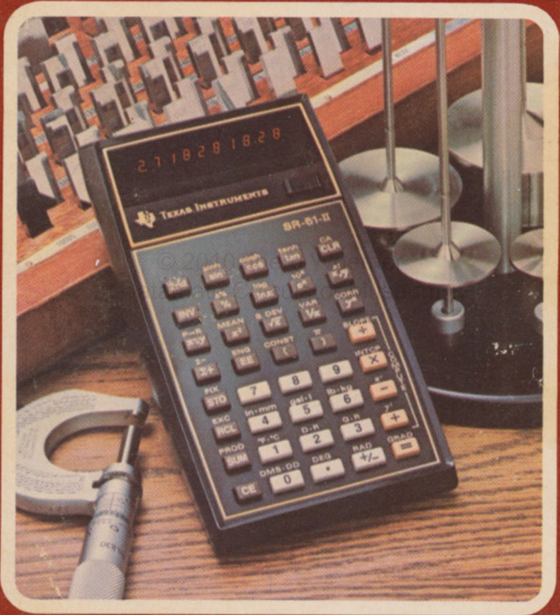
Texas Instruments

advanced professional calculator
SR-51-II



OWNER'S MANUAL

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

Toll-Free Telephone Assistance

For service information for your SR-51-II calculator call one of the following toll-free numbers:

800-858-1802 (within all contiguous United States except Texas)

800-692-1353 (within Texas)

See Appendix A and back cover for further information on service.

I. FEATURES AND FUNCTIONS

The SR-51-II you have just purchased is an advanced professional calculator designed specifically for those who demand a versatile and reliable business, scientific and mathematical tool. The availability of conversions, statistical analyses and a wide range of mathematical functions have been combined with the easy-to-use Algebraic Operating System to provide straightforward solutions to your most complex problems.

- **Algebraic Operating System (AOS)** allows you to enter mathematical expressions in the same order that they are algebraically stated. Parentheses, an integral part of AOS, ensure proper and accurate interpretation of expressions. Up to 9 parenthesis levels with 5 pending operations are available. Consider the expression
  $\frac{(3 \times 4 + 5 \times \tan 7°)}{9^3}$ = .0173030491 that can be entered directly as: [(] 3 [×] 4 [+] 5 [×] 7 [tan] [)] [÷] 9 [y^x] 3 [=].

- **Complete Set of Mathematical Functions** including:
  Arithmetic Functions with algebraic hierarchy
  Trigonometric Functions (including inverse functions)
  Angles measured in degrees, radians or grads
  Hyperbolic Functions (including inverse functions)
  Logarithmic Functions (both natural and common) with 10^x and e^x
  Factorial, Reciprocal, Percent and Change of Percent
  Square and Square Root, y^x and $\sqrt[x]{y}$
  Pi (π) accurate to 12 digits
  Constant feature for easy execution of repetitive calculations
- **Addressable Memory System** with 3 separate memories for instant storage and recall of data. Complete memory arithmetic allows you to add, subtract, multiply or divide directly into any memory. Includes memory exchange with display.

- **Linear Regression** routine provides both immediate statistical analysis of data and projection of new points. Trend-Line Analysis is also available.
- **Mean, Standard Deviation, Variance and Correlation** capabilities to analyze one or two-dimensional statistical data.
- **Totally Portable** when operating on its rechargeable battery system. It can also be operated while charging from an AC power source.
- **Conversions** available from the keyboard provide easy transition between:
  - inches and millimeters
  - gallons (US) and liters
  - pounds (av) and kilograms
  - Fahrenheit and Celsius
  - degrees, radians and grads
  - polar and rectangular coordinates
  - degrees, minutes, seconds and decimal degrees
- **Complete Display Versatility,** featuring:
  - Standard 10-digit display
  - Scientific Notation entry from keyboard and automatically from calculations
  - Engineering Format displays scientific notation exponents as multiples of 3
  - Scientific or Engineering Notation removal
  - Fix Decimal control to select desired number of decimal places in the displayed number
  - Display value accuracy ensured by internal rounding
  - All results are calculated with 12 digits and rounded to obtain the displayed values.
- **Automatic Clearing** – when the [=] key is pressed, all calculations are completed, the answer is displayed and the calculator is ready for the start of a new problem.

II. BASIC OPERATIONS

The keys have been selectively positioned on the keyboard to provide for efficient calculator operation. Although many of the operations may be obvious, the following instructions and examples can help you develop skill and confidence in your problem solving routine.

INITIAL OPERATION

The fast-charge, nickel-cadmium battery pack furnished with your calculator was fully charged at the factory before shipping. However, due to shelf-life discharging, it may require charging before initial operation. If initially or during portable operation the display becomes dim or erratic, the battery pack needs to be charged.

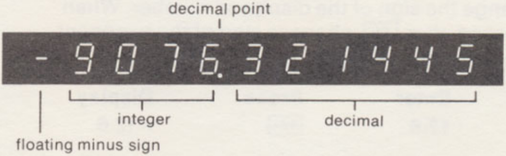
Under normal conditions, a fully charged battery pack provides typically 2-3 hours of continuous operation.

With the battery pack properly installed, charging is accomplished by plugging the AC Adapter/Charger AC9131 into a convenient 115V/60 Hz outlet and connecting the attached cord to the calculator socket. About 4 hours of charging restores full charge with the power switch off or 10 hours if the calculator is in use. **CAUTION:** The battery pack will not charge if not properly installed in the calculator.

Sliding the ON/OFF switch to the right applies power to the calculator and sliding it to the left removes power. The power-on condition is indicated by a lighted display.

STANDARD DISPLAY

In addition to power-on indication, the display provides numerical information complete with negative sign and decimal point and flashes on and off for an overflow, underflow or error condition. An entry can contain as many as 10 digits. All digits entered after the tenth are ignored.



Any negative number is displayed with a minus sign immediately to the left of the number.

See Appendix C for the accuracy of the displayed result.

DATA ENTRY KEYS

[0] through [9] **Digit Keys** – Enters the numbers 0 through 9.

[•] **Decimal Point Key** – Enters Decimal Point. The decimal point can be entered wherever needed. If no decimal point is entered, it is assumed to be to the right of the number, and will appear when a non-number key is pressed. A zero will precede the decimal point for numbers less than 1 unless all ten available display digits are used. Trailing zeros on the decimal portion of a number are not normally displayed. Only the first decimal point entered is accepted, all others are ignored.

[π] **Pi Key** – Enters the value of pi (π) to 12 significant digits (3.14159265359) for calculations; display indicates the rounded value.

EE **Enter Exponent Key** – Instructs the calculator that the subsequent number entry is an exponent of 10. After the EE key is pressed, all further results are displayed in scientific notation format until CLR or 2nd CA is pressed or until the calculator is turned off. INV EE or INV 2nd EE can remove this format if the displayed number is in the range $\pm 1 \times 10^{10}$ to $\pm 5 \times 10^{-11}$.

+/− **Change Sign Key** – Instructs the calculator to change the sign of the displayed number. When pressed after EE, changes sign of the exponent.

Example: Enter −12.6

Enter	Press	Display
12.6	+/−	−12.6

CLEARING OPERATIONS

CE **Clear Entry Key** – Clears entries made with the digit, decimal point and change-sign keys when pressed before a function key. This key does not clear calculated results, numbers recalled from memory or π. CE also stops the flashing of the display when needed. Use of this key does not affect pending operations.

CLR **Clear Key** – Clears calculations in progress, the constant and the display. It resets scientific notation to standard format and will stop a flashing display. This key does not affect the contents of user memories, fixed-point (fix-decimal) location, angular mode or engineering format.

2nd CA **Clear All Key** – Clears the display, all memories, the constant and calculations in progress. Restores standard display mode and resets angular mode to degrees. Eliminates fixed-point (fix-decimal) format.

The calculator effectively clears itself after most calculations. When the = key is pressed to complete a calculation, the answer is displayed and the calculator is ready for the start of a new problem without pressing any of the clear keys. The contents of the user memories are not automatically cleared.

DUAL FUNCTION KEYS ([2nd] and [INV])

Most of your calculator's keys have dual functions. The first function is printed on the key and the second function is written above it. To execute a function shown on a key, simply press the desired key. To use the second function of a key, press the [2nd] key, then press the key immediately below the desired second function. For example, to find the natural logarithm of a number, press [lnx]. To find the common logarithm of a number, press [2nd] [lnx]. In order to make sequences of this type clear, in this manual it will be shown as [2nd] [log]. First function operations, therefore, are indicated by [ ]. Second functions are indicated by [2nd] ■. When [2nd] is pressed twice in succession or if a key that does not have a second function is pressed, the calculator returns to first function operation.

The inverse key [INV] provides additional computing capabilities without increasing the number of keys on the keyboard just like the [2nd] key does. When [INV] precedes another key, the purpose of that key is reversed. The inverse can be used with the following keys to obtain the indicated function.

1st function keys	2nd function keys
sin → $\sin^{-1}$	sinh → $\sinh^{-1}$
cos → $\cos^{-1}$	cosh → $\cosh^{-1}$
tan → $\tan^{-1}$	tanh → $\tanh^{-1}$
SUM → subtract	PROD → divide
EE → removes EE	ENG → removes ENG
	FIX → removes FIX
	conversions → reverses conversion

This key can also be used to obtain the mean, standard deviation and variance of the independent variable, x, in the linear regression routine. An inverse instruction may be cancelled by pressing [INV] a second time, if no other keys have been pressed, or by pressing a key without an inverse function. When used in conjunction with the second function key, the inverse key can be pressed before or after the second function key is pressed, i.e., [INV] [2nd] ■ or [2nd] [INV] ■.

For examples of [INV] uses with a specific key, see the section relating to each key.

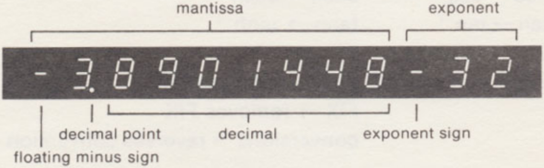
DISPLAY FORMATS

Even though a maximum of 10 digits can be entered or displayed, the internal display register always retains results to 12 digits. The results are then rounded for display only.

In addition to the versatile 10-digit standard display, there are several other display capabilities that increase the operating range and flexibility of your calculator.

Scientific Notation

Any number can be entered as the product of a value (mantissa) and 10 raised to some power (exponent).



This capability allows you to work with numbers as small as $\pm 1 \times 10^{-99}$ or as large as $\pm 9.9999999 \times 10^{99}$. Numbers smaller than $\pm 1 \times 10^{-10}$ or larger than $\pm 9.9999999 \times 10^{10}$ must be entered in scientific notation. When calculations exceed these limits, the calculator automatically shifts into scientific notation. The entry procedure is to key in the mantissa (including its sign), then press [EE] and enter the exponent of 10 and its sign.

For example, the number 320,000,000,000 can be written as 3.2×10^{11} and can be entered into the calculator as:

Enter	Press	Display
	[CLR]	0
3.2		3.2
	[EE]	3.2 00
11		3.2 11

More than 2 digits can be entered after pressing [EE], but only the last two entered are retained as the exponent.

In scientific notation, a positive exponent indicates how many places the decimal point of the mantissa should be shifted to the right. If the exponent is negative, the decimal should be moved to the left.

Regardless of how a mantissa is entered for scientific notation, the calculator *normalizes* the number, displaying a single digit to the left of the decimal point, when any function or operation key is pressed.

Example: Enter 6025×10^{20}

Enter	Press	Display
	[CLR]	0
6025		6025
	[EE]	6025 00
20		6025 20
	[+]	6.025 23

In scientific notation, the mantissa is limited to 8 digits to allow display space for the exponent. A mantissa resulting from a calculation is also displayed to 8 digits, but internally is carried to 12 digits. This 12-digit value is the one used for all ensuing calculations. See Appendix C.

Note: the calculator will not enter scientific notation when [EE] is pressed if there are more than 8 digits entered or displayed.

The change sign key can be used to attach a negative sign to the mantissa and to the power-of-ten exponent. Simply press [+/−] after entry of the mantissa to change its sign or after the exponent to change its sign. To change the sign of the mantissa or to enter numbers in its decimal portion after the [EE] key has been pressed, press [•], then enter the mantissa's sign change or additional numbers to the decimal portion.

Example: Enter -4.962×10^{-12} then complete the decimal portion of the mantissa to read -4.96236×10^{-12}.

Enter	Press	Display	Comments
	[CLR]	0	
4.962	[+/−]	−4.962	Enter mantissa and sign
	[EE]	−4.962 00	
12	[+/−]	−4.962−12	Enter exponent and sign
	[+/−]	−4.962 12	Change exponent sign
	[+/−]	−4.962−12	Change exponent sign again
	[•] [+/−]	4.962−12	Change mantissa sign
36	[+/−]	−4.96236−12	Complete the mantissa

Data in scientific notation form can be intermixed with data in standard form. The calculator converts the entered data for proper calculation. After the [EE] key has been pressed, the calculator displays all results in scientific notation format until [CLR], [2nd] [CA], [INV] [EE] or [INV] [2nd] [ENG] is pressed, or until the calculator is turned off.

Example: $1.816 \times 10^3 - 581.432191 = 1.2345678 \times 10^3$ $= 1234.567809$

Enter	Press	Display
	CLR	0
1.816	EE	1.816 00
3	−	1.816 03
581.432191	=	1.2345678 03
	INV EE	1234.567809

When INV EE is pressed to remove scientific notation and the number is outside of the range $\pm 1 \times 10^{10}$ to $\pm 5 \times 10^{-11}$, the calculator will return to standard format only when or if a calculated result is in the displayable range.

Example: $(7 \times 10^{11} + 5 \times 10^{10}) \div 25 \div 25 = 1200000000$

Enter	Press	Display
7	EE	7 00
11	+	7. 11
5	EE	5 00
10	= INV EE	7.5 11
	÷	7.5 11
25	= ÷	3. 10
25	=	1200000000.

Engineering Notation

This modified form of scientific notation is accessed by pressing 2nd ENG. The displayed value in this mode consists of a mantissa and an exponent that have been adjusted so that the exponent is a multiple of three (10^{12}, 10^{-6}, etc.) and the mantissa has 1, 2 or 3 digits to the left of the decimal point. This allows the calculator to display results in units that are readily usable such as 10^{-12} for picofarads, 10^{-3} for millimeters, 10^6 for megohms or 10^{-9} for nanoseconds.

Example: What is the diameter of a cable in microns (1 micron = 10^{-6} meter) whose circumference is 3 × 10^{-3} meters?

$C = \pi d \qquad d = C/\pi$

Enter	Press	Display
	2nd ENG	0. 00
3	EE	3 00
3	+/− ÷	3.−03
	2nd π =	954.92966−06

Pressing INV 2nd ENG or 2nd CA will remove this display mode, CLR does not affect it.

Fix-Decimal Control

In standard display format, scientific notation or engineering notation, you can selectively choose the number of digits to display following the decimal point. Pressing 2nd FIX, then entering the desired number of decimal places (0 to 8), instructs the calculator to round all results to the selected number of decimal places.

Pressing 2nd CA, 2nd FIX 9 or INV 2nd FIX returns the calculator to the standard display. Data entries can still be made with 10 digits (8 in scientific notation) with all subsequent calculations using the 12-digit unrounded results, except the DMS-DD conversion that uses the displayed value only. Only the display is altered to the requested number of decimal places.

Example: 2/3 = .6666666667

Enter	Press	Display
2	÷	2.
3	=	.6666666667
	2nd FIX 5	0.66667
	2nd FIX 2	0.67
	2nd FIX 0	1.

Remember that the display value is *rounded* to the desired format.

Example: $1 \times 10^{-3} \div 2 = .0005$

Enter	Press	Display
	2nd CA	0
1	EE	1 00
3	+/− ÷	1.−03
2	=	5.−04
	2nd FIX 2	5.00−04
	INV EE	0.00
	2nd FIX 3	0.001
	2nd FIX 4	0.0005
	2nd FIX 5	0.00050

Flashing Display

The display flashes off and on whenever the limits of the calculator are violated or when an improper mathematical operation is requested. Press CE to stop the flashing without disturbing any calculations in progress. Calculations can continue from this point if the number in the display is still usable. See Appendix B for a complete list of error and overflow/underflow conditions and the results they produce.

III. ARITHMETIC CALCULATIONS

The Algebraic Operating System's method of entering numbers and operations is straightforward allowing entry of most problems just as they are mathematically stated. The accuracy of results is discussed in Appendix C.

BASIC KEYS

[+], [−] **Add and Subtract Keys** – Correspondingly alters the present display value by the next entered quantity. These keys also complete any previously entered arithmetic (+, −, ×, ÷), y^x, $\sqrt[x]{y}$ or Δ% functions.

[×], [÷] **Multiply and Divide Keys** – Correspondingly alters the present display value by the next entered quantity. These keys also complete any previously entered multiply, divide, y^x, $\sqrt[x]{y}$ or Δ% functions.

[=] **Equals Key** – Computes results by completing all previously entered numbers with associated operations, preparing the calculator for a new problem.

[x:y] **x Exchange y Key** – Exchanges factors in multiplication and exchanges divisor and dividend in division. Interchanges x and y in Δ%, y^x and $\sqrt[x]{y}$ calculations. Also used for data entry and result display for polar to rectangular conversions and linear regression problems.

Pressing [CLR] at the beginning of a new sequence clears any calculations in progress and always ensures that no pending operations from prior calculations remain. This is not required if the previous problem used [=] to obtain the result. Following [=] with a numeric entry accomplishes the same as pressing [CLR], except that [=] does not remove scientific notation or stop a flashing display or clear the constant.

Pressing any two of the operation keys (+, −, ×, ÷, y^x, $\sqrt[x]{y}$, and Δ%) in succession causes a flashing display. Also, following any of these with = or), or preceding with (, causes the same result.

Example: 23.79 + .54 − 6 = 18.33

Enter	Press	Display
	CLR	0
23.79	+	23.79
.54	−	24.33
6	=	18.33

Again note that the numbers and functions are entered in the same order as they are mathematically stated.

Example: −4 × 7.3 ÷ 2 = −14.6

Enter	Press	Display
4	+/− ×	−4.
7.3	÷	−29.2
2	=	−14.6

COMBINING OPERATIONS

After a result is obtained in one calculation it may be directly used as the first number in a second calculation. There is no need to reenter the number from the keyboard.

Example:
1.84 + 0.39 = 2.23 then (1.84 + 0.39)/365 = .006109589

Enter	Press	Display	Comments
1.84	+	1.84	
.39	=	2.23	1.84 + 0.39
	÷	2.23	
365	=	0.006109589	2.23 ÷ 365

HIERARCHY OF OPERATIONS

Algebraic hierarchy is an essential feature of the Algebraic Operating System. To efficiently combine operations, the standard rules of algebraic hierarchy have been specifically programmed into the calculator.

These algebraic rules assign priorities to the various mathematical operations. Without a fixed set of rules, expressions such as $5 \times 4 + 3 \times 2$ could have several meanings:

$$5 \times (4 + 3) \times 2 = 70$$
or $$5 \times 4 + 3 \times 2 = 26$$
or $$(5 \times 4 + 3) \times 2 = 46$$
or $$5 \times (4 + 3 \times 2) = 50$$

Algebraic hierarchy rules state that multiplication is to be performed before addition. So algebraically, the correct answer is $(5 \times 4) + (3 \times 2) = 26$. The complete list of priorities for interpreting expressions is:

1) Special Functions
2) Percent Change (Δ%)
3) Exponentiation (y^x), Roots ($\sqrt[x]{y}$)
4) Multiplication, Division
5) Addition, Subtraction
6) Equals

1) Special functions (trigonometric and hyperbolic, logarithmic, square, square root, factorial, e^x, 10^x, percent, reciprocal and conversions) immediately replace the displayed value with its functional value.
2) Percent change has only the ability to complete other percent change operations.
3) Exponentiation (y^x) and roots ($\sqrt[x]{y}$) are performed as soon as the special functions and percent change are completed.
4) Multiplication and division are performed after completing special functions, percent change exponentiation, root extraction and other multiplication and division.
5) Addition and subtraction are performed only after completing all operations through multiplication and division as well as other addition and subtraction.
6) Equals completes all operations.

Operations of the same priority are performed left to right.

To illustrate, consider the interpretative order of the following example:

Example: $4 \div 5^2 \times 7 + 3 \times 0.5^{\cos 60°} = 3.241320344$

Enter	Press	Display	Comments
4	[÷]	4.	(4÷) is stored
5	[x^2]	25.	(5^2) special function [x^2] evaluated immediately
	[×]	0.16	($4 \div 5^2$) ÷ evaluated because × is same priority as ÷.
7	[+]	1.12	× higher priority than + so ($4 \div 5^2 \times 7$) evaluated, + stored
3	[×]	3.	(3×) stored
.5	[y^x]	0.5	.5 entered, y^x stored
60	[cos]	0.5	Cos 60° evaluated immediately
	[=]	3.241320344	Completes all operations $.5^{\cos 60°}$ evaluated, then $3 \times .5^{\cos 60°}$ next, then this is added to 1.12.

Thus, by entering the expression just as it is written, the calculator correctly interprets it as $\{[(4 \div 5^2) \times 7] + (3 \times 0.5^{\cos 60°})\}$

The important things to remember here are that operations are enacted strictly according to their relative priority as stated in the rules. The calculator remembers all stored operations and recalls each and its associated number for execution at exactly the correct time and place. Once familiar with the order of these operations, you will find most problems are extremely easy to solve because of the straightforward manner in which they can be entered into the calculator. Additional control over the order of interpretation is provided through the use of parentheses.

PARENTHESES

There are sequences of operations for which you must instruct the calculator exactly how to evaluate the problem and produce the correct answer. For example:

$$4 \times (5 + 9) \div (7 - 4)^{(2+3)} = ?$$

To evaluate this expression as written using only the calculator hierarchy, many independent steps would be required. Also, intermediate results would have to be stored and the sequence certainly could not be input in the same order in which it is written. Parentheses should be used here and whenever a mathematical sequence cannot be directly entered using the previously mentioned algebraic rules or to simplify entry of a problem without reference to the hierarchy rules.

To illustrate the benefit of parentheses, try the following experiment: Press (5 × 7), and you will see the value 35 displayed. The calculator has evaluated 5 × 7 and replaced it with 35 even though the [=] was not pressed. Because of this function of parentheses, the algebraic rules now apply their hierarchy of operations to each set of parentheses. Use of parentheses ensures that your problem can be keyed in just as you have written it down. The calculator remembers each operation and evaluates each part of the expression as soon as all necessary information is available. When a closed parenthesis is encountered, all operations back to the corresponding open parenthesis are completed.

Example: $4 \times (5 + 9) \div (7 - 4)^{(2+3)} = .2304526749$

Key in this expression and follow the path to completion.

Enter	Press	Display	Comments
4	[×] [(]	4.	(4×) stored pending evaluation of parentheses
5	[+]	5.	(5+) stored
9	[)]	14.	(5 + 9) evaluated
	[÷]	56.	Hierarchy evaluates 4 × 14
	[(]	56.	56 ÷ stored pending evaluation of parentheses
7	[−]	7.	(7−) stored
4	[)]	3.	(7 − 4) evaluated
	[y^x] [(]	3.	Prepares for exponent
2	[+]	2.	
3	[)]	5.	(2 + 3) evaluated
	[=]	.2304526749	$(7-4)^{(2+3)}$ evaluated then it is divided into 4 × (5 + 9)

There are limits on how many operations and associated numbers can be stored. Actually, as many as nine parentheses can be open at any one time and five operations can be pending, but only in the most complex situations would this limit be approached. If you do attempt to open more than 9 parentheses or if the calculator tries to store more than five operations, the display flashes.

Example: $5 + \{8/[9 - (2/3)]\} = 5.96$

Enter	Press	Display	Comments
5	[+] [(]	5.	
8	[÷] [(]	8.	
9	[−] [(]	9.	
2	[÷]	2.	
3	[)]	.6666666667	(2/3) evaluated
	[)]	8.333333333	[9 − (2/3)] evaluated
	[)]	0.96	{8/[9 − (2/3)]}
	[=]	5.96	5 + {8/[9 − (2/3)]}

Because the [=] key has the capability to complete all pending operations whenever it is used, it could have been used here instead of the [)] keys. Try working this problem again and pressing [=] instead of the first [)].

Example: $3 \times \{4^{[2^{(-\sqrt[4]{7})}]}\} = 4.700043401$

Enter	Press	Display	Comments
	[CLR] [(]	0.	
3	[×] [(]	3.	
4	[y^x] [(]	4.	
2	[y^x] [(]	2.	
7	[$\sqrt[x]{y}$]	7.	
4	[)]	1.626576562	$\sqrt[4]{7}$
	[+/−]	−1.626576562	$-(\sqrt[4]{7})$
	[)]	.3238557891	$2^{-(\sqrt[4]{7})}$
	[)]	1.566681134	$4^{.323...}$
	[)]	4.700043401	$3 \times 4^{.323...}$

Each time a closed parenthesis is encountered, the contents are evaluated back to the nearest open parenthesis and are replaced with a single value. Knowing this you can structure the order of interpretation for whatever purpose you may want. Specifically, you can check intermediate results.

IV. MATH FUNCTIONS

The simplest operations to describe and understand are the single-variable functions. These functions operate on the displayed value immediately, replacing the displayed value with its corresponding function value. These functions do not interfere with any calculations in progress and can therefore be used at any point in a calculation. Be sure that each calculation has been completed before the next key is pressed. Key entries are not recognized while a calculation is being performed.

RECIPROCAL AND FACTORIAL

[1/x] **Reciprocal Key** – Calculates the reciprocal of the value, x, in the display register by dividing x into 1. $x \neq 0$.

[2nd] [x!] **Factorial Key** – Calculates the factorial ($1 \times 2 \times 3 \times 4 \times .. \times x$) of the value, x, in the display for integers $0 < x \leqslant 69$. 0! = 1 by definition.

Example: 1/3.2 = 0.3125

Enter	Press	Display
3.2	[1/x]	0.3125

Example: 1/(−12 + 5!) = .0092592593

Enter	Press	Display
12	[+/−] [+]	−12.
5	[2nd] [x!]	120.
	[=]	108.
	[1/x]	.0092592593

Note that as soon as one of the math function keys is pressed, the displayed value is immediately replaced with its corresponding function value.

LOGARITHMS

[lnx] **Natural Logarithm Key** – Calculates the natural logarithm (base e) of the value, x, in the display register. $x > 0$.

[2nd] [log] **Common Logarithm Key** – Calculates the common logarithm (base 10) of the value, x, in the display register. $x > 0$.

Example: $\log(1 + \ln 1.7) = .1848697249$

Enter	Press	Display
	[(]	
1	[+]	1.
1.7	[lnx]	.5306282511
	[)]	1.530628251
	[2nd] [log]	.1848697249

POWERS OF 10 AND e

[eˣ] **e to the x Power Key** – Calculates the natural antilogarithm of the value, x, in the display register. $-227.9559242 \leq x \leq 230.2585092$.

[2nd] [10ˣ] **10 to the x Power Key** – Calculates the common antilogarithm of the value, x, in the display register. $-99 \leq x < 99.999999998$.

Example: $e^{(3 + 10^{0.3})} = 147.7116873$

Enter	Press	Display
	[(]	0.
3	[+]	3.
.3	[2nd] [10ˣ]	1.995262315
	[)]	4.995262315
	[eˣ]	147.7116873

ANGLE CALCULATIONS

Your calculator provides maximum flexibility when performing calculations involving angles.

Angular Modes

Angles can be measured in degrees, radians or grads (right angle $= 90° = \pi/2$ radians $=$ 100 grads). You select the mode desired by pressing either [2nd] [DEG], [2nd] [RAD] or [2nd] [GRAD]. The calculator powers-up in the degree mode and stays in that mode until altered by one of the other choices. Once in a certain angular mode, all entered and calculated angles are measured in the units of that mode until another mode is selected, [2nd] [CA] is pressed or until the calculator is turned off. [2nd] [CA] restores the degree mode. [CE] and [CLR] do not affect the angular mode.

The angular mode has absolutely no effect on calculations unless the trigonometric functions or polar to rectangular conversions are being performed. Selecting the angular mode is easy to do – **and easy to forget.** *Neglecting this step is responsible for a large number of errors in operating any calculation device that offers a choice of angular units.*

TRIGONOMETRIC FUNCTIONS

[sin], [cos], [tan] **Trigonometric Keys** – Calculates the sine, cosine or tangent of the value in the display register.

Example: sin 30° + tan 315° = −0.5

Enter	Press	Display
	[2nd] [CA]	0
30	[sin] [+]	0.5
315	[tan]	−1.
	[=]	−0.5

Trigonometric values can be calculated for angles greater than one revolution. As long as the trig function is displayed in standard format rather than in scientific notation, all displayed digits are accurate for ±36,000 degree range, ±200π radians and ±40,000 grads. In general, the accuracy decreases one digit for each decade outside of this range. If the argument x is greater than $\pm 3.6 \times 10^{14}$ degrees (4.0×10^{14} grads or $\pm 6.2799993 \times 10^{12}$ radians, no partial rotation is recognized.

HYPERBOLIC FUNCTIONS

[2nd] [sinh], [2nd] [cosh], [2nd] [tanh] **Hyperbolic Function Keys** Calculates the hyperbolic sine, cosine or tangent of the value x in the display register. These functions operate similar to the regular trig functions. $-227.9559242 \leq x \leq 230.2585093$, $x \leq \pm 227.9559242$ for sinh and cosh.

INVERSE TRIGONOMETRIC AND HYPERBOLIC FUNCTIONS

[INV] **Inverse Key** – Preceding another key, reverses the intention of that key. When used with the trig or hyperbolic functions, the inverse of those functions is obtained. For example, arcsine ($\sin^{-1}$) is obtained by pressing [INV] [sin], hyperbolic arctangent ($\tanh^{-1}$) results from [INV] [2nd] [tanh].

The inverse trig functions calculate the angle whose functional value is in the display. The largest angle resulting from an arc function is 180 degrees (π radians or 200 grads). Because these functions have many angle equivalents, i.e., arcsin = .5 for 30°, 150°, 390°, etc., the angle returned by each function is restricted as follows:

Arc Function	**Range of Resultant Angle**
arcsin x ($\sin^{-1}$ x)	0 to 90°, $\pi/2$ radians, or 100G
arcsin – x ($\sin^{-1}$ – x)	0 to –90°, $-\pi/2$ radians, or –100G
arccos x ($\cos^{-1}$ x)	0 to 90°, $\pi/2$ radians, 100G
arccos – x ($\cos^{-1}$ – x)	90° to 180°, $\pi/2$ to π radians, or 100 to 200G
arctan x ($\tan^{-1}$ x)	0 to 90°, $\pi/2$ radians, or 100G
arctan – x ($\tan^{-1}$ – x)	0 to –90°, $-\pi/2$ radians, or –100G

For arcsin x and arccosin x, $-1 \leq x \leq 1$.

Example: $\pi/4 + \tan^{-1}(.2\pi) = 1.34638028$

Enter	**Press**	**Display**
	[2nd] [RAD]	0
	[2nd] [π] [÷]	3.141592654
4	[+] [(]	.7853981634
.2	[×] [2nd] [π] [)]	.6283185307
	[INV] [tan]	.5609821161
	[=]	1.34638028

The selection of the radian mode could have been made at any point before [INV] [tan] . It is generally best, though, to select the angular mode at the start of a problem. This makes sure that the mode is correctly set before you get involved in keying in the problem. The angular mode, whenever selected, only affects angle measurements.

The hyperbolic functions behave similar to the trig functions. Note the following restrictions.

arcsinh x ($\sinh^{-1}$ x)	$-10^{50} < x < 10^{50}$
arccosh x ($\cosh^{-1}$ x)	$1 \leq x < 10^{50}$
arctanh x ($\tanh^{-1}$ x)	$-1 < x < 1$

Example: $.25 + \tanh^{-1} (.866) = 1.566856291$

Enter	Press	Display
.25	[+]	0.25
.866	[INV] [2nd] [tanh]	1.316856291
	[=]	1.566856291

SQUARE AND SQUARE ROOT

[x^2] **Square Key** – Calculates the square of the number in the display register.

[$\sqrt{x}$] **Square Root Key** – Calculates the square root of the number in the display register. $x \geq 0$.

Example: $[\sqrt{3.1452} - 7 + (3.2)^2]^{1/2} = 2.239078197$

Enter	Press	Display
3.1452	[(] [$\sqrt{x}$] [−]	1.773471173
7	[+]	−5.226528827
3.2	[x^2]	10.24
	[)]	5.013471173
	[$\sqrt{x}$]	2.239078197

UNIVERSAL ROOTS AND POWERS

[y^x] **Universal Power Key** – Raises the display register value, y, to the x power. The entry sequence is y [y^x] x followed by an operation key or equal. $y \geq 0$

[$\sqrt[x]{y}$] **Universal Root Key** – Takes the x root of the value, y, in the display register. $y \geq 0, x \neq 0$

[x:y] **x Exchange y Key** – Interchanges the x and y values after they have been keyed in. Can also be used with arithmetic operations and special calculations.

These math functions do not act on the display register immediately. They require entry of a second value followed by an operation before the function can be realized.

Example: $\sqrt[3]{2.36^{-.23}} = .9362893421$

Enter	Press	Display	Comments
2.36	[y^x]	2.36	Enter y for y^x
.23	[+/–]	–0.23	Enter x for y^x
	[$\sqrt[x]{y}$]	.8207865654	Produces y for $\sqrt[x]{y}$
3	[=]	.9362893421	Enter x for $\sqrt[x]{y}$ and produce answer

Use of logarithms to evaluate these functions and the standard mathematical definitions yield the following reactions to various x and y values. Quote marks indicate a flashing display.

Function Reaction

y	x	y^x	$\sqrt[x]{y}$
0	0	1	"1"
0	–x	"9.9999999 99"	"9.9999999 99"
0	x	0	0
1	0	1	"1"
y	0	1	"9.9999999 99"
–1	0	"1"	"1"
–y	0	"1"	"9.9999999 99"
–y	±x	"$\lvert y\rvert^{\pm x}$"	"$\sqrt[\pm x]{\lvert y\rvert}$"

PERCENT AND CHANGE PERCENT

[%] **Percent Key** – Converts the displayed number from a percentage to a decimal.

[2nd] [Δ%] **Percent Change Key** – Calculates the percentage change between two values. Press x_1 [2nd] [Δ%] x_2 [=] and $\frac{x_2 - x_1}{x_1} \times 100$ is calculated.

Example: 43.6% = .436

Enter	Press	Display
43.6	[%]	0.436

Example: What is the percentage increase (markup) of a $766.48 refrigerator that wholesales for $515.22?

Enter	Press	Display
515.22	[2nd] [Δ%]	515.22
766.48	[=]	48.76751679

The refrigerator has been marked up almost 49%.

When [%] is pressed after an arithmetic operation, add-on, discount and percentage can be computed.

[+] n [%] [=] adds n% to the displayed value

Example: What is the total cost of a $45 pair of boots when there is a 5% sales tax?

Enter	Press	Display
45	[+]	45.
5	[%]	2.25
	[=]	47.25

Note that the percent (tax) is shown for recording, if necessary, then the total is displayed.

[−] n [%] [=] subtracts n% from the displayed value

Example: How much do you have to pay for a $110 sleeping bag that has been discounted 15% with 6% sales tax?

Enter	Press	Display	Comments
110	[−]	110.	Enter amount
15	[%]	16.5	15% of 110
	[+]	93.5	110-15%
6	[%]	5.61	6% of 93.50
	[=]	99.11	Total Cost

[×] n [%] [=] multiplies the displayed value by n%

Example: If you have hiked 35% of a 62-mile trail, how far have you traveled? In other words, what is 35% of 62?

Enter	Press	Display
62	[×]	62.
35	[%]	0.35
	[=]	21.7

You have traveled 21.7 miles.

[÷] n [%] [=] divides the displayed value by n%

Example: If you have eaten 9 meals and find that 30% of your food supply is gone, how many meals will your initial food supply provide? 9 is 30% of what number?

Enter	Press	Display
9	[÷]	9.
30	[%]	0.3
	[=]	30.

Your initial food supply provided for 30 meals.

V. MEMORY CAPABILITIES

Your calculator has three user-accessible memories to greatly increase the flexibility of calculations. Use of the memory keys does not affect the displayed number or calculations in progress, so they can be used at any point in a calculation. Because there are three memories, you must specify which memory you are addressing by entering its number, n = 1, 2 or 3, immediately after pressing any memory related key. Failure to enter one of these numbers after a memory key results in a flashing of the current display value. These memory registers can store or accumulate data for later use, in a variety of ways.

STORING AND RECALLING DATA

[STO] **n Store Key** – Stores the display value into memory register n. n = 1, 2, or 3. Any previously stored data in n is cleared.

[RCL] **n Recall Key** – Recalls and displays the value stored in memory register n and retains the value in memory. A recalled number can be used as a number entry in any mathematical expression.

Example: Store and recall 3.012 in memory 2.

Enter	Press	Display
3.012	[STO] **2**	3.012
	[CLR]	0
	[RCL] **2**	3.012

Use of these keys can save you keystrokes by storing long numbers that are to be used several times.

Example: Evaluate $3x^2 - x - 7.1$ for x = 2.9467281

Enter	Press	Display
	CLR	0
3	×	3.
2.9467281	STO 1	2.9467281
	x^2	8.683206495
	−	26.04961949
	RCL 1	2.9467281
	−	23.10289139
7.1	=	16.00289139

The long value of x only had to be entered once. The storage and recall did not interfere with calculator operations.

The memories can also be used to hold intermediate results as well as repetitive numbers.

Example: Evaluate $\frac{[\sin(3x/2) - \cos(3x/2)]}{x}$
for x = 20.6821776 degrees

Enter	Press	Display	Comments
	2nd CA ((	0.	
3	×	3.	
20.6821776	STO 1 ÷	62.0465328	Store x
2	) STO 2	31.0232664	Store 3x/2
	sin −	.5153861069	
	RCL 2	31.0232664	Recall 3x/2
	cos	.8569580858	Cos(3x/2)
	) ÷	−.3415719789	
	RCL 1	20.6821776	Recall x
	=	−.0165152812	Answer

DIRECT REGISTER ARITHMETIC

You can store a displayed number at any time during a calculation without affecting the calculation in any way. Additionally, you can add, subtract, multiply and divide the displayed value or calculations in progress. Pressing [2nd] [CA] clears the memories as well as the entire calculator.

[SUM] n **Sum Key** – Adds the displayed value to the content of memory register n and stores the result in n. n = 1, 2 or 3.

[INV] [SUM] n **Subtract Sequence** – Subtracts the displayed value from the content of memory register n and stores the result in n. n = 1, 2 or 3.

[2nd] [PROD] n **Product Key** – Multiplies the content of memory register n by the displayed value and stores this product in n. n = 1, 2 or 3.

[INV] [2nd] [PROD] n **Divide Key** – Divides the content of memory register n by the displayed value and stores the result in n. n = 1, 2 or 3.

These capabilities eliminate the lengthy recall, perform operation, store-again sequences.

Example: Evaluate $x^2 + 9$ for $x = -1, 2, 3$ and total the results.

Enter	Press	Display	Memory 3
1	[+/-] [x^2] [+]	1.	0
9	[=] [STO] 3	10.	10
2	[x^2] [+]	4.	10
9	[=] [SUM] 3	13.	23
3	[x^2] [+]	9.	23
9	[=] [SUM] 3	18.	41
	[RCL] 3	41.	41

Notice that the first evaluation was placed in memory 3 using the [STO] key. This is a recommended procedure when performing direct register arithmetic to ensure that you are accumulating only the values you need in that particular register. The [STO] clears any previous content of that register before storing the new value.

Example: The percentage of students completing each year at a particular college is 76.8% first year, 81.3% second year, 92.2% third year and 95.9% last year. What percentage of the students graduate and what percentage complete their third and fourth years?

Enter	Press	Display
76.8	[%] [×]	0.768
81.3	[%] [×]	0.624384
92.2	[%] [STO] 1 [×]	0.575682048
95.9	[%] [2nd] [PROD] 1 [=]	0.552079084
	[RCL] 1	0.884198

About 55% of the students that enter the school graduate. Over 88% of those entering their junior year graduate.

MEMORY/DISPLAY EXCHANGE

[2nd] [EXC] n Exchange Key – Exchange the content of memory register n with the display. The display value is stored and the previously stored value is displayed.

The exchange key has several uses. You can use it to examine two results without losing either. Also, numbers can be temporarily stored and used as needed.

Example: Evaluate $A^2 + 2AB + B^2$ for A = .258963 and B = 1.255632

Enter	Press	Display	Comments
.258963	[STO] 1 [x^2] [+]	.0670618354	Store A
1.255632	[×]	1.255632	Enter B
	[2nd] [EXC] 1	0.258963	Store B, Recall A
	[×]	.3251622296	A × B
2	[+]	.7173862946	$A^2 + 2AB$
	[RCL] 1	1.255632	Recall B
	[x^2]	1.576611719	B^2
	[=]	2.293998014	Answer

VI. SPECIAL CALCULATIONS

There are several often-used mathematical sequences that have been programmed into your calculator. These operations have been specially designed to provide optimum calculator efficiency by minimizing the number of keystrokes required to execute these iterative sequences.

CALCULATIONS WITH A CONSTANT

[2nd] [CONST] **Constant Key** – Stores a number and an operation for use in repetitive calculations. Used with the +, −, ×, ÷, y^x, $\sqrt[x]{y}$ and Δ% operations.

The entry sequence is the same for all operations – enter the repetitive number, m, then the operation, followed by [2nd] [CONST]. After the constant is stored, additional calculations are completed by entering the variable and pressing [=].

m [+] [2nd] [CONST] adds m to each subsequent entry.

m [−] [2nd] [CONST] subtracts m from each subsequent entry.

m [×] [2nd] [CONST] multiplies each subsequent entry by m.

m [÷] [2nd] [CONST] divides each subsequent entry by m.

m [y^x] [2nd] [CONST] raises each subsequent entry to the m power, i.e., y^m

m [$\sqrt[x]{y}$] [2nd] [CONST] takes the mth root of each subsequent entry, i.e., $\sqrt[m]{y}$

m [2nd] [Δ%] [2nd] [CONST] calculates the percentage change between each subsequent entry y and m by $\frac{m - y}{y} \times 100$.

Performing statistical calculations (linear regression, mean, standard deviation, etc.), pressing [CLR] or [2nd] [CA] or entering any of the above arithmetic operations removes the constant.

Example: Divide .02, tan 22°, 2×10^{22} and $(2222)^2$ by .89.

Enter	Press	Display
	[2nd] [DEG]	0
.89	[÷] [2nd] [CONST]	0.89
.02	[=]	.0224719101
22	[tan] [=]	.4539620515
2	[EE]	2 00
22	[=]	2.247191 22
2222	[x^2] [=]	5.5475101 06

During these calculations you can use any of the math functions, select a fixed decimal point, use memory operations and conversions or vary the display format.

UNIT CONVERSIONS

A selected number of conversions is available directly from the keyboard. These are accessed by entering the number to be converted, then pressing [2nd] followed by the desired conversion. Conversions can be made between the following quantities.

Degrees, minutes, seconds (DDD.mmss)	and	Decimal Degrees (DDD.dd)
Fahrenheit	and	Celsius (Centigrade)
Degrees	and	Radians
Grads	and	Radians
Inches	and	Millimeters
Gallons (U.S.)	and	Liters
Pounds (av)	and	Kilograms

The [INV] key can be used to reverse the effect of the conversion as listed on the keyboard. Conversions between degrees, minutes and seconds and decimal degrees is based on the relationship of degrees in decimal (DD.dd) = Integer degrees (DD) + minutes (mm)/60 + seconds (ss)/3600. Minutes and seconds must each be less than 99.

The Fahrenheit – Celsius conversion is

$$°F = °C \times 9/5 + 32.$$

Degrees are multiplied by $\pi/180$ to yield radians.

Grads are multiplied by $\pi/200$ to produce radians.

Inches are multiplied by 25.4 to get millimeters.

U.S. gallons are multiplied by 3.785411784 to get liters.

Avoirdupois pounds are multiplied by 0.45359237 to yield kilograms.

Example: 212°F = 100°C

Enter	Press	Display
	2nd CA	0
212	2nd °F·°C	100.
	INV 2nd °F·°C	212.

You can use these conversions to convert square units of one system to square units of another system.

Example: 1520 square inches = 980643.2 square millimeters

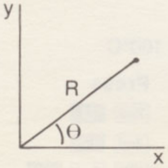
Enter	Press	Display
1520	2nd in·mm 2nd in·mm	980643.2

Going through the conversion process twice effectively multiplies by the conversion factor twice. Cubic conversion would work the same way, except that three conversion sequences are required.

POLAR TO RECTANGULAR SYSTEM CONVERSIONS

[2nd] [P→R] **Polar/Rectangular** – Converts polar coordinates to rectangular.

[x:y] **x Exchange y Key** – Enters and retrieves data for the special calculations. Also used for arithmetic operations and exchanging x and y in root and power calculations.



Polar to Rectangular Key Sequence

R [x:y] θ [2nd] [P→R] yields y [x:y] x

Rectangular to Polar Key Sequence

x [x:y] y [INV] [2nd] [P→R] yields θ [x:y] R

The θ calculated from the rectangular to polar sequence will be:

$$\left.\begin{array}{l} -90^\circ \\ -\pi/2 \text{ rad} \\ -100 \text{ grad} \end{array}\right\} \leq \Theta \leq \left\{\begin{array}{l} 270^\circ \\ 3\pi/2 \text{ rad} \\ 300 \text{ grad} \end{array}\right.$$

This conversion routine monitors the angular mode of the calculator to determine the angular units desired for both entry and retrieval of data.

Example: Convert (5, 30°) polar coordinate point to rectangular then reconvert giving the result in radians.

Enter	Press	Display	Comments
	2nd DEG	0	Select degree mode
5	x:y	0.	Enter R
30	2nd P▸R	2.5	Enter Θ, display y
	x:y	4.330127019	Display x
	2nd RAD	4.330127019	Radian mode
	x:y	2.5	Enter x
	INV 2nd P▸R	.5235987756	Display Θ
	x:y	5.	Display R

MEAN, VARIANCE, STANDARD DEVIATION

Σ+ **Sum Plus Key** – Enters data points, y_i, for calculation of mean, variance and standard deviation and for the linear regression routines.

2nd Σ– **Sum Minus Key** – Removes unwanted data entries for mean, variance, standard deviation and linear regression calculations.

2nd MEAN **Mean Key** – Calculates the mean of the y array of data. Mean $= \bar{y} = \frac{\sum_{i=1}^{N} y_i}{N}$, i = 1, 2, 3...N

2nd VAR **Variance Key** – Calculates the variance of the y array of data using N weighting.

$$\text{Variance} = \frac{\Sigma y_i^2}{N} - \frac{(\Sigma y_i)^2}{N^2}$$

2nd S.DEV **Standard Deviation Key** – Calculates the standard deviation of the y array of data using N – 1 weighting.

$$\text{Standard Deviation} = \sqrt{\text{Var} \times \frac{N}{N-1}}$$

All calculating here must begin and end by pressing [2nd] [CA] to totally clear the calculator. While the calculator is being used for statistical operations, it is still possible to perform regular math calculations. Due to the complexity of the statistical features and the internal work area they require, only 2 pending operations are available. Statistical values are stored in the 3 user-accessible memories, so external values cannot be stored here without destroying the statistical data.

Data points are entered by pressing [Σ+] after each y_i entry and removed by pressing [2nd] [Σ-] after reentry of an incorrect point. The entry number N is displayed after each entry, N = 0, 1, 2...

Once entered, the data can be used to calculate the mean, variance and standard deviation by simply pressing the necessary keys. The data are accumulated in the memory registers with Σy_i in 1, Σy_i^2 in 2 and N in 3.

Example: Analyze the following test scores: 96, 81, 87, 70, 93, 77

Enter	Press	Display	Comments
	[2nd] [CA]	0	Clear
96	[Σ+]	1.	1st Entry
81	[Σ+]	2.	2nd Entry
97	[Σ+]	3.	3rd Entry (incorrect)
97	[2nd] [Σ-]	2.	Remove 3rd Entry
87	[Σ+]	3.	Correct 3rd Entry
70	[Σ+]	4.	4th Entry
93	[Σ+]	5.	5th Entry
77	[Σ+]	6.	6th Entry
	[2nd] [S.DEV]	9.879271228	Standard Deviation
	[2nd] [MEAN]	84.	Mean
	[2nd] [VAR]	81.33333333	Variance
	[RCL] 1	504.	Total of Scores

Note that the standard deviation can be calculated first even though the mean is used to determine the standard deviation.

The values stored in the memory registers can be recalled and used in other calculator operations. Mean, variance and standard deviation though, should not be used during a mathematical expression because an [=] key is used internally in these calculations which completes all pending operations.

For your convenience, the option has been provided to select N or N−1 weighting for standard deviation and variance calculations. N weighting results in a maximum likelihood estimator that is generally used to describe populations, while the N−1 is an unbiased estimator customarily used for sampled data.

Standard deviation and variance can be obtained with N or N−1 weighting. The variance key uses N weighting and the standard deviation key uses N−1 weighting. Variance is the square of the standard deviation. So, variance with N−1 weighting is obtained by pressing [2nd] [S.DEV] [x^2] and standard deviation with N weighting results from [2nd] [VAR] [$\sqrt{x}$] .

LINEAR REGRESSION

[x:y] **x Exchange y Key** – Enters the x values for linear regression calculations. Also used in conversions, roots and powers and certain arithmetic operations.

[Σ+] **Sum Plus Key** – Enters the y values for linear regression calculations.

[2nd] [Σ−] **Sum Minus Key** – Removes undesired data entries.

[2nd] [SLOPE] **Slope Key** – Calculates the slope of the calculated linear regression curve. If the line is vertical, the display will flash because the slope is infinite.

[2nd] [INTCP] **Intercept Key** – Calculates the y-intercept of the calculated linear regression curve. If the line is vertical, the display will flash because there is no y-intercept.

[2nd] [x'] **Compute x Key** – Calculates a linear estimate of x corresponding to a y entry from the keyboard.

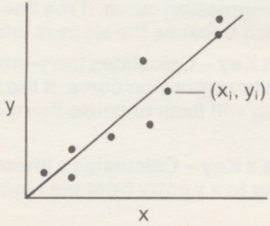
[2nd] [y'] **Compute y Key** – Calculates a linear estimate of y corresponding to an x entry from the keyboard.

[2nd] [CORR] **Correlation Key** – Calculates the correlation coefficient of the data entered in the linear regression routine. The value will be between ±1 with ±1 being a perfect correlation.

[2nd] [MEAN], [2nd] [VAR], [2nd] [S.DEV] – Calculates the mean, variance and standard deviation of the y-array of data.

[INV] [2nd] [MEAN], [INV] [2nd] [VAR], [INV] [2nd] [S.DEV] – Calculates the mean, variance and standard deviation of the x-array of data.

In many disciplines it is desirable to express one variable in terms of another even though the variables are independent and are not necessarily analytical functions of each other. An accepted practice is to perform a least-squares linear regression which is designed to minimize the sum of the squares of the deviations of the actual data points from the straight line of best fit. In practice, we are essentially constructing a plot of the variables (called a scatter diagram) and drawing the best straight line which uniformly divides the data points as shown below. Because the data may not be best represented by a straight-line curve, it is desirable to measure how well the linear curve actually does fit the data. This measure is called the correlation coefficient and may be calculated from the independent variables and the linear equation parameters.



Scatter diagram

Your calculator automatically computes the slope and y-intercept with its linear regression routine. The result is a linear equation of the form

$$y = mx + b$$

It can be shown that the slope and y-intercept are determined as follows

$$m = \frac{\dfrac{\Sigma x_i \Sigma y_i}{N} - \Sigma x_i y_i}{\dfrac{(\Sigma x_i)^2}{N} - \Sigma x_i^2}$$

$$b = \bar{y} - m\bar{x}$$

$$\bar{x} = \text{average x value} = \frac{\sum_{i=1}^{N} x_i}{N}$$

$$\bar{y} = \text{average y value} = \frac{\sum_{i=1}^{N} y_i}{N}$$

$$\sigma_x^2 = \text{variance of the x values}$$

$$= \frac{\sum_{i=1}^{N} x_i^2}{N} - \bar{x}^2$$

After the linear regression curve is determined, you can measure the degree of association between the random variables $(x_i, y_i), \ldots (x_n, y_n)$. This correlation coefficient is usually denoted by r and is calculated using the following expression

$$r = \frac{m\sigma_x}{\sigma_y}$$

where

$$\sigma_y^2 = \text{variance of the y values}$$

$$= \frac{\sum_{i=1}^{N} y_i^2}{N} - \overline{y^2}$$

From these equations, it is easy to see that the sum of the squares of the data points must not exceed the upper limit of the calculator $\pm 9.9999999 \times 10^{99}$.

The array of x_i, y_i data points is entered by pressing

x_i [x:y] y_i [Σ+]

for each data point. Undesired data points can be removed by reentering the faulty pair, but press [2nd] [Σ-] instead of [Σ+], just as in mean, standard deviation, and variance calculations.

Example: A quantity of tubing has been ordered cut into 100 cm long sections to be checked for length accuracy and uniformity that should be 6.0 gm/cm ±0.01. The test requires that 6 samples be analyzed at a time.

Sample	1	2	3	4	5	6
Length (cm)	101.3	103.7	98.6	99.9	97.2	100.1
Weight (gm)	609	626	586	594	579	605

What is the average weight of the samples taken? How accurate is the cutting machine? What is the uniformity of the samples? How close were the samples to the standard?

Enter	Press	Display	Comments
	[2nd] [CA]	0	Clear all
101.3	[x:y]	0.	Enter x_1
609	[Σ+]	1.	Enter y_1
103.7	[x:y]	102.3	Enter x_2
626	[Σ+]	2.	Enter y_2
98.6	[x:y]	104.7	
586	[Σ+]	3.	
99.9	[x:y]	99.6	
594	[Σ+]	4.	
97.2	[x:y]	100.9	
579	[Σ+]	5.	
100.1	[x:y]	98.2	Enter x_6
605	[Σ+]	6.	Enter y_6
	[2nd] [MEAN]	599.8333333	Average of y array
	[÷] [INV] [2nd] [MEAN]	100.1333333	Average of x array
	[=]	5.990346205	Average uniformity
	[2nd] [CORR]	.9815053641	Correlation coefficient

The average weight of the samples is about 599.8 grams. The machine is cutting the length to about 100.1 centimeters. The uniformity is better than 5.99 grams/centimeter, easily within the acceptable tolerance. The correlation coefficient, being very near 1 (perfect correlation) shows that the individual samples were quite close to the uniformity standard.

TREND-LINE ANALYSIS

This process is a variation of linear regression. Calculations must begin and end with [2nd] [CA]. Here, the x values are automatically incremented by 1 for each data point. The calculator normally assigns an x value of 0 to the first y data point. The data points are then entered by pressing [Σ+]. The initial x value can be set to any number other than 0 by entering the first value as in normal linear regression x_1 [x:y] y_1 [Σ+], then y_2 [Σ+], y_3 [Σ+], etc. The x values are still internally incremented by 1 for each y value. There is no limit on the number of data points that can be entered.

Undesired data points can be removed by the following sequence:

y_{bad} [Σ+], then [x:y] −1 [=] [x:y] y_{bad} [2nd] [Σ−] y_{good} [Σ+], continue

Example: A company began in 1972. Profits each year since then have been −1.2, −0.3, 2.1, 1.8, and 2.7 million dollars. What profit can be expected in 1977 and in 1980? When should profits reach 10 million dollars?

Enter	Press	Display	Comments
	[2nd] [CA]	0	Clear All
1972	[x:y]	0.	Starting x value
1.2	[+/−] [Σ+]	1.	y_1
.3	[+/−] [Σ+]	2.	y_2
2.1	[Σ+]	3.	y_3
1.8	[Σ+]	4.	y_4
3.7	[Σ+]	5.	y_5
	[x:y] [−]	1977.	
1	[=]	1976.	Faulty entry year
	[x:y]	0.	
3.7	[2nd] [Σ−]	4.	Faulty value removed
2.7	[Σ+]	5.	Correct value
1977	[2nd] [y′]	3.99	Expected profit in 1977
1980	[2nd] [y′]	6.96	Expected profit in 1980
10	[2nd] [x′]	1983.070707	10 million profit year

VII. SAMPLE MATH PROBLEMS

In the previous sections, the capabilities and operations of your calculator have been explained. This section demonstrates some of the math situations in which your calculator can prove invaluable. For simplicity, M1, M2, M3 will represent memories 1, 2 and 3.

VECTOR ADDITION

Add the following vectors:

$$5 \angle 30^\circ + 10 \angle 45^\circ = r' \angle \Theta'$$

Our solution is to first find the individual x and y components of each vector using the polar rectangular conversion routine. Next we sum both x and y components separately to achieve the resultant X and Y values. The equations used are:

$$X = 5 \cos 30^\circ + 10 \cos 45^\circ$$
$$Y = 5 \sin 30^\circ + 10 \sin 45^\circ$$

Finally, we perform a rectangular to polar transformation on the X and Y resultant values to arrive at r' and Θ'. The equations used are:

$$r' = \sqrt{X^2 + Y^2} = 14.88598612$$

$$\Theta' = \tan^{-1} \frac{Y}{X} = 40.01276527$$

The calculator solution is:

Enter	Press	Display	Comments
	[2nd] [CA]	0	
5	[x:y]	0.	Enter radius of first vector.
30	[2nd] [P▸R] [STO] 1	2.5	Enter angle of first vector, complete polar
	[x:y] [STO] 2	4.330127019	rectangular conversion. Y stored in M1 and X stored in M2.
10	[x:y]	2.5	Enter radius of second vector.
45	[2nd] [P▸R] [SUM] 1	7.071067812	Enter angle of second vector, complete polar/ rectangular
	[x:y] [SUM] 2	7.071067812	conversion. Sum Y components in M1 and X components in M2.
	[RCL] 2 [x:y] [RCL] 1	9.571067812	Resultant X and Y components recalled for rectangular/ polar conversion.
	[INV] [2nd] [P▸R]	40.01276527	Angle Θ′ in degrees
	[x:y]	14.88598612	Magnitude r′

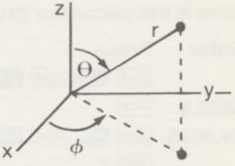
RECTANGULAR/SPHERICAL COORDINATE CONVERSIONS

To convert (5, 8, 10) from rectangular to spherical coordinates use the following reference system.

Where $r = \sqrt{x^2 + y^2 + z^2}$

$$\phi = \tan^{-1} \frac{y}{x}$$

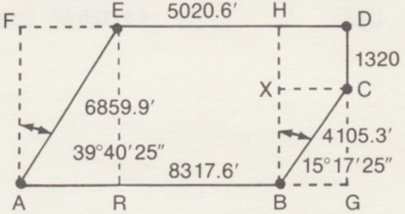
$$\Theta = \tan^{-1} \frac{\sqrt{x^2 + y^2}}{z}$$



To solve on the calculator:

Enter	Press	Display	Comments
	[2nd] [CA]	0	
5	[x⇌y]	0.	Enter x
8	[INV] [2nd] [P▸R]	57.99461679	Enter y; value of ϕ displayed in degrees.
10	[x⇌y] [INV] [2nd] [P▸R]	43.33171975	Enter z; value of Θ displayed in degrees.
	[x⇌y]	13.74772708	Value of r

AREA OF IRREGULAR POLYGONS



An investor wishes to purchase the tract of land shown for future development. With land prices at $0.012 per square foot how much can he expect to spend? The parts of the figure have been labeled to help you follow the solution.

(Total area) × (Price/unit area) = Total Cost

Total area = AGDF − AEF − BGC

Here is the calculator procedure:

Enter	Press	Display	Comments
	[2nd] [CA] [2nd] [FIX] 2	0.00	
6859.9	[x:y]	0.00	
39.4025	[2nd] [DMS-DD] [2nd] [P→R]	4379.45	FE
	[STO] 1	4379.45	FE in M1
	[x:y] [STO] 2 [×] [(]	5280.02	FA in M2
	[RCL] 1 [+]	4379.45	
5020.6	[)]	9400.05	FD
	[−]	49632477.73	Area AGDF
	[RCL] 1 [×] [RCL] 2 [÷]	23123601.16	FE × FA
2	[=] [STO] 3	38070677.15	AGDF-AFE
4105.3	[x:y]	0.00	
15.1725	[2nd] [DMS-DD] [2nd] [P→R]	1082.61	BG
	[STO] 1	1082.61	BG in M1
	[x:y] [×] [RCL] 1 [÷]	4287299.94	BG × CG
2	[=]	2143549.97	Area BGC
	[+/−] [+] [RCL] 3 [=]	35927127.18	AREA
	[×]		
.012	[=]	431125.53	Cost of plot

APPROXIMATING INTEGRALS

The area of a quarter circle is given by

$$A = \int_0^1 \sqrt{1 - x^2}\, dx$$

Simpson's rule of approximate integration states that $A = \frac{1}{3} h[(y_0 + y_n) + 4(y_1 + y_3 + \ldots + y_{n-1}) + 2(y_2 + y_4 + \ldots + y_{n-2})]$; n is even, h is the length of the uniform subdivisions, and y_i is value of the function at each division point, x_i, of the interval of integration.

For comparison, we give two solutions. On the interval [0, 1] we pick $h = \frac{1}{2}$, so $x_0 = 0$, $x_1 = \frac{1}{2}$, $x_2 = 1$.

Therefore,

$$A = \int_0^1 \sqrt{1 - x^2} dx = \frac{1}{3} \cdot h \left[(y_0 + y_2) + 4(y_1) \right]$$

$$= \frac{1}{3} \cdot \frac{1}{2} \left[\sqrt{1 - 0^2} + \sqrt{1 - 1^2} + 4\sqrt{1 - (\tfrac{1}{2})^2} \right]$$

$$= .7440169359$$

On the calculator we proceed as follows:

Enter	Press	Display	Comments
6	[1/x] [×] [(]	.1666666667	
1	[+]	1.	
4	[×] [(]	4.	
1	[−]	1.	
.5	[x²]	0.25	
	[)]	0.75	
	[√x]	.8660254038	
	[=]	.7440169359	Approximate area A

Accuracy improves considerably if we take four subintervals instead of the two above. Notice that some simple preliminary arithmetic helps in producing an efficient calculator algorithm. The following equation expresses the situation for four subintervals:

$$h = \frac{1}{4},\ x_0 = 0,\ x_1 = \frac{1}{4},\ x_2 = \frac{1}{2},\ x_3 = \frac{3}{4},\ x_4 = 1$$

$$A = \int_0^1 \sqrt{1 - x^2}dx = \frac{1}{3}h\left[(y_0+y_4) + 4(y_1+y_3) + 2(y_2)\right]$$

$$= \frac{1}{3} \cdot \frac{1}{4}\left[\left(\sqrt{1-0^2} + \sqrt{1-1^2}\right) + 4\left(\sqrt{1-.25^2} + \sqrt{1-.75^2}\right)\right.$$

$$\left. + 2\sqrt{1-.5^2}\right]$$

$$= .7708987887$$

Enter	Press	Display
	[2nd] [CA]	0
1	[÷]	1.
12	[×] [(]	.0833333333
1	[+]	1.
4	[×] [(] [(]	4.
1	[−]	1.
.25	[x^2] [)] [$\sqrt{x}$] [+] [(]	.9682458366
1	[−]	1.
.75	[x^2] [)] [$\sqrt{x}$] [)] [+]	7.518734657
2	[×] [(]	2.
1	[−]	1.
.5	[x^2] [)] [$\sqrt{x}$] [)] [=]	.7708987887

APPROXIMATING DERIVATIVES

Your calculator can also aid in the approximation of derivatives. For example, let's approximate the derivative of f(x) = sin x at $x_0 = 45°$ or $\frac{\pi}{4}$ radians. Recall that if f(x) = sin x, then f'(x) = cos x. Also,

$$f'(x_0) = \lim_{\Delta x \to 0}\left[\frac{f(x_0 + \Delta x) - f(x_0 - \Delta x)}{2\Delta x}\right]$$

$$= \frac{\sin\left(\frac{\pi}{4} + .0001\right) - \sin\left(\frac{\pi}{4} - .0001\right)}{2(.0001)}$$

The calculator algorithm for this process is:

1. Convert 45° to radians and store in M1.
2. Add contents of M1 to $\Delta x = .0001$, take sin and store in M2.
3. Subtract .0001 from contents of M1. Take the sin, change sign and add to contents of M2.
4. Multiply 2 and .0001, take reciprocal and multiply the result times contents of M2.

Enter	Press	Display	Comments
	2nd RAD ((	0.	Radian mode
45	2nd D-R	.7853981634	Degrees to radians
	STO 1 +	.7853981634	
.0001	) sin − (	.7071774883	
	RCL 1 −	.7853981634	
.0001	) sin)	.0001414214	
	× (	.0001414214	
2	×	2.	
.0001	) 1/x =	0.70710678	Value of $f'\left(\frac{\pi}{4}\right)$
	− RCL 1	.7853981634	
	cos =	−.0000000012	Difference of $f'\left(\frac{\pi}{4}\right)$ and $\cos\frac{\pi}{4}$

SOLUTION OF A DIFFERENTIAL EQUATION

Now suppose we have a differential equation of the form $y' = f(x,y)$, $y(0) = a$. It can be shown that approximate solutions can be obtained by using the following recursive equation: $y_{n+1} = y_n + hf(x_n,y_n)$. Therefore, to solve $y' = x + y$, $y(0) = 0$, $h = .2$, our recursion relation becomes:

$$y_{n+1} = y_n + h(x_n + y_n)$$

Where $\quad x_n = nh$

By inspection, the value of $y_{n+1} = 0$, with $n = 0$. Therefore the calculator solution will begin with $n = 1$ and $h = 0.2$.

Enter	Press	Display	Comments
	2nd FIX 3	0.000	
0	STO 1 +	0.000	y_n in M1
.2	× (	0.200	h
.2	×	0.200	h
1	+ RCL 1 = STO 1	0.040	y_{n+1} (new y_n)
	+	0.040	Repeat sequence for n = 2
.2	× (	0.200	
.2	×	0.200	
2	+ RCL 1 =	0.128	New y_{n+1} for next y_n

Since the procedure is repetitive, the results of ten calculation sequences are shown in the following table. Also, for comparison of accuracy, the table shows the actual y_{n+1} value computed with the equation:

$$y = e^{x_n} - x_n - 1$$

n	x_n	y_n	$y_n + h(x_n + y_n)$	actual y-value
0	0.0	0.000	0.000	0.000
1	0.2	0.000	0.040	0.021
2	0.4	0.040	0.128	0.092
3	0.6	0.128	0.274	0.222
4	0.8	0.274	0.488	0.426
5	1.0	0.488	0.786	0.718
6	1.2	0.786	1.183	1.120
7	1.4	1.183	1.700	1.655
8	1.6	1.700	2.360	2.353
9	1.8	2.360	3.192	3.250
10	2.0	3.151	4.230	4.389

The accuracy of the above algorithm can be increased by selecting a smaller value of h.

SOLUTION OF ALGEBRAIC EQUATIONS

Using similar iterative techniques we may solve algebraic equations. For example, consider the following equation.

$$f(x) = x^3 + x - 1 = 0$$

There are several methods applicable here. This equation is easily determined using Descartes' rule of signs that this equation has exactly one real positive root. We shall approximate the real root by noting that we can rewrite the equation as

$$x = \frac{1}{1 + x^2}$$

Thus, we obtain an approximation routine using the form

$$x_{n+1} = \frac{1}{1 + x^2_n}$$

We start our routine in the following table with x = 0 which is an arbitrary guess. The routine will in general correct itself.

n	x_n	x_{n+1}
0	0.000	1.000
1	1.000	0.500
2	0.500	0.800
3	0.800	0.610
4	0.610	0.729
5	0.729	0.653
6	0.653	0.701
7	0.701	0.670
8	0.670	0.690
9	0.690	0.678
10	0.678	0.685

Notice that each derived x is squared, the result is added to 1 and the reciprocal taken of that sum. For example:

Enter	Press	Display	Comments
	[2nd] [FIX] 3		
.653	[x^2] [+]	0.426	
1	[=] [1/x]	0.701	Value of x_{n+1} with n = 6
	[x^2] [+]	0.491	
1	[=] [1/x]	0.670	Value of x_{n+1} with n = 7

To check how near we are to a solution at the tenth step shown in the table:

Enter	Press	Display
.685	[STO] 1 [y^x]	0.685
3	[+] [RCL] 1 [−]	1.006
1	[=]	0.006

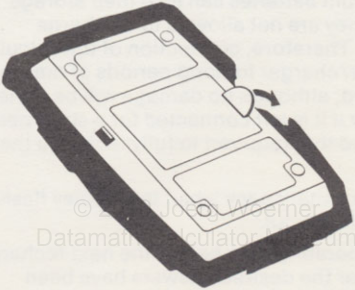
Therefore, we are 0.006 away from zero and more iterations will be necessary for more accuracy.

APPENDIX A

MAINTENANCE AND SERVICE

Battery Pack Replacement

The battery pack can be quickly and simply removed from the calculator. Hold the calculator with the keys facing down. Place a small coin (penny, dime) in the slot in the bottom of the calculator. A slight prying motion with the coin will pop the slotted end of the pack out of the calculator. Disconnect the wires that attach the battery pack to the calculator. The pack can then be removed entirely from the calculator.



The exposed metal contacts on the battery pack are the battery terminals. Care should always be taken to prevent any metal object from coming into contact with these terminals and shorting the batteries.

To re-insert the battery pack, first, attach the connecting wires to the terminals of the battery pack (DO NOT FORCE, it will fit easily when properly oriented). Then, place the pack into the compartment so that the small step on the end of the pack fits under the edge of the calculator bottom. A small amount of pressure on the battery pack will snap it properly into position. Again, it should fit easily.

Spare and replacement battery packs can be purchased directly from a Texas Instruments Consumer Service Facility as listed on the back cover.

AC Adapter/Charger

Battery pack recharge or direct operation from standard voltage outlets is easily accomplished with the AC Adapter/Charger model AC9131 included with the SR-51-II. The calculator cannot be overcharged; it can be operated indefinitely with the adapter/charger connected.

Operating Conditions

For maximum rechargeable battery life, it is recommended that the calculator be operated as a portable, recharging the batteries when necessary. Nickel-cadmium batteries can lose their storage capability if they are not allowed to discharge occasionally. Therefore, connection of the calculator to the adapter/charger for long periods of time is not recommended; although no damage will be done to the calculator if it is left connected for a short period of time beyond that required to fully recharge the batteries.

Recharge the battery pack when the display flashes erratically or fades out.

To prolong operating time before the next recharging, press [CLR] after the desired answers have been displayed. Turn your SR-51-II off when not in use.

Battery Operation

The "fast-charge" nickel-cadmium battery pack BP-6 furnished with the calculator was fully charged at the factory before shipping. However, due to shelf life discharging, it may require charging before initial operation.

With the battery pack properly installed, charging is accomplished by plugging the AC Adapter/Charger AC9131 into a convenient 115 volt/60 Hz electrical outlet and plugging the attached cord into the SR-51-II socket. A full charge will take approximately 4 hours with the calculator off, 10 hours if the calculator is in use.

If the calculator is left on for an extended period of time after the batteries become discharged, one of the batteries may be driven into deep discharge. This condition is indicated by failure of the calculator to operate after being recharged for a few minutes. The batteries can usually be restored to operating condition by charging the calculator overnight. Repeated deep discharging will permanently damage batteries.

In Case of Difficulty

1. Check to be sure the battery pack is properly attached to the calculator and that the adapter/charger is securely connected to a live electrical outlet.

CAUTION: Use of other than the AC9131 Adapter/Charger may apply improper voltage to your SR-51-II calculator and cause damage.

2. Check to be sure ON-OFF switch is in the ON position. If a 0 does not appear in the display, switch the calculator OFF then ON again.
3. Press [2nd] [CA] and reenter problem.
4. If display fails to light on battery operation, recharge batteries. The calculator should operate properly after several minutes of recharging.
5. Review operating instructions to be certain calculations are performed correctly.
6. If the battery pack has completely discharged, charge the battery overnight.

If none of the above procedures corrects the difficulty, return the **calculator and charger** PREPAID and INSURED to the applicable SERVICE FACILITY listed on the back cover.

NOTE: The P.O. box number listed for the Texas Service Facility is for United States parcel post shipments only. If you desire to use another carrier, the street address is: Texas Instruments Incorporated, 2305 University Ave., Lubbock, Texas 79415.

For your protection, the calculator must be sent insured; Texas Instruments cannot assume any responsibility for loss of or damage to uninsured shipments. Please include information on the difficulty experienced, as well as return address information including name, address, city, state, and zip code. The shipment should be carefully packaged and adequately protected against shock and rough handling.

Calculator Exchange Centers

If your calculator requires service, instead of returning the unit to a service facility for repair, you may elect to exchange the calculator for a factory-rebuilt calculator of the SAME MODEL at one of the exchange centers which have been established across the United States. A $3.00 charge will be made by the exchange center for in-warranty exchanges. Out-of-warranty exchanges will be charged at the rates in effect at the time of the exchange. Please call the Consumer Relations Department for further details and the location of the nearest exchange center.

If You Need Service Information

If you need service information for your calculator, write the Consumer Relations Department at:

Texas Instruments Incorporated
P. O. Box 53
Lubbock, Texas 79408

or call Consumer Relations at 800-858-1802 (toll-free within all contiguous United States except Texas) or 800-692-1353 (toll-free within Texas). If outside contiguous United States call 806-747-3841. (We regret that we cannot accept collect calls at this number.)

APPENDIX B
ERROR CONDITIONS

A flashing display indicates that the displayable limits of the calculator have been violated or that an invalid calculator operation has been requested. Pressing [CE], [CLR] or [2nd] [CA] stops the flashing. [CLR] and [2nd] [CA] also clears the display and pending operations. [CE] stops the flashing only, permitting further calculations with undisturbed pending operations. The display will flash for the following reasons:

1. Calculation entry or result (in display or memories) outside the range of the calculator, $\pm1 \times 10^{-99}$ to $\pm9.9999999 \times 10^{99}$. The exceeded limit is flashed.
2. Inverse of a trigonometric or hyperbolic function with an invalid value for the argument, such as $\sin^{-1} x$ with x greater than 1. The invalid value x is flashed.
3. Root or logarithm of a negative number. The root or logarithm of the absolute value of the argument is flashed to indicate the sign error.
4. Raising a negative number to any power. The power of the absolute value of the number is flashed.
5. Pressing two operation keys in succession. This affects +, −, ×, ÷, y^x, $\sqrt[x]{y}$ and Δ%. The last entered number is flashed.
6. Pressing [=] or [)] after +, −, ×, ÷, y^x, $\sqrt[x]{y}$ or Δ%. The last entered number is flashed.
7. Having more than 9 open parentheses or more than 5 pending operations. The 10th parenthesis or 6th operation is not accepted so processing can continue. The last displayed number is flashed.
8. Dividing a number by zero. "9.9999999 99" is flashed.
9. Factorial of any number except a non-negative integer ≤ 69. The absolute value of the integer portion factorial is flashed.

10. Any memory operation that is not followed by 1, 2 or 3, [CLR] or [2nd] [CA]. The value being operated on is flashed.
11. Radius outside the range $10^{\pm 50}$ in Rectangular to Polar Conversions. The radius is flashed.
12. Pressing [2nd] 7, 8 or 9.
13. In linear regression calculations, if the line parallels the y-axis, attempting to calculate slope, intercept, correlation, x′ or y′ will cause flashing. If the line parallels the x-axis, the display flashes when attempting to calculate x′ or correlation.
14. Calculation of slope, intercept, correlation, x′, y′ or standard deviation with less than 2 data points entered. The last displayed number flashes in the display.
15. Having more than 2 pending operations during linear regression, trend-line analysis or statistical routines.
16. 0^{-x} and $\sqrt[-x]{0}$ produces flashing overflow "9.9999999 99".
17. Key sequence 0 [2nd] [Δ%] 0 produces flashing "1."
18. Key sequence 0 [2nd] [Δ%] N, where N ≠ 0 produces flashing "±9.9999999 99".
19. Arguments that do not satisfy the following limits cause a flashing display.

Function	Limit
$\sin^{-1}x$, $\cos^{-1}x$	$-1 \leq x \leq 1$
sinh x, cosh x	$0 \leq \lvert x \rvert \leq 227.9559242$
ln x	$1 \times 10^{-99} \leq \lvert x \rvert < 1 \times 10^{100}$
log x	$1 \times 10^{-99} \leq x < 1 \times 10^{100}$
$\sinh^{-1}x$, $\cosh^{-1}x$	$0 \leq \lvert x \rvert < 1 \times 10^{50}$
$\tanh^{-1}x$	$0 \leq \lvert x \rvert < 1.0$
e^x	$-227.9559242 \leq x \leq 230.2585092$
10^x	$-99 < x < 100$
x!	$0 \leq x \leq 69$ (integer)

APPENDIX C
DISPLAYED RESULTS VERSUS ACCURACY

Calculators, like all other electrical and mechanical devices, must operate with a fixed set of rules within preset limits.

The basic mathematical tolerance of the calculator is controlled by the number of digits it uses for calculations. The calculator appears to use 10 digits as shown by the display, but actually uses 12 digits to perform all calculations. Combined with the built-in 5/4 rounding capability, these extra digits guard the ten-digit display to improve accuracy. Consider the following example in the absence of these guard digits.

$$1/3 \times 3 = .9999999999 \text{ (inaccurate)}$$

The example shows that $1 \div 3 = .3333333333$ when multiplied by 3 and produces an inaccurate answer. A twelve-digit string of nines would *round* to 1.

The higher order mathematical functions use iterative calculations. The cumulative rounding error is maintained below the ten-digit display so that no effect can be seen. The 12-digit representation of a number is two orders of magnitude from the displayed tenth digit. In this way, the display assures that results are rounded accurately to ten digits.

Normally, there is no need to even consider these guard digits. On certain calculations, however, the guard digits may appear as an answer when not expected. The mathematical limits of finite operation: word length, truncation and rounding errors do not allow the guard digits to always be completely accurate. Therefore, when subtracting two functions which are mathematically equal, the calculator may display a non-zero result.

Example: Sin 45° − Cos 45° ≠ 0

Select degree mode

Enter	Press	Display
45	[sin] [−]	.7071067812
45	[cos]	.7071067812
	[=]	1.−12

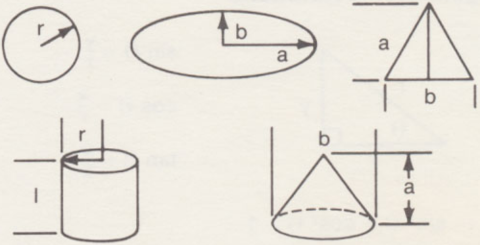
The identical display results of sin 45° and cos 45° show that the functions are accurate to at least ten digits. The final result indicates a discrepancy in the twelfth digit. The significance is that results smaller than entry or intermediate results off by a factor of 10^{-11} to 10^{-12} are potentially equal to zero.

For the standard display, results are accurate for all calculations that do not violate the restrictions listed in Appendix B, except as defined below.

Trigonometric Functions – All displayed digits are accurate for a ±36,000 degree range, ±200π radians and ±40,000 grads. When the argument range reaches $\pm 3.6 \times 10^{14}$ degrees ($\pm 6.2799993 \times 10^{12}$ radians or $\pm 4.0 \times 10^{14}$ grads) or more, no partial rotation is recognized. In general, the accuracy decreases one digit for each decade outside the specified accuracy range. An exception is the tangent of multiples of ±90°, ±π/2 radians or ±100 grads that results in an overflow condition because the function is undefined at these points. For example, the tangent of 89 degrees is accurate throughout the display range, whereas the tangent of 89.99999 degrees is accurate to 4 places.

Roots and Powers – There is some accuracy loss for roots and powers in calculations only where the base y gets very close to 1 *and* the power x gets very large. For example, $.99999944^{-160000}$ is accurate through 8 digits, whereas $.99999944^{-400}$ is accurate throughout all 10 standard display digits.

APPENDIX D
GEOMETRIC FORMULAS



Circumference: Circle $2\pi r$

Area:

Circle	πr^2
Ellipse	πab
Sphere	$4\pi r^2$
Cylinder	$2\pi r[r+l]$
Triangle	½ab

Volume:

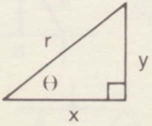
Ellipsoid of revolution about "a" axis	$4/3\pi b^2a$
Ellipsoid of revolution about "b" axis	$4/3\pi a^2b$
Sphere	$4/3\pi r^3$
Cylinder	$\pi r^2 l$
Cone	$\frac{\pi b^2 a}{12}$

Analytical:

Circle	$\frac{x^2}{r^2}+\frac{y^2}{r^2}=1$
Ellipse	$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$
Hyperbola	$\frac{x^2}{a^2}-\frac{y^2}{b^2}=1$
Parabola	$y^2=\pm 2px$
Line	$y=mx+b$

APPENDIX E
MATHEMATICAL EXPRESSIONS

Trigonometric Relations



$\sin \Theta = \frac{y}{r}$

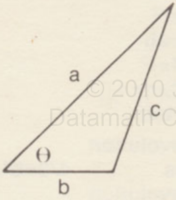
$\cos \Theta = \frac{x}{r}$

$\tan \Theta = \frac{y}{x}$

$\sin^2 \Theta + \cos^2 \Theta = 1$

$e^{i\Theta} = \cos \Theta + i \sin \Theta \qquad i = \sqrt{-1}$

Law of Cosines



$a^2 + b^2 - 2ab \cos \Theta = c^2$

Laws of Exponents

$a^x \times a^y = a^{x+y}$ $\qquad \frac{1}{a^x}\ a^{-x}$

$(ab)^x \quad = a^x \times b^x$ $\qquad \frac{a^x}{a^y} = a^{x-y}$

$(a^x)^y \quad = a^{xy}$ $\qquad a^0 = 1$

Laws of Logarithms

$\ln(y^x) \quad = x \ln y$

$\ln(ab) \quad = \ln a + \ln b$

$\ln\left(\frac{a}{b}\right) \quad = \ln a - \ln b$

APPENDIX F
VALUES OF FUNDAMENTAL PHYSICAL CONSTANTS

			Units	
Constant	Symbol	Value	mks	cgs
1. Speed of Light	c	2.9979250	10^{8}msec^{-1}	10^{10}cmsec^{-1}
2. Electron Charge	e	1.6021917	10^{-19}C	10^{-20}emu
3. Avogadro Number	N	6.022169	10^{26}kmole^{-1}	10^{23}mole^{-1}
4. Electron Rest Mass	m_e	9.109558	10^{-31}kg	10^{-28}g
	m_e	5.485930	10^{-4}amu	10^{-4}amu
5. Proton Rest Mass	M_p	1.672614	10^{-27}kg	10^{-24}g
	M_p	1.00727661	amu	amu
6. Neutron Rest Mass	M_n	1.674920	10^{-27}kg	10^{-24}g
	M_n	1.00866520	amu	amu
7. Atomic Mass Unit	amu	1.660531	10^{-27}kg	10^{-24}g
8. Ratio of proton to electron rest mass	M_p/m_e	1836.109	–	–
9. Electron Charge to Mass ratio	e/M_e	1.7588028	10^{11}Ckg^{-1}	10^{7}emu g^{-1}
10. Planck Constant	h	6.626196	10^{-34}J-sec	10^{-27}erg-sec
11. Rydberg Constant	R_∞	1.09737312	10^{7}m^{-1}	10^{5}cm^{-1}
12. Gas Constant	R_o	8.31434	10^{3}J-kmole^{-1}K^{-1}	10^{7}erg-mole^{-1}-K^{-1}
13. Boltzmann Constant	k	1.380622	10^{-23}JK^{-1}	10^{-16}erg K^{-1}
14. Gravitational Constant	G	6.6732	10^{-11}N-M^{2}kg^{-2}	10^{-8}dyn-cm^{2}g^{-2}
15. Electron Volt	eV	1.6021917	10^{-19}J	10^{-12}erg
16. Magnetic Flux Quantum	Φ_0	2.0678538	10^{-15}T-m^{2}	10^{-7}G-cm^{2}
17. Bohr Magneton	μ_B	9.274096	10^{-24}JT^{-1}	10^{-21}erg G^{-1}
18. Electron Magnetic Moment	μ_e	9.284851	10^{-24}JT^{-1}	10^{-21}ergG^{-1}
19. Proton Magnetic Moment	μ_p	1.4106203	10^{-26}JT^{-1}	10^{-23}ergG^{-1}
20. Compton Wavelength of the Electron	λ_C	2.4263096	10^{-12}m	10^{-10}cm
21. Compton Wavelength of the Proton	$\lambda_{C,P}$	1.3214409	10^{-15}m	10^{-13}cm
22. Compton Wavelength of the Neutron	$\lambda_{c,n}$	1.3196217	10^{-15}m	10^{-13}cm
23. Faraday Constant	F	9.648670	10^{7}Ckmole^{-1}	10^{3}emu mole^{-1}

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