Texas Instruments
advanced professional calculator
TI-55

OWNER'S MANUAL

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IMPORTANT

Record the serial number from the bottom of the unit and purchase date in the space below. The serial number is identified by the words "SERIAL NO." on the bottom case. Always reference this information in any correspondence.

TI-55		
Model No.	**Serial No.**	**Purchase Date**

I. FEATURES AND FUNCTIONS

The TI-55 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 4 pending operations are available. Consider the expression

  $\frac{(3 \times 4 + 5 \times \tan 7^\circ)}{9^3} = 0.017303$ 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 11 digits
  Constant feature for easy execution of repetitive calculations

- **Addressable Memory System** with 10 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 and radians
  - grads and radians
  - polar and rectangular coordinates
  - degrees, minutes, seconds and decimal degrees
- **Complete Display Versatility,** featuring:
  - Standard 8-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
  - All results are calculated with 11 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.
- **Programmability** – 4 programming keys and 32 program steps are available for running "straight-line" programs.

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.

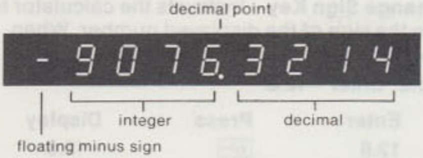
With the battery pack properly installed, charging is accomplished by plugging the AC Adapter/Charger AC9132 into a convenient 115V/60 Hz outlet and connecting the attached cord to the calculator socket. About 4 hours of charging restores full charge with the power switch off or 10 hours if the calculator 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.

Your calculator is designed to be energy efficient. After about 1 to 3 minutes of non-use, the display will shut down to a single decimal point traveling in the display. To restore the display at any time, just proceed with a calculation, or press the [2nd] key twice.

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 8 digits. All digits entered after the eighth 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 function key is pressed. A zero will precede the decimal point for numbers less than 1. 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.

[2nd] [π] **Pi Key** – Enters the value of pi (π) to 11 significant digits (3.1415926536) for calculations; display indicates the rounded value to 8 digits.

[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] [Eng] can remove this format if the displayed number is in the range $\pm 9.9999999 \times 10^7$ to $\pm 1 \times 10^{-7}$.

[+/-] **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, program memory, fixed-point (fix-decimal) location, angular mode or engineering format.

[2nd] [CA] **Clear All Key** – Clears the display, all memories including program memory, 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 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 or EE
	Fix → removes Fix
	conversions → reverses conversions
	Mean → Mean of x data
	Var → Variance of x data
	S.Dev → Standard Deviation of x data

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] ■. When programming, the [INV] key must always precede the [2nd] key.

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

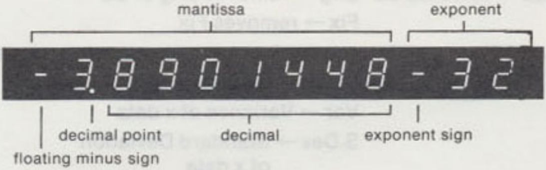
DISPLAY FORMATS

Even though a maximum of 8 digits can be entered or displayed, the internal display register always retains results to 11 digits. The results are then rounded for display only.

In addition to the versatile 8-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 $\pm 1 \times 10^{-7}$ or larger than $\pm 9.9999999 \times 10^{7}$ 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

A mantissa resulting from a calculation is displayed to 8 digits, but internally is carried to 11 digits. This 11-digit value is the one used for all ensuing calculations. See Appendix C.

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.

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: $1.816 \times 10^3 - 581.43219 = 1.2345678 \times 10^3$ = 1234.5678

Enter	Press	Display
	[CLR]	0
1.816	[EE]	1.816 00
3	[-]	1.816 03
581.43219	[=]	1.2345678 03
	[INV] [EE]	1234.5678

When [INV] [EE] is pressed to remove scientific notation and the number is outside of the range $\pm 9.9999999 \times 10^7$ to $\pm 1 \times 10^{-7}$, the calculator will return to standard format only when or if a calculated result is in the displayable range.

Example: $(7 \times 10^7 + 5 \times 10^{10}) \div 25 \div 25 = 80112000$

Enter	Press	Display
7	[EE]	7 00
7	[+]	7. 07
5	[EE]	5 00
10	[=] [INV] [EE]	5.007 10
	[÷]	5.007 10
25	[=] [÷]	2.0028 09
25	[=]	80112000.

Pressing [EE] while a result is displayed will cause the non-displayed digits to be discarded and only the rounded display value will be carried to the next calculation.

Example: $3.1415927 - 3.1415926536 = 4.64 \times 10^{-8}$.

Press	Display	Comments
[2nd] [π]	3.1415927	11 digits internally
[EE]	3.1415927 00	Discards non-displayed digits
[−] [2nd] [π]	3.1415927 00	11 digits internally
[=]	4.64−08	Difference

This feature can be used in conjunction with Fix-Decimal Control to limit the number of decimal places used by the calculator at any point in a calculation. Remember that [EE] will only affect the displayed number and has to be repeated each time you want the non-displayed digits discarded.

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
	[CLR] [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] or [INV] [EE] 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 7), instructs the calculator to round all results to the selected number of decimal places.

Pressing [2nd] [CA], [2nd] [Fix] 8, [2nd] [Fix] 9, or [INV] [2nd] [Fix] returns the calculator to the standard display. Data entries can still be made with 8 digits with all subsequent calculations using the 11-digit unrounded results. Only the display is altered to the requested number of decimal places.

Example: 2/3 = 0.6666667

Enter	Press	Display
	2nd CA	0
2	÷	2.
3	=	0.6666667
	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 list of error and overflow/ underflow conditions.

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
	[2nd] [CA]	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 = 0.0061096

Enter	Press	Display	Comments
1.84	[+]	1.84	
.39	[=]	2.23	1.84 + 0.39
	[÷]	2.23	
365	[=]	0.0061096	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: $4 \div 5^2 \times 7 + 3 \times 0.5^{\cos 60^\circ} = 3.2413203$

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
	[=]	3.2413203	Completes all operations $.5^{\cos 60^\circ}$ evaluated, then $3 \times .5^{\cos 60^\circ}$ next, then this is added to 1.12.

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

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: $4 \times (5 + 9) \div (7 - 4)^{(2+3)} = 0.2304527$

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
	[=]	0.2304527	$(7-4)^{(2+3)}$ 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 four 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 four 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	[)]	0.6666667	(2/3) evaluated
	[)]	8.3333333	[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: $3 \times \{4^{[2^{(-\sqrt[4]{7})}]}\} = 4.7000434$

Enter	Press	Display	Comments
	[CLR] [(]	0.	
3	[×] [(]	3.	
4	[y^x] [(]	4.	
2	[y^x] [(]	2.	
7	[$\sqrt[x]{y}$]	7.	
4	[)]	1.6265766	$\sqrt[4]{7}$
	[+/−]	−1.6265766	$-(\sqrt[4]{7})$
	[)]	0.3238558	$2^{-(\sqrt[4]{7})}$
	[)]	1.5666811	$4^{.323...}$
	[)]	4.7000434	$3 \times 4^{.323...}$

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 $(1 \times 2 \times 3 \times 4 \times \ldots \times x)$ of the value, x, in the display for integers $0 \leq x \leq 69$. $0! = 1$ by definition.

Example: $1/3.2 = 0.3125$

Enter	Press	Display
3.2	[1/x]	0.3125

Example: $1/(-12 + 5!) = 0.0092593$

Enter	Press	Display
12	[+/-] [+]	-12.
5	[2nd] [x!]	120.
	[=]	108.
	[1/x]	0.0092593

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: $\log(1 + \ln 1.7) = 0.1848697$

Enter	Press	Display
	(	
1	+	1.
1.7	lnx	0.5306283
	)	1.5306283
	2nd log	0.1848697

POWERS OF 10 AND e

eˣ **e to the x Power Key** – Calculates the natural antilogarithm of the value, x, in the display register. $-227.95592 \leq x \leq 230.25850$.

2nd 10ˣ **10 to the x Power Key** – Calculates the common antilogarithm of the value, x, in the display register. $-99 \leq x < 100$

Example: $e^{(3 + 10^{0.3})} = 147.71169$

Enter	Press	Display
	(	
3	+	3.
.3	2nd 10ˣ	1.9952623
	)	4.9952623
	eˣ	147.71169

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 angular mode is easy – **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. See page 85 for additional information.

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. $|x| \le 227.95592$ for sinh and cosh.

Example: $\tanh(100 \div 3.3 \times 10^2) = 2.940833 \times 10^{-1}$

Enter	Press	Display
100	[÷]	100.
3.3 [EE] 2	[=]	3.030303-01
	[2nd] [tanh]	2.940833-01

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 = 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: $\pi/4 + \tan^{-1}(.2\pi) = 1.3463803$

Enter	Press	Display
	[2nd] [Rad]	0
	[2nd] [π] [÷]	3.1415927
4	[+] [(]	0.7853982
.2	[×] [2nd] [π] [)]	0.6283185
	[INV] [tan]	0.5609821
	[=]	1.3463803

The selection of the radian mode could have been made at any point before [INV] [tan].

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: $.25 + \tanh^{-1}(.866) = 1.5668563$

Enter	Press	Display
.25	[+]	0.25
.866	[INV] [2nd] [tanh]	1.3168563
	[=]	1.5668563

SQUARE AND SQUARE ROOT

[x^2] **Square Key** – Calculates the square of the number in the display register. $10^{-49} \leq |x| < 10^{50}$

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

Example: $[\sqrt{3.1452} - 7 + (3.2)^2]^{1/2} = 2.2390782$

Enter	Press	Display
3.1452	[(] [$\sqrt{x}$] [−]	1.773471 2
7	[+]	−5.2265288
3.2	[x^2]	10.24
	[)]	5.0134712
	[$\sqrt{x}$]	2.2390782

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. The entry sequence is y [$\sqrt[x]{y}$] x followed by an operation key or equals. $y \geq 0, x \neq 0$

[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: $\sqrt[3]{2.36^{-.23}} = .9362893$

Enter	Press	Display	Comments
2.36	[y^x]	2.36	Enter y for y^x
.23	[+/-]	−0.23	Enter x for y^x
	[$\sqrt[x]{y}$]	0.8207866	Produces y for $\sqrt[x]{y}$
3	[=]	0.9362893	Enter x for $\sqrt[x]{y}$ and produce answer

Note that logarithms are used in computing universal powers and roots. Therefore, a few entries involving negative numbers, zero and one are invalid and will produce a flashing display. For example, any negative y value will cause a flashing display.

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 $\frac{x_1 - x_2}{x_2} \times 100$ is calculated.

Example: 43.6% = 0.436

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
766.48	[2nd] [Δ%]	766.48
515.22	[=]	48.767517

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 will provide for 30 meals.

V. MEMORY CAPABILITIES

Your calculator has ten user-accessible memories to greatly increase the flexibility of calculations. Because there are ten memories, you must specify which memory you are addressing by entering its number, n = 0 thru 9 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 = 0 thru 9. 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. n = 0 thru 9.

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]	8.6832065
	[−]	26.049619
	[RCL] 1	2.9467281
	[−]	23.102891
7.1	[=]	16.002891

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 = 20.682177 degrees

Enter	Press	Display	Comments
	[2nd] [CA] [(] [(]	0.	
3	[×]	3.	
20.682177	[STO] 1 [÷]	62.046531	Store x
2	[)] [STO] 2	31.023266	Store 3x/2
	[sin] [−]	0.5153861	
	[RCL] 2	31.023266	Recall 3x/2
	[cos]	0.8569581	Cos(3x/2)
	[)] [÷]	−0.341572	
	[RCL] 1	20.682177	Recall x
	[=]	−0.0165153	Answer

MEMORY ORGANIZATION

Because of the complexity of some of the statistical calculations, the calculator preempts certain memories to store data and results for these advanced computations. Also, memories 8 and 9 are used for storing program steps 17 through 31 (steps 17-24 in memory 9, steps 25-31 in memory 8). The chart below shows the arrangement and use of the calculator's 10 memories.

Memory Number

0	1	2	3	4	5	6	7	8	9
	STATISTICAL CALCULATIONS							PROGRAMMING	

← Cleared By [2nd] [CA] →

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 for 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 = 0 thru 9

[INV] [SUM] n **Subtract Sequence** – Subtracts the displayed value from the content of memory register n and stores the result in n. n = 0 thru 9

[2nd] [Prod] n **Product Key** – Multiplies the content of memory register n by the displayed value and stores this product in n. n = 0 thru 9

[INV] [2nd] [Prod] n **Divide Key** – Divides the content of memory register n by the displayed value and stores the result in n. n = 0 thru 9

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. 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 [×]	0.575682
95.9	[%] [2nd] [Prod] 1 [=]	0.5520791
	[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 = 0.258963 and B = 1.255632

Enter	Press	Display	Comments
.258963	[STO] 1 [x^2] [+]	0.0670618	Store A
1.255632	[×]	1.255632	Enter B
	[2nd] [Exc] 1	0.258963	Store B, Recall A
	[×]	0.3251622	A × B
2	[+]	0.7173863	$A^2 + 2AB$
	[RCL] 1	1.255632	Recall B
	[x^2]	1.5766117	B^2
	[=]	2.293998	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 operation, then the repetitive number, m, 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.

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

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

[2nd] [Δ%] m [2nd] [Const] calculates the percentage change between each subsequent entry x_1 and m by $\frac{x_1 - m}{m} \times 100$.

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

Note in the following example that the constant can be entered as part of a normal problem sequence.

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

Enter	Press	Display
	[2nd] [Deg]	0.
.02	[÷]	0.02
.89	[2nd] [Const] [=]	0.0224719
22	[tan] [=]	0.4539621
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 are 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 units.

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

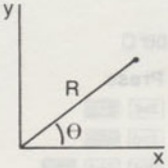
Enter	Press	Display
1520	2nd in-mm 2nd in-mm	980643.2

Going through the conversion process twice, such as for area, 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 coordinates.

[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.

Note that arithmetic operations should not be pending when using the polar/rectangular conversion.

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

Enter	Press	Display	Comments
	CLR 2nd Deg	0.	Select degree mode
5	x:y	0.	Enter R
30	2nd P→R	2.5	Enter Θ, display y
	x:y	4.330127	Display x
	2nd Rad	4.330127	Radian mode
	x:y	2.5	Enter x
	INV 2nd P→R	0.5235988	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 calculations here must begin and end by pressing [2nd] [CA] to totally clear the calculator. There are 4 pending operations available between entries and calculations of statistics, linear regression and trend line. However, arithmetic operations cannot be pending while actually entering data points. When doing trend-line problems, the implied x value must be reentered with the [x:y] key if arithmetic calculations are performed prior to entry of all data points. Statistical values are stored in memories 1 thru 7, 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.

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]	9.8792712	Standard Deviation
	[2nd] [Mean]	84.	Mean
	[2nd] [Var]	81.333333	Variance
	[RCL] 5	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 data are accumulated in the memory registers with Σy_i in 5, Σy_i^2 in 6 and N in 7. The values stored in the memory registers can be recalled and used in other calculator 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.

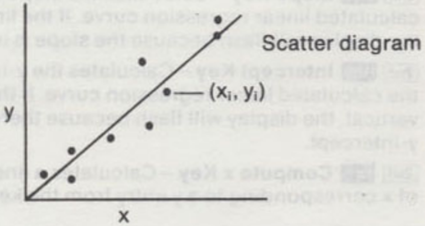
2nd Corr **Correlation Key** – Calculates the correlation coefficient of the data entered in the linear regression routine. The value will be between ±1 with ±1 being a perfect correlation.

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.

Please note the general information at the top of page 38.

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.



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

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

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

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

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

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

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

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.

The x-array data are accumulated with Σx_i in memory 2, Σx_i^2 in memory 3 and Σxy in memory 4. Locations of y-array data are given on page 39.

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]	599.83333	Average of y array
	[÷] [INV] [2nd] [Mean]	100.13333	Average of x array
	[=]	5.9903462	Average uniformity
	[2nd] [CORR]	0.9815054	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]	1976.	
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']	1983.0707	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:

$$r' = \sqrt{X^2 + Y^2} = 14.885986$$

$$\Theta' = \tan^{-1} \frac{Y}{X} = 40.012765$$

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 rectangular
	[x:y] [STO] 2	4.330127	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	7.0710678	Enter angle of second vector, complete polar/ rectangular
	[x:y] [SUM] 2	7.0710678	conversion. Sum Y components in M1 and X components in M2.
	[RCL] 2 [x:y] [RCL] 1	9.5710678	Resultant X and Y components recalled for rectangular/ polar conversion.
	[INV] [2nd] [P→R]	40.012765	Angle Θ′ in degrees
	[x:y]	14.885986	Magnitude r′

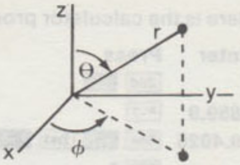
RECTANGULAR/SPHERICAL COORDINATE CONVERSIONS

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

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

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

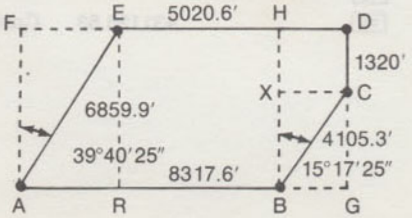
$\Theta = \tan^{-1} \dfrac{\sqrt{x^2 + y^2}}{z}$



To solve on the calculator:

Enter	Press	Display	Comments
	2nd CA	0	
5	x:y	0.	Enter x
8	INV 2nd P→R	57.994617	Enter y; value of ϕ displayed in degrees.
10	x:y INV 2nd P→R	43.33172	Enter z; value of Θ displayed in degrees.
	x:y	13.747727	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	0	
6859.9	x:y	0	
39.4025	2nd DMS-DD 2nd P→R	4379.452	FE
	STO 1	4379.452	FE in M1
	x:y STO 2 × (	5280.0216	FA in M2
	RCL 1 +	4379.452	
5020.6	)	9400.052	FD
	−	49632478.	Area AGDF
	RCL 1 × RCL 2 ÷	23123601.	FE × FA
2	= STO 3	38070677.	AGDF-AFE
4105.3	x:y	38070677.	
15.1725	2nd DMS-DD 2nd P→R	1082.6061	BG
	STO 1	1082.6061	BG in M1
	x:y × RCL 1 ÷	4287099.9	BG × CG
2	=	2143550.	Area BGC
	+/− + RCL 3 =	35927127.	AREA
	×		
.012	=	431125.53	Cost of plot

VIII. PROGRAMMING KEYS AND EXAMPLES

At this point you've looked at a lot of keys on your calculator – and you've explored how to use them in a variety of problem solving situations. Now we're ready to take a look at how you can expand the use of these features even more – with programming.

When many people first hear the word "programming" they conjure up visions of large machines, punched cards, complex procedures, etc. However, programming your calculator is expressly designed to be a natural, straightforward process – that can save you considerable time whenever you handle a repetitive calculating situation. Basically, your calculator just *learns* or remembers keystrokes you put into it. It will then execute these keystrokes for you again at any time – as many times as you require – with the touch of a single key. The calculator is actually "pushing its own buttons" for you.

Let's see how this procedure works by jumping right into a simple example:

Let's suppose that you are shopping and spot a store that is having a "40 percent off" sale. To calculate the sale price of any item, you'd simply enter the price into the display and press [−] 40 [%] [=]. A coat which normally sells for $56 would cost: 56 [−] 40 [%] [=] 33.6 or $33.60. As you check various items in the store, you press the same five keys again and again, [−] 40 [%] [=]. If you wander through the store and calculate 15 different discount prices, you'll use these same keystrokes 15 times. However, with your programmable calculator, you can "program" (or more simply, teach) the calculator to remember the [−] 40 [%] [=], keystroke sequence for you. From then on in, all you'll need to do is enter the price, tell the calculator to begin, and the calculator will push the "programmed" buttons automatically for you.

A *program* for your calculator, then, is just a list of the series of keystrokes in the order needed to perform a particular calculation. Once you know these keystrokes you can program your calculator to remember them. To do this you simply press the [2nd] [Lrn] (Learn) key sequence. When you do this, you "turn on" a special memory in your machine that remembers the keystrokes that follow. You're telling the calculator "please remember the keystroke instructions I enter next".

At this point you just enter the keystrokes you'd need to solve your problem. When your program keystrokes are all entered, you press [2nd] [Lrn] again to turn "off" the program memory – and you're ready to use or "run" your stored program.

Let's program our 40% discount problem and see how we can teach the calculator to remember the [−] 40 [%] [=] keystrokes. To do this, follow these steps:

Press	Display	Comments
[2nd] [CA] [2nd] [Fix] 2	0.00	Clears all calculator memory registers and fixes the decimal point at two places.
[2nd] [Lrn]	00 00	Tells the calculator to "remember" all of the following keystrokes. The special display format (00 00) confirms that the calculator is in "learn mode". (This is discussed more in a moment.)
[−] 40 [%] [=]	05 00	Your calculator "counts steps" as you enter them, at this point step 5 is "up next".

After your calculator completes these keystrokes, you want it to stop and show you the result. You tell it to do this by finishing your program with a *stop* instruction.

2nd R/S	06 00	Tells calculator to stop.
2nd Lrn	0	Leave learn mode. The program is complete. This second use of the learn sequence "turns off" the program memory to leave the "learn mode".

Now, to use or "run" your program, follow these steps:

When we left the learn mode, after keying in the program, the step counter (program pointer) was sitting waiting for the next step, step 06. The calculator had "learned" our program step-by-step and these program steps we've stored in steps 00, 01, 02, 03, 04, and 05. Before we can run the program we must get back to step 00 so that the program pointer will run (or execute) the program from the beginning. You can do this by pressing the reset key, 2nd Rst . Then the program is ready to run.

Press	Display	Comments
2nd Rst	0.00	
53.95	53.95	Enter the list price of the merchandise Now press Run/Stop to run the program. (− 40 % =)
2nd R/S	32.37	Sale price.

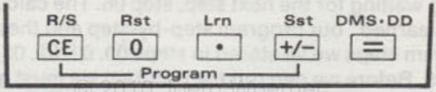
As you go through the store, you can quickly and easily calculate the sale price of any item by pressing 2nd Rst , entering the list price, then pressing 2nd R/S .

To prove to yourself just how easy the program is to use, find the price after discount on these items: $155.97, $86.49, and $13.88.

Press	Display	Comments
[2nd] [Rst] **155.97** [2nd] [R/S]	93.58	Discount price
[2nd] [Rst] **86.49** [2nd] [R/S]	51.89	Discount price
[2nd] [Rst] **13.88** [2nd] [R/S]	8.33	Discount price

To help you to better understand what's going on within the calculator when you run a program, let's take a closer look at the four special programming keys on your calculator. They're shown here as they appear on the keyboard and include [R/S], [Rst], [Lrn] and one we haven't used yet, [Sst].

Programming Keys



PROGRAMMING KEYS

[2nd] [Lrn] **The Learn Mode Key** – Pressing the sequence [2nd] [Lrn] one time puts the calculator in what we'll call the "learn" mode of operation. This allows you to begin writing a program into program memory which is "learned" and remembered by the machine and can be run later. Pressing the sequence [2nd] [Lrn] again takes the calculator out of the learn mode. (The display is cleared to a single zero when you leave the learn mode.)

When you press [2nd] [Lrn] the first time and enter the learn mode the display changes to a unique format:

00 00

The two digits on the left tell you the program step number you are working on. As you are programming the machine these two digits will always indicate the number of the next available program step. Thirty-two program steps (numbered 00 through 31) are available for your use.

The right two digits in the display will be zeros as you program the machine, but as you'll be seeing in a moment, these two digits will tell you which keystroke is at each program step when you review your program with the [2nd] [Sst] key. The keystrokes will be indicated by a two-digit number code (called the key code) representing the row and column number of the key. (More on this later.)

[2nd] [R/S] **The Run/Stop Key** – When your calculator is out of learn mode, the [2nd] [R/S] key is the start/stop switch for any program you may have in the machine. If the program is stopped, pressing [2nd] [R/S] will start it running. If the program is running along, pressing [2nd] [R/S] or [CE] will stop it. The [2nd] [R/S] key can also be put in a program where you want the calculator to stop to display an answer. The calculator will run through your program steps until it comes to a [2nd] [R/S] instruction, at which point it will stop.

[2nd] [Rst] **The Reset Key** – In order for you and your calculator to be able to keep track of your programming steps, they are numbered sequentially from 00 to 31. As you key in a program (and as a program is running) the program step counter, or program pointer, advances step-by-step from 00 to 31 (or to a [R/S] instruction before step 31.) The [2nd] [Rst] key instructs the calculator to reset the program counter to step 00. Pressing [2nd] [Rst], then, takes you back to the beginning of your program.

[2nd] [Sst] **The Single-Step Key** – If you press this key sequence while your calculator is in "learn" mode, you "step through" your program one step at a time. This allows you to check on the keystrokes in any program you've entered, as we'll discuss below. When you press [2nd] [Sst] out of "learn" mode, you step through and execute your program one step at a time.

To see the [2nd] [Sst] key sequence in action, let's go back and key in the simple program we used previously to compute price markdowns:

Press	Display	Comments
[2nd] [CA] [2nd] [Fix] 2	0.00	Clears machine, fixes decimal at 2 places.
[2nd] [Lrn]	00 00	Enter learn mode
[−] 40 [%] [=] [2nd] [R/S]	06 00	Key in program steps
[2nd] [Lrn]	0	Exit learn mode

Now to go back and review this program using the [2nd] [Sst] key sequence, just perform the following keystrokes:

Press	Display	Comments
[2nd] [Rst] [2nd] [Lrn]		Reset and enter learn.
	00 65	Step 00
[2nd] [Sst]	01 04	Step 01
[2nd] [Sst]	02 00	Step 02
[2nd] [Sst]	03 22	Step 03
[2nd] [Sst]	04 85	Step 04
[2nd] [Sst]	05 86	Step 05
[2nd] [Sst]	06 00	Step 06
[2nd] [Sst]	07 00	Unprogrammed steps

(Leave your calculator on for the next example)

Notice again that four digits appear in the display. The left two digits tell you the calculator's program step number location. The right two digits are a number code that tells you what keystroke that particular step will execute when the program runs.

If you continue to press the [2nd] [Sst] key sequence while your calculator is in learn mode, it will go to step 31, then repeat back to step 00.

Refer to page 75 for special programming notes.

KEY CODES

The key code your calculator uses to indicate each step is a fairly straightforward one. The two digits simply represent the row and column numbers of the key in question (except for the number keys [0] through [9] which are represented by their number; e.g. 05 represents [5] etc.). For second functions on your calculator, the keycodes for the column are 6, 7, 8, 9, and 0 rather than 1 through 5, as shown in the diagram below.

Rows

Code for [2nd] [tanh] is 19.

31 (row 3 column 1 is [x:y])

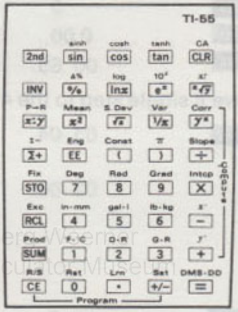
42 (row 4 column 2 is [EE])

08 (number key [8])

65 (row 6 column 5 is [−])

03 (number key [3])

85 (row 8 column 5 is [=])



Rows: 1 2 3 4 5 6 7 8

Column numbers for second functions 6 7 8 9 0

Columns 1 2 3 4 5

See Appendix D for a complete list of key codes.

The display "00 65" tells you that step 00 is [−], display "01 03" tells you that step 01 is 3, and so forth. All of the keys used in your program are displayed with their key codes when you single step through "learn mode". You can check to see if your program is entered properly using this method.

If a step is not entered correctly (or you want to change it) you can enter a new keystroke at any step by simply keying it in. A new keystroke will "write over" and replace any step that's already there. (The display will then move on to the next step.)

NOTE: When entering the second function keys, pressing [2nd] and then the desired second function uses only one of your 32 allowable program steps.

Let's go back and modify the program you now have in the calculator to discount 30% instead of 40% (change the 4 to a 3). (Notice: At this point your calculator may have switched over to its power saving display – pressing [2nd] [2nd] restores the display – even in the learn mode.)

Press	**Display**	**Comments**
[2nd] [Lrn]	0	Leaves learn mode
[2nd] [Rst]	0.00	Returns to step 00
[2nd] [Lrn]	00 65	Enters learn mode

Now we'll single step to the 4 and change it to a 3.

[2nd] [Sst]	01 04	This is the step we want to change to a 3.
[3]	02 00	The 3 has replaced the 4 in step 01 and the calculator has moved on – showing the contents of step 02.
[2nd] [Lrn]	0	Leaves learn mode

Now the program discounts 30% instead of 40%. To see this, let's use our modified program to calculate a sale price with 30% discount. For example, find the sale price of an item regularly costing $25.95.

Press	**Display**	**Comments**
[2nd] [Rst]	0.00	Resets to step 00
25.95	25.95	Enters the regular price

Now start the program

[2nd] [R/S]	18.17	The sale price is $18.17

To continue to find other 30% discounted items, press [2nd] [Rst], enter the price, and press [2nd] [R/S]. However, if you have several discount items, you can save yourself some effort by including [2nd] [Rst] as the last step of the program.

USING THE RESET KEY – [Rst] – INSIDE A PROGRAM

When [Rst] is entered as a program step, it tells the calculator to return to step 00. By placing a [2nd] [Rst] instruction right in your programs, you can eliminate the need for pressing [2nd] [Rst] each time you use the program.

Let's write a program to discount the number you enter in the display by 25%. This time to use the program, you'll enter the regular price and press [R/S] You want the calculator to then compute the discounted price and stop, and have it ready to reset automatically for the next calculation. Here's how you can do it.

ENTERING YOUR PROGRAM

Press	Display	Comments
[2nd] [CA] [2nd] [Fix] 2	0.00	Clears all registers and fixes decimal at two places.
[2nd] [Lrn]	00 00	Enters learn mode.
[−] 25 [%] [=]	05 00	Enters program you want.
[2nd] [R/S]	06 00	Tells calculator to stop.

After running the program once, the program counter would stop at this R/S instruction. Now you can tell the calculator to reset "automatically" to the beginning so you can enter a new price, start the program again, and compute the discount price.

Press	Display	Comments
[2nd] [Rst]	07 00	
[2nd] [Lrn] [2nd] [Rst]	0.00	Exit learn mode and reset for the first calculation.

Running Your Program: To use this program to find the sale price of items costing $25.95, $15.42, and $17.87, just enter the regular price of each item and start the program.

Press	Display	Comments
25.95 [2nd] [R/S]	19.46	Sale price
15.42 [2nd] [R/S]	11.57	Sale price
17.87 [2nd] [R/S]	13.40	Sale price

Automatic reset is a convenient tool to help make it easy for you to use this program for as many items as you need to compute the discount.

The examples thus far give you a basic understanding of your calculator's four programming keys. However, before moving on to more programming examples, let's briefly look at how you enter the numbers you need for your program calculations.

DATA ENTRY

Every program you write of necessity involves using some data for calculations. Because of this you need to be aware of how to enter data for your program to use. Basically there are two ways to enter data into a program: either from the display, or by recalling the data from memories.

One of the simplest methods of entering data for your program is to just use the number in the display. This works well even if you need to enter more than one number since you can always include a [2nd] [R/S] in the program to stop and allow the entry of the second value.

Another way to enter data is to store it in memories (either as part of the program or before you start the program) and then let the program recall the numbers from memory as needed for the calculation.

With this in mind, let's go on to more program examples.

TYPICAL PROGRAMMING EXAMPLES

The real beauty of the programmable calculator lies in its ability to help you solve your day-to-day problems quickly and accurately. Here are four different problems that show how you can use programming to speed up your problem solving.

Mail Order Program

You work in a mail-order discount house and fill 75 to 100 orders per day, discounting the list price by 20% and adding $1.50 for shipping and handling. An average calculation looks like this:
56.15 [−] 20 [%] [+] 1.5 [=] 46.42

You push the same keys over and over all day long. Why not let the *calculator* push the keys for you? You can by using this simple calculator program.

Press	Display	Comments
[2nd] [CA] [2nd] [Fix] 2	0.00	"Clears All" and fixes decimal at 2 places
[2nd] [Lrn]	00 00	Puts calculator in "Learn" mode—allows you to teach it step sequence.
[−] 20 [%]	04 00	Discounts cost by 20%
[+] 1.5 [=]	09 00	Adds handling charge
[2nd] [R/S]	10 00	Stops program
[2nd] [Rst]	11 00	Resets program back to step 00 (Automatic reset)
[2nd] [Lrn]	0	Leave learn mode

Now use the program to find the final order price for these orders: $29.95, $32.50, $167.95 and $20.00.

Press	Display	Comments
[2nd] [Rst]	0.00	Resets calculator to first program step for first calculation
29.95 [2nd] [R/S]	25.46	Order price
32.50 [2nd] [R/S]	27.50	Order price
167.95 [2nd] [R/S]	135.86	Order price
20 [2nd] [R/S]	17.50	Order price

Conversion Program

You work in the "off shore accounts" division of a large chemical company. It's your job to fill orders asking for liters with containers that hold U.S. Gallons. You must convert liters to gallons, determine the order price, add a special handling charge ($5.00) onto each offshore order, plus sales tax (4.5%).

Here's how to enter this program into your calculator:

Press	Display	Comments
[2nd] [CA] [2nd] [Fix] 2	0.00	Clear all and fix decimal at two places
[2nd] [Lrn]	00 00	Enter learn mode
[INV] [2nd] [gal-l]	02 00	Converts liters to gallons
[STO] 1	04 00	Stores gallons reqd, in memory 1
[×] [RCL] 2 [=]	08 00	Multiplies gallons by cost/gallon
[+] 5	10 00	Adds $5.00 handling charge
[+] 4.5 [%] [=]	16 00	Adds sales tax
[2nd] [R/S]	17 00	Stops program
[2nd] [Rst]	18 00	Resets to step 00
[2nd] [Lrn]	0	Exit learn mode
[2nd] [Rst]	0.00	Reset program to 00 for first calculation

Let's work some sample orders. First you'll store the cost per gallon in memory 2. Then enter the quantity ordered, run the program and the total cost is displayed. You can then recall memory 1 if you want to know the liter-to-gallon conversion.

Store Cost/Gal.	Enter Qty. Ordered	Total Cost	Recall U.S. Gal.
25 [STO] 2	100 [2nd] [R/S]	**695.37**	[RCL] 1 **26.42**
13.75 [STO] 2	62 [2nd] [R/S]	**240.57**	[RCL] 1 **16.38**
12.60 [STO] 2	25 [2nd] [R/S]	**92.18**	[RCL] 1 **6.60**
5.35 [STO] 2	87 [2nd] [R/S]	**133.72**	[RCL] 1 **22.98**

Area Calculation

Your company produces custom-made wooden products. You receive an order for the following quantities of plywood discs:

6 ea – 5″ radius
8 ea – 9.5″ radius
7 ea – 13.6″ radius
5 ea – 19″ radius.

How many square feet of plywood should you buy? The equation $A = \pi r^2$ can be used to find the area (A) of each disc. However, you have several different size discs. First you'll need to find the area of each disc and multiply by the number of discs (of the same size) to get the total area need for each size disc. Then add up the total areas of each size disc, and finally compute the total area needed in square feet. Since there are several different sizes involved it would be difficult to try to program the entire problem. However, you can program the equation $A = \pi r^2$ into your calculator to increase your problem-solving speed and accuracy.

Here's how to program the problem:

Press	Display	Comments
2nd CA	0	Clears all registers
2nd Lrn	00 00	Places calculator in learn mode
x^2	01 00	Squares number in display
×	02 00	
2nd π =	04 00	Area of circle
2nd R/S	05 00	Stops program
2nd Rst	06 00	Sends program counter back to "top" of program
2nd Lrn	0	Removes calculator from learn mode
2nd Rst	0.	Resets calculator to first program step for first calculation.

To run the program,

Press	Display	Comments
2nd Fix 2	0.00	Fixes decimal at 2 places
5 2nd R/S	78.54	Area of a 5″ radius disc in square inches
× 6 =	471.24	Total area of 6 5″ discs
STO 1	471.24	Hold answer in memory 1
9.5 2nd R/S	283.53	Area of a 9.5″ radius disc
× 8 =	2268.23	Total area of 8 9.5″ discs
SUM 1	2268.23	Sums to memory 1 to get a running total of area
13.6 2nd R/S	581.07	Area of 13.6″ disc
× 7 =	4067.48	Total area of 7 13.6″ discs
SUM 1	4067.48	Sum to memory 1
19 2nd R/S	1134.11	Area of 19″ disc
× 5 =	5670.57	Total area of 5 19″ discs

(continued)

(continued)

[SUM] 1	5670.57	Sum to memory 1
[RCL] 1	12477.53	Total area of discs in square inches
[÷] 12 [x^2] [=]	86.65	Converts square inches to square feet of lumber required for job if *no* lumber is wasted. (For more realistic estimate add 20%)
[+] 20 [%] [=]	103.98	Approximate square feet of plywood needed.

Graphing

Using pencil and paper, or even a calculator in graphing a curve can be a tedious job, since the function to be graphed must be solved again and again. However, your programmable calculator makes graphing a snap! Just enter the keystrokes necessary to solve the equation as a program and sit back. Let your calculator do the work!

As an example, let's graph the function:

$$f(\theta) = \frac{\tan \theta}{(1 - \sin \theta)}$$

for $\theta = 0°$ to $360°$ in 15° steps.

Here's how to program the problem:

Press	Display	Comments
[2nd] [CA] [2nd] [Fix] 2	0.00	Clears all registers. Fixes decimal at 2 places
[2nd] [Lrn]	00 00	Enter learn mode
[STO] 1	02 00	Store displayed number
[tan] [÷] [(] 1 [−] [RCL] 1	09 00	Keystrokes to evaluate f(θ) and stop to display result.
[sin] [)] [=] [2nd] [R/S]	13 00	

(continued)

(continued)

RCL 1 + RCL 2 =	19 00	Add degrees to be incremented (15° step stored in memory 2)
2nd Rst	20 00	Reset to step 00
2nd Lrn	0	Exit learn mode
2nd Rst	0.00	Reset program to 00

To run the program:

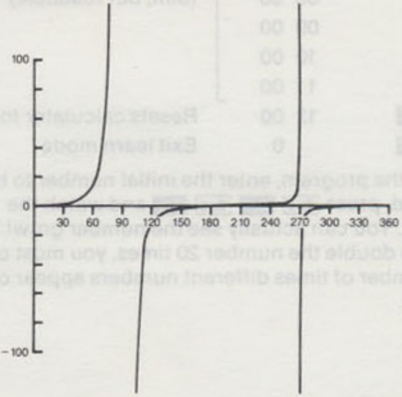
Press	Display	Comments
15 STO 2	15.00	Store value of degree increment in memory 2
CLR 2nd R/S	0.00	Starts at 0°, f(θ) = 0
2nd R/S	0.36	At 15° f(θ) = .36
2nd R/S	1.15	30°
2nd R/S	3.41	45°
2nd R/S	12.93	60°
2nd R/S	109.53	75°
2nd R/S	"9.99 99"	90° – Undefined operation. At 90°, f(θ) equals infinity.
CLR 2nd Rst	0.00	To complete graph, clear and reset.
105	105	Enter next desired point, 90° + 15° = 105°
2nd R/S	–109.53	105°
.	.	.
.	.	.
.	.	.
2nd R/S	.93	240°
2nd R/S	1.90	255°
2nd R/S	"–9.99 99"	270° Undefined operation. To proceed use procedure shown at 90° point and continue around to 360°.

A Change for More Accuracy

The portion of the curve between 255° and 270° is very steep. So steep in fact, that we cannot properly evaluate it using 15° steps. In this case as in many cases, it is necessary to examine the behavior of a rapidly changing function one degree at a time instead of 15°. You can reprogram your calculator to do this by going to Memory 2 and inserting a "1" where the "15" currently resides. Here are the exact keystrokes necessary to modify your program.

Press	Display	Comments
1 [STO] 2	1.00	Old contents of memory 2 bumped out, 1 inserted

To run this "step-by-degree" program, enter the point at which you wish to start, say 255°, press [2nd] [Rst] and then [2nd] [R/S] to observe the values of succeeding 1° steps. Shown below is the completed graph. Note how sharply the curve rises approaching 90° and 270°.



SPECIAL TRICKS

Pause Function

The pause key found on some calculators allows the user to look at a number within a program for a moment before the program moves on. You may accomplish the same effect with your calculator by entering consecutive [=]'s following a number you want to observe during program operation.

Example: You want to double a sum of money each day for several days, and watch it grow during the process.

Press	Display	Comments
[2nd] [CA]	0	
[2nd] [Lrn]	00 00	Enter learn mode
[×] 2 [=]	03 00	Doubles displayed value
[=]	04 00	
[=]	05 00	
[=]	06 00	
[=]	07 00	Holds new value on display
[=]	08 00	(dim, but readable)
[=]	09 00	
[=]	10 00	
[=]	11 00	
[2nd] [Rst]	12 00	Resets calculator to 00
[2nd] [Lrn]	0	Exit learn mode

To run the program, enter the initial number to be doubled, press [2nd] [Rst] [2nd] [R/S] and watch the display. You can actually see the number grow! If you want to double the number 20 times, you must count the number of times different numbers appear on the display.

Continuous Loops

The previous program is a good example of what is called a "continuous loop." A loop is a program that will continue to repeat over and over without extra instructions. In this way, your calculator can perform many calculations in the time it would take you to manually make one or two "loops" through the problem.

However, as in the preceding program, it's difficult to count (and remember) one number while watching another number flash on the display. Using some clever maneuvering, though, we can program the calculator to keep count for us as it works the problem.

Here's the above example rewritten slightly to include a "counting" sequence.

Press	Display	Comments
2nd CA	0	
2nd Lrn	00 00	Enter learn mode
× 2	02 00	Double number in display
= = = =		
= = = =	10 00	"Pause"
STO 1	12 00	Store number in display
RCL 2	14 00	Recall step number stored in memory 2
+ 1	16 00	Add 1 to number of steps
= = = =		
= = = =	24 00	"Pause"
STO 2	26 00	Store new step number
RCL 1	28 00	Recall number to be doubled
2nd Rst	29 00	Reset to step 00
2nd Lrn	0	Exit learn mode

To run the Program:

Press	Display	Comments
[2nd] [Rst]	0.	Reset calculator to step 00
[CLR] [STO] 1 [STO] 2	0.	Clears memories 1 and 2
1	1	Number to be doubled
[2nd] [R/S]	"2"	1 doubled (Value flickers in display)
	"1"	Loop 1
	"4"	2 doubled
	"2"	Loop 2
	"8"	4 doubled
	"3"	Loop 3
	"16"	8 doubled

The advantage of this program is that it counts for you. You must still watch the display carefully and stop the program on the loop *before* the desired loop. You may then press [2nd] [Sst], stepping the program through to the "doubled" number.

This program is easier to use than the first. However, the ideal way to run this program would be to have the calculator stop after it has completed a specified number of loops.

Finite Loops

Your calculator does not have special keys which would allow you to set certain conditions like stopping after a specified number of loops. You do, however, have access to certain operations which will stop the program whenever these operations are encountered. These are called "illegal" or undefined operations. Here is a short list of undefined operations:

Press	Display
0 [1/x]	"9.9999999 99" (Flashing)
0 [lnx]	"−9.9999999 99"
90 [tan]	"9.9999999 99"

For a list of "undefined operations," see Appendix B.

By using these "undefined operations" you can cause the program to "stop in its tracks". Here's how:

If your calculator encounters the instruction "90 [tan]", it will stop on that program step and flash 9's in the display because the tangent of 90° is an undefined operation. In the last program, we were doubling a number a certain number of times. If we wanted to see what 1 doubled 20 times was, we had to manually stop the calculator on Loop 20.

We can have the machine stop itself after 20 steps by inserting an illegal operation at that point. We know that 90 [tan] will stop the machine, right? OK, to stop the machine after 20 steps, just subtract 20 from 90. Insert 70 into a memory and have the machine add 1 to it each time a loop is completed, then find [tan] of that number. When it tries to compute tan 90°, the program will stop. Here's how the program would look:

Press	Display	Comments
[2nd] [CA]	00 00	Enter learn mode
[2nd] [Lrn]		
[×] 2 [=]	03 00	Double number in display
[STO] 1	05 00	Store results of doubling operation so it can be recalled after program stops.
[RCL] 2	07 00	90 minus number of loops desired stored here
[+] 1 [=]	10 00	Increment memory 2 by 1
[STO] 2	12 00	Store
[tan]	13 00	Check to see if memory 2 is equal to 90. If it is, program will stop on this step. If not, the program continues.
[RCL] 1	15 00	Recall number to be doubled
[2nd] [Rst]	16 00	Reset machine to step 00
[2nd] [Lrn]	0	Exit learn mode

To run it:

Press	Display	Comments
70 STO 2	70.	Store 90 minus number of loops desired in memory 2
2nd Rst	70.	Reset to step 00.
1	1	Enter initial number to be doubled
2nd R/S	"9.9999999 99"	Run program .... program stops
CLR RCL 1	1048576.	1 doubled 20 times

The above results can also be achieved by reducing a number in a memory to zero, and taking its reciprocal each time (1/0 = "9.9999999 99").

Zero Check

The method previously shown can be used if you know the exact number of loops you want to execute. If you do *not* know how many loops you want to make, and simply want the answer to a problem, you can use what we'll call a "Zero Check".

Certain types of problems can be solved by using an iterative approach. The equation you use must be structured so that it "closes in" on the answer in succeeding steps. As succeeding steps become closer and closer to the answer, the difference between the steps approaches zero. When zero difference is achieved, the calculator has solved the problem. By using our "Zero Check" the display can be made to flash when the calculator has solved the problem.

Consider the following equation:

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

By applying Descartes' rule of signs we find that this equation has only one real positive root. We can approximate the real root by writing the equation as:

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

We can now construct an approximation routine using the form:

$$X_{n+1} = \frac{1}{1 + X^2_n}$$

The program would look like this:

Press	Display	Comments
2nd CA 2nd Fix 4	0.0000	Clear all, fix decimal at 4 places
2nd Lrn	00 00	Enter learn mode
x^2 + 1 = 1/x	05 00	Equation
EE	06 00	Sets accuracy to 4 places*
STO 1	08 00	Store first approximation in memory 1
− RCL 2	11 00	Subtract second approximation from first approximation
= 1/x	13 00	"Zero Check" – if memories 1 and 2 are equal, difference is zero-display flashes.
RCL 1 STO 2	17 00	Store latest approximation in memory 2
2nd Rst	18 00	Reset machine to step 00
2nd Lrn	0	Exit learn mode

To run it:

Press	Display	Comments
2nd Rst	0.0000	Reset program to 00
2nd R/S	"9.9999 99"	Run program . . . program stops
CLR RCL 1	0.6823	Answer correct to 4 places (to see 5th digit, press 2nd Fix 5)

*Pressing EE causes the nondisplayed digits to be discarded. More digits accuracy requires more loops of the program to achieve zero difference.

PROGRAMMING APPLICATIONS

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 $x_o = 45°$, or $\pi/4$ radians. Recall that if f(x) = sin x, then f′(x) = cos x. Also,

$$f(x) = \lim_{\Delta x \to 0} \frac{f(x_o + \Delta x) - f(x_o - \Delta x)}{2\Delta x}$$

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

Enter the following program:

Press	Display	Comments
[2nd] [CA] [2nd] [Lrn]	00 00	Enter learn mode
[RCL] 1 [+] [RCL] 2 [=]	06 00	
[sin] [−] [(] [RCL] 1	11 00	
[−] [RCL] 2 [)]	15 00	
[sin] [=] [÷] [(]	19 00	
2 [×] [RCL] 2	23 00	
[)] [=]	25 00	
[2nd] [R/S]	26 00	Stop
[2nd] [Rst]	27 00	Reset to step 00
[2nd] [Lrn]	0	Exit learn mode

To run it:

Press	Display	Comments
[2nd] [π] [÷] 4 [=] [STO] 1	0.7853982	Calculate x_o in radians and store in memory 1
.0001 [STO] [2]	0.0001	Store Δx in memory 2
[2nd] [Rst] [2nd] [Rad]	0.0001	Reset machine to 00, select radians mode
[2nd] [R/S]	0.7071076	Value of f′ (π/4)

To find the difference between f′ (π/4) and cos (π/4):

Press	Display	Comments
[−] [RCL] 1	0.7853982	x_o in radians
[cos] [=]	0.0000008	difference

Solving Differential Equations

Suppose that we have a differential equation of the form y′ = f(x,y), y(0) = a. Approximate solutions can be obtained by using the following recursive equation:

$$Y_{n+1} = Y_n + hf(X_n, Y_n)$$

$$Y' = X + Y,\ Y(0) = 0,\ h = 2$$

recursion relation becomes:

$$Y_{n+1} = Y_n + h(X_n + Y_n)$$

Where: $X_n = nh$

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 the following program:

Press	Display	Comments
[2nd] [CA]	0	Clear all memories
[2nd] [Lrn]	00 00	Enter learn mode
[RCL] 1 [+] [RCL] 2	05 00	$Y_n + h$
[×] [(] [CE]	08 00	CE permits memory 2 value to be used again.
[×] [RCL] 3	11 00	n
[+] [RCL] 1	14 00	Y_n
[=] [STO] 1	17 00	new Y_n
1 [SUM] 3	20 00	Add 1 to n
[RCL] 1	22 00	Y_n
[2nd] [R/S]	23 00	Stop program
[2nd] [Rst]	24 00	
[2nd] [Lrn]	0	Exit learn mode

To run it:

Press	Display	Comments
.2 [STO] 2	0.2	Store h in memory 2
1 [STO] 3	1.	Store n in memory 3
[2nd] [Rst] [2nd] [Fix] 3	1.000	Reset machine to step 00 Fix decimal at 3 places
[2nd] [R/S]	0.040	Y_n (n = 0)
[2nd] [R/S]	0.128	Y_n (n = 1)
.		.
.		.
.		. (See Table)

n	Xn	Yn	$Y_n+h(X_n+Y_n)$	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	3.192	4.230	4.389

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

PROGRAMMING NOTES

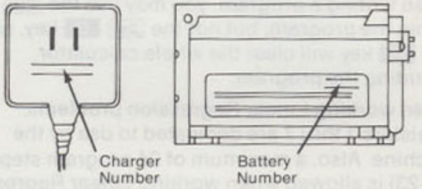
1. When programming, you may use memory registers 0 through 7. Registers 8 and 9 are reserved for program steps 25-31 and 17-24 respectively. If registers 8 and 9 are used, the program can be up to 17 steps (00-16) long.
2. When programming a problem that requires second, inverse functions (such as arc sinh) be sure to press the *inverse* key *before* you press the 2nd function key.
3. When writing a program, you may use the [CLR] key within the program, but not the [2nd] [CA] key, as the [2nd] [CA] key will clear the whole calculator, including the program.
4. When working Linear Regression problems, Registers 1 thru 7 are dedicated to use by the machine. Also, a maximum of 24 program steps (00-23) is allowed when working Linear Regression problems.

APPENDIX A

MAINTENANCE AND SERVICE

Normal Operation

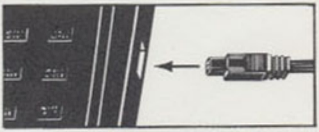
Your calculator is designed for portable operation with periodic recharging of the battery pack with the adapter/charger supplied. It is important that the proper adapter/charger is used. If replacement of the battery pack or charger becomes necessary, be sure that an exact replacement is obtained.



Your calculator uses the BP-7 with the AC9132 adapter/charger.

Caution: Use of other than the proper Adapter/ Charger may apply improper voltage to your calculator and damage the unit. Connecting or disconnecting the Adapter/Charger may clear the calculator.

To ensure maximum portable operation time, connect the Adapter/Charger to a standard 115V/60 Hz outlet, plug into calculator, and charge battery pack at least 4 hours with the calculator OFF or 10 hours with the calculator ON. The adapter/charger and battery pack may become warm when used on AC power. This is normal and of no consequence.



When the battery pack is fully charged, the calculator will operate approximately 2 to 3 hours before recharging is necessary. However, don't hesitate to connect the adapter/charger if you know or suspect the battery pack is nearly discharged. A battery pack near discharge can adversely affect all calculator operations, giving erroneous results. A discharged battery pack is typically indicated by a dim, erratic or blank display.

While individual cell life in a battery pack is difficult to predict, under normal use, rechargeable batteries have a life of 2 to 3 years or about 500 to 1000 recharge cycles.

Periodic Recharging

Although the calculator will operate indefinitely with the adapter/charger connected, the rechargeable battery pack can lose its storage capacity if it is not allowed to discharge occasionally. For maximum battery life, it is recommended that you operate the calculator as a portable at least twice a month, allowing the batteries to discharge, then recharge accordingly.

Excessive Battery Discharging

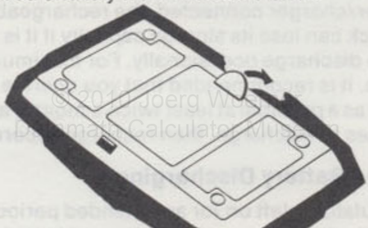
If the calculator is left on for an extended period of time after the battery pack is discharged (accidentally left on overnight, for example), connect the adapter/charger for at least 24 hours with the calculator OFF. If this does not restore normal battery operation, the battery pack should be replaced. Repeated occurrences of excessive battery discharging will permanently damage the battery pack. Spare and replacement battery packs can be purchased directly from Texas Instruments Incorporated, P.O. Box 53, Lubbock, Texas 79408.

Storage

If the calculator is stored or unused for several weeks, the battery pack will probably need recharging before portable use. The battery pack will not leak corrosive material; therefore, it is safe to store the calculator with the battery pack installed.

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 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. Carefully disconnect the wires that attach the battery pack to the calculator. The pack can then be removed entirely from the calculator.



The metal contacts on the battery pack (where charger and calculator plug in) 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. Alignment should not be a problem as the connector will only fit in one position. 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. (Do not force. It will fit easily when properly oriented.)

In Case Of Difficulty

In the event that you have difficulty with your calculator, the following instructions will help you to analyze the problem. You may be able to correct your calculator problem without returning the unit to a service facility. If the suggested remedies are not successful, contact the Consumer Relations Department by mail or telephone (refer to *If You Need Service Information* later in this appendix). Please describe in detail the symptoms of your calculator.

Sympton

1. Display is blank for no obvious reason.	The battery pack may be discharged or improperly installed. Also, check to be sure the ON-OFF switch is fully in the ON position.
2. Display flashes various numbers at a high rate.	Press and hold [R/S] momentarily. If display returns, the calculator was running a long program or operating in a continuous program loop.
3. Display shows erroneous results, flashes erratic numbers, grows dim, or goes blank.	The battery pack is probably discharged or improperly connected. Refer to *Normal Operation*.
4. Display flashes while performing keyboard operations.	An invalid operation or key sequence has been pressed or the limits of the calculator have been violated. See Appendix B for a list of these conditions.

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.

If the calculator is out of warranty, service rates in effect at time of return will be charged. Please include information on the difficulty experienced with the calculator 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.

NOTE: The P.O. Box number listed for the Lubbock Service Facility is for United States parcel post shipments only. If you use another carrier, the street address is:

Texas Instruments Incorporated
2305 University Avenue
Lubbock, TX 79415

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 by going *in person* to 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. *Do not mail your calculator to these exchange centers.*

If You Need Service Information

If you have questions concerning calculator repair, accessory purchase or the basic functions of your calculator, please call our Consumer Relations Department at 800-858-1802 (toll free within the contiguous United States except Texas) or 800-692-1353 within Texas.

For Technical Assistance

For technical questions such as programming, specific calculator applications, etc., you can call 806-747-3841. We regret that this is not a toll-free number, and we cannot accept collect calls. As an alternative, you can write to:

Consumer Relations Department
Texas Instruments Incorporated
P.O. Box 53
Lubbock, TX 79408

Because of the number of suggestions which come to Texas Instruments from many sources, containing both new and old ideas, Texas Instruments will consider such suggestions only if they are freely given to Texas Instruments. It is the policy of Texas Instruments to refuse to receive any suggestions in confidence. Therefore, if you wish to share your suggestions with Texas Instruments, or if you wish us to review any calculator program key sequence which you have developed, please include the following in your letter:

> "All of the information forwarded herewith is presented to Texas Instruments on a nonconfidential, nonobligatory basis; no relationship, confidential or otherwise, expressed or implied, is established with Texas Instruments, by this presentation. Texas Instruments may use, copyright, distribute, publish, reproduce, or dispose of the information in any way without compensation to me."

APPENDIX B
ERROR CONDITIONS

A flashing display indicates that the internal 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] or [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, $\pm 1 \times 10^{-99}$ to $\pm 9.9999999 \times 10^{99}$. Some entries or results smaller than 10^{-97} or larger than 10^{98} can cause an internal underflow/overflow condition which results in a flashing display.
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.
3. Root or logarithm of a negative number.
4. Raising of a negative number to any power.
5. Pressing two operation keys in succession. This affects +, −, ×, ÷, y^x, $\sqrt[x]{y}$ and Δ%.
6. Pressing [=] or [)] after +, −, ×, ÷, y^x, $\sqrt[x]{y}$ or Δ%.
7. Having more than 9 open parentheses or more than 4 pending operations. The 10th parenthesis or 5th operation is not accepted so processing can be continued after pressing [CE].
8. Dividing a number by zero.
9. Factorial of any number except a non-negative integer ≤ 69.

10. Any memory operation that is not followed by 0→9, [CLR] or [2nd] [CA].

11. An x or y value outside the range $\pm 10^{\pm 50}$ in Rectangular to Polar Conversions.

12. 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.

13. Calculation of slope, intercept, correlation, x', y' or standard deviation with less than 2 data points entered.

14. 0^{-x} and $\sqrt[x]{0}$ produces flashing overflow.

15. Key sequence x_1 [2nd] [Δ%] x_2 [=] where $x_2 = 0$.

16. Arguments that do not satisfy the following limits cause a flashing display.

Function	Limit
$\sin^{-1}x$, $\cos^{-1}x$	$-1 \le x \le 1$
sinh x, cosh x	$0 \le \lvert x \rvert \le 227.95592$
ln x	$1 \times 10^{-99} \le x < 1 \times 10^{100}$
log x	$1 \times 10^{-99} \le x < 1 \times 10^{100}$
$\sinh^{-1}x$	$-10^{50} < x < 10^{50}$
$\cosh^{-1}x$	$1 \le x < 10^{50}$
$\tanh^{-1}x$	$0 \le \lvert x \rvert < 1.0$
e^x	$-227.95592 \le x \le 230.25850$
10^x	$-99 \le x < 100$
x!	$0 \le x \le 69$ (integer)

APPENDIX C

DISPLAYED RESULTS VERSUS ACCURACY

Rounding and Guard Digits – 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 8 digits as shown by the display, but actually uses 11 digits to perform all calculations. Combined with the built-in 5/4 rounding capability, these extra digits guard the eight digit display to improve accuracy. Consider the following example in the absence of these guard digits.

$$1/3 \times 3 = 0.9999999 \text{ (inaccurate)}$$

The example shows that $1 \div 3 = 0.3333333$ when multiplied by 3 and produces an inaccurate answer. An eleven-digit string of nines would *round* to 1.

The higher order mathematical functions use iterative calculations. The three guard digits normally allow the accuracy of higher order functions to be better than or equal to ± 1 in the last displayed digit.

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. For example, the difference in results from solving $(16)^2$ using [x^2] and [y^x] is 3×10^{-8}.

Mathematical Limits – There are a few instances in the iterative solution of higher order functions where display accuracy begins to deteriorate as the function approaches a discontinuous or undefined point. For example, the tangent of 89 degrees is accurate for all displayed digits. However, the tangent of 89.99999 is accurate to only four places. Another example is when the y^x function has a y value that approaches 1 and the x value is very large. The displayed result for 0.999^{-160} is accurate for all displayed digits, where $0.999^{-160000}$ is only accurate to five places.

Trigonometric Angle Conversions – When using trigonometric functions with angles greater than ±360 degrees, ±2π radians or ±400 grads at multiples of 90 degrees, etc., the results may appear as very small values in scientific notation. Examples are sin 3600° = 2×10^{-9} and sin 36000° = 2×10^{-8}. These nonzero results are due to slight guard digit inaccuracies developed when the large angle is converted back to a first revolution angle.

APPENDIX D

INSTRUCTION CODES

In the learn mode, the display shows you where the program counter is positioned and the instruction presently in that location. The instruction is represented by a two-digit code that comes directly from that key's location on the keyboard.

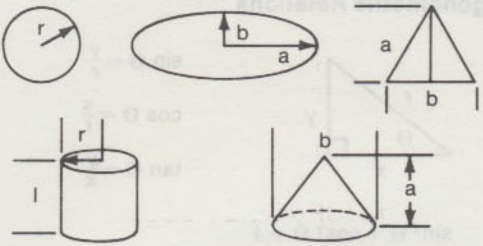
The table below illustrates the key codes for each function.

PROGRAM KEY CODES

Key	Code	Key	Code	Key	Code	Key	Code	Key	Code
	None	sinh	17	cosh	18	tanh	19	CA	10
2nd	None	sin	12	cos	13	tan	14	CLR	15
	26	Δ%	27	log	28	10^x	29	x!	20
INV	21	%	22	lnx	23	e^x	24	$\sqrt[x]{y}$	25
P→R	36	Mean	37	S.Dev.	38	Var	39	Corr	30
x:y	31	x^2	32	$\sqrt{x}$	33	1/x	34	y^x	35
Σ-	46	Eng	47	Const	48	π	49	Slope	40
Σ+	41	EE	42	(	43	)	44	÷	45
Fix	56	Deg	57	Rad	58	Grad	59	Intcp	50
STO	51	7	07	8	08	9	09	×	55
Exc	66	in-mm	67	gal-l	68	lb-kg	69	x'	60
RCL	61	4	04	5	05	6	06	−	65
Prod	76	°F-°C	77	D-R	78	G-R	79	y'	70
SUM	71	1	01	2	02	3	03	+	75
R/S	86	Rst	87	Lrn	None	Sst	None	DMS-DD	80
CE	81	0	00	·	83	+/−	84	=	85

Through normal usage you will become familiar with the more common instruction codes so that constant reference to this table will not be necessary. The others are quickly determined by counting row and column numbers on the keyboard itself.

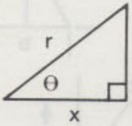
APPENDIX E
GEOMETRIC FORMULAS



Circumference:	Circle $2\pi r$	
Area:	Circle	πr^2
	Ellipse	πab
	Sphere	$4\pi r^2$
	Cylinder	$2\pi r[r+l]$
	Triangle	$\frac{1}{2}ab$
Volume:	Ellipsoid of revolution about "a" axis	$4/3\pi b^2 a$
	Ellipsoid of revolution about "b" axis	$4/3\pi a^2 b$
	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 F
MATHEMATICAL EXPRESSIONS

Trigonometric Relations



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

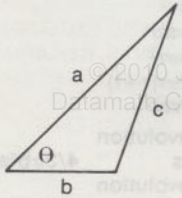
$\cos \Theta = \frac{x}{r}$

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

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

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

Law of Cosines



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

Laws of Exponents

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

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

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

Laws of Logarithms

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

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

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

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Texas Instruments
Consumer Service
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California 92626
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10700 Southwest Beaverton Highway
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