places, trailing zeros are added.

In scientific or engineering notation, [2nd] [FIX] n sets the number of decimal places in the mantissa.

[EE] Scientific Notation

The [EE] key converts the display format from "standard" (floating-decimal or fixed-decimal) notation to scientific notation.

[2nd] [ENG] Engineering Notation

The [2nd] [ENG] key sequence converts the display format from either standard or scientific notation to engineering notation, which is similar to scientific notation except that the exponent is always a multiple of three. (You cannot use [2nd] [ENG] to *enter* a number in engineering notation.)

[2nd] [ENG] Engineering Notation (Continued)

Engineering notation is useful for science and engineering calculations that use the metric system of measurement, in which the most commonly used units have exponents that are multiples of three.

[INV] [EE], [INV] [2nd] [ENG] Standard Notation

The [INV] [EE] key sequence converts the display format from scientific notation to standard notation. (The [CE/C] key also performs the same function.)

The [INV] [2nd] [ENG] key sequence converts the display format from engineering notation or scientific notation to standard notation.

Notice that you can use [INV] [2nd] [ENG] to convert the display format to standard notation from either scientific or engineering notation; however, you can use [INV] [EE] to convert the display format to standard notation only from scientific notation.

Note: If the displayed number is outside the range of standard notation, converting it to standard notation causes no change. However, if a later calculation produces a result within this range, the display format changes to standard notation at that point.

Display Differences

The following chart shows how the same number is displayed in three different formats.

Floating-Decimal	Scientific	Engineering
62789	6.2789 04	62.789 03
0.00000021	2.1 −07	210 −09
−16389000	−1.6389 07	−16.389 06

Display Formats (Continued)

Example

Enter 12345.678 in floating-decimal notation. Then perform the following steps.

1. Set the display to show two decimal places.
2. Convert the display to scientific and engineering notation.
3. Remove the fixed-decimal setting.
4. Convert the display back to floating-decimal notation.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Enter the number	12345.678 =	12345.678
Fix the number to two decimal places	2nd [FIX] 2	12345.68
Convert the number to scientific notation	EE	1.23 04
Convert the number to engineering notation	2nd [ENG]	12.35 03
Remove the fixed-decimal setting	INV 2nd [FIX]	12.345678 03
Convert the number back to floating-decimal notation	INV 2nd [ENG]	12345.678

Display Accuracy and Rounding

Internally, the calculator stores results as 13-digit numbers. In the display, however, results are rounded to 10 digits. The extra internal digits, called "guard" digits, increase the calculator's accuracy. Any subsequent calculations are performed on the internal value, not the value in the display.

Automatic Rounding

If a calculation produces an 11-digit (or greater) fractional result, the calculator uses the guard digits to determine how to display the result. If the eleventh digit of the result is 5 or greater, the calculator automatically rounds the result to the next larger value for display.

For example, consider the following problem.

$1 \div 3 \times 3 = ?$

The calculator solves the problem in these two steps.

- ► $1 \div 3 = 0.3333333333333$
- ► $0.3333333333333 \times 3 = 0.9999999999999$

The calculator rounds the result and displays it as 1.

Most calculations are accurate to within ±1 in the last displayed digit. However, the higher-order mathematical functions use iterative calculations, and inaccuracies can accumulate in the guard digits. In most cases, the cumulative error from these calculations is maintained beyond the 10-digit display so that no inaccuracy is shown.

2nd [RND] Round

The 2nd [RND] key sequence replaces the internal value with the displayed value. The 2nd [RND] key sequence normally rounds the internal value to 10 digits; however, you can specify the number of digits for rounding by fixing the number of digits after the decimal point before you press 2nd [RND].

Note: If you press 2nd [RND] when the displayed number is an angle or timer value in D:M.m, D:M:S, or H:M:S format, the number is converted to D.d format.

Chapter 2: Arithmetic

This chapter discusses the operations that you use in performing arithmetic. These operations include simple arithmetic, the AOS™ Algebraic Operating System, parentheses, powers, roots, reciprocals, constant calculations, percentages, logarithms, factorials, number portions, and absolute value.

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Arithmetic Operations

The arithmetic keys enable you to perform the most commonly used mathematical operations: addition, subtraction, multiplication, and division.

[+], [−], [×], [÷], [=] Arithmetic

The [+], [−], [×], and [÷] keys perform the arithmetic operations of addition, subtraction, multiplication, and division. The [=] key completes all pending operations and displays the result of a calculation.

After you press [=] at the end of a calculation, the calculator is ready for you to enter a new problem.

Example 1

Calculate $5.43 + 10.6 - 5$.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the problem	5.43 [+]	5.43
	10.6 [−]	16.03
	5 [=]	11.03

Example 2

Calculate $5.43 \times 10.6 \div 5$.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the problem	5.43 [×]	5.43
	10.6 [÷]	57.558
	5 [=]	11.5116

AOS™ Algebraic Operating System

The AOS Algebraic Operating System enables you to enter numbers and combined operations into the calculator in a simple, straightforward sequence. To make sure your calculations are performed in the correct order, the AOS system uses widely accepted algebraic rules to assign priorities to the various mathematical operations.

Algebraic Hierarchy

Without a fixed set of algebraic rules, a problem such as $16 - 8 \div 2 + 6$ might have several possible answers, depending on the order in which the operations are completed. However, the rules of algebraic hierarchy solve this problem by first completing the division $(8 \div 2)$ and then completing the subtraction and addition. Therefore, $16 - 8 \div 2 + 6 = 18$.

Purpose of the AOS System

The Algebraic Operating System completes all operations according to the priorities indicated by the rules of algebraic hierarchy, as shown in the following table.

Priority	Operations
1 (highest)	trigonometric, square, square root, factorial, reciprocal, conversion, absolute value, number portions, percent, logarithms
2	universal power and root
3	multiplication and division
4	addition and subtraction
5 (lowest)	equals

(continued)

AOS™ Algebraic Operating System (Continued)

Purpose of the AOS System (Continued)

With the Algebraic Operating System, lower-priority operations are delayed until higher-priority operations are complete.

- Operations in priority 1 are immediate functions. These functions operate on the number in the display as soon as you press the operation keys.
- Operations in priorities 2 through 4 are completed by any operation with the same priority or with a lower priority. For example, multiplication and division are completed by another [×] or [÷] operation or by [+], [−], or [=].
- The [=] key completes all operations.

Pending Operations

A pending operation is any operation that is delayed until you press a key with an equal or lower priority. If you enter 4 [×] 5, for example, the result is not displayed until you complete the operation by pressing an appropriate key such as [=]. (You can also complete the [×] by pressing any operation key in priorities 3 or 4.) Until completed, 4 [×] 5 creates a pending multiplication.

Because the operation keys in priorities 2, 3, and 4—[y^x], [INV] [y^x], [×], [÷], [+], and [−]—create pending operations, they are called the pending operation keys.

The calculator allows you to enter a maximum of four pending operations. If you attempt to enter a fifth, an error condition occurs. All pending operations are cleared when you turn the calculator off, perform an integration, or press [CE/C] [CE/C], [2nd] [P⇆R], [INV] [2nd] [P⇆R], or a statistical operation or data entry key (except [3rd] [FRQ]).

Example

Calculate $4 \div 5^2 \times 7 + 3 \times .5^{\cos 60°}$.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the pending division	4 [÷]	4
Calculate the square immediately	5 [2nd] [x^2]	25
Multiply (completes the division)	[×]	0.16
Add (completes the multiplication)	7 [+]	1.12
Enter a second pending operation	3 [×]	3
Enter a third pending operation	.5 [y^x]	0.5
Calculate the cosine immediately	60 [COS]	0.5
Complete all pending operations	[=]	3.241320344

Parentheses

A series of numbers and operations enclosed in parentheses is given priority over operations outside the parentheses. Within each set of parentheses, the calculator operates according to the rules of the algebraic hierarchy provided by the AOS system.

[(], [)] Parentheses

The [(] key opens a parenthetical expression, and the [)] key closes a parenthetical expression. When you press [)], the calculator evaluates the parenthetical expression back to the most recent open parenthesis that has not been closed.

Note: Pressing [(] does not clear the display. If there is a value in the display when you press [(], you can use that value in an expression just by pressing an operation key.

Example

Calculate $7 \times (3 + 5)$.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the pending multiplication	7 [×]	7
Enter the expression	[(] 3 [+] 5 [)]	8
Complete the pending multiplication	[=]	56

If this calculation were performed without parentheses, the AOS would complete the multiplication before the addition. The result would be 26.

Note: It is not necessary to press [)] at the end of a calculation. Pressing [=] evaluates the expression in the proper order. However, if you want to display intermediate results, as shown in the example above, you must press [)].

Application: Elevator Capacity

An elevator's capacity depends on the amount of power available from its engine and the forces acting on the elevator.

Principle

Power and velocity are defined by these equations:

$P = W/t$ $v = d/t$

Work is derived from these equations as: $W = P \times d/v$.

Example

An elevator is to lift a load of boxes. It is powered by an engine that produces 500 kw of power to lift the elevator at a velocity of 2 meters/sec. Calculate the work done to move the elevator 400 meters.

Also calculate the number of 60 kg boxes the elevator can lift at once, using this equation.

$n = (W/d - F)/(mg)$

The elevator has weight (F = 1000 Newtons) when empty and experiences standard earth gravity (g).

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate the work	500000 [×] 400 [÷] 2 [=]	100000000
Calculate the load	[(] [÷] 400 [−] 1000 [)] [÷] [(] 60 [×] [3rd] [g(ms⁻²)] [)] [=]	423.1822284

To lift the elevator 400 meters requires 100,000,000 Joules. In one load, the elevator has a capacity of 423 boxes.

Powers, Roots, and Reciprocals

The TI-65 enables you to raise a number to a power, find the root of a number, or calculate the reciprocal of a number. The universal power key and the universal root key sequence calculate any power or root within the range of the calculator. The square key and the square root key sequence calculate specific powers or roots.

[yˣ] Universal Power

The [yˣ] key raises any positive number to any power, within the range of the calculator (from $\pm 1 \times 10^{-99}$ to $\pm 9.999999999 \times 10^{99}$).

1. Enter the number (y) to be raised to a power.
2. Press [yˣ].
3. Enter the power (x).
4. Press [=] or any key that completes the operation.

To raise a negative number to an integer power, you must enter the number as a positive value and change the sign of the result as appropriate.

- If the power is odd, press the [+/−] key to change the result to a negative value.
- If the power is even, the result is correct.

Example

Calculate $3.1897^{4.7343}$ and -25^5.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter a y value	3.1897 [yˣ]	3.1897
Calculate y^x	4.7343 [=]	242.6067388
Enter a y value as a positive number	25 [yˣ]	25
Calculate y^x	5 [=] [+/−]	−9765625

[INV] [yˣ] Universal Root

The [INV] [yˣ] key sequence calculates any root of any positive number, within the range of the calculator. To use the [INV] [yˣ] key sequence:

1. Enter the number (y) whose root you want to find.
2. Press [INV] [yˣ].
3. Enter the root (x).
4. Press [=] or any key that completes the operation.

Example

Calculate $\sqrt[3.871]{21.496}$

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the y value	21.496 [INV] [yˣ]	21.496
Enter the x value	3.871	3.871
Calculate $\sqrt[x]{y}$	[=]	2.208968514

Powers, Roots, and Reciprocals (Continued)

2nd [x²]
Square

The 2nd [x²] key sequence raises the displayed number to the 2nd power, which is the same as multiplying the number by itself. The number can be any value whose square is in the range of the calculator.

√x
Square Root

The √x key calculates the square root of the displayed number. The displayed number must be positive; otherwise, an error condition occurs. The result is always positive.

1/x
Reciprocal

The 1/x key calculates the reciprocal of the displayed number, which is the same as dividing the number into one.

Example

Calculate $\frac{1}{2} \times 6^2 \div \sqrt{9}$.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Find the reciprocal	2 1/x	0.5
Find the square	× 6 2nd [x²]	36
Find the square root	÷ 9 √x	3
Calculate the result	=	6

Application: Pythagorean Theorem

The Greek philosopher Pythagoras (580-500 B.C.) defined an important mathematical relationship between the length of the sides of a right triangle: the square of the longest side (hypotenuse) equals the sum of the squares of the other two sides. This relationship is known as the Pythagorean Theorem.

Principle

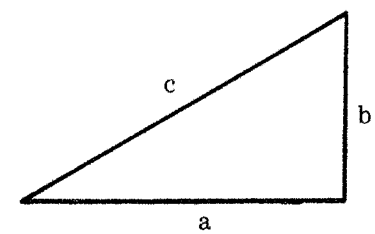
The Pythagorean Theorem can be written as:

$c^2 = a^2 + b^2$

where c = the length of the hypotenuse
a = the length of one of the sides adjacent to the right angle
b = the length of the other side adjacent to the right angle

Example

You want to put up a new antenna that is 10 feet tall. If you anchor it with three guy wires placed 6 feet from the base, how much wire do you need? (Disregard any additional wire for fastening.)



$c = \sqrt{a^2 + b^2}$

where c is the length of one guy wire, a is the height of the antenna, and b is the distance between the anchor point and the base of the antenna.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Find the length of one wire	10 2nd [x²] + 6 2nd [x²] = √x	11.66190379
Multiply by 3	× 3 =	34.98571137

You need a total of about 35 feet of wire.

Correcting Entry Errors

If you enter an incorrect number or press the wrong function key, you can always clear the calculation and begin again. In many instances, however, you can correct an entry error without clearing the entire calculation.

[→] Digit Delete

The [→] key removes the last digit from a number you are entering. If the deleted digit is preceded by a decimal point, [→] also removes the decimal point.

[CE/C] Clear Entry/Clear

The [CE/C] key clears incorrect entries or pending operations:

- To clear a numerical entry, press [CE/C] once.
- To clear all pending operations and begin the calculation again, press [CE/C] twice.

Note: When clearing an incorrect number, be sure to press [CE/C] before you press [(], [)], or a pending operation key. Pressing [CE/C] following any of these keys clears the calculator as if you had pressed [CE/C] twice.

Example

Calculate 10.1235 + 12.356, but enter the second number incorrectly.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the first number, and add	10.1235 [+]	10.1235
Enter the incorrect second number	22.356	22.356
Clear the display	[CE/C]	0
Complete the calculation	12.356 [=]	22.4795

Correcting Pending Operations

If you press an incorrect pending operation key, you may or may not be able to correct the operation without clearing the calculation.

- If the incorrect operation has an equal or higher priority than the intended operation, you can press the correct operation key immediately after the incorrect one and continue with your calculation.
- If the incorrect operation has a lower priority than the intended operation, simply pressing the correct key may not correct the problem. If there are any existing pending operations, pressing a lower-priority operation key completes the previous pending operations. In this case, you should press [CE/C] [CE/C] to clear the calculation and begin again.

Example

Calculate $7+6\times5$, but press [÷] instead of [×].

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the incorrect function	7 [+] 6 [÷]	6
Press the correct key, and continue	[×] 5 [=]	37

Correcting Immediate Functions

You can often correct an immediate function by performing its "reverse" operation. If you press [2nd] [x²] when a positive number is displayed, for example, you can correct the operation by pressing [√x].

Correcting Entry Errors (Continued)

[x⇆y] x Exchange y

The [x⇆y] key enables you to exchange the values of x and y in universal power and root calculations. If you enter x and y in the incorrect order, you can press [x⇆y] to reverse them before you complete the calculation.

You can also use [x⇆y] to reverse the x and y values in the following situations.

- To exchange the values of the minuend and subtrahend in subtraction.
- To exchange the values of the divisor and dividend in division.
- To exchange the constant value and the value to be operated on in a constant calculation.

Example

Calculate 4^3, but enter the numbers in the wrong order.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the values in the wrong order	3 [y^x] 4	4
Exchange x and y to correct the inputs	[x⇆y]	3
Calculate y^x	[=]	64

If you calculate 3^4 instead of 4^3, the result is 81.

Application: Vibration Frequencies

The vibration frequency for a string undergoing tension is determined by several factors. It is common to change the frequency by changing the length of the string and leaving all other conditions the same.

Principle

The string on a musical instrument has a starting length L_0 and vibrates at a frequency F_0. You can shorten the vibrating portion by placing your finger at points along the string. The frequencies you want to generate are the tones of the scale.

Calculate the frequencies of each scale tone from:

$$F = F_0 \times 2^{(N/12)}$$

where N is the number of half-steps above the starting frequency. The length to vibrate is:

$$L = L_0 \times F_0/F$$

Subtract this result from L_0 to determine the finger placement in relation to the end of the string.

Example

A string on a musical instrument is 60 cm long and vibrates at 440 Hz. Find the frequency and finger position for a pitch three half-steps above 440 Hz.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Find the frequency	440 [×] 2 [y^x] [(] 3 [÷] 12 [)] [=]	523.2511306
Find the finger position	[÷] 440 [x⇆y] [×] 60 [−] 60 [x⇆y] [=]	9.546215085

Place your finger about 9.5 cm from the end of the string to generate a frequency of about 523.25 Hz.

Constant Calculations

The constant register enables you to perform repetitive calculations with addition, subtraction, multiplication, division, and universal powers and roots without having to re-enter the operation and constant number each time.

[3rd] [K] Constant

The [3rd] [K] key sequence stores an operation and a number in the constant register. Then, when you enter a value and press [=], the calculator completes the problem using the operation and number in the constant register.

You can store an operation and a number in the constant register as follows.

1. Enter the operation ([+], [−], [×], [÷], [yˣ], or [INV] [yˣ]).
2. Enter the number.
3. Press [3rd] [K].
4. Press [=].

Note: You can exchange the stored constant with the displayed number by pressing the [x⇆y] key.

The constant register is cleared when you:

- Press [CE/C] [CE/C].
- Press a pending operation key.
- Perform a polar/rectangular conversion.
- Press a statistical operation or data entry key (except [3rd] [FRQ]).
- Perform an integration.
- Turn the calculator off.

Example 1 Calculate 2π, 4π, and 8π.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Begin the first calculation	2 [×] [2nd] [π]	3.141592654
Store × π in the constant register	[3rd] [K] [=]	6.283185307
Calculate 4π	4 [=]	12.56637061
Calculate 8π	8 [=]	25.13274123

Example 2 Calculate 2π, 4π, and 4×8.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Begin the first calculation	2 [×] [2nd] [π]	3.141592654
Store × π in the constant register	[3rd] [K] [=]	6.283185307
Store 4 as the constant and calculate 4π	4 [x⇆y] [=]	12.56637061
Calculate 4 × 8	8 [=]	32

Percentage Operations

A percentage represents a specific number of hundredths. For example, 50% is 50/100, which equals 1/2. Percentage calculations are useful in a wide variety of business and everyday applications.

[2nd] [%] Percent

The [2nd] [%] key sequence divides the number in the display by 100, which converts the number to its equivalent decimal percent. For example, if you enter 43.9 and press [2nd] [%], 0.439 is displayed.

You can use [2nd] [%] to calculate percentages, add-ons, discounts, and percentage ratios. The "principal amount" shown below is the number in the display when you begin the key sequence.

Key Sequence	Function
[×] n [2nd] [%] [=]	Percentages—Calculates n% of the principal amount.
[+] n [2nd] [%] [=]	Add-ons—Adds n% to the principal amount.
[−] n [2nd] [%] [=]	Discounts—Subtracts n% from the principal amount.
[÷] n [2nd] [%] [=]	Percentage Ratios—Divides the principal amount by n%.

Percentage Example

Calculate 4% of 453.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the percentage	453 [×] 4 [2nd] [%]	0.04
Calculate the result	[=]	18.12

Add-On Example

Calculate 145 + 15% add-on.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate the add-on	145 [+] 15 [2nd] [%]	21.75
Calculate the result	[=]	166.75

Discount Example

Calculate 69.95 − 10% discount.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate the discount	69.95 [−] 10 [2nd] [%]	6.995
Calculate the result	[=]	62.955

Ratio Example

29.5 is what percent of 25?

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the percentage	29.5 [÷] 25 [2nd] [%]	0.25
Calculate the result	[=]	118

Logarithms

A variety of technical and theoretical calculations require the use of logarithms. Logarithms form an important part of many mathematical models of natural phenomena. The logarithmic key sequences give you access to common and natural logarithms and common and natural antilogarithms.

[2nd] [LOG] Common Logarithm — The [2nd] [LOG] key sequence calculates the common logarithm (base 10) of the displayed number. The number must be positive; otherwise, an error occurs.

[LN] Natural Logarithm — The [LN] key calculates the natural logarithm (base e; e = 2.71828182845) of the displayed number. The number must be positive; otherwise, an error occurs.

[INV] [2nd] [LOG] Common Antilogarithm — The [INV] [2nd] [LOG] key sequence calculates the common antilogarithm of the displayed number. This is equivalent to the value of 10 raised to the power of the number in the display.

[INV] [LN] Natural Antilogarithm — The [INV] [LN] key sequence calculates the natural antilogarithm of the displayed number. This is equivalent to the value of e raised to the power of the number in the display.

Example — Calculate log 15.32, ln 203.45, 10^{π}, and $e^{-.69315}$.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate the common log of 15.32	15.32 [2nd] [LOG]	1.185258765
Calculate the natural log of 203.45	203.45 [LN]	5.315420274
Raise 10 to the π power	[2nd] [π] [INV] [2nd] [LOG]	1385.455731
Raise e to the −0.69315 power	.69315 [+/−] [INV] [LN]	0.49999859

Factorials

In probability calculations, you often need to multiply a series of consecutive integers. The factorial key sequence enables you to multiply consecutive integers quickly and easily.

[2nd] [x!] Factorial — The [2nd] [x!] key sequence calculates the factorial of the displayed number. The displayed number must be a positive integer less than or equal to 69; otherwise, an error condition occurs.

The factorial of any integer (x) is written x! and is equal to the product of all integers from 1 to x. By definition, 0! is equal to 1.

Note: A calculated result may internally have a fractional part even though it is displayed as an integer. To ensure that a calculated result is a valid argument for the factorial function, press [2nd] [RND] before pressing [2nd] [x!]. Otherwise, an error may occur.

Example 1 — Calculate 5! (which equals 5 × 4 × 3 × 2 × 1).

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate 5!	5 [2nd] [x!]	120

Example 2 — Calculate 12 × 11 × 10 × 9 × 8 (which equals 12! ÷ 7!).

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate 12!	12 [2nd] [x!] [÷]	479001600
Calculate 7!	7 [2nd] [x!]	5040
Calculate the result	[=]	95040

Integer and Fractional Portions

The number portion key sequences calculate the integer and fractional portions of a number.

2nd [INTG], 2nd [FRAC] Number Portions

The 2nd [INTG] key sequence calculates the integer portion of the displayed number and discards the fractional portion. This is the same as "truncating" a number at the decimal point.

The 2nd [FRAC] key sequence calculates the fractional portion of the displayed number and discards the integer portion.

Note: These key sequences actually operate on the 13 internal digits, *not just the 10 digits shown in the* display. For example, the internal value 4.999999999994 is displayed as 5. Pressing 2nd [INTG] displays 4, not 5; but pressing 2nd [FRAC] displays 1.

Example

Find the integer and fractional portions of 100 ÷ 7.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Store the operation	÷ 7 3rd [K] =	0
Enter the value	100 =	14.28571429
Find the integer portion	2nd [INTG]	14
Restore the value	100 =	14.28571429
Find the fractional portion	2nd [FRAC]	0.285714286

Absolute Value

The absolute value key sequence calculates the magnitude of a number, regardless of its algebraic sign.

2nd [ABS] Absolute Value

The 2nd [ABS] key sequence calculates the absolute value of the displayed number. The absolute value of a number is its magnitude, regardless of its sign. The absolute value of a number cannot be negative; it is always positive or zero.

Example

Find the absolute value of 100 ÷ −7.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Enter the problem	100 ÷ 7 +/– =	–14.28571429
Find the absolute value	2nd [ABS]	14.28571429

Chapter 3: Memory Operations

This chapter presents the keys that perform user memory operations.

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The User Memories

The TI-65 has a maximum of 16 user memories, each of which can store any numeric value within the range of the calculator. When the calculator is in the statistics mode, avoid using memories 1 through 6, because they are used as statistical registers.

User Memory Addresses

Any memory operation must include a memory "address," which can be 0 through 9 or A through F. You do not use the hexadecimal mode or the [3rd] key to address user memories A–F; after you press a memory key, addresses A–F are accessible with one keystroke.

Determining Which User Memories Are Available

Program steps occupy portions of the memory area normally reserved for user memories. A user memory that is occupied by program steps is not available until you delete those steps. An error occurs if you enter the address of an unavailable user memory.

The number of user memories that are available depends on the size of the entered program. If you erase the program, all 16 user memories are available.

You can ascertain the number of available user memories by pressing [2nd] [LRN]. The digit that appears to the right of the colon (:) above the **PS:M** indicator represents the highest available user memory number, as in the table below.

Indicator	Available Memories	Number of Memories	Indicator	Available Memories	Number of Memories
St:F	0–9, A–F	16	49-55:7	0–7	8
00-06:E	0–9, A–E	15	56-62:6	0–6	7
07-13:d	0–9, A–D	14	63-69:5	0–5	6
14-20:C	0–9, A–C	13	70-76:4	0–4	5
21-27:b	0–9, A–B	12	77-83:3	0–3	4
28-34:A	0–9, A	11	84-90:2	0–2	3
35-41:9	0–9	10	91-97:1	0–1	2
42-48:8	0–8	9	98-99:0	0	1

Press [2nd] [LRN] again to erase the **PS:M** indicator.

User Memory Operations

You can use a user memory to compare a value with the result of a subsequent calculation or to recall a number that is used several times during a calculation.

[STO] m Store

The [STO] **m** key sequence stores the displayed value in user memory **m**, where **m** is the address of the user memory.

Press [STO] followed by a key that represents the address of a user memory. For example,

- Press [STO] [3] to store the displayed value in user memory 3.
- Press [STO] ‹B› to store the displayed value in user memory B.

Note: When 0 is displayed, you can clear a user memory by pressing [STO] and the key representing the address of the memory.

Storing the Timer

While the timer is running and displayed, you can store the displayed timer value just by pressing a key that represents the address of a user memory. It is not necessary to press [STO].

Refer to "Using the Calculator as a Timer" in Chapter 5 for more information about storing the timer.

User Memory Operations (Continued)

Memory Arithmetic

You can use [STO] to perform an arithmetic operation on a value in a user memory by following these steps.

1. Enter the number that is to operate on the value in a user memory, so that it is shown in the display.
2. Press [STO].
3. Enter one of the following operations.

Key	Function
[+]	Adds the displayed value to the value in memory.
[−]	Subtracts the displayed value from the value in memory.
[×]	Multiplies the displayed value by the value in memory.
[÷]	Divides the value in memory by the displayed value.
[y^x]	Raises the value in memory (y) to the power represented by the displayed value (x).
[INV] [y^x]	Finds the root represented by the displayed value (x) of the value in memory (y).

4. Press the key representing the address of the user memory.

[RCL] m Recall

The [RCL] **m** key sequence displays (recalls) the number stored in user memory **m**, without affecting the contents of the memory.

Press [RCL] followed by a key that represents the address of a user memory; the value previously displayed is cleared, and the contents of the specified memory are displayed. For example, press [RCL] [5] to display the value stored in user memory 5.

[2nd] [EXC] m Exchange

The [2nd] [EXC] **m** key sequence exchanges the displayed value with the number stored in user memory **m**.

Press [2nd] [EXC] followed by a key that represents the address of a user memory; the displayed value is exchanged with the value in the specified memory.

You can use the [2nd] [EXC] **m** key sequence twice to check the contents of a memory without losing the displayed value. For example, press [2nd] [EXC] [0] to exchange the displayed value with the value stored in user memory 0. Then press [2nd] [EXC] [0] again to restore the previously displayed value to the display and return the value previously stored in user memory 0 to that memory.

[2nd] [CM] Clear Memories

The [2nd] [CM] key sequence clears all of the user memories, setting the value of each of them to zero. The display, the statistical registers, and the program memory are not affected.

Note: When the calculator is in the statistics mode, pressing [2nd] [CM] clears only user memory 0.

User Memory Operations (Continued)

Example

For practice with the user memories, perform the following steps.

1. Store 50 in user memory 0, and add 14.8.
2. Enter 84.42 into the display.
3. Exchange the display with the result in memory 0.
4. Recall the number stored in user memory 0.
5. Clear all user memories.
6. Recall the number stored in user memory 0.

Procedure	Press	Display	Memory 0
Clear the calculator	[OFF] [ON]	0	
Store 50 in memory 0	50 [STO] [0]	50	50
Add 14.8 to memory 0	14.8 [STO] [+] [0]	14.8	64.8
Enter 84.42	84.42	84.42	64.8
Exchange the display with memory 0	[2nd] [EXC] [0]	64.8	84.42
Recall memory 0	[RCL] [0]	84.42	84.42
Clear all the user memories	[2nd] [CM]	84.42	0
Recall memory 0	[RCL] [0]	0	0

Chapter 4: Trigonometric Operations

This chapter presents the keys that perform various *trigonometric operations*, including trigonometric functions, polar/rectangular conversions, angle mode selection, and angle measurement conversions.

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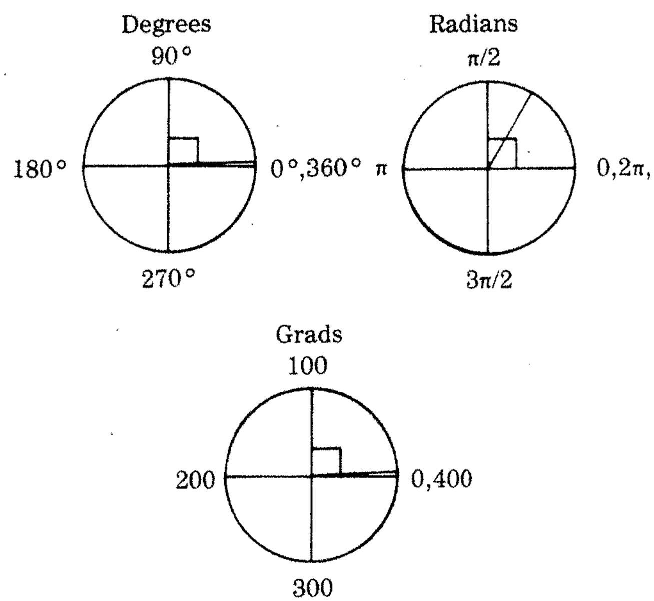
Angle Mode Selection

Before you begin calculations that involve angles, be sure to set the calculator for the correct angle units. You can select any of the three angle modes—the degree mode, the radian mode, or the grad mode. You can change the angle mode to convert angles from one unit to another.

Angle Units

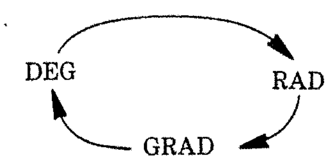
The three angle-mode units—degrees, radians, and grads—are defined as portions of a circle.



- One degree equals 1/360 of a circle. A right angle equals 90°.
- One radian equals 1/2π of a circle, which is 57.29577951305°. A right angle equals π/2 radians.
- One grad equals 1/400 of a circle, which is 0.9°. A right angle equals 100 grads.

[2nd] [DRG] Angle Mode Advance

The [2nd] [DRG] key sequence changes the angle mode without affecting the angle in the display. The current angle mode is indicated by **DEG**, **RAD**, or **GRAD** in the display. Each time you press [2nd] [DRG], the angle mode advances from one mode to the next in the order shown below.



The calculator is automatically set to the degree mode when you turn it on.

[INV] [2nd] [DRG] Angle Mode Reverse

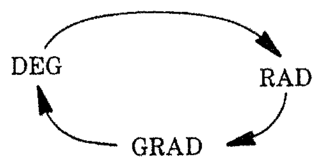
The [INV] [2nd] [DRG] key sequence changes the angle mode in the reverse direction from the [2nd] [DRG] key sequence, without affecting the angle in the display. Each time you press [INV] [2nd] [DRG], the angle mode advances from one mode to the next in the reverse of the order shown above.

Angle Mode Selection (Continued)

[2nd] [DRG►] Angle Conversion

The [2nd] [DRG►] key sequence changes the angle mode and converts the angle in the display to the new units.

To convert an angle from one unit to another, first make sure the calculator is in the correct angle mode and enter the number. Press [2nd] [DRG►] until the calculator is in the desired angle mode. Each time you press [2nd] [DRG►], the angle mode advances from one mode to the next in the order shown below.



The converted angle value appears in the display.

[INV] [2nd] [DRG►] Reverse Angle Conversion

The [INV] [2nd] [DRG►] key sequence changes the angle mode in the reverse direction from the [2nd] [DRG►] key sequence, and converts the angle in the display to the new units.

Each time you press [INV] [2nd] [DRG►], the angle mode advances from one mode to the next in the reverse of the order shown above, and the converted angle value appears in the display.

Conversion Display Format

When you press [2nd] [DRG►] or [INV] [2nd] [DRG►] to convert angle units, the angle is always displayed in D.d (decimal degree) format. See "Subdivisions of an Angle" for more information about angle display formats.

Example

Convert 90° to radians, grads, and then back to degrees.

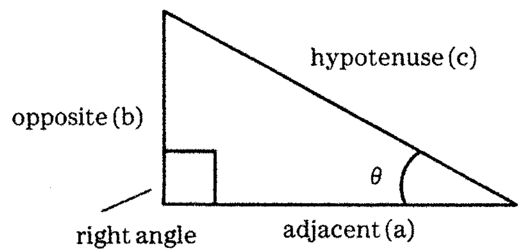
Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the angle	90	90
Convert the angle to radians	[2nd] [DRG►]	1.570796327
Convert the angle to grads	[2nd] [DRG►]	100
Convert the angle back to degrees	[2nd] [DRG►]	90

Trigonometric Functions

You can easily perform trigonometric calculations involving sine, cosine, tangent, and their inverses. Because all angles are interpreted according to the current setting of the angle mode (degree, radian, or grad), be sure the calculator is in the correct angle mode before you begin your calculation.

Trigonometric Function Keys

The trigonometric functions sine, cosine, and tangent are mathematical relationships between the lengths of the sides of a right triangle and the size of an angle θ, as shown below.



$\sin\theta = \frac{b}{c}$ $\cos\theta = \frac{a}{c}$ $\tan\theta = \frac{b}{a}$

[SIN] Sine

The [SIN] key calculates the sine of the angle in the display.

[COS] Cosine

The [COS] key calculates the cosine of the angle in the display.

[TAN] Tangent

The [TAN] key calculates the tangent of the angle in the display.

Note: The tangent of 90° (or any odd-numbered multiple of 90°, such as 270°) is undefined. If you calculate the tangent of such an angle, an error condition occurs.

[INV] [SIN] Arcsine

The [INV] [SIN] key sequence calculates the arcsine of the number in the display. The arcsine is the smallest angle (in the units selected) whose sine is in the display.

[INV] [COS] Arccosine

The [INV] [COS] key sequence calculates the arccosine of the number in the display. The arccosine is the smallest angle (in the units selected) whose cosine is in the display.

[INV] [TAN] Arctangent

The [INV] [TAN] key sequence calculates the arctangent of the number in the display. The arctangent is the smallest angle (in the units selected) whose tangent is in the display.

Example

Calculate the sine of 30° and the arctangent of 1.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter 30°	30	30
Calculate its sine	[SIN]	0.5
Enter 1	1	1
Calculate its arctangent	[INV] [TAN]	45

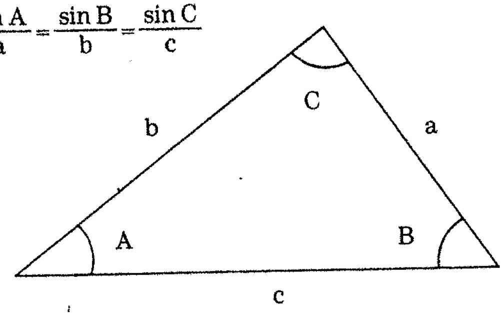
Application: Law of Sines

The Law of Sines is an important relationship between the sides and angles of any triangle. If you know the lengths of any two sides and an angle, or any two angles and the length of a side, the Law of Sines enables you to calculate the remaining sides and angles.

Principle

The Law of Sines is expressed as:

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$



Example

If $A = 29°$, $B = 60°$, and $c = 2$ meters in the triangle on the previous page, find C, a, and b. To calculate C, remember that $A + B + C = 180°$.

$$a = \frac{c \sin A}{\sin C} \qquad b = \frac{a \sin B}{\sin A}$$

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate C	180 [−] 29 [−] 60 [=]	91
Calculate a	2 [×] 29 [SIN] [÷] 91 [SIN] [=]	0.969766941
Calculate b	[×] 60 [SIN] [÷] 29 [SIN] [=]	1.732314647

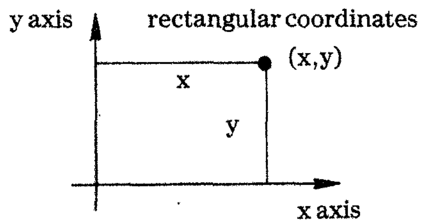
Angle C is 91°, side a is 0.969766941 meters, and side b is 1.732314647 meters.

Polar/Rectangular Conversions

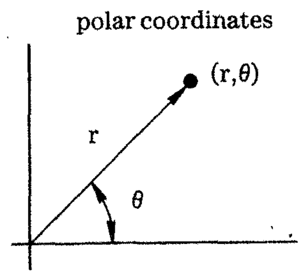
Points in a plane can be located by an ordered pair of coordinates. The rectangular coordinate system is the most commonly used method of locating a point. In science and engineering calculations, the polar coordinate system is often used. The calculator can easily convert a pair of coordinates from one system to the other.

Coordinate Systems

In the rectangular coordinate system, the coordinates (x,y) locate a point x units along the x-axis and y units along the y-axis.



In the polar coordinate system, the coordinates (r,θ) locate a point r units from the origin and at an angle θ from a reference line. θ is positive if the angle is measured in a counterclockwise direction and is negative if it is measured in a clockwise direction.



When you use [2nd] [P⇄R] or [INV] [2nd] [P⇄R] to perform polar/rectangular conversions, the calculator automatically performs the following calculations.

Polar to Rectangular	Rectangular to Polar
$x = r \cos \theta$	$r = \sqrt{x^2 + y^2}$
$y = r \sin \theta$	$\theta = \tan^{-1}(y/x)$ corrected to the proper coordinates

[2nd] [P⇄R] Polar to Rectangular Conversion

To convert from polar (r,θ) to rectangular (x,y) coordinates, follow this procedure.

1. Select the correct angle mode.
2. Enter the r coordinate and press [x⇄y].
3. Enter the θ coordinate.
4. Press [2nd] [P⇄R] to convert the coordinates and display the y coordinate, indicated by **Y** in the display.
5. Press [x⇄y] to display the x coordinate, indicated by **X** in the display.

Note: To recall the y coordinate, press [x⇄y] again. You can use [x⇄y] to recall alternately the x and y coordinates until you enter a new number into the display, press a function key, or press [CE/C].

[INV] [2nd] [P⇄R] Rectangular to Polar Conversion

To convert from rectangular (x,y) to polar (r,θ) coordinates, follow this procedure.

1. Select the correct angle mode.
2. Enter the x coordinate and press [x⇄y].
3. Enter the y coordinate.
4. Press [INV] [2nd] [P⇄R] to display the θ coordinate, indicated by θ in the display.
5. Press [x⇄y] to display the r coordinate, indicated by **R** in the display.

(continued)

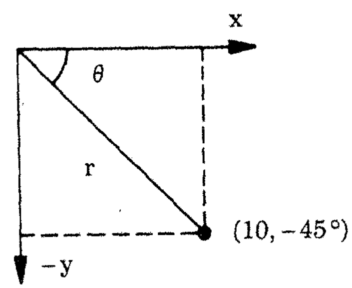
Polar/Rectangular Conversions (Continued)

INV 2nd [P⇆R] Rectangular to Polar Conversion (Continued)

Note: To recall the θ coordinate, press x⇆y again. You can use x⇆y to recall alternately the r and θ coordinates until you enter a new number into the display, press a function key, or press CE/C.

Example 1

Convert the polar coordinates (r = 10, θ = −45°) to rectangular coordinates.



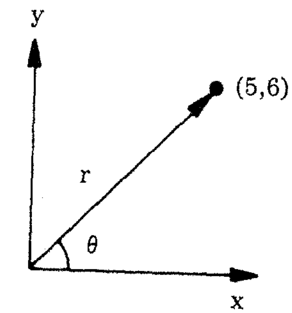
Procedure	Press	Display
Clear the calculator	OFF ON	0
Enter r and θ	10 x⇆y 45 +/−	−45
Find the y coordinate	2nd [P⇆R]	−7.071067812
Find the x coordinate	x⇆y	7.071067812
Recall the y coordinate	x⇆y	−7.071067812

The polar coordinates (10, −45°) convert to rectangular coordinates (7.071067812, −7.071067812).

Note that the X and Y indicators are displayed to identify the x and y coordinates, respectively.

Example 2

Convert the rectangular coordinates (x = 5, y = 6) to polar coordinates.



Procedure	Press	Display
Clear the calculator	OFF ON	0
Enter x and y	5 x⇆y 6	6
Find the θ coordinate	INV 2nd [P⇆R]	50.19442891
Find the r coordinate	x⇆y	7.810249676
Recall the θ coordinate	x⇆y	50.19442891

The rectangular coordinates (5,6) convert to the polar coordinates (7.810249676, 50.19442891°).

Note that the θ and R indicators are displayed to identify the θ and r coordinates, respectively.

Angle Display Formats

You can enter angle measurements in four display formats: decimal degrees, degrees/decimal minutes, degrees/minutes/seconds, and hours/minutes/seconds. The calculator can display angles in any of these formats, and can convert angle measurements from one format to another.

[•], [:] Angle Entry Separators

In the degrees/decimal minutes, degrees/minutes/seconds, or hours/minutes/seconds format, the [•] and [:] keys function in a special way. (You can use the [•] and [:] keys only if the calculator is in the decimal number-system mode.)

- Use the [:] key to separate degrees and minutes, minutes and seconds, or hours and minutes.
- Use the [•] key to separate integer and fractional portions of minutes or seconds.

When you press [•] or [:], the calculator displays a decimal point or a colon followed by two zeros. Enter the appropriate portion of the angle as a one- or two-digit number. If you press an incorrect digit key, re-enter the correct digits. (The calculator uses only the last two digits entered as the angle portion.)

Decimal Degrees

In the degree mode, the decimal degrees (D.d) format represents integer degrees and (optionally) the fractional part of a degree.

```
                              D . dddddddd
Integer degrees --------------┘      |
Fractional part of a degree ---------┘
```

In the radian or grad mode, an angle displayed in the decimal degrees format represents integer radians or grads and the fractional part of a radian or grad.

To enter an angle in the decimal degrees format:

1. Enter the integer portion.
2. If the angle includes a fractional portion, press [•] and enter the fractional (decimal) portion.

Degrees/ Decimal Minutes

In the degree mode, the degrees/decimal minutes (D:M.m) format represents integer degrees, integer minutes, and the fractional part of a minute (a minute is a 60th of a degree).

```
                                  DDDD ° MM ′ m m
Integer degrees ---------------------┘     |     |
Integer minutes ---------------------------┘     |
Fractional part of a minute ---------------------┘
```

In the radian or grad mode, an angle displayed in the degrees/decimal minutes format represents integer radians or grads, integer "minutes" (60th's of a radian or grad), and the fractional part of a "minute."

To enter an angle in the degrees/decimal minutes format:

1. Enter the integer degrees as up to four digits.
2. Press [:] and enter the integer minutes.
3. Press [•] and enter the fractional part of a minute.
4. Press an operation key (such as [=]).

Angle Display Formats (Continued)

Degrees/Minutes/ Seconds

In the degree mode, the degrees/minutes/seconds (D:M:S) format represents integer degrees, integer minutes, integer seconds, and the fractional part of a second (a second is a 60th of a minute).

DDDD ° MM ′ SS ″ ss

- Integer degrees — DDDD
- Integer minutes — MM
- Integer seconds — SS
- Fractional part of a second — ss

In the radian or grad mode, an angle displayed in the degrees/minutes/seconds format represents integer radians or grads, integer "minutes" (60th's of a radian or grad), integer "seconds" (60th's of a "minute"), and the fractional part of a second.

Note: Although you can *display* an angle measurement in the degrees/minutes/seconds format in the radian or grad mode, you cannot *enter* an angle in this format in the radian or grad mode. Instead, you must enter a radian or grad angle measurement in another format (usually hours/minutes/seconds) and then convert it to the degrees/minutes/seconds format.

To enter an angle in degrees/minutes/seconds format:

1. Enter the integer degrees as up to four digits.
2. Press [:] and enter the integer minutes.
3. Press [:] and enter the integer seconds.
4. If the angle includes a fractional part of a second, press [•] and enter the fractional portion.
5. Press an operation key (such as [=]).

Hours/Minutes/ Seconds

In the radian or grad mode, the hours/minutes/seconds (H:M:S) format represents integer "hours" (radians or grads), integer "minutes," integer "seconds," and the fractional part of a "second."

HHHH : MM : SS . ss

- Integer "hours" — HHHH
- Integer "minutes" — MM
- Integer "seconds" — SS
- Fractional part of a "second" — ss

In the degree mode, an angle displayed in the hours/minutes/seconds format represents integer "hours" (degrees), integer minutes, integer seconds, and the fractional part of a second.

Note: Although you can *display* an angle measurement in the hours/minutes/seconds format in the degree mode, you cannot *enter* an angle in this format in the degree mode. Instead, you must enter a degree angle measurement in another format (usually degrees/minutes/seconds) and then convert it to the hours/minutes/seconds format.

To enter an angle in the hours/minutes/seconds format:

1. Enter the integer "hours" as up to four digits.
2. Press [:] and enter the integer "minutes."
3. Press [:] and enter the integer "seconds."
4. If the angle includes a fractional part of a "second," press [•] and enter the fractional portion.
5. Press an operation key (such as [=]).

Angle Display Formats (Continued)

2nd [D.d], 2nd [D:M.m], 2nd [D:M:S], 2nd [H:M:S] Angle Format Conversions

Press the 2nd [D.d] key sequence to convert a displayed angle to the decimal degrees format.

Press the 2nd [D:M.m] key sequence to convert a displayed angle to the degrees/decimal minutes format.

Press the 2nd [D:M:S] key sequence to convert a displayed angle to the degrees/minutes/seconds format.

Press the 2nd [H:M:S] key sequence to convert a displayed angle to the hours/minutes/seconds format.

Note: If you perform calculations with angle measurements that are in different display formats, the result is displayed in the format of the first operator. If the result cannot be displayed in that format, an error occurs.

Example

In degree mode enter 3° 1′30.46″. Convert it to the decimal degrees format, to the degrees/decimal minutes format, and back to the degrees/minutes/seconds format.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Enter the angle in D:M:S format	3 : 1 : 30 . 46 =	3°01′30″46
Convert to D.d	2nd [D.d]	3.025127777
Convert to D:M.m	2nd [D:M.m]	3°01′.50
Restore to D:M:S	2nd [D:M:S]	3°01′30″46

Chapter 5: Timer Features

Although the calculator does not have a clock or an alarm, it does feature calculations with timer values in any of four formats, conversions from one timer format to another, and a timer for counting up or down.

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Timer Display Formats

You can enter timer values in four display formats: decimal hours, hours/decimal minutes, hours/minutes/seconds, and degrees/minutes/seconds. Timer values must be greater than or equal to zero, and must be less than 40 hours; timer values outside this range are automatically converted to zero.

[·], [:] Timer Entry Separators

In the hours/decimal minutes, hours/minutes/seconds, or degrees/minutes/seconds format, the [·] and [:] keys function in a special way. (You can use the [·] and [:] keys only in the decimal number-system mode.)

- ► Use the [:] key to separate hours and minutes, minutes and seconds, or degrees and minutes.
- ► Use the [·] key to separate integer and fractional portions of minutes or seconds.

When you press [·] or [:], the calculator displays a decimal point or a colon followed by two zeros. Enter the appropriate portion of the timer value as a one- or two-digit number.

If you press an incorrect digit key, re-enter the correct digits. (The calculator uses only the last two digits entered as the timer value portion.)

Decimal Hours

The decimal hours (D.d) format represents integer hours and the fractional part of an hour.

D . dddddddd

- Integer hours — D
- Fractional part of an hour — dddddddd

1. Enter the integer portion.
2. If the value includes a fractional portion, press [·] and enter the fractional (decimal) portion.

Hours/Decimal Minutes

The hours/decimal minutes (D:M.m) format represents integer hours, integer minutes, and the fractional part of a minute.

Hours/Decimal Minutes (Continued)

DDDD ° MM ' m m

- Integer hours — DDDD
- Integer minutes — MM
- Fractional part of a minute — m m

1. Enter the integer hours as up to four digits.
2. Press [:] and enter the integer minutes.
3. Press [·] and enter the fraction of a minute.
4. Press an operation key (such as [=]).

Hours/Minutes/Seconds

The hours/minutes/seconds (H:M:S) format represents integer hours, integer minutes, integer seconds, and the fractional part of a second.

HHHH : MM : SS . s s

- Integer hours — HHHH
- Integer minutes — MM
- Integer seconds — SS
- Fractional part of a second — s s

To enter a timer value in hours/minutes/seconds format:

1. Enter the integer hours as up to four digits.
2. Press [:] and enter the integer minutes.
3. Press [:] and enter the integer seconds.
4. If the timer value includes a fractional part of a second, press [·] and enter the fractional portion.
5. Press an operation key (such as [=]).

Timer Display Formats (Continued)

Degrees/Minutes/Seconds

The degrees/minutes/seconds (D:M:S) format represents integer "degrees" (hours), integer minutes, integer seconds, and the fractional part of a second.

DDDD °MM ′SS ″ss

- Integer "degrees" — DDDD
- Integer minutes — MM
- Integer seconds — SS
- Fractional part of a second — ss

To enter a value in degrees/minutes/seconds format:

1. Enter the integer "degrees" as up to four digits.
2. Press [:] and enter the integer minutes.
3. Press [:] and enter the integer seconds.
4. If the timer value includes a fractional part of a second, press [.] and enter the fractional portion.
5. Press an operation key (such as [=]).

[2nd] [D.d], [2nd] [D:M.m], [2nd] [H:M:S], [2nd] [D:M:S] Timer Format Conversions

Press the [2nd] [D.d] key sequence to convert a displayed timer value to the decimal hours format.

Press the [2nd] [D:M.m] key sequence to convert a displayed timer value to the hours/decimal minutes format.

Press the [2nd] [H:M:S] key sequence to convert a displayed timer value to the hours/minutes/seconds format.

Press the [2nd] [D:M:S] key sequence to convert a displayed timer value to the degrees/minutes/seconds format.

Timer Calculation Example

Multiply 1 hour and 51 minutes by 12; then subtract 6 hours, 22 minutes, and 7 seconds.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the 1st value	1 [:] 51 [×]	1°51′00″00
Multiply by 12	12 [−]	22°12′00″00
Subtract the 2nd value	6 [:] 22 [:] 7 [=]	15°49′53″00

Timer Conversion Example

Convert 2.51 hours to the D:M.m and H:M:S formats. Then, convert 11 hours and 90 minutes to the D.d format and back.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter the 1st value	2.51	2.51
Convert it to D:M.m	[2nd] [D:M.m]	2°30″60
Convert it to H:M:S	[2nd] [H:M:S]	2:30:36.00
Enter the 2nd value	11 [:] 90	11:90
Convert it to D.d	[2nd] [D.d]	12.5
Convert it to H:M:S	[2nd] [H:M:S]	12:30:00.00

Using the Calculator as a Timer

The TI-65 has special keys that enable you to use the calculator as a timer. The timer is always displayed as hours, minutes, and seconds, separated by colons. You can display the timer as it counts up or down, or you can perform calculations while the timer is running.

[3rd] [TUp▲] "Time Up"

The [3rd] [TUp▲] key sequence starts the "time up" feature, counting up in whole seconds starting from the timer value in the display. The T↑ indicator is displayed to signify that the timer is counting up.

You can also press [3rd] [TUp▲] to stop the timer (whether it is counting up or down), or to continue counting up after you have stopped the timer.

[2nd] [TDn▼] "Time Down"

The [2nd] [TDn▼] key sequence starts the "time down" feature, counting down in whole seconds starting from the timer value in the display. The T↓ indicator is displayed to signify that the timer is counting down.

You can also press [2nd] [TDn▼] to stop the timer (whether it is counting down or up), or to continue counting down after you have stopped the timer.

Performing Calculations while Timing

You cannot perform calculations while the timer is displayed. You can, however, press [CE/C] to erase the timer from the display so that you can perform calculations.

If the timer is running when you press [CE/C], it continues to run even though it is not displayed (the T↑ or T↓ indicator reminds you that the timer is running). Press [RCL] [:] to restore the running timer to the display.

Stopping the Timer

Whether or not the running timer is displayed, you can stop it by pressing [3rd] [TUp▲], [2nd] [TDn▼], or [OFF]. (When you turn the calculator off, the timer value is retained; it is still available when you turn the calculator back on.)

Storing the Timer

You can store the timer value in a user memory just by pressing a key that represents a memory address.

Using the "Countdown Timer" Feature

You can use the calculator as a "countdown timer" by following the procedure given below.

Timing a Predetermined Interval

To use the calculator as a "countdown timer," first make certain that the calculator is in the decimal mode. Enter the timer value into the display, and press [2nd] [TDn▼] to start the timer.

As the countdown proceeds, you can press [CE/C] to clear the display and perform calculations; the timing continues internally. Press [RCL] [:] to restore the running timer to the display.

Whether or not the timer is displayed, it stops running when it reaches zero. The T↓ indicator is erased one second after the timer reaches zero. (If an operation is in progress, the calculator waits until the operation is complete before erasing the T↓ indicator.)

To stop the timer, press [2nd] [TDn▼].

Using the "Stopwatch" Feature

To determine the amount of time it takes for an event to occur, you can time it with the calculator's "stopwatch" feature. If several events start at the same time and end at varying times, you can use the stopwatch feature to time them all.

Timing a Single Event

To use the calculator as a stopwatch, first make certain that the calculator is in the decimal mode; then press [CE/C] to clear the display. When the event begins, press [3rd] [TUp▲] to start the timer.

As the event proceeds, you can press [CE/C] to clear the display and perform calculations; the timing continues internally. Press [RCL] [:] to restore the running timer to the display.

When the event ends, press [3rd] [TUp▲] to stop the timer.

If the timer counts up to 40 hours, it automatically resets to zero and continues counting up.

Timing Concurrent Events

To time concurrent events, first make certain that the calculator is in the decimal mode. Decide which user memories you are going to use to store the timing for each event; make certain that the user memories that you need are available.

Press [CE/C] to clear the display. When the events begin, press [3rd] [TUp▲] to start the timer.

When each event finishes, store the timer value by pressing the address of the appropriate user memory. The timer briefly changes to "full" H:M:S format (including hundredths of seconds), and then continues to run. When all the events have finished, press [3rd] [TUp▲] to stop the timer.

To recall an individual timer value to the display, press [RCL] and the address of the appropriate user memory.

Example

You are comparing the speeds of three acid neutralizers. Three equal volumes of the same acidic solution contain a compound that changes color when the acidity is cancelled. You add equal amounts of the neutralizers to the three containers simultaneously. Time the three chemical processes to determine the speeds of the acid neutralizers.

You label the containers 1, 2, and 3. Store the timer values in user memories 1, 2, and 3 when the acid is neutralized.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Begin the events, start the timer	[3rd] [TUp▲]	(running timer)
Store the timer values as they reach completion	[1] [2] [3]	(running timer)
Stop the timer	[3rd] [TUp▲]	(final timer value)
Recall the 1st value	[RCL] [1]	(first timer value)
Recall the 2nd value	[RCL] [2]	(second timer value)
Recall the 3rd value	[RCL] [3]	(third timer value)

Chapter 6: Number Systems

In previous sections of this manual, numbers are entered and displayed in the decimal number system. However, you can also enter numbers and perform arithmetic calculations in the octal and hexadecimal number systems, and you can convert a number from one number system to another.

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Number-System Modes

The [3rd] [DEC], [3rd] [HEX], and [3rd] [OCT] key sequences select the decimal, hexadecimal, and octal number-system modes. You also use these key sequences to convert numbers from one number system to another.

[3rd] [DEC] Decimal Mode

The [3rd] [DEC] key sequence selects the decimal mode. When you press [3rd] [DEC], the number in the display is automatically converted to its equivalent in the decimal number system.

In the decimal mode, the calculator interprets all numbers as decimal (base 10) numbers. Normally, you should keep the calculator in the decimal mode. This mode enables you to perform all the calculations described thus far in this guidebook. You can enter the digits 0–9 in decimal mode.

There is no display indicator for the decimal mode. Rather, the decimal mode is indicated by the absence of the **HEX** and **OCT** indicators.

Note: The calculator is always in the decimal mode when you turn it on.

[3rd] [HEX] Hexadecimal Mode

The [3rd] [HEX] key sequence selects the hexadecimal mode. When you press [3rd] [HEX], the integer portion of the number in the display is automatically converted to its equivalent in the hexadecimal number system.

In the hexadecimal mode, indicated by **HEX** in the display, the calculator interprets all numbers as hexadecimal (base 16) numbers. You can enter the digits 0–9 and A–F in the hexadecimal mode. If you attempt to convert a number to the hexadecimal mode that is outside the calculator's range of hexadecimal numbers, an error condition occurs.

Refer to "Performing Hexadecimal Calculations" later in this chapter for more information about the hexadecimal mode.

[3rd] [OCT] Octal Mode

The [3rd] [OCT] key sequence selects the octal mode. When you press [3rd] [OCT], the integer portion of the number in the display is automatically converted to its equivalent in the octal number system.

In the octal mode, indicated by **OCT** in the display, the calculator interprets all numbers as octal (base 8) numbers. You can enter the digits 0–7 in the octal mode. If you attempt to convert a number to the octal mode that is outside the calculator's range of octal numbers, an error condition occurs.

Refer to "Performing Octal Calculations" later in this chapter for more information about octal mode.

Number System Notations

When working with more than one number system, you need to know which system is being used. For example, if you see the number 10, how do you know which number system it represents?

Where more than one number system is involved, this guidebook uses the following notations to represent decimal, hexadecimal, and octal numbers.

$10_{(dec)}$ $10_{(hex)}$ $10_{(oct)}$

[+/–] Two's Complement

In the hexadecimal and octal modes, press [+/–] to find the two's complement of the displayed number.

In the decimal mode, negative numbers are represented with a minus sign. In the hexadecimal and octal modes, negative numbers are represented in their two's complement form; a minus sign is not displayed.

For each number-system mode, the calculator allows a specified range of positive and negative numbers. These ranges are listed in the following sections.

Performing Hexadecimal Calculations

To perform hexadecimal calculations, select the hexadecimal mode by pressing [3rd] [HEX]. You can then add, subtract, multiply, and divide hexadecimal numbers.

Entering Hexadecimal Numbers

In this mode, you can enter the digits 0 through 9 and the letters A through F. Any leading zeros are ignored. The calculator can perform calculations with positive hexadecimal numbers as large as 2540bE3FF. Numbers from FdAbF41C01 through FFFFFFFFFF are interpreted as negative (two's complement) numbers.

The following table shows the positive hexadecimal numbers and their two's complements. It also shows the decimal equivalent for each number.

Decimal Value (+)	Positive Hexadecimal	Two's Complement	Decimal Value (−)
0	0	0	0
1	1	FFFFFFFFFF	−1
2	2	FFFFFFFFFE	−2
⋮	⋮	⋮	⋮
9999999998	2540bE3FE	FdAbF41C02	−9999999998
9999999999	2540bE3FF	FdAbF41C01	−9999999999

Note: Although you can enter hexadecimal numbers between 2540bE3FF and FdAbF41C01 (such as EEEEEEEEEE), an error condition occurs when you attempt to perform a calculation with the number.

Entering Hexadecimal Numbers (Continued)

In the hexadecimal mode, the calculator remaps the keyboard so that the letters A through F are the only functions of the following keys. To enter these as hexadecimal digits, simply press the key.

D	E	F
[P⇄R / SIN]	[DRG / COS]	[DRG▸ / TAN]

A	B	C
[LOG / LN]	[x^2 / $\sqrt{x}$]	[x! / 1/x]

Note that the calculator displays the letters B and D as lowercase letters (**b** and **d**). This helps prevent confusion between the letter B and the number 8, and between the letter D and the number 0.

Example

Calculate $3A_{(hex)} - 3F_{(hex)}$ and then convert the result to its decimal equivalent.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Select the hexadecimal mode	[3rd] [HEX]	0
Enter the problem	3A [−] 3F [=]	FFFFFFFFFb
Convert to decimal	[3rd] [DEC]	−5

Performing Octal Calculations

To perform octal calculations, select the octal mode by pressing [3rd] [OCT]. You can then add, subtract, multiply, and divide octal numbers.

Entering Octal Numbers

In this mode, you can enter only the digits 0 through 7. Any leading zeros are ignored. The calculator allows you to enter positive octal numbers as large as 3777777777. Numbers beyond this are interpreted as negative (two's complement) numbers.

The following table shows the positive octal numbers and their two's complements. It also shows the decimal equivalent for each number.

Decimal Value (+)	Positive Octal	Two's Complement	Decimal Value (−)
0	0	0	0
1	1	7777777777	−1
2	2	7777777776	−2
⋮	⋮	⋮	⋮
536870910	3777777776	4000000002	−536870910
536870911	3777777777	4000000001	−536870911

Notice that the largest positive octal number represents $536870911_{(dec)}$, and the smallest two's complement number represents $-536870911_{(dec)}$.

Note: Although you can enter the octal number 4000000000, an error condition occurs when you attempt to perform a calculation with the number.

Example 1

Convert $77_{(oct)}$ to its hexadecimal and decimal equivalents.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Select octal	[3rd] [OCT]	0
Enter the number and convert it to hexadecimal	77 [3rd] [HEX]	3F
Convert to decimal	[3rd] [DEC]	63

Example 2

Calculate $100_{(oct)} \div 3_{(oct)}$. Convert the result to decimal mode. Also determine the decimal result of $64_{(dec)} \div 3_{(dec)}$ ($64_{(dec)} = 100_{(oct)}$).

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Select octal	[3rd] [OCT]	0
Enter the problem	100 [÷] 3 [=]	25
Convert to decimal	[3rd] [DEC]	21
Enter in decimal	64 [÷] 3 [=]	21.33333333

Notice that the octal mode retains only the integer portion of the result.

Performing Mixed-Mode Calculations

You can also perform arithmetic calculations with a combination of decimal, octal, and hexadecimal numbers. Intermediate results are converted automatically when you change from one mode to another.

Example 1

Calculate the decimal result of $45_{(hex)} + 25_{(dec)}$.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Select the hexadecimal mode	3rd [HEX]	0
Enter the problem	45 3rd [DEC] + 25 =	94

Example 2

Calculate $8_{(hex)} + 7_{(oct)}$ and convert the result to its decimal equivalent.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Select the hexadecimal mode	3rd [HEX]	0
Enter the problem problem	8 3rd [OCT] + 7 =	17
Convert the result to decimal	3rd [DEC]	15

Chapter 7: Metric Units and Physical Constants

Eight keys convert units between the English system of measurement, which most Americans use, and the more convenient metric system, used by the rest of the world and in scientific and engineering calculations. The values of nine physical constants are also built into the calculator.

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Converting Length

The TI-65 can convert length values between inches (in) and centimeters (cm).

[3rd] [in-cm] Inches to Centimeters

The [3rd] [in-cm] key sequence converts a length displayed in inches to the equivalent length in centimeters. The conversion factor is 2.54 centimeters per inch.

[INV] [3rd] [in-cm] Centimeters to Inches

The [INV] [3rd] [in-cm] key sequence converts a length displayed in centimeters to the equivalent length in inches. The conversion factor is .3937007874 inches per centimeter.

Example

Convert 36 inches to centimeters and back to inches.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter 36 inches	36	36
Convert it to centimeters	[3rd] [in-cm]	91.44
Convert it back to inches	[INV] [3rd] [in-cm]	36

Converting Mass and Volume

The TI-65 can convert mass values between ounces (oz) and grams (g). The calculator can also convert volume values between U.S. gallons (gal) and liters (l).

[3rd] [oz-g] Ounces to Grams

The [3rd] [oz-g] key sequence converts a value displayed in ounces avoirdupois to the equivalent value in grams. The conversion factor is 28.349523125 grams per ounce.

[INV] [3rd] [oz-g] Grams to Ounces

The [INV] [3rd] [oz-g] key sequence converts a value displayed in grams to the equivalent value in ounces avoirdupois. The conversion factor is .03527396194958 ounces per gram.

[3rd] [gal-l] U.S. Gallons to Liters

The [3rd] [gal-l] key sequence converts a volume displayed in U.S. liquid gallons to the equivalent volume in liters. The conversion factor is 3.785411784 liters per gallon.

[INV] [3rd] [gal-l] Liters to U.S. Gallons

The [INV] [3rd] [gal-l] key sequence converts a volume displayed in liters to the equivalent volume in U.S. liquid gallons. The conversion factor is .2641720523581 gallons per liter.

Example

Convert 36 ounces to grams and convert 50 liters to gallons.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter 36 ounces	36	36
Convert it to grams	[3rd] [oz-g]	1020.582833
Enter 50 liters	50	50
Convert it to gallons	[INV] [3rd] [gal-l]	13.20860262

Converting Temperature and Pressure

The TI-65 can convert temperature values between degrees Fahrenheit (°F) and degrees Celsius (°C). It can also convert pressure values between psi (pounds per square inch) and Pascals (Pa: Newtons per square meter).

[3rd] [°F-°C] Fahrenheit to Celsius

The [3rd] [°F-°C] key sequence converts a temperature displayed in degrees Fahrenheit to the equivalent temperature in degrees Celsius.

The Fahrenheit-to-Celsius conversion is calculated according to the following formula.

$$°C = \frac{5}{9} \times (°F - 32)$$

[INV] [3rd] [°F-°C] Celsius to Fahrenheit

The [INV] [3rd] [°F-°C] key sequence converts a temperature displayed in degrees Celsius to the equivalent temperature in degrees Fahrenheit.

The Celsius-to-Fahrenheit conversion is calculated according to the following formula.

$$°F = (\frac{9}{5} \times °C) + 32$$

Example

Convert 98.6 °F to Celsius and back to Fahrenheit.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter 98.6 degrees Fahrenheit	98.6	98.6
Convert it to degrees Celsius	[3rd] [°F-°C]	37
Convert it back to degrees Fahrenheit	[INV] [3rd] [°F-°C]	98.6

[3rd] [psi-Pa] psi to Pascals

The [3rd] [psi-Pa] key sequence converts a pressure displayed in pounds per square inch to the equivalent pressure in Pascals. The conversion factor is 6894.757293169 Pascals per psi.

[INV] [3rd] [psi-Pa] Pascals to psi

The [INV] [3rd] [psi-Pa] key sequence converts a pressure displayed in Pascals to the equivalent pressure in pounds per square inch. The conversion factor is .0001450377377302 psi per Pascal.

Example

Convert 14.696 psi to Pascals and convert 1 megapascal to psi.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Enter 14.696 psi	14.696	14.696
Convert it to Pascals	[3rd] [psi-Pa]	101325.3532
Enter 1,000,000 Pascals	1000000	1000000
Convert it to psi	[INV] [3rd] [psi-Pa]	145.0377377

Converting Power, Energy, and Force

The TI-65 can convert power values between horsepower (hp) and kilowatts (kw), energy values between Joules (J) and calories (cal), and force values between pounds (lb) and Newtons (N).

[3rd] [hp-kw] Horsepower to Kilowatts

The [3rd] [hp-kw] key sequence converts an amount of power displayed in mechanical horsepower to the equivalent amount of power in kilowatts. The conversion factor is .7456998715823 kilowatts per horsepower.

[INV] [3rd] [hp-kw] Kilowatts to Horsepower

The [INV] [3rd] [hp-kw] key sequence converts an amount of power displayed in kilowatts to the equivalent amount of power in mechanical horsepower. The conversion factor is 1.341022089594 horsepower per kilowatt.

[3rd] [J-cal] Joules to Calories

The [3rd] [J-cal] key sequence converts an amount of energy displayed in Joules to the equivalent amount of energy in U.S. Bureau of Standards calories. The conversion factor is .290057361376 calories per Joule.

[INV] [3rd] [J-cal] Calories to Joules

The [INV] [3rd] [J-cal] key sequence converts an amount of energy displayed in U.S. Bureau of Standards calories to the equivalent amount of energy in Joules. The conversion factor is 4.184 Joules per calorie.

[3rd] [lb-N] Pounds to Newtons

The [3rd] [lb-N] key sequence converts an amount of force displayed in pounds to the equivalent amount of force in Newtons. The conversion factor is 4.448221615261 Newtons per pound.

[INV] [3rd] [lb-N] Newtons to Pounds

The [INV] [3rd] [lb-N] key sequence converts an amount of force displayed in Newtons to the equivalent amount of force in pounds. The conversion factor is .2248089430996 pounds per Newton.

Conversion Key Summary

This table summarizes the actions of the English/metric conversion key sequences explained in detail on the preceding pages.

Key Sequence	Convert From	Convert To	Conversion Factor (or Formula)
[3rd] [in-cm]	inches	centimeters	2.54
[INV] [3rd] [in-cm]	centimeters	inches	.3937007874
[3rd] [oz-g]	ounces avoirdupois	grams	28.349523125
[INV] [3rd] [oz-g]	grams	ounces avoirdupois	.03527396194958
[3rd] [gal-l]	U.S. liquid gallons	liters	3.785411784
[INV] [3rd] [gal-l]	liters	U.S. liquid gallons	.2641720523581
[3rd] [°F-°C]	°Fahrenheit	°Celsius	$C=(5/9)\times(F-32)$
[INV] [3rd] [°F-°C]	°Celsius	°Fahrenheit	$F=((9/5)\times C)+32$
[3rd] [psi-Pa]	psi	Pascals	6894.757293169
[INV] [3rd] [psi-Pa]	Pascals	psi	.0001450377377302
[3rd] [hp-kw]	mechanical horsepower	kilowatts	.7456998715823
[INV] [3rd] [hp-kw]	kilowatts	mechanical horsepower	1.341022089594
[3rd] [J-cal]	Joules	U.S. Bureau of Standards calories	.290057361376
[INV] [3rd] [J-cal]	U.S. Bureau of Standards calories	Joules	4.184
[3rd] [lb-N]	pounds	Newtons	4.448221615261
[INV] [3rd] [lb-N]	Newtons	pounds	.2248089430996

Source: *Handbook of Chemistry and Physics*, 67th ed. (CRC Press, Inc., 1986).

Physical Constants

The TI-65 has built-in values for nine physical constants. Each constant is accessed by two keystrokes. These constants enable you to enter the value of a constant without pressing the key for every digit of the number.

Physical Constants

The table below describes the key sequence and units of each physical constant built into the calculator.

Name	Key Sequence	Value
Pi	[2nd] [π]	3.141592653590
Speed of Light	[3rd] [c(ms-1)]	299792458 meters per second
Gravitational Acceleration	[3rd] [g(ms-2)]	9.80665 meters per second^2
Electron Mass	[3rd] [me(kg)]	9.109534×10^{-31} kilograms
Electron Charge	[3rd] [e(C)]	$1.6021892 \times 10^{-19}$ coulombs
Planck's Constant	[3rd] [h(Js)]	6.626176×10^{-34} Joule sec
Boltzmann's Constant	[3rd] [k(JK-1)]	1.380662×10^{-23} Joules/°K
Avogadro's Number	[3rd] [NA(mol-1)]	6.022045×10^{23} molecules/mole
Ideal Gas Constant	[3rd] [R(Jmol-1K-1)]	8.31441 Joules per mole °K

Source (except Gravitational Acceleration): *Handbook of Chemistry and Physics,* 67th ed. (CRC Press, Inc., 1986).

Source (Gravitational Acceleration): *International Critical Tables,* vol. 1 (McGraw-Hill Book Company, 1926).

Example

A 1.5-liter sealed vessel contains .1 mole of gas at a temperature of 300K. Find the pressure (P = mRT/V) in Pascals. The dimensional analysis for this problem is:

$$\frac{.1\text{ mole}}{1} \times \frac{\text{R J}}{\text{mole K}} \times \frac{300\text{K}}{1} \times \frac{1}{1.5\text{ liters}} \times \frac{1000\text{ liters}}{\text{m}^3}$$

$$\times \frac{\text{Nm}}{\text{J}} \times \frac{\text{Pascal m}^2}{\text{N}} = (.1 \times \text{R} \times 300 \times 1000/1.5)\text{ Pascals}$$

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Calculate the pressure	.1 [×] [3rd] [R(Jmol-1K-1)] [×]	0.831441
	300 [×] 1000 [÷]	249432.3
	1.5 [=]	166288.2

The pressure of the gas in the vessel is 166288.2 Pascals.

Chapter 8: Programming the Calculator

You can save time and effort by entering frequently used calculations into the program memory. This chapter explains the functions of the programming keys and presents guidelines for entering, running, editing, and listing programs. The programming applications enable you to practice entering, running, and revising programs.

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Preparing to Program

If you perform a certain calculation frequently, you may be able to save time and keystrokes by programming that calculation into the calculator.

The Programming Process

You can "teach" the TI-65 to automatically perform a calculation with up to 100 keystrokes. When the calculator is in the learn mode, it stores the keystroke sequences that you enter, rather than performing operations. You simply press the keys in the same sequence as you would perform the calculation manually; each keystroke (or keystroke sequence) is stored as a code. When you "run" (execute) the program, the calculator reads the codes and duplicates the key sequences.

There are six main steps in the programming process.

1. Protecting user memories (if necessary).
2. Entering the learn mode.
3. Entering the keystrokes as program steps.
4. Editing the program (if necessary).
5. Leaving the learn mode.
6. Running the program.

The Memory

If no program is present, the memory space of the calculator is used entirely for user memories. Each user memory can be converted into seven program steps. If you enter a program of the maximum size (100 steps), only one user memory remains available. All 16 user memories are available only when there are no program steps entered.

Note: To place the calculator in the statistics mode, you must have fewer than 64 program steps entered. When the calculator is in the statistics mode, only program steps 0–62 are available.

Arrangement of the Program Steps and User Memories

The size of a program is limited by the number of user memories that are available for conversion to program steps. You can enter a program only when fewer than 16 user memories are protected. Each user memory (except memory 0) can be converted to seven program steps; the lowest program step is numbered 00.

Memory Table

The following table shows the user memories that are available for any number of program steps.

Program Step Numbers Entered	Available User Memories	Number of User Memories	Program Step Numbers Entered	Available User Memories	Number of User Memories
(none)	0–9, A–F	16	49–55	0–7	8
00–06	0–9, A–E	15	56–62	0–6	7
07–13	0–9, A–D	14	63–69	0–5	6
14–20	0–9, A–C	13	70–76	0–4	5
21–27	0–9, A–B	12	77–83	0–3	4
28–34	0–9, A	11	84–90	0–2	3
35–41	0–9	10	91–97	0–1	2
42–48	0–8	9	98–99	0	1

[2nd] [PUM] m Protect User Memory

To prevent the accidental deletion of user memories while you are writing a program, press [2nd] [PUM] m where m is the highest user memory you need to protect. Press [2nd] [PUM] [0] to remove the protection from all of the user memories except memory 0 (which is always protected).

Note: You cannot protect a user memory that is occupied by program steps. You must delete those program steps or clear the program memory before you protect the user memory.

The Learn Mode

After you ensure that sufficient program memory is available, you can enter the learn mode so that you can enter your program into the program memory. When the calculator is in the learn mode, the data entry and operation key sequences you enter are stored as keystroke codes in the program memory.

[2nd] [LRN] Learn Mode

Press [2nd] [LRN] to enter or to leave the learn mode. In the learn mode, each keystroke (or keystroke sequence) is recorded as a program step.

The Learn Mode Display Format

As you enter keystrokes in the learn mode, two sets of codes appear in the display. The code on the left represents the key or key sequence (an inverse function is preceded by a minus sign). The two digits on the right represent the number of the program step.

Keystroke code → **−2nd 16 05** ← Program step number

The **PS:M** indicator is also displayed in the learn mode, representing the numbers of the highest program step entered and the highest user memory available.

Learn Mode Characteristics

Program step numbers begin with 00 and are numbered consecutively to the highest step number available. (Step **St**, the "Start" of program memory, precedes step 00.) Each step can be a digit or an operation. When you enter a keystroke or keystroke sequence, the calculator inserts that keystroke code in the program step *after* the step currently displayed; the display then advances to the program step you just entered.

When you enter a key sequence that involves a label ([SBR], [2nd] [LBL], [2nd] [GTO]) or a memory operation ([STO], [RCL], [2nd] [EXC]), an underline appears to prompt you to enter the name of the label or the memory address. If you press an invalid key:

- If the key is "learnable," the keycode for that key is stored as a program step.
- If the key is not "learnable" but performs a valid operation in the learn mode, no keycode is stored and the operation is performed.

Learn Mode Characteristics (Continued)

- If the key is not "learnable" and does not perform a valid operation in the learn mode, no keycode is stored and no operation is performed. The previous program step is redisplayed.

[2nd] [CP] Clear Program

In the learn mode [2nd] [CP] clears the program steps, starting with the step immediately following the current step, through the end of the program. Outside the learn mode, [2nd] [CP] clears the entire program.

[RST] Reset

Outside the learn mode, the [RST] key returns you to the beginning of the program (program step **St**). (To be certain that a program starts executing from the beginning, press [RST] before running the program.) [RST] "clears" any subroutines (so that a [2nd] [RTN] terminates program execution), transfers program execution to step 00, and continues program execution.

[2nd] [PAUSE] Pause

When coded as a program step, [2nd] [PAUSE] briefly halts the program so that a result can be displayed. (An error occurs if you press [2nd] [PAUSE] outside the learn mode.)

[R/S] Run/Stop

The [R/S] key has several functions.

- Outside the learn mode, press [R/S] to run the program currently in the program memory, or to stop the execution of the program if it is running.
- When coded as a step within a program, [R/S] halts the program. Press [R/S] to resume execution.
- When you are listing a program, hold down [R/S] for a few seconds to stop the listing. The calculator remains in the learn mode.

Changing the Execution Sequence

Many problem-solving strategies involve the repetition of a mathematical task. Instead of writing your program with the same task repeated several times, you can include the task only once and direct the program to perform the task whenever it is needed. This requires that you be able to transfer program execution to specified program steps.

[2nd] [LBL] n
Label

A label marks the beginning of a program segment. To enter a label, press [2nd] [LBL] n, where n is the "name" of the label. A label name can be one of these keys:

[0]-[9]
<A>-<D>
[F1], [F2]

A label has no effect on program execution or calculations.

[2nd] [GTO] n
Go To Label

You can direct the program to transfer execution to a label. Pressing [2nd] [GTO] n (where n is the name of the label) enters a "go to label" instruction.

[F1], [F2]
Go To Label and Execute

The [F1] and [F2] keys run the program from a specific label, enabling you to run the program from a point other than the beginning by pressing just one key. [F1] executes the program beginning with label F1; [F2] executes the program beginning with label F2.

Note: Pressing [F1] or [F2] has exactly the same effect as pressing [SBR] [F1] or [SBR] [F2].

[SBR] n,
[2nd] [RTN]
Subroutine and Subroutine Return

A subroutine is a program segment that performs a specific task. You can execute a subroutine many times during a program. Begin the subroutine with a label and end it with [2nd] [RTN].

LBL 1
(instructions of
the subroutine)
RTN

At the places in a program where you want to "call" (access) the subroutine, enter an [SBR] n instruction (where n is the label that begins the subroutine). When the program calls a subroutine, the subroutine is executed. When the execution of the subroutine is complete, the [2nd] [RTN] instruction at the end of the subroutine transfers program execution back to the program step immediately following the [SBR] n instruction that called the subroutine.

You can call one subroutine from within another subroutine by including an [SBR] instruction within the "calling" subroutine. When you call one subroutine from another, you are executing two "levels" of subroutines. You can execute up to five levels of subroutines at the same time; if you attempt to execute a sixth level, an error occurs.

The calculator keeps track of subroutine return points by associating the most recently-executed subroutine call ([SBR] n) with the next return ([2nd] [RTN]) it encounters. If the program encounters a [2nd] [RTN] while it is not executing a subroutine, program execution stops. You can use this feature to stop program execution by including a [2nd] [RTN] instruction in a program not preceded by an [SBR] instruction.

Conditional Statements

You can design a program to make decisions on the basis of conditions that it can detect. These conditions include the comparison of numbers and the number of times a program sequence has been executed. (Conditional statements are only valid in the decimal mode; they are ignored in the hexadecimal and octal modes.)

Relational Tests A relational test compares the value of a displayed number with the value stored in a user memory.

- If the tested condition is *true*, program execution continues with the next program step.
- If the tested condition is *false*, program execution skips one program step. However, if the the next program step is a "two-part" step (a conditional statement or a memory arithmetic operation), program execution skips *two* program steps.

Comparison	Key Sequence (m is the memory address)
x = m	[3rd] [x=m] m
x ≠ m	[INV] [3rd] [x=m] m
x < m	[3rd] [x<m] m
x ≤ m	[INV] [3rd] [x>m] m
x > m	[3rd] [x>m] m
x ≥ m	[INV] [3rd] [x<m] m

You can use a relational test to direct program execution to two different points in the program.

```
   5 STO A
┌▶ LBL 1
│  (program segment calculating x)
│  x = m A
│  GTO 2   ──▶ LBL 2 (segment to execute when the
└─ GTO 1             display is equal to five)
```

Decrement Tests A decrement test reduces the absolute value of the content of a memory by one and tests for equality with zero. (If the absolute value of the memory before the decrement test is less than or equal to 1, the decrement test sets the memory to zero.)

- If the tested condition is *true*, program execution skips one program step. However, if the next program step is a "two-part" step (a conditional statement or a memory arithmetic operation), program execution skips *two* program steps.
- If the tested condition is *false*, program execution continues with the next program step.

Test	Key Sequence (m is the memory address)
Decrement and skip if zero	[3rd] [DSZ] m
Decrement and skip if not zero	[INV] [3rd] [DSZ] m

You can use a decrement test to direct program execution to two different points in the program depending on the number of times the decrement instruction has been repeated.

```
   3 STO A
┌▶ LBL 1
│  (program segment
│  being repeated 3 times)
│  DSZ A
└─ GTO 1
   (rest of program)
```

The Keystroke Codes

This chart lists the keycodes that you can use in a program. The key symbols shown in parentheses indicate key functions in the hexadecimal mode.

Code	Key (Sequence)	Code	Key (Sequence)
0	0	13.55	RCL :
:	:	15	EE
9	9	−15	INV EE
12.0	STO 0	16	(
:	:	17	)
12.9	STO 9	18	y^x
12.A	STO <A>	−18	INV y^x
:	:	19	CE/C
12.E	STO <E>	22	SIN (<D>)
12.18	STO y^x	−22	INV SIN
−12.18	STO INV y^x	23	COS (<E>)
12.28	STO ÷	−23	INV COS
12.38	STO ×	24	TAN (<F>)
12.49	STO −	−24	INV TAN
12.59	STO +	28	÷
13.0	RCL 0	32	LN (<A>)
:	:	−32	INV LN
13.9	RCL 9	33	$\sqrt{x}$ (<B>)
13.A	RCL <A>	34	1/x (<C>)
:	:	38	×
13.E	RCL <E>	39	=

Code	Key (Sequence)	Code	Key (Sequence)
41	RST	2nd 12	2nd [CM]
44	x⇆y	2nd 13.0	2nd [EXC] 0
45	Σ+	:	:
49	−	2nd 13.9	2nd [EXC] 9
51	R/S	2nd 13.A	2nd [EXC] <A>
52.0	SBR 0	:	:
:	:	2nd 13.E	2nd [EXC] <E>
52.9	SBR 9	2nd 15.0	2nd [FIX] 0
52.A	SBR <A>	:	:
:	:	2nd 15.9	2nd [FIX] 9
52.D	SBR <D>	−2nd 15	INV 2nd [FIX]
52.53	SBR F1	2nd 16	2nd [ENG]
52.54	SBR F2	−2nd 16	INV 2nd [ENG]
52.53	F1	2nd 17	2nd [π]
52.54	F2	2nd 18	2nd [%]
55	:	2nd 22	2nd [P⇆R]
57	·	−2nd 22	INV 2nd [P⇆R]
58	+/−	2nd 23	2nd [DRG]
59	+	−2nd 23	INV 2nd [DRG]

(continued)

The Keystroke Codes (Continued)

Code	Key (Sequence)	Code	Key (Sequence)
2nd 24	2nd [DRG►]	2nd 53.0	2nd [LBL] 0
–2nd 24	INV 2nd [DRG►]	:	:
2nd 25	2nd [RND]	2nd 53.9	2nd [LBL] 9
2nd 26	2nd [ABS]	2nd 53.A	2nd [LBL] <A>
2nd 27	2nd [INTG]	:	:
2nd 28	2nd [FRAC]	2nd 53.D	2nd [LBL] <D>
2nd 32	2nd [LOG]	2nd53.53	2nd [LBL] F1
–2nd 32	INV 2nd [LOG]	2nd53.54	2nd [LBL] F2
2nd 33	2nd [x^2]	2nd 54.0	2nd [GTO] 0
2nd 34	2nd [x!]	:	:
2nd 35	2nd [CORR]	2nd 54.9	2nd [GTO] 9
2nd 36	2nd [SLOPE]	2nd 54.A	2nd [GTO] <A>
2nd 37	2nd [INTCP]	:	:
2nd 38	2nd [FCST Y]	2nd 54.D	2nd [GTO] <D>
2nd 39	2nd [CSR]	2nd54.53	2nd [GTO] F1
2nd 45	2nd [Σ–]	2nd54.54	2nd [GTO] F2
2nd 46	2nd [MEAN]	2nd 55	2nd [TDn▼]
2nd 47	2nd [σ_{n-1}]	2nd 56	2nd [D.d]
2nd 48	2nd [σ_n]	2nd 57	2nd [H:M:S]
2nd 49	2nd [FCST X]	2nd 58	2nd [D:M.m]
2nd 51	2nd [PAUSE]	2nd 59	2nd [D:M:S]
2nd 52	2nd [RTN]		

Code	Key (Sequence)	Code	Key (Sequence)
3rd 12	3rd [DEC]	3rd 39	3rd [K]
3rd 13	3rd [HEX]	3rd 41	3rd [DSZ]
3rd 14	3rd [OCT]	–3rd 41	INV 3rd [DSZ]
3rd 25	3rd [in-cm]	3rd 42	3rd [x<m]
–3rd 25	INV 3rd [in-cm]	–3rd 42	INV 3rd [x<m]
3rd 26	3rd [oz-g]	3rd 43	3rd [x=m]
–3rd 26	INV 3rd [oz-g]	–3rd 43	INV 3rd [x=m]
3rd 27	3rd [gal-l]	3rd 44	3rd [x>m]
–3rd 27	INV 3rd [gal-l]	–3rd 44	INV 3rd [x>m]
3rd 28	3rd [°F-°C]	3rd 45	3rd [FRQ]
–3rd 28	INV 3rd [°F-°C]	3rd 46	3rd [$c(ms^{-1})$]
3rd 35	3rd [psi-Pa]	3rd 47	3rd [$g(ms^{-2})$]
–3rd 35	INV 3rd [psi-Pa]	3rd 48	3rd [me(kg)]
3rd 36	3rd [hp-kw]	3rd 49	3rd [e(C)]
–3rd 36	INV 3rd [hp-kw]	3rd 55	3rd [TUp▲]
3rd 37	3rd [J-cal]	3rd 56	3rd [h(Js)]
–3rd 37	INV 3rd [J-cal]	3rd 57	3rd [$k(JK^{-1})$]
3rd 38	3rd [lb-N]	3rd 58	3rd [$N_A(mol^{-1})$]
–3rd 38	INV 3rd [lb-N]	3rd 59	3rd [$R(Jmol^{-1}K^{-1})$]

Entering and Running a Program

After you enter the learn mode, you are ready to record the keystrokes you need for the calculation. The calculator codes each keystroke or sequence as a program step and then performs the keystroke operations when you run the program.

Entering Program Steps

Use the following procedure to enter a program.

1. If necessary, press [2nd] [CP] before entering the learn mode to clear any previously entered program steps.

2. Use the [2nd] [PUM] m key sequence to ensure that there is enough room available for your program. For example, enter [2nd] [PUM] [0] to have access to all 100 program steps.

3. Press [2nd] [LRN] to enter the learn mode. **St** and the **PS:M** indicator appear at the right of the display.

4. Press the keys in the sequence that you would press them if you were performing the calculation. Remember to include pauses where needed.

5. Press [2nd] [LRN] to leave the learn mode. The display returns to its regular format.

Running the Program

To run the program, first enter any necessary values in the user memories or in the display, according to the design of your program. Press [RST] to return to the beginning of the program (**St**); then press [R/S] to run the program. The calculator performs the calculation stored in the program memory, and stops when all program steps have been performed or when an [R/S] (or an "unmatched" [2nd] [RTN]) is encountered in the program.

Example

Enter a program that subtracts a 15% discount from an amount entered in the display. Perform this calculation on $120 and $63. (The equation is x - 15%x = ?).

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Clear the program	[2nd] [CP]	0
Unprotect the user memories	[2nd] [PUM] [0]	0
Enter the learn mode	[2nd] [LRN]	St St:F
Code the keystrokes	[-] 15	5 02 02:E
	[2nd] [%]	2nd 18 03 03:E
	[=]	39 04 04:E
Leave the learn mode	[2nd] [LRN]	0
Run the program for $120	[RST] 120 [R/S]	102
Run the program for $63	[RST] 63 [R/S]	53.55

Note: Do not clear the program memory. The program is used in the next example.

Listing the Program

You may want to review a program in memory, one step at a time. The [3rd] [LIST] key sequence enables you do so.

[3rd] [LIST]
List Program

The [3rd] [LIST] key sequence displays each program step currently in memory. Each step is displayed for a short time to allow you to view each program step, and then the program listing continues.

- If the calculator is in the learn mode when you press [3rd] [LIST], the listing process begins at the step following the current program step.
- If the calculator is not in the learn mode when you press [3rd] [LIST], the listing process begins with the step following the program step that was most recently displayed or executed (whichever occurred last).

You can interrupt the listing process at any time by pressing the [R/S] key and holding it down for several seconds. If you press [R/S] while the listing is in progress, the calculator remains in the learn mode at the current step, even if it was not in the learn mode when you pressed [3rd] [LIST].

If you do not press [R/S], the listing process continues to the end of the program and then performs an automatic reset to the beginning of the program (step St). The calculator leaves the learn mode, even if it was in the learn mode when you pressed [3rd] [LIST].

Editing the Program

When you enter your program, special keys allow you to move through the program steps. At that time, you can use the editing keys to revise, insert, or delete program steps without affecting the rest of the program.

[SST], [BST]
Single Step and Back Step

In the learn mode, the [SST] and [BST] keys enable you to view the program steps without affecting the program. The [SST] key moves *forward* one step in the program; the [BST] key moves *back* one step. When [SST] reaches the end of a program, it "wraps around" to the beginning; when [BST] reaches the beginning of a program, it wraps around to the end.

Outside the learn mode, [SST] executes one program step. Pressing [BST] outside the learn mode causes an error.

Inserting a Program Step

In the learn mode, the "automatic insert" feature interprets any keystroke (or sequence) as a new program step to be inserted.

To insert a program step, use [SST] and [BST] to position the program at the step immediately preceding the desired location, and then press the key (or key sequence) to be inserted. All codes following the one currently displayed are shifted forward one step to create a space for the inserted code.

[2nd] [DEL]
Delete Program Step

The [2nd] [DEL] key sequence deletes the displayed program step. All keystroke codes following the one currently displayed are shifted back one step to fill the space vacated by the code you delete.

The [2nd] [DEL] key sequence has an "automatic backstep" feature. When you press [2nd] [DEL] to delete a program step, the step is deleted and then the *previous* step is displayed. For example, to delete a [+] that is currently in step 09, press [SST] until 59 09 appears in the display; then press [2nd] [DEL]. The [+] is deleted, and the following keystrokes all move back one step. After step 09 is deleted, the previous step (step 08) is displayed.

Editing the Program (Continued)

Revising a Program Step

To revise an existing program step, first delete it and then enter a new one. For example, to replace a [+] in step 13 with a [−], press [SST] until 59 13 appears in the display; then press [2nd] [DEL] to delete the [+]. The calculator displays step 12; press [−] to insert the new keycode in step 13.

Revising a Block of Program Steps

If you need to revise a block of steps in an existing program, it is easiest to delete all the unwanted program steps and then enter the new ones.

1. Press [SST] or [BST] until the *last* step you want to delete is displayed.
2. Press [2nd] [DEL] to delete the step. The step is deleted and the automatic backstep feature displays the previous step. Repeat [2nd] [DEL] until all the unwanted steps have been deleted.
3. Enter the keystrokes you want to replace the deleted steps. As you enter them, the new keycodes are inserted as new program steps.

Example

Start with the program (x − 15%x = ?) from the previous example. Change the [−] to a [+], and replace the [2nd] [%] with a [√x]. (Refer to "The Keystroke Codes" earlier in this chapter).

Procedure	Press	Display
Clear the display	[CE/C]	0
Reset to start (**St**)	[RST]	0
Re-enter the learn mode	[2nd] [LRN]	St 04:E

Example (Continued)

Procedure	Press	Display
Review step 00 ([−])	[SST]	49 00 04:E
Review step 01 ([1])	[SST]	1 01 04:E
Review step 02 ([5])	[SST]	5 02 04:E
Review step 03 ([2nd] [%])	[SST]	2nd 18 03 04:E
Review step 04 ([=])	[SST]	39 04 04:E
Return to step 00	[BST] [BST] [BST] [BST]	49 00 04:E
Delete [−]	[2nd] [DEL]	St 03:E
Insert [+]	[+]	59 00 04:E
Advance to step 03	[SST] [SST] [SST]	2nd 18 03 04:E
Delete [2nd] [%] and insert [√x]	[2nd] [DEL] [√x]	33 03 04:E
Return to step 00	[BST] [BST] [BST]	59 00 04:E
Review step 01 ([1])	[SST]	1 01 04:E
Review step 02 ([5])	[SST]	5 02 04:E
Review step 03 ([√x])	[SST]	33 03 04:E
Review step 04 ([=])	[SST]	39 04 04:E
Leave the learn mode	[2nd] [LRN]	0

Application: Projectile Calculations

The best type of program is one that can be used repeatedly with different data. In this example, the program uses the original velocity and angle from the horizontal of a projectile to determine the time in the air before it lands, the maximum height, and the distance from the launch point when it lands.

Example

The formulas are as follows.

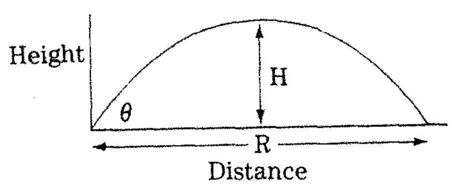
$$T = \frac{\sin\theta \times 2 \times v}{g}$$

$$H = \frac{(\sin\theta \times v)^2}{2 \times g}$$

$$R = \frac{\sin 2\theta \times v^2}{g}$$

where T = the time (seconds)
H = the maximum height (meters)
R = the distance traveled (meters)
θ = the angle at which the projectile starts (degrees, radians, or grads)
v = the starting velocity (meters/second)
g = the gravitational constant

The situation is illustrated below.



Entering the Program

To enter the steps into program memory, follow the procedure below.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Clear the program	2nd [CP]	0
Protect user memories 0–2	2nd [PUM] 2	0

Entering the Program (Continued)

Procedure	Press	Display
Enter the learn mode	2nd [LRN]	St St:F
Find the sine of θ, store it in memory 2	RCL 0 SIN STO 2	12.2 02 02:E
Multiply it by 2 and by v	× 2 × RCL 1	13.1 06 06:E
Divide it by g, stop, display the time	÷ 3rd [g(ms⁻²)] = R/S	51 10 10:d
Multiply the sine of θ by v	RCL 2 × RCL 1 =	39 14 14:C
Square the numerator and divide by 2g	2nd [x²] ÷ (2 × 3rd [g(ms⁻²)])	17 21 21:b
Display the maximum height, stop	= R/S	51 23 23:b
Calculate 2θ	2 × RCL 0 =	39 27 27:b
Find the sine, multiply it by v^2	SIN × RCL 1 2nd [x²]	2nd 33 31 31:A
Divide it by g	÷ 3rd [g(ms⁻²)]	3rd 47 33 33:A
Display the distance traveled	=	39 34 34:A
Leave the learn mode	2nd [LRN]	0

Application: Projectile Calculations (Continued)

Running the Program

After entering the program, you can solve projectile problems by entering the values for θ and v into the user memories and running the program to compute the unknown values.

For example, a projectile is launched at angle (θ) of 45° with a starting velocity of 20 meters per second. Determine the length of time in the air, the maximum height, and the distance from its launch point to its landing site.

Procedure	Press	Display
Store θ in memory 0	45 [STO] [0]	45
Store starting velocity (v) in memory 1	20 [STO] [1]	20
Run the program to determine the time	[RST] [R/S]	2.884192996
Resume the program to determine the height	[R/S]	10.19716213
Resume the program to determine the distance	[R/S]	40.78864852

The time in the air is nearly 3 seconds, the maximum height is over 10 meters, and the distance from the launch site to the landing site is more than 40 meters.

Note: To simplify the problem, considerations of air friction, earth rotation, and other factors have been omitted.

Application: Prime Factors

In this example, the program searches for numbers that are evenly divisible into the number you enter. It finds the prime factors in ascending order.

Example

The program takes the following approach to finding the prime factors of a number (x).

1. Determine if 2 (the only even prime) is a factor of x.
2. If 2 is a factor, display **2** and divide x by 2. Repeatedly check to determine if 2 is a factor of x until x is no longer divisible by 2.
3. If 2 is not a factor, do not change x.
4. Determine if any odd numbers are factors of x.
5. If an odd number is a factor of x, display the factor and divide x by the odd number. If the odd number is not a factor, do not change x.
6. Continue the search until you reach a value that is equal to x.

Entering the Program

To enter the steps into program memory, follow the procedure below.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Clear the program	[2nd] [CP]	0
Protect user memories 0–2	[2nd] [PUM] [2]	0
Enter the learn mode	[2nd] [LRN]	St St:F

(continued)

Application: Prime Factor (Continued)

Entering the Program (Continued)

Procedure	Press	Display
Store the displayed number, a zero for comparisons, and a trial factor of 3	[STO] [1] 0 [STO] [0] 3 [STO] [2]	12.2 04 04:E
Test 2 as a factor	[2nd] [LBL] [0] [RCL] [1] [÷] 2 [=] [2nd] [FRAC] [INV] [3rd] [x=m] [0] [2nd] [GTO] [1]	2nd 54.1 13 13:d
Halve the number and display 2 as a factor	2 [STO] [÷] [1] [R/S] [2nd] [GTO] [0]	2nd 54.0 18 18:C
Determine if all factors have been found	[2nd] [LBL] [1] [RCL] [1] [INV] [3rd] [x<m] [2] [2nd] [GTO] [2]	2nd 54.2 23 23:b
Display 1 when factoring is complete	[RCL] [1] [R/S] [2nd] [GTO] [1]	2nd 54.1 26 26:b
Test the next prospective factor	[2nd] [LBL] [2] [RCL] [1] [÷] [RCL] [2] [=] [2nd] [FRAC] [INV] [3rd] [x=m] [0] [2nd] [GTO] [3]	2nd 54.3 35 35:9

Entering the Program (Continued)

Procedure	Press	Display
Display each odd factor, reduce the number	[RCL] [2] [R/S] [STO] [÷] [1] [2nd] [GTO] [1]	2nd 54.1 40 40:9
Count to the next odd number for testing as a factor	[2nd] [LBL] [3] 2 [STO] [+] [2] [2nd] [GTO] [1]	2nd 54.1 45 45:8
Leave the learn mode	[2nd] [LRN]	0

Running the Program

After entering the program, you can use it to find an integer's prime factors.

Procedure	Press	Display
Enter a number	102	102
Run the program	[RST] [R/S]	2
Continue with the next factor	[R/S]	3
Continue with the next factor	[R/S]	17
The number is now factored	[R/S]	1

The prime factors of 102 are 2, 3, and 17.

Application: Multiple Entry Points

In this example, you store three different programs in the program memory at the same time. You then use different methods to execute each of the three programs.

In this example you enter three programs, each of which calculates the area of a different geometric figure. The programs use the following formulas.

- The area of a rectangle: $A = lw$
  where l = length, w = width
- The area of a triangle: $A = \sqrt{S(S-a)(S-b)(S-c)}$
  where a = length of side a, b = length of side b, c = length of side c, $S = (a+b+c) \div 2$
- The area of a circle: $A = \pi r^2$
  where r = radius

Entering the Program

This program assumes that the required variables are stored in user memories and calculates the area based on those variables. To enter the steps into program memory, follow the procedure below.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Clear the program	2nd [CP]	0
Protect user memories 0–3	2nd [PUM] 3	0

Entering the Program (Continued)

Procedure	Press	Display
Enter the learn mode	2nd [LRN]	St St:F
Calculate the area of a rectangle	RCL 0 × RCL 1 = 2nd [RTN]	2nd 52 04 04:E
Calculate the area of a triangle: first find S; then use the formula	2nd [LBL] 1 (RCL 0 + RCL 1 + RCL 2) ÷ 2 = STO 3 × (RCL 3 − RCL 0) × (RCL 3 − RCL 1) × (RCL 3 − RCL 2) = √x 2nd [RTN]	2nd 52 37 37:9
Calculate the area of a circle	2nd [LBL] F1 RCL 0 2nd [x²] × 2nd [π] = 2nd [RTN]	2nd 52 44 44:8
Leave the learn mode	2nd [LRN]	0

After you enter the program, you can use it to calculate the area of either a rectangle, a triangle, or a circle.

Example 1

Calculate the area of a rectangle 9″ wide and 5.5″ high.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Store the variables	9 [STO] [0] 5.5 [STO] [1]	5.5
Position the program and calculate the area	[RST] [R/S]	49.5

Because the formula for the area of a rectangle is at the beginning of the program, you pressed [RST] before you ran the program.

Example 2

Calculate the area of a triangle with sides of 3″, 4″, and 5″.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Store the variables	3 [STO] [0] 4 [STO] [1] 5 [STO] [2]	5
Position the program and calculate the area	[2nd] [GTO] [1] [R/S]	6

Because the formula for the area of a triangle follows label 1, you pressed [2nd] [GTO] [1] before you ran the program.

Example 3

Calculate the area of a circle with a 4″ radius.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Store the variable	4 [STO] [0]	4
Position the program and calculate the area	[F1]	50.26548246

Because the formula for the area of a circle follows label F1 in program memory, you pressed [F1] to position the program at label F1 and execute the program.

To execute a program beginning from label F1 (or label F2), just press [F1] (or [F2]). The calculator positions the program at the label, then automatically executes the program from that point.

Application: Third Order Simultaneous Equations

In this example, the program finds the solutions of a third order system of simultaneous equations you enter as a matrix.

Example

The program takes the following approach.

1. Calculate the first solution by finding the ratio of two determinants. One of the determinants is the matrix with the solution vector substituted for the first column. The other determinant is the matrix of original coefficients.

2. Calculate the second solution by finding the ratio of two determinants and changing the sign. One of the determinants is the matrix with the solution vector substituted for the second column. The other determinant is the matrix of original coefficients.

3. Calculate the third solution by finding the ratio of two determinants. One of the determinants is the matrix with the solution vector substituted for the third column. The other determinant is the matrix of original coefficients.

Entering the Program

To enter the steps into program memory, follow the procedure below.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Clear the program	[2nd] [CP]	0
Protect user memories 0–9	[2nd] [PUM] [9]	0

Entering the Program (Continued)

Procedure	Press	Display
Enter the learn mode	[2nd] [LRN]	St St:F
Evaluate the minor of row 1 column 1 and end with a pending subtraction	[2nd] [LBL] [F1] [×] [(] [RCL] [5] [SBR] [4] [RCL] [8] [)] [−] [2nd] [RTN]	2nd 52 08 08:d
Evaluate the negative of the minor of row 2 column 2 and end with a pending addition	[2nd] [LBL] [2] [×] [(] [RCL] [4] [SBR] [4] [RCL] [7] [)] [+] [2nd] [RTN]	2nd 52 17 17:C
Evaluate the minor of row 3 column 3 and end with the value of the determinant	[2nd] [LBL] [3] [×] [(] [RCL] [4] [×] [RCL] [8] [−] [RCL] [7] [×] [RCL] [5] [=] [2nd] [RTN]	2nd 52 29 29:A
Perform a sequence that is used by subroutine F1 and subroutine 2	[2nd] [LBL] [4] [×] [RCL] [9] [−] [RCL] [6] [×] [2nd] [RTN]	2nd 52 36 36:9
Calculate a numerator determinant	[2nd] [LBL] [F2] [RCL] [2] [SBR] [2] [RCL] [3] [SBR] [3]	52.3 41 41:9
Leave the learn mode	[2nd] [LRN]	0

Application: Third Order Simultaneous Equations (Continued)

Running the Program

After entering the program, you can solve the system of simultaneous equations:

$$a_1x_1 + a_4x_2 + a_7x_3 = b_1$$
$$a_2x_1 + a_5x_2 + a_8x_3 = b_2$$
$$a_3x_1 + a_6x_2 + a_9x_3 = b_3$$

$$\begin{bmatrix} a_1 & a_4 & a_7 \\ a_2 & a_5 & a_8 \\ a_3 & a_6 & a_9 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}$$

$$D = \begin{vmatrix} a_1 & a_4 & a_7 \\ a_2 & a_5 & a_8 \\ a_3 & a_6 & a_9 \end{vmatrix} \qquad M1 = \begin{vmatrix} b_1 & a_4 & a_7 \\ b_2 & a_5 & a_8 \\ b_3 & a_6 & a_9 \end{vmatrix}$$

$$M2 = -\begin{vmatrix} b_1 & a_1 & a_7 \\ b_2 & a_2 & a_8 \\ b_3 & a_3 & a_9 \end{vmatrix} \qquad M3 = \begin{vmatrix} b_1 & a_1 & a_4 \\ b_2 & a_2 & a_5 \\ b_3 & a_3 & a_6 \end{vmatrix}$$

$x_1 = M1 \div D \qquad x_2 = M2 \div D \qquad x_3 = M3 \div D$

Solve for x_1, x_2, and x_3 of this matrix:

$$\begin{bmatrix} 4 & 8 & 0 \\ 8 & 8 & 8 \\ 2 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 4 \\ 6 \end{bmatrix}$$

Procedure	Press	Display
Store the second and third columns in user memories 4–9	8 [STO] [4] 8 [STO] [5] 0 [STO] [6] 0 [STO] [7] 8 [STO] [8] 1 [STO] [9]	1

Running the Program (Continued)

Procedure	Press	Display
Store the solution vector in user memories 1–3	4 [STO] [1] 4 [STO] [2] 6 [STO] [3]	6
Evaluate the determinant and store it for later use	4 [F1] 8 [SBR] [2] 2 [SBR] [3] [STO] [0]	96
Evaluate M1	[RCL] [1] [F1] [F2]	384
Find x_1	[÷] [RCL] [0] [=]	4
Replace column 2 with column 1	4 [STO] [4] 8 [STO] [5] 2 [STO] [6]	2
Evaluate – M2	[RCL] [1] [F1] [F2]	144
Evaluate M2	[+/–]	– 144
Find x_2	[÷] [RCL] [0] [=]	– 1.5
Replace column 3 with column 2	8 [STO] [7] 8 [STO] [8] 0 [STO] [9]	0
Evaluate M3	[RCL] [1] [F1] [F2]	– 192
Find x_3	[÷] [RCL] [0] [=]	– 2

The solutions are as follows.

$x_1 = 4$
$x_2 = -1.5$
$x_3 = -2$

Application: Quadratic Roots

In this example, the program calculates the roots of a quadratic equation whose coefficients you enter. It displays the real and imaginary parts of both roots.

Example

The program takes the following approach.

1. Check for an imaginary part by determining the sign of the number whose square root is needed.

2. If there is no imaginary part, calculate the roots from the following formulas:

$$r1(re) = -b/(2a) + \sqrt{(b^2/(4a^2) - c/a)}$$
$$r1(im) = 0$$
$$r2(re) = -b/(2a) - \sqrt{(b^2/(4a^2) - c/a)}$$
$$r2(im) = 0$$

3. If there is an imaginary part, calculate the roots from the following formulas:

$$r1(re) = -b/(2a)$$
$$r1(im) = \sqrt{abs(b^2/(4a^2) - c/a)}$$
$$r2(re) = -b/(2a)$$
$$r2(im) = -\sqrt{abs(b^2/(4a^2 - c/a)}$$

Entering the Program

To enter the steps into program memory, follow the procedure below.

Procedure	Press	Display
Clear the calculator	OFF ON	0
Clear the program	2nd [CP]	0
Protect user memories 0–6	2nd [PUM] 6	0
Enter the learn mode	2nd [LRN]	St St:F

Entering the Program (Continued)

Procedure	Press	Display
Check for complex roots	0 STO 0 SBR 2 3rd [x<m] 0 2nd [GTO] 3	2nd 54.3 05 05:E
Calculate real roots and display them	SBR 1 + SBR 2 √x = R/S 0 R/S SBR 1 − SBR 2 √x = R/S 0 R/S RST	41 22 22:b
Calculate the complex roots and display them	2nd [LBL] 3 SBR 1 R/S SBR 2 2nd [ABS] √x R/S SBR 1 R/S SBR 2 2nd [ABS] √x +/− R/S RST	41 37 37:9
Calculate −b/(2a)	2nd [LBL] 1 (RCL 2 ÷ 2 ÷ RCL 1) +/− 2nd [RTN]	2nd 52 47 47:8
Calculate $b^2/(4a^2) - c/a$	2nd [LBL] 2 (RCL 2 2nd [x²] ÷ 4 ÷ RCL 1 2nd [x²] − RCL 3 ÷ RCL 1) 2nd [RTN]	2nd 52 62 62:6
Leave the learn mode	2nd [LRN]	0

Running the Program

After entering the program, you can use it to find the roots of a quadratic equation.

Find the roots of $2x^2 + 2x - 1 = 0$.

Procedure	Press	Display
Store the coefficients	2 [STO] [1] 2 [STO] [2] 1 [+/−] [STO] [3]	−1
Position the program	[RST]	−1
Calculate the real part of r1	[R/S]	0.366025404
Calculate the imaginary part of r1	[R/S]	0
Calculate the real part of r2	[R/S]	−1.366025404
Calculate the imaginary part of r2	[R/S]	0

Chapter 9: Integration

The calculator is preprogrammed to compute definite integrals according to Simpson's rule.

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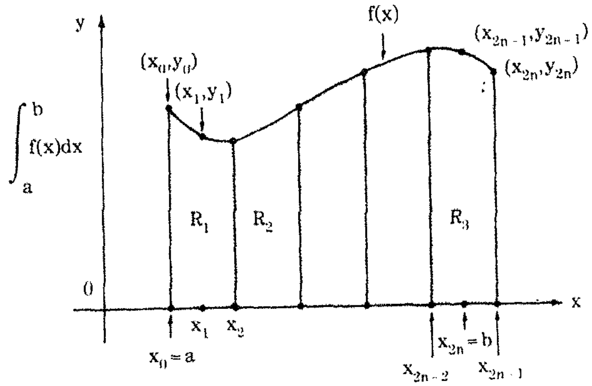
Simpson's Rule

The [2nd] [∫dx] key sequence on the TI-65 uses Simpson's Rule, which is a method of approximating the definite integral of a function.

Area Under A Curve

An integral can be considered as the area under a curve, as shown below.



The area under the curve may be divided into an even number of subintervals, such as 2n subintervals of length $h = (b - a) \div 2n$ with endpoints $x_0 (= a)$, x_1, . . . , x_{2n-1}, $x_{2n} (= b)$.

$A_1 = (h \div 3) \times (y_0 + 4y_1 + y_2)$ is an approximation of the area of R_1.

Similarly, A_2 is an approximation of R_2. Therefore, A_n is an approximation of the area of R_n. Then, adding $A_1 + A_2 + \ldots + A_n$ gives an approximation of the area under the curve.

This approximation for definite integrals is stated in Simpson's Rule:

$$\int_a^b f(x)dx = \frac{h}{3}(y_0 + 4y_1 + 2y_2 + \ldots + 2y_{2n-2} + 4y_{2n-1} + y_{2n})$$

Note that the first and last terms in the parentheses have 1 for a coefficient. All other y terms with even subscripts have 2 for a coefficient, and all y terms with odd subscripts have 4 for a coefficient.

The Integration Feature

The integration feature finds the approximate areas under portions of the curve and sums them. The more portions under the curve, the more accurate the answer—but the more time it takes.

[2nd] [∫dx] Integration

The [2nd] [∫dx] key sequence finds the definite integral of a function, which must be entered as a program.

Entering a Function

Use the following procedure to enter a function.

1. Protect user memories 0 through 2. If they are not protected, pressing [2nd] [∫dx] causes an error condition.

2. Enter the learn mode and program the function to be integrated.

   - Do not not store any values in user memories 0, 1, or 2 within the program. The calculator uses these user memories to perform the integration.

   - For each occurence of the integration variable, use a [RCL] [1] instruction. If your function begins with the variable, you can omit [RCL] [1] at the start of the program; the integration argument is automatically recalled from user memory 1 at the beginning of each integration interval.

   - End the function with [=] [R/S]. (Do not use any other [R/S] instructions in the program.)

3. Leave the learn mode.

Performing an Integration

After entering the function in program memory, follow the steps below to find the definite integral.

1. Enter the lower limit in user memory 1 and the upper limit in user memory 2.
2. Press [2nd] [∫dx]. The calculator displays **00 Frint** to prompt you to enter the number of integration intervals you want to use.
3. Enter a one- or two-digit number, according to the desired accuracy and calculation time. This number must be a decimal value, regardless of the current number-system mode.

   If you press an incorrect digit key, simply re-enter the correct digits. (The calculator uses only the last two digits entered as the number of integration intervals.)
4. Press [R/S].

The integration is figured according to Simpson's Rule. At the end of the integration, the integral is displayed and placed in user memory 0; user memories 1 and 2 both contain the upper limit.

If you press [R/S] while the integration is in progress, an error occurs and the integration process terminates. To complete the integration, you must re-enter the upper and lower limits and press [2nd] [∫dx] to restart the calculation.

Note: If you stop an integration by pressing [R/S], an error condition occurs. The values in user memories 0–2 may not be valid.

Trigonometric Integrals

The functions in a table of trigonometric integrals require angles to be given in radians. In using the table, you look up the integral, evaluate it at the integration limits, and subtract. To obtain the same answer using the calculator, it must be put in the radian mode before performing the integration. (Note that the calculator's integration feature computes the answer without actually finding the integral.)

Although a function may not contain any trigonometric functions, its integral may be an inverse trigonometric function. The answer for such a function is always in terms of radians, regardless of the angle-mode setting. For example, the integral of

$$(1/\sqrt{2x-x^2})\,dx$$

is $\cos^{-1}(1-x)$. If you evaluate

$$\int_1^{1.5}(1/\sqrt{2x-x^2})\,dx$$

using 10 intervals and pressing [2nd] [∫dx], you get 0.5235988 regardless of the angle units setting. But if you evaluate

$$[\cos^{-1}(1-x)]_1^{1.5}$$

you must set the calculator to radians to get the same answer (0.5235988).

Integrals that involve trigonometric functions usually require the radian angle unit because it is dimensionless. However, some problems are better solved in terms of dimensioned units (degrees or grads). Be sure to select the angle units that apply to your problem before performing the integration.

Example

Integrate sin x cos x between 0 and π ÷ 4 radians.

Procedure	Press		Display
Clear the calculator	OFF ON		0
Select radians	2nd [DRG]		0
Clear the program	2nd [CP]		0
Protect user memories 0–2	2nd [PUM] 2		0
Enter the learn mode	2nd [LRN]		St St:F
Recall memory 1	RCL 1	13.1	00 00:E
Find the sine and multiply	SIN ×	38	02 02:E
Recall memory 1	RCL 1	13.1	03 03:E
Find the cosine	COS	23	04 04:E
Complete the operation	=	39	05 05:E
End the program	R/S	51	06 06:E
Leave the learn mode	2nd [LRN]		0
Store the lower limit	STO 1		0
Store the upper limit	2nd [π] ÷ 4 = STO 2	0.785398163	
Enter subintervals and run the program	2nd [∫dx] 20 R/S	0.250000003	

Example (Continued)

While the integral is being calculated, the **RAD** and **RUN** indicators are displayed and digits disappear and flash sporadically. You can time this program; typically it takes about three minutes to execute.

Because there is an automatic RCL 1 at the beginning of each iteration of the integration, step 00 (RCL 1) is not actually necessary. The displayed value is ignored. There are two advantages to removing these steps.

- You save a step that you might need for an additional keystroke.
- The program runs more quickly.

Remove step 00 (RST, 2nd [LRN], SST, 2nd [DEL]). Then leave the learn mode and put the lower limit in user memory 1 and the upper limit in user memory 2. Run the program again with the 2nd [∫dx] 20 R/S key sequence. Now the problem typically takes about four percent less time than when the first step was included.

If fewer intervals are used, the problem is solved more quickly, but the answer varies slightly. The variation may be acceptable for your requirements.

Chapter 10: Statistics

In many situations in business and everyday life, you may find yourself handling a set of data points that can best be analyzed with statistical techniques. This chapter discusses the keys that perform various statistical functions, including entering statistical data and performing common statistical calculations.

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The Statistics Mode

The first time you press the [Σ+] key to enter a data point, the calculator enters the statistics mode, indicated by STAT in the display.

Entering the Statistics Mode

When you enter the statistics mode:

- The **STAT** indicator appears in the display.
- The statistical registers (user memories 1-6) are cleared.
- Temporary "memory protection" is set for user memories 0-6, limiting a program to 63 steps.

Note: If you have protected user memories 1-6 with [2nd] [PUM], **Error 4** is displayed when you press [Σ+]. You must remove the protection before entering statistical data. An error also occurs if you have a stored program larger than 63 steps. You must either delete the excess steps or clear the program memory.

All statistical operations except [3rd] [FRQ] clear any pending operations.

If the calculator is in the statistics mode when you turn it off, the Constant Memory feature retains the values in the statistical registers. When you turn the calculator back on, the calculator remains in the statistics mode and the values in the statistical registers are still available.

User Memories 1 through 6

The calculator uses memories 1-6 to store certain statistical values as you enter data. You can recall these values to display additional information about the data or to calculate other statistical values.

Avoid using memories 1 through 6 while the calculator is in the statistics mode. The values in those memories must be related to the data set, as discussed later in this chapter. (When the calculator is in the statistics mode, pressing [2nd] [CM] clears only user memory 0.)

The Statistics Procedure

You use a three-step procedure to solve a statistics problem: tabulate the data, enter the data, and view the results.

Step 1: Tabulate the Data

Gathering your data into a table is the first step in solving a statistics problem. The way you tabulate your data depends on the situation you are studying.

If each of your observations is described by a single number (like grades in class), your data is considered to be "one-variable data."

If each of your observations is described by two numbers (like measurements of temperature and time in a thermal system), your data is considered to be "two-variable data."

Tabulating the data helps you to enter it without repeating an entry or leaving one out.

Step 2: Enter the Data

Enter the data as unpaired (one-variable) or paired (two-variable) entries.

Step 3: View the Results

You can view the results at any time during the entry or modification of a data set.

- If you want the results of entering only some of the data, press the keys that show results after you have entered that data.
- If you want the results of entering all the data, press the keys that show results after you have entered the entire data set.
- If you want the results of the data set with some points deleted, press the keys that show results after you have deleted those points.
- If you want the results of the data set with some new data added, press the keys that show results after you have entered the additional data.

Entering and Removing Data

The statistics data-entry keys enable you to enter data values into the calculator's statistical registers. You can then analyze the data by performing any of several statistical calculations, including linear regression and trend line analysis.

[Σ+]
Data Entry

The [Σ+] key enters the displayed number as a data point in the statistical registers. Each time you press [Σ+], the display shows the number of data points currently stored in the statistical registers.

[2nd] [Σ−]
Data Removal

The [2nd] [Σ−] key sequence removes the displayed data point from the statistical registers. Each time you press [2nd] [Σ−], the display shows the number of data points currently stored in the statistical registers.

[3rd] [FRQ]
Frequency

Use the [3rd] [FRQ] key sequence to enter the same data point up to 99 times.

1. Enter the data point in the display and press [3rd] [FRQ]. The calculator displays **00 Frint**.
2. Enter a one- or two-digit number indicating the number of times you want to enter the data point. This number must be a decimal value, regardless of the current number-system mode.

   If you press an incorrect digit key, simply re-enter the correct digits. (The calculator uses only the last two digits entered as the frequency.)
3. Press [Σ+].

You can use [3rd] [FRQ] to remove multiple data points, instead of adding them, by pressing [2nd] [Σ−] instead of [Σ+] in step 3, above.

Entering Pairs of Data Values

You can use the [x⇆y] key in conjunction with the [Σ+] key to enter a data point with both x and y values, as follows.

Entering Pairs of Data Values (Continued)

1. Enter an x value and press [x⇆y].
2. Enter a y value and press [Σ+].

Repeat the procedure to enter additional data points.

Note: If the x values increase in increments of 1, you can enter the first pair of data values and then enter just the y values. The calculator enters the previous x value plus 1 each time you enter a y value.

You can also follow this procedure with the [2nd] [Σ−] key sequence to remove data points, and with the [3rd] [FRQ] key sequence to enter or remove multiple data points.

[2nd] [CSR]
Clear Statistical Registers

Use the [2nd] [CSR] key sequence when you have finished your statistical calculations and are ready to return to general calculator usage. When you press [2nd] [CSR], the following events occur.

- The **STAT** indicator is erased from the display.
- The statistical registers are cleared.
- The temporary "memory protection" of user memories 0–6 is released.
- The calculator leaves the statistics mode and returns to normal operating conditions.

If the calculator is not in the statistics mode when you press [2nd] [CSR], an error occurs.

Note: Before starting a statistics problem with new data, be sure to press [2nd] [CSR] to clear any old data from the statistical registers.

Mean and Standard Deviation

The statistics keys described on these pages calculate the mean and the standard deviation of the data values you enter.

[2nd] [MEAN] Data Mean

The [2nd] [MEAN] key sequence displays the mean of all the data values currently collected in the statistical registers. The mean, represented by the $\bar{x}$ symbol, is calculated according to this equation:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

If you enter data points with x and y values, press [2nd] [MEAN] to display the mean of the y values; then press [x⇌y] to display the mean of the x values.

[2nd] [σn], [2nd] [σn-1] Standard Deviation

The [2nd] [σn] and [2nd] [σn-1] key sequences calculate the standard deviation of the data values in the statistical registers. The standard deviation is a measure of how widely the values vary from the mean.

If you have entered data points with x and y values, press [2nd] [σn] or [2nd] [σn-1] to display the standard deviation of the y values; then press [x⇌y] to display the standard deviation of the x values.

Population Deviation

Use the [2nd] [σn] key sequence when data is taken from every member of a population. This "n weighted" (or "population") standard deviation is calculated according to this equation:

$$\sigma_n = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}}$$

Sample Deviation

Use the [2nd] [σn-1] key sequence when data is taken from a sample of a population. This "n − 1 weighted" (or "sample") standard deviation is calculated according to this equation:

$$\sigma_{n-1} = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$$

Example

A class of 12 students made the following scores on a test. Calculate the mean and the standard deviation.

96 81 85 76 86 57 98 75 78 100 72 70

Because you are entering all of the scores, use the "n weighted" (population) standard deviation.

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Clear the statistical registers (only if in the statistics mode)	[2nd] [CSR]	0
Enter the test scores	96 [Σ+] 81 [Σ+] 85 [Σ+] 76 [Σ+] 86 [Σ+] 57 [Σ+] 98 [Σ+] 75 [Σ+] 78 [Σ+] 100 [Σ+] 72 [Σ+] 70 [Σ+]	12
Enter an extra value	66 [Σ+]	13
Remove the extra value	66 [2nd] [Σ−]	12
Calculate the mean	[2nd] [MEAN]	81.16666667
Calculate the population standard deviation	[2nd] [σn]	12.12321006
Leave the stat mode	[2nd] [CSR]	12.12321006

Correlation, Intercept, Slope, and Predicted Value

The TI-65 includes several keys that help you analyze information about the best straight line through the points entered, including its correlation coefficient, intercept, slope, and predicted x and y values.

2nd [CORR] Correlation

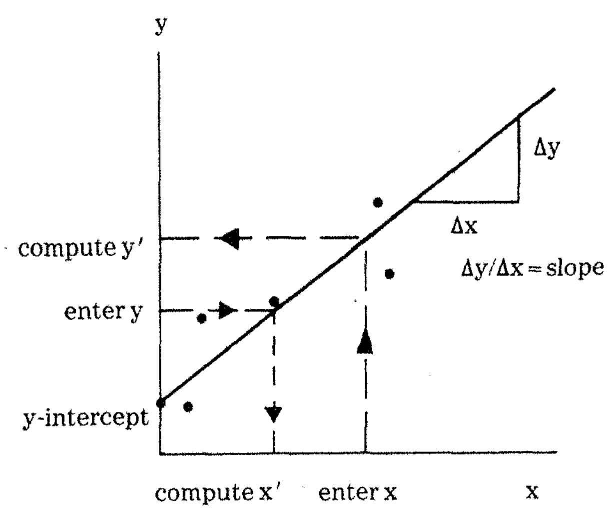
The 2nd [CORR] key sequence gives the correlation between the x and y values in a set of data points.

A result near 1 indicates that the values have a strong linear relationship. A result near 0 indicates that the values are only slightly related. A value near −1 indicates that the values are very closely related, but in a negative way; that is, an increase in one is related to a decrease in the other.

2nd [INTCP], 2nd [SLOPE] Intercept/Slope

The 2nd [INTCP] key sequence displays the y-intercept of the best straight line through the points entered.

The 2nd [SLOPE] key sequence displays the slope of the best straight line through the points entered.



2nd [FCST Y], 2nd [FCST X] Predicted Value

After you enter an x value, you can press 2nd [FCST Y] to display the y value that corresponds with that x on the best straight line through the points entered. Similarly, after you enter a y value, you can press 2nd [FCST X] to display the corresponding x value.

You should use caution in the following calculations.

- Computing an x (independent) value on the basis of a y (dependent) value.
- Computing a y value on the basis of an x that is outside the range of entered x values.

The predictions that result may or may not have statistical validity, depending on the number of the data points and their correlation coefficient. However, trend line analysis and forecasting calculations often use these computations to make predictions or estimations of probability about the future.

Stored Statistical Values

As you enter your data, specific statistical values are automatically calculated and stored in the statistical registers (user memories 1 through 6).

User Memory Assignments

As you enter data points, the calculator processes them and stores intermediate results in user memories 1 through 6, as shown in the following chart.

User Memory	Contents	Explanation
1	Rxy	$n\Sigma(x-\bar{x})(y-\bar{y}) = n\Sigma xy - \Sigma x\Sigma y$
2	n	the number of data points you entered
3	Σy	the sum of the y values
4	Qy	$n\Sigma(y-\bar{x}y)^2 = n\Sigma y^2 - (\Sigma y)^2$
5	Σx	the sum of the x values
6	Qx	$n\Sigma(x-\bar{x})^2 = n\Sigma x^2 - (\Sigma x)^2$

Note: When you are performing single-variable statistics, the only valid values are Σy, Qy, and n.

Using the Stored Values

You can recall these values from the user memories for several purposes.

- To review them for additional information about your data set.
- To record them for later use in updating your data.
- To calculate traditional statistical values such as Σx^2, Σy^2, and Σxy.

Because the means are subtracted from the second-order values (Qx, Qy, and Rxy), the calculator can work with smaller values in calculating statistical and linear regression functions. The calculator therefore maintains greater accuracy in these calculations than would be possible with traditional statistical data (Σx^2, Σy^2, and Σxy).

You can calculate these traditional values easily by following the key sequences shown below.

Value	Formula	Key Sequence
Σx^2	$(Qx + (\Sigma x)^2)/n$	[RCL] [6] [+] [RCL] [5] [2nd] [x²] [=] [÷] [RCL] [2] [=]
Σy^2	$(Qy + (\Sigma y)^2)/n$	[RCL] [4] [+] [RCL] [3] [2nd] [x²] [=] [÷] [RCL] [2] [=]
Σxy	$(Rxy + \Sigma x\Sigma y)/n$	[RCL] [1] [+] [RCL] [5] [×] [RCL] [3] [=] [÷] [RCL] [2] [=]

Application: Analyzing a Random Sample

Instead of testing every element in a population, you may decide to test just a sample of the elements. If you select the sample at random, you can assume that it represents the entire population. Then, you can describe the population by calculating mean, variance, and "n – 1 weighted" standard deviation of the random sample.

Example

You want to find the average height for a class of 99 students, but you cannot measure every student.

Randomly select a sample of eight students, and measure their heights. The height measurements (in inches) are listed below in ascending order.

63, 66, 69, 69, 71, 72, 74, 76

Calculate sample mean, standard deviation (σ_{n-1}), and variance ($(\sigma_{n-1})^2$).

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Clear the statistical registers (only if in the statistics mode)	[2nd] [CSR]	0
Enter the data values	63 [Σ+] 66 [Σ+] 69 [3rd] [FRQ] 2 [Σ+] 71 [Σ+] 72 [Σ+] 74 [Σ+] 76 [Σ+]	8
Calculate the mean	[2nd] [MEAN]	70
Calculate the standard deviation	[2nd] [σ_{n-1}]	4.208834246
Calculate variance	[2nd] [x^2]	17.71428571

For the sample of eight measurements, the average height is 70 inches, the standard deviation is about 4.2, and the variance is about 17.7.

Predicting Future Sales: Linear Regression

With linear regression, you can establish a relationship among known events that will enable you to estimate future occurrences. In this example, you determine how the amount of sales relates to the number of salespeople. Then, you use this information to predict the amount of sales achievable by a specific number of salespeople.

Example

A life insurance company has found that the volume of sales in each office varies according to the number of salespeople. Offices in various cities have the following number of salespeople and resulting sales.

Number of salespeople	7	12	3	5	11	8
Sales in $1000 per month	99	152	81	98	151	112

Perform a linear regression analysis to predict the amount of sales if the company establishes a new office with nine salespeople. Determine the correlation coefficient of the data values and the slope and intercept of the line.

Example— Part A

First, tabulate the data in terms of x and y. Then, enter the x and y values into the statistical registers to predict the y value if the x value is 9.

x	y
7	99000
12	152000
3	81000
5	98000
11	151000
8	112000

(continued)

Predicting Future Sales: Linear Regression (Continued)

In parts B and C of the example, you use the data in the statistical registers to determine how closely the pairs of data values are related to each other. The correlation among the pairs (points) determines how accurately the constructed line represents the trend.

Example—Part A (Continued)

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Clear the statistical registers (only if in the statistics mode)	[2nd] [CSR]	0
Enter the x and y data	7 [x⇆y] 99000 [Σ+] 12 [x⇆y] 152000 [Σ+] 3 [x⇆y] 81000 [Σ+] 5 [x⇆y] 98000 [Σ+] 11 [x⇆y] 151000 [Σ+] 8 [x⇆y] 112000 [Σ+]	6
Enter the x value	9	9
Predict the y value	[2nd] [FCST Y]	126601.1236

The company can expect nine salespeople to sell about $126,600 per month.

Note: Do not erase the data from the statistical registers. The data values are used in the next part of the example.

Example—Part B

Use the x and y data in Part A to determine the correlation coefficient of the data.

Procedure	Press	Display
Find the correlation coefficient	[2nd] [CORR]	0.969757193

Because this value is close to 1, the data values have a strong positive relationship.

Note: Do not erase the data from the statistical registers. The data is used in the next part of the example.

Example—Part C

Determine the equation that best represents the data (y = mx + b) by calculating the slope and intercept.

Procedure	Press	Display
Display the intercept	[2nd] [INTCP]	51668.53933
Display the slope	[2nd] [SLOPE]	8325.842697

Therefore, the equation for this line is:

$$y = (8325.842697)x + 51668.53933$$

Later, if you have cleared the statistical registers and want to predict y for any given x value, you can use this equation without re-entering all the data.

Predicting Yearly Events: Trend Line Analysis

You can also apply a form of linear regression to analyze data that is in the form of yearly figures. This type of linear regression is referred to as "trend line analysis" and is helpful in predicting what will happen in subsequent years.

Example

A stock has reported the following earnings per share from 1982 through 1986.

$1.52 $1.35 $1.53 $2.17 $3.60

Use trend line analysis to predict the earnings per share for the next three years and to predict the year in which you could expect the earnings per share to reach $6.50.

Example—Part A

First tabulate the data in terms of x and y.

x	y
1982	$1.52
1983	$1.35
1984	$1.53
1985	$2.17
1986	$3.60

Then follow the steps below to enter the data.

1. Enter the first known x value (1982), and press [x⇆y].
2. Enter the corresponding y value (1.52), and press [Σ+].
3. Enter the rest of the known y values; press [Σ+] after each value.

Example—Part A (Continued)

Procedure	Press	Display
Clear the calculator	[OFF] [ON]	0
Clear the statistical registers (only if in the statistics mode)	[2nd] [CSR]	0
Fix the decimal point at two places	[2nd] [FIX] [2]	0.00
Enter the first pair of data values	1982 [x⇆y] 1.52 [Σ+]	1.00
Enter the remaining y data	1.35 [Σ+] 1.53 [Σ+] 2.17 [Σ+] 3.6 [Σ+]	5.00
Project 1987 earnings	1987 [2nd] [FCST Y]	3.53
Project 1988 earnings	1988 [2nd] [FCST Y]	4.03
Project 1989 earnings	1989 [2nd] [FCST Y]	4.52
Find the year that projected earnings will be $6.50	6.5 [2nd] [FCST X]	1992.97

(continued)

Predicting Yearly Events: Trend Line Analysis (Continued)

Example— Part A (Continued)

According to the trend calculated from the known data, the earnings predicted for 1987 are $3.53, the earnings predicted for 1988 are $4.03, and the earnings predicted for 1989 are $4.52. The predicted earnings will reach $6.50 in 1993 (the first full year after 1992.97).

Note: Do not clear the statistical registers. The data values are used in the next part of the example.

Example— Part B

Using the data values entered in Part A, determine the relationship among the pairs of data values by calculating the correlation coefficient.

Procedure	Press	Display
Calculate the correlation coefficient	2nd [CORR]	0.85

Trend line analysis differs from linear regression in that one of the factors (the year) is not a random normal variable. To determine the significance of the correlation coefficient you must use a statistic called the "coefficient of determination," which is the square of the correlation coefficient. It expresses the proportion of variation in y explained by x.

In this example, the correlation coefficient (r) = .85; the coefficient of determination (r^2) = .72. Therefore, 72% of the variance in y is explained by the knowledge of x.

Appendix A: Reference Information

This appendix provides supplemental information that may be helpful as you use your TI-65 Programmable Scientific calculator.

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Inverse Functions

The [INV] key enables you to perform a variety of inverse functions. To perform an inverse function, press [INV], then press a key (or key sequence) in the following table to perform the appropriate inverse function.

Inverse Function Table

Key (or Sequence)	Function	Inverse Function
[SIN]	sine	arcsine
[COS]	cosine	arccosine
[TAN]	tangent	arctangent
[2nd] [DRG]	angle mode advance	angle mode reverse
[2nd] [DRG▸]	angle conversion	reverse angle conversion
[EE]	scientific notation	standard notation (only from scientific notation)
[2nd] [ENG]	engineering notation	standard notation
[2nd] [FIX]	fix decimal point	floating decimal point
[2nd] [LOG]	common logarithm	common antilogarithm
[LN]	natural logarithm	natural antilogarithm
[y^x]	y to the xth power	the xth root of y ($x\sqrt{y}$)
[2nd] [P⇆R]	polar to rectangular conversion	rectangular to polar conversion

Inverse Function Table (Continued)

Key Sequence	Function	Inverse Function
[3rd] [in-cm]	inches to centimeters	centimeters to inches
[3rd] [oz-g]	ounces to grams	grams to ounces
[3rd] [gal-l]	U.S. gallons to liters	liters to U.S. gallons
[3rd] [°F-°C]	Fahrenheit to Celsius	Celsius to Fahrenheit
[3rd] [psi-Pa]	psi to Pascals	Pascals to psi
[3rd] [hp-kw]	horsepower to kilowatts	kilowatts to horsepower
[3rd] [J-cal]	Joules to calories	calories to Joules
[3rd] [lb-N]	pounds to Newtons	Newtons to pounds
[3rd] [x<m]	$x <$ memory	$x \geq$ memory
[3rd] [x=m]	$x =$ memory	$x \neq$ memory
[3rd] [x>m]	$x >$ memory	$x \leq$ memory
[3rd] [DSZ]	decrement and skip if zero	decrement and skip if not zero

Error Conditions

When an error condition occurs, Error and an error number appear in the display. The calculator will not accept a keyboard entry until you press [CE/C] to clear the error condition. The following table explains the error numbers that may be displayed when an error condition occurs.

Error Table

Error	Description
1	overflow, underflow, or undefined
2	conflict between user memory and program memory
3	the available program memory is full
4	the statistical registers are unavailable (conflict with [2nd] [PUM] or program)
5	function only available in the statistics mode
6	the function is only available in the learn mode or during program execution
7	the label was not found
8	subroutine level overflow
9	the integration memories (0-2) are unavailable, there is no integration program, or integration was manually halted with the [R/S] key

General Error Conditions

The error conditions listed in this section occur in most modes when you attempt to do the following.

- Calculate a result outside the range $\pm 1 \times 10^{-99}$ to $\pm 9.999999999499 \times 10^{99}$ or 0.
- Calculate a function for numbers that are not valid input according to the "Function Ranges" table later in this appendix.
- Divide a number by zero or calculate [1/x] of zero.

General Error Conditions (Continued)

- Calculate [y^x] for a negative y.
- Use [y^x] or [INV] [y^x] to calculate zero to the 0th power or root.
- Use [INV] [2nd] [P⇄R] when both x and y are zero or when the sum of the squares of x and y exceeds the upper limit of the calculator.
- Calculate [TAN] of 90° or 270°, $\pi/2$ or $3\pi/2$ radians, 100 or 300 grads, or their rotational multiples such as 450°.
- Use more than 15 levels of open parentheses or more than four pending operations.
- Follow a memory operation with an address specifying a memory that is not available.
- Press [2nd] [PAUSE], [2nd] [DEL], or [BST] when the calculator is not in the learn mode.
- Use [2nd] [PUM] to interfere with a program.
- Integrate with fewer than three memories protected.
- Use [2nd] [Σ−] outside of the statistics mode.

Hexadecimal Mode Error Conditions

These error conditions occur in the hexadecimal mode when you attempt to do the following.

- Calculate a result that is outside the range of hexadecimal numbers. (Refer to "Performing Hexadecimal Calculations" in Chapter 6.)
- Use [3rd] [DEC] to convert a number that is outside the range of decimal numbers.

(continued)

Error Conditions (Continued)

Octal Mode Error Condition

This error condition occurs in the octal mode when you attempt to do the following.

- Calculate a result that is outside the range of octal numbers. (Refer to "Performing Octal Calculations" in Chapter 6.)

Statistical Error Conditions

These error conditions occur when you attempt to perform the following statistical operations.

- Use [Σ+] to enter a data point (x) such that $|x| \geq 10^{50}$.
- Use [2nd] [Σ−] when there are no data values in the statistical registers.
- Use [2nd] [Σ−] to remove the last remaining data value in the statistical registers.
- Press [2nd] [MEAN], [2nd] [σn], [2nd] [σn-1], [2nd] [CORR], [2nd] [SLOPE], [2nd] [INTCP], [2nd] [FCST X], or [2nd] [FCST Y] when there are no data values in the statistical registers.
- Calculate [2nd] [CORR], [2nd] [SLOPE], [2nd] [INTCP], [2nd] [FCST X], or [2nd] [FCST Y] of a line that parallels the y-axis (a vertical line).
- Calculate [2nd] [CORR] or [2nd] [FCST X] of a line that parallels the x-axis (a horizontal line).
- Calculate [2nd] [σn-1], [2nd] [CORR], [2nd] [SLOPE], [2nd] [INTCP], [2nd] [FCST X], or [2nd] [FCST Y] with only one data point entered.
- Press [2nd] [CSR] when the calculator is not in the statistics mode.

Function Ranges

An error may result if you perform a calculation outside the range of certain functions. The following tables give the limits and ranges within which the display must be when you calculate certain functions.

General Function Limits

Function	Range of Input Values
$\sin^{-1}x$, $\cos^{-1}x$	$-1 \leq x \leq 1$
ln x, log x	$10^{-99} \leq x < 10^{100}$
e^x	$-227.95592 \leq x \leq 230.25850$
10^x	$-99 \leq x < 100$
$\sqrt{x}$	$0 \leq x < 10^{100}$
x!	$0 \leq x \leq 69$ where x is an integer

Inverse Trigonometric Function Ranges

Function	Range of Resultant Angle
arcsin x, arccos x, arctan x	0° to 90°, π/2 radians, or 100G
arcsin −x, arctan −x	0° to −90°, −π/2 radians, or −100G
arccos −x	90° to 180°, −π/2 to π radians, or 100G to 200G

Battery Information

The TI-65 cannot hold data in its memory when the batteries are removed or become discharged. Use two of any of the following silver-oxide batteries for up to 2000 hours of operation: Mallory 10L14, Union Carbide (Eveready) 357, Panasonic WL-14, Toshiba G-13, Ray-O-Vac RW-42, or the equivalent.

Replacing the Batteries

Caution: Dispose of old batteries properly. Do not incinerate them or leave them where a child can find them.

1. Turn the calculator off. Place a small screwdriver or other instrument into the slot and gently lift the battery cover.

2. Remove the old batteries and install new ones as shown. Be sure that the + symbol on the left battery is facing down (toward the front of the calculator); be sure that the + symbol on the right battery is facing up (toward the back of the calculator).

3. Replace the cover top edge first, and then gently press until the bottom edge snaps into place.

4. **Wait at least ten seconds.** Press [OFF]. Then hold down the [R/S] key; while you are holding down [R/S], press [ON], and then release both keys. The display shows **0** and **DEG**, and the calculator is ready to be used.

Note: If the calculator is inoperable after new batteries are installed, remove the batteries, wait two minutes or longer, and reinstall them. Then repeat step 4, being sure to wait ten seconds before turning the calculator on.

Appendix B: Service and Warranty Information

This appendix describes routines that may help you correct any problems in using your TI-65 Programmable Scientific calculator, as well as the service and warranty provided by Texas Instruments.

Table of Contents

In Case of Difficulty

If you have difficulty operating the calculator, you may be able to correct the problem without returning the calculator for service. The following table lists several problems and their possible solutions. If these solutions do not correct the problem, refer to "Service Information" later in this appendix.

Possible Solutions

Difficulty	Solution
The calculator is displaying incorrect results.	You may be interrupting a calculation by pressing the next key sequence too soon. Allow enough time for the calculator to complete each step in a calculation before making new entries.
Trig functions and polar/rectangular conversions do not give the correct results.	Be sure the angle mode is set for the correct units—degrees, radians, or grads.
The calculator does not allow you to enter certain digits.	Be sure the calculator is set for the correct number-system mode—decimal, hexadecimal, or octal.
An error occurs.	Check the error conditions listed in Appendix A.
The calculator does not work after new batteries are installed.	Remove the new batteries, wait two minutes or longer, and reinstall them. **Wait at least ten seconds.** Then hold down the [R/S] key and press [ON].

Possible Solutions (Continued)

If you experience difficulties other than those listed in the chart, press [OFF] [ON] to clear the calculator completely and then repeat your calculations. If the problem persists, turn the calculator off. Then hold down the [R/S] key; while you are holding down [R/S], press [ON]. Then release both keys. The display should then show **0** and **DEG**.

If you are programming and experience difficulties, check the **PS:M** indicator to ensure that the required number of program steps are available. If necessary, press [2nd] [LRN] to leave the learn mode. Then use the [2nd] [PUM] key sequence to adjust the number of protected memories. If the problem persists, leave the learn mode, press [2nd] [CP] to clear the program memory, and then re-enter the program.

You should also review the operating instructions in this guidebook to be sure that you are performing the calculations correctly.

Service Information

If the solutions suggested by "In Case of Difficulty" do not correct a problem you may have with your calculator, please call or write Consumer Relations to discuss the problem.

For Service and General Information

If you have questions about service or the general use of your calculator, please call Consumer Relations at:

1-806-747-1882

Please note that this is a toll number, and collect calls are not accepted.

You may also write to the following address:

Texas Instruments Incorporated
Consumer Relations
P.O. Box 53
Lubbock, Texas 79408

Please contact Consumer Relations:

- Before returning the calculator for service
- For general information about using the calculator

For Technical Information

If you have technical questions about calculator operation or programming applications, write to Consumer Relations at the address given above, or call 1-806-741-2663. Please note that this is a toll number, and collect calls are not accpeted.

Express Service

Texas Instruments offers an express service option for fast return delivery. Please call Consumer Relations for information.

Calculator Accessories

If you are unable to purchase calculator accessories (such as carrying cases or adapters) from your local dealer, you may order them from Texas Instruments. Please call Consumer Relations for information.

Returning Your Calculator for Service

A defective calculator will be either repaired or replaced with the same or comparable reconditioned model (at TI's option) when it is returned, postage prepaid, to a Texas Instruments Service Facility.

Texas Instruments cannot assume responsibility for loss or damage during incoming shipment. For your protection, carefully package the calculator for shipment and insure it with the carrier. Be sure to enclose the following items with your calculator:

- Your full return address
- Any accessories related to the problem
- A note describing the problem you experienced
- A copy of your sales receipt or other proof of purchase to determine warranty status

Please ship the calculator postage prepaid; COD shipments cannot be accepted.

In-Warranty Repair

For a calculator covered under the warranty period, no charge is made for service.

Out-of-Warranty Repair

A flat-rate charge by model is made for out-of-warranty service. To obtain the service charge for a particular model, call Consumer Relations **before** returning the product for service. (We cannot hold products in the Service Facility while providing charge information.)

Texas Instruments Service Facilities

U.S. Residents (U.S. Postal Service)
Texas Instruments
P.O. Box 2500
Lubbock, Texas 79408

U.S. Residents (other carriers)
Texas Instruments
2305 N. University
Lubbock, Texas 79415

Canadian Residents Only
Texas Instruments
41 Shelley Road
Richmond Hill, Ontario L4C 5G4

One-Year Limited Warranty

This Texas Instruments electronic calculator warranty extends to the original consumer purchaser of the product.

Warranty Duration

This calculator is warranted to the original consumer purchaser for a period of one (1) year from the original purchase date.

Warranty Coverage

This calculator is warranted against defective materials or workmanship. **This warranty is void if the product has been damaged by accident, unreasonable use, neglect, improper service, or other causes not arising out of defects in material or workmanship.**

Warranty Disclaimers

Any implied warranties arising out of this sale, including but not limited to the implied warranties of merchantability and fitness for a particular purpose, are limited in duration to the above one-year period. Texas Instruments shall not be liable for loss of use of the calculator or other incidental or consequential costs, expenses, or damages incurred by the consumer or any other user.

Some states do not allow the exclusion or limitations of implied warranties or consequential damages, so the above limitations or exclusions may not apply to you.

Legal Remedies

This warranty gives you specific legal rights, and you may also have other rights that vary from state to state.

Warranty Performance

During the above one-year warranty period, a defective TI calculator will either be repaired or replaced with a reconditioned comparable model (at TI's option) when the product is returned, postage prepaid, to a Texas Instruments Service Facility.

The repaired or replacement calculator will be in warranty for the remainder of the original warranty period or for six months, whichever is longer. Other than the postage requirement, no charge will be made for such repair or replacement.

Texas Instruments strongly recommends that you insure the product for value prior to mailing.

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