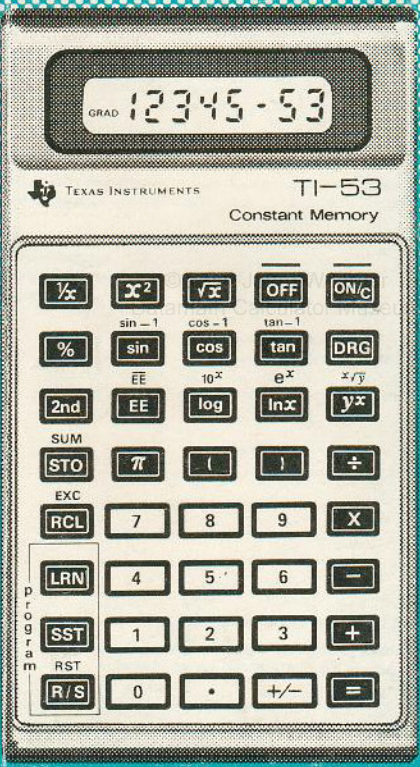
Texas Instruments TI-53

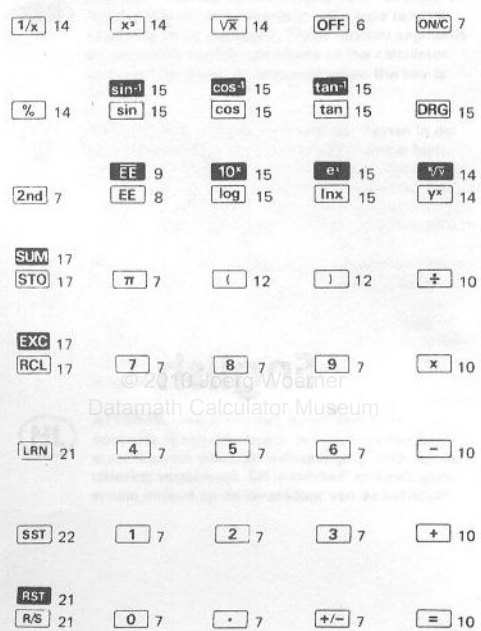
Owner's Manual. Gebrauchsanweisung. Manuel d'Utilisation. Gebruiksaanwijzing.



English

KEY INDEX

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



N.B. : All second (above) functions = black key symbols.

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DESCRIPTION

The TI-53 slide rule calculator is an accurate, reliable and versatile tool designed to solve a wide range of problems. Its capability for simple repetitive calculations makes the TI-53 the ideal way to approach the concept of programming. A library of pre-written programs allows you to use the maximum computing power of your calculator immediately. Use the TI-53 regularly and it will soon become a vital part of your problem solving system.

Summary of the features and functions of your TI-53 :

- Complete Solid-State Circuitry with high quality components.
- Electronic ON and OFF switch with Automatic Power Down (APD).

  The TI-53 turns itself off completely after typically 12 to 18 minutes of non-use. This feature can increase the life of each battery up to 50%.
- AOS(*) - Algebraic method of entry allows you to enter mathematical sequences in the same order that they are algebraically stated.
- Easy to read Liquid Crystal Display (LCD).
- Constant Memory (*) holds numbers in user memory and instructions in program memory even while the calculator is turned off.
- Battery indicator provides information on battery condition.
- Mathematical functions:
  - Arithmetic functions with algebraic hierarchy (up to 4 pending operations) and data grouping (up to 15 sets of parentheses).
  - Trigonometric functions (and inverse functions) with 3 angular modes (degree, radian and grad).
  - Logarithmic functions (natural and common) and inverse functions (10^x and e^x).
  - Algebraic functions: $1/x$, x^2, $\sqrt{x}$, y^x, $\sqrt[y]{}$, %.
  - 4 function - memory: store, recall, exchange and sum.
  - Scientific notation and removal.
  - Pi (π) accurate to 11 digits
  - Clearing and clear entry.
- Programmability: 4 programming keys and 32 program steps are available to store repetitive calculations sequences.

- **Automatic Clearing** - When the [=] key is pressed, all pending calculations are completed, the answer is displayed, and the calculator is prepared for the start of a new problem.
- **Accuracy** - The internal calculating capacity is 11 digits even though only 8 can be displayed.

(*)Trade Mark of Texas Instruments Incorporated.

CALCULATOR OPERATION

IMPORTANT : Many numerical examples are grouped at the end of this manual, page 159 to 164. Please refer to these examples while reading the operating instructions.

Turning the Calculator On

Pressing [ON/C] applies power to the calculator and clears the calculator. Power-on condition is indicated by the presence of a " ▲ "and an "0" in the display. The [OFF] key, of course, removes power from the calculator.

When the calculator is turned off and then back on, the display, all pending operations and operands, and the program pointer (see programming section) are cleared. However, the contents of the user memory and the program memory stored in the calculator are left intact, due to the Constant Memory (*) feature.

NOTICE : Pressing upper row keys when your calculator is off may cause segments of the display to appear. This is a normal function due to the sophisticated technique of display multiplexing that your calculator uses, and will not affect the battery life.

Initial Display

In addition to battery condition and numerical information, the display provides indication of negative number, decimal point, overflow, underflow, angular mode, memory and error. Numbers as larg as 8 digits (7 to the right of the decimal) can be entered. All digit keys pressed after the 8th are ignored.

Any negative number displays a minus sign immediately to the left of the mantissa.

Battery Condition Indicator

The small " ▲ " in the upper left hand portion of the display indicates a "good battery" condition. When the " ▲ " is no longer displayed, it means that the batteries are growing weak, and should be replaced. However, they may still operate the calculator for several more hours before it begins to operate erratically.

Note : the entire display, including the small " ▲ "battery condition indicator, is blanked during the key entries and calculations.

Automatic Power Down (Battery Saver)

Electronic control (as opposed to switch control) of ON and OFF, allows the calculator to minimise power consumption by displaying a number for only a limited length of time. The benefit is a substantial increase in the operating life of your batteries. If not interrupted for a period of 12 to 18 minutes the calculator automatically turns itself off.

Data Entry

[0] through [9] **Digits Keys** : enter number 0 through 9.

[.] **Decimal Point Key** : enters a decimal point ; not displayed for integer numbers.

For maximum versatility, your calculator operates with a floating decimal point. When entering numbers, the decimal is assumed to be to the right of the mantissa until [.] is pressed. Then the fractional part of the number is entered. A maximum of 7 digits may be entered to the right of the decimal point.

[+/−] **Change Sign Key** : When pressed after number entry or a calculation, changes the sign of the displayed number. The sign of the exponent is changed when this key is pressed after the [EE] key.

[π] **Pi key** : Enters the value of pi correct to 11 digits, rounded to 8 digits in the display.

Note : Numbers up to 8 digits in length can be entered into the calculator directly from the keyboard. The calculator can hold and work with 11 digits. Numbers of this length can be entered as the sum of two numbers.
For example, the number 389182.70636 can be entered as 389182 + 0.70636. The calculator will display 389182,71, but will actually carry the 11 digits internally.

[ON/C] **Clear Entry/Clear Key** : Removes an incorrect entry from the display when pressed before any function or operation key is pressed. When pressed once after an operation or function key (including [=]), or when pressed twice, this key clears the display and all pending operations. The user memory, the program memory and the program pointer (see programming section) are not affected by this key.

Second function keys

Some of your calculator keys have second functions which are accessed by using the [2nd] key. The second function keys are described in the appropriate sections of this manual, and will be indicated with black key symbols like this : [2nd] [SUM]

Input Error Correction

At any point in a calculation, [ON/C] can be pressed twice to clear all calculations, including any errors. This drastic action is seldom necessary.

If an incorrect number entry is made, pressing the [ON/C] key before any non number key clears the incorrect number without affecting any calculation in progress.

Correction of an incorrect operation entry while there are incomplete operations in the calculator is dependent on the table below.

Incorrect Entry	Desired Entry			
	+, −	×, ÷	y^x	$\sqrt[x]{y}$
+, −	CK	ON/C	ON/C	ON/C
×, ÷	CK	CK	ON/C	ON/C
y^x	CK	CK		ON/C
$\sqrt[x]{y}$	CK	CK	CK	

CK means you need to press the correct key and continue.

The ON/C key in the table indicates that the incorrect entry cannot safely be corrected to the desired operation for all conditons so the problem must be restarted.

Scientific Notation

To enter very large or very small numbers you must use scientific notation where the number is entered as a mantissa multiplied by 10 raised to some power (exponent) such as -3.6089×10^{-32}.

EE **Exponent Entry Key** - When pressed after a keyboard entry or calculation, prepares the calculator to accept the next digits entered as the exponent.

The entry procedure is to key in the mantissa (including its sign), then press EE and enter the power of ten. Any number smaller than $\pm 1 \times 10^{-7}$ or larger than ± 99999999 must be entered in scientific notation.

The last two digits on the right side of the display are used to indicate the exponent of 10. Additional digits can be entered after pressing EE , but only the last two numbers pressed are retained as the exponent.

In scientific notation a positive exponent indicates how many places the decimal point 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 in 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.

Data in scientific notation form may be entered intermixed with data in standard form. The calculator converts the entered data for proper calculation.

The decimal point of the entered mantissa must not be beyond the 5th digit from the left because the mantissa for scientific notation is limited to 5 digits in the display. Eight digits can be entered, but only 5 are displayed when EE is pressed. The entire eight digit mantissa is used for calculations. The display does not go into scientific notation format if more than 5 numbers are entered to the left of the decimal point.

[x] 1 [EE] [=] **Scientific Notation Key Sequence**
Converts a number in normal display format to scientific notation display format. The mantissa is normalized.
IMPORTANT : Pressing [EE] without [x] 1 will cause any non-displayed digits of a result or intermediate result to be discarded and only the rounded display value will be carried into the next problem.
[2nd] [EE] [=] - **Scientific Notation Removal Key Sequence** -
Removes displayed numbers from scientific notation if they are between $\pm 1 \times 10^{-7}$ and $\pm 9.9999999 \times 10^{7}$, and displays them in standard display format. If the displayed number is outside the range listed above, the scientific notation removal key sequence will be ignored and the number will remain in scientific notation format until the number occurs in the standard display range.

Error indication

The display shows "Error" whenever the limits of the calculator are violated or when an improper mathematical operation is requested. When this occurs, any entry from the keyboard is not accepted until [ON/C] is pressed. This clears the error condition and all pending operations. You must now begin your problem again.

ARITHMETIC FUNCTIONS

To perform simple addition, subtraction, multiplication or division, the calculator with its algebraic type of entry allows you to key in the problem just as it is stated.

Basic Keys

[+]	**Add Key**	Instruct the calculator to execute the respective operation on the displayed number and the next entered quantity.
[−]	**Subtract Key**	
[×]	**Multiply Key**	
[÷]	**Divide Key**	

NOTE : Pressing one of these keys completes any previously entered divide or multiply, y^x or $\sqrt[x]{y}$ functions.

[=] **Equals Key** - Completes all previously entered numbers and operations. This key can be used to obtain both intermediate and final results.

It is a safe procedure to press the [ON/C] key before the start of each new problem but this is not necessary if [=] has been used to obtain the final result of a previous problem.

Combining Operations (Calculator hierarchy)

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 re-enter the number from the keyboard.

In order to efficiently combine operations, you need to understand the standard algebraic rules that 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 x 4 + 3 x 2 could have several meanings:

5 x (4 + 3) x 2 = 70
or (5 x 4) + (3 x 2) = 26
or ((5 x 4) + 3) + 2 = 46
or 5 x (4 + (3 x 2)) = 50

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

1. Special functions (trigonometric, logarithmic, square, square root, percent and reciprocal).
2. Exponentiation (y^x) Roots ($\sqrt[x]{y}$)
3. Multiplication. Division.
4. Addition. Subtraction.
5. Equals.

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

$$4 \div 5^2 \times 7 + 3 \times \sin 30^{\circ\cos 60^{\circ}} = 3.2413203$$

Enter	Press	Displays	Comments
4	[÷]	4	(4 ÷) is stored
5	[x²]	25	(5^2) special function [x²] evaluated immediately
	[x]	0.16	($4 \div 5^2$) evaluated because x is same priority as ÷
7	[+]	1.12	x higher priority than +, so ($4 \div 5^2 \times 7$) evaluated, + stored.
3	[x]	3	(3x) stored
30	[sin] [yˣ]	0.5	Sin 30° evaluated immediately, y^x stored.
60	[cos]	0.5	Cos 60° evaluated immediately.
	[=]	3.2413203	Completes all operations: sin $30^{\circ\cos 60^{\circ}}$ evaluated, then 3 x sin $30^{\circ\cos 60^{\circ}}$ next, then this is added to 1.12.

Thus, by entering the expression just as it is written, the calculator correctly interprets it as : $[(4 \div 5^2) \times 7] + (3 \times \sin 30^{\circ\cos 60^{\circ}})$. This enables you to perform sum of products directly on the keyboard. When you have a special case where this hierarchy of interpretation does not give you the results you require, parentheses are available to clarify the mathematical expression for the calculator.

NOTE : The keys on the right side of your calculator are positioned in such a way as to help you remember the AOS(*) hierarchy :

[yˣ] exponentiation and roots

[÷] [x] multiplication and division

[−] [+] addition and subtraction

[=] "equals" which completes all operations

(All single variable functions are performed on the displayed number immediately when pressed).

Parentheses

[( ] [ )] **Parentheses Keys** : Used to isolate particular numerical expressions for separate mathematical interpretation.

Parentheses should be used whenever a mathematical sequence cannot be directly entered using the previously mentioned algebraic rules or when there is doubt in your mind as to how the calculator is going to reduce an expression.

To illustrate the benefit of parentheses, try the following experiment:

press [( ] 5 [x] 7 [ )] ,and you will see the value 35 displayed.

The calculator has evaluated 5 x 7 and replaced it with 35 even though the [=] key 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	[x] [( ]	4	(4x) stored pending evaluation of parentheses
5	[+]	5	(5+) stored.
9	[ )]	14	(5 + 9) evaluated.
	[÷]	56	Hierarchy evaluates 4 x 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	$4 \times (5 + 9) \div (7 - 4)^{(2 + 3)}$evaluated

As many as 15 parentheses can be open at any one time and 4 operations can be pending. If you do attempt to open more than 15 parentheses or if the calculator tries to store more than 4 operations, "Error" appears in the display.

Each time a closed parenthesis is encountered, the contents are evaluated back to the nearest open parenthesis and are replaced with a single value. Specifically, you can check intermediate results. Note that in all the examples, the expressions are entered in a straight left to right sequence.

Accuracy and Rounding

Each calculation produces an 11-digit result. The result is rounded to an 8-digit standard display or to a 5-digit mantissa and 2-digit exponent for scientific notation. The 5/4 rounding technique built into this calculator adds 1 to the last significant digit of the display if the next, non displayed digit is five or more. If this digit is less than five, no rounding is applied.

The higher mathematical functions use iterative calculations. The cumulative error from these calculations in most cases is maintained beyond the eight-digit display so that no inaccuracy is displayed.

Most calculations are accurate to ± 1 in the eighth digit. Exceptions are the tangent function as it approaches undefined limits and y^x where y is within 10^{6} of 1.

SPECIAL FUNCTIONS

Single-variable functions operate on the displayed value instantly replacing the displayed value with its function. These functions do not interfere with any calculations in progress and can therefore be used at any point in a calculation.

NOTE : The display is blank during the short time the calculator is computing a result. Be sure the calculator has completed an operation before pressing the next key.

Roots and Powers

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

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

[y^x] **y to the x^{th} Power Key** : Raises the displayed value y to the x^{th} power.

[2nd] [$\sqrt[x]{y}$] **x^{th} Root of y Key** : Takes the x^{th} root of the displayed value y.

y^x and $\sqrt[x]{y}$ are the only special functions that do not act on the displayed value immediately. They require a second value before the function can be realised. Enter y, press [y^x] or [2nd] [$\sqrt[x]{y}$], enter x, and press [=] or an arithmetic function key to yield the answer.

There is a restriction on these functions : the variable y must be greater than zero. When y is negative "Error" appears on the display after x and an operation key is pressed. Any non-negative number taken to the zero power is 1.

Reciprocal

[1/x] **Reciprocal Key** : Divides the display value x into 1, $x \neq 0$.

Percent

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

When [%] is pressed after an arithmetic operation, add on, discount and percentage can be computed as follows :

[+] [−] [×] [÷] } n [%] [=] { adds n% to / subtracts n% from / multiplies by n% / divides by n% } the number displayed

Natural logarithm and e^x

[lnx] **Natural logarithm key** : Calculates the natural logarithm (base e) of the number x in the display. $x > 0$.

[2nd] [e^x] **e to the x^{th} Power Key Sequence** : Calculates the natural antilogarithm of the number in the display.

Common Logarithm and 10^x

[log] **Common Logarithm Key** - Calculates the common logarithm (base 10) of the number x in the display. $x > 0$.

[2nd] [10^x] **10 to the x^{th} Power Key Sequence** : Calculates the common antilogarithm of the display value.

Trigonometric functions

[DRG] **Degree, Radian, Grad Key** : Selects the units for angular measurement. When turned on, the calculator is in the degree mode. Pressing the [DRG] key once, places it in the radian mode, twice in the grad mode. Another key push returns the calculator to the degree mode. The display indicates "RAD" for radians and "GRAD" for grads. Degree mode has no indicator. The angular mode has absolutely no effect on calculations unless the trigonometric functions are being used.

[sin] Sine key
[cos] Cosine key
[tan] Tangent key

} Compute the respective trigonometric value of the angle in the display

[2nd] [$\sin^{-1}$] Arcsin Key Sequence
[2nd] [$\cos^{-1}$] Arccosin Key Sequence
[2nd] [$\tan^{-1}$] Arctangent Key Sequence

} Find the smallest angle whose respective trigonometric value is in the display

Trigonometric values can be calculated for angles greater than one revolution. As long as the trigonometric function is displayed in normal form rather than in scientific notation all display digits are accurate for any angle from -36000 to +36000 degrees ($-200\ \pi$ to $+200\ \pi$ radians or -40000 to +40000 grads). In general, the accuracy decreases one digit for each decade outside this range.

The largest angle resulting from an arc function is 180 degrees (π radians or 200 grads). Because certain angles have identical function values within one revolution, the angle returned by each function is restricted as follows :

Arc Function	Quadrant
Arcsin x, Arccos x, Arctan x	First
Arcsin $-x$, Arctan $-x$	Fourth
Arccos $-x$	Second

Degree, Radian, Grad Conversions

Conversion	Key Sequence
Degrees to Radians Radians to Grads Grads to Degrees	sin DRG 2nd sin⁻¹
Degrees to Grads Grads to Radians Radians to Degrees	sin DRG DRG 2nd sin⁻¹

The angular range of the above conversions must be limited to the first and fourth quadrants. Larger angles are returned in those quadrants.

MEMORY USAGE

Your calculator has one "constant" user memory which is able to store data even while the calculator is turned off. This feature allows you to store often used numbers in memory or to keep a running total of figures over a long period of time without having to write them down and re-enter them each time the calculator is turned back on.

Use of the memory does not affect any calculations in progress, so memory operations can be used wherever needed.

STO **Memory Store Key** : Stores the displayed quantity in the memory without removing it from the display. Any previously stored value is replaced by the new entry.

RCL **Memory Recall Key** : Retrieves stored data from the memory to the display without affecting the contents of the memory.

2nd EXC **Memory Exchange Key Sequence** : Swaps the content of the memory with the displayed value. The displayed value is stored and the previously stored value is displayed. This key combines the store and recall operations into a single key. Use of this key, like the other memory keys, does not disturb a sequence of calculations and can consequently be used anywhere in the solution of a problem.

2nd SUM **Sum to Memory Key Sequence** : Algebraically adds the displayed value to the memory contents, without affecting the value in the display. This key is used to accumulate the results from a series of independent calculations, and replaces a sequence such as + RCL = STO

IMPORTANT : Because of your calculator's Constant Memory™ feature, the memory is not automatically cleared when the calculator is turned off and on. Therefore, the first quantity should always be stored using STO , or a zero should be stored (ON/C STO) to ensure the memory is empty before using SUM .

PROGRAMMING

Introduction :

At this point you've looked at almost all of the 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.

Programming your calculator is expressly designed to be a natural, straightforward process - that can save you considerable time whenever you handle repetitive calculations. 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.

We'll see how this procedure works by asking you to enter a "program" into your calculator and use it for a while. Then, we'll come back to the details of each key you've pressed, and the reason for it.

An example of a problem and its solution through programming

The safe altitude (ho) at which a skydiver must pull his ripcord to open his parachute is in the range 600 to 700 metres. Let's calculate the theoretical length of time he should wait after jumping out of the plane before pulling the ripcord - assuming we neglect the wind resistance - for each 200 metres between 1000 and 2000 metres of jumping altitude :

The classic physics formula giving the answer is :

$$t = \sqrt{\frac{2\,(x - ho)}{9.81}}$$

x = jumping altitude (metres)
ho = ripcord pulling altitude (metres) - say 700 m
t = timing (seconds)

Press [OFF] and [ON/C], and then :

[2nd] [ON/C] [LRN] [−] 700 [=] [x] 2 [÷] 9.81 [=] [√x] [R/S]
[2nd] [RST] [LRN]

Now press [2nd] [RST] once and simply enter the different x values; your calculator knows your problem from now on, and will give you the answer each time you press [R/S]

Press		Display	Comments
1000	[R/S]	(*) 7.8206189	Timing for a 1000m-jump
1200	[R/S]	10.096376	Timing for a 1200m-jump
.	.	.	.
.	.	.	.
.	.	.	.
2000	[R/S]	16.279916	Timing for a 2000m-jump

(*) **NOTE** : After pressing [R/S], the entire display, including the battery condition indicator, will be blanked until the next [R/S] instruction - or an "Error" condition - is encountered. You must wait a few seconds before the answer appears in the display.

Now switch off your calculator, and then switch it back on; re-enter one of the values you have just used and press [R/S] : your calculator still retains the problem and gives you the right answer, thanks to its Constant Memory feature !

This means once you've taught a specific problem to the calculator, it will solve this problem again and again at any time, even after being switched off for days or months ! (Provided the batteries are not removed or discharged.)

After the program is stored in your calculator, pressing the [R/S] key becomes the equivalent of operating 14 keys ([−] 700 [=] [×] 2 [÷] 9.81 [=] [√x]) -otherwise used to get the answer.

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. The corresponding instructions will be stored in a special memory - called "program memory" - of your calculator.

Let's review in detail the keystrokes you've entered to program the skydiver problem :

1) [2nd] [ON/C] : As we've just seen, your calculator "remembers" instructions even after having been switched off. The purpose of the [2nd] [ON/C] key sequence is hence to clear the program memory from previously stored instructions. This key sequence should be used each time before you enter a new program.

2) [LRN] (learn)

When you press this key, 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".

The special display format (00 00) confirms that the calculator is in "learn mode".

3) [−] 700 [=] [×] 2 [÷] 9.81 [=] [√x]

This is the basic series of keystrokes needed to compute the answer "manually". As you enter each step, you will see your calculator counting them : the two zeros on the left in the display have been replaced by 01,02, etc.., until 14.

4) [R/S] (run/stop)

After your calculator completes the above steps, you want it to stop and show you the result. You do this by finishing your program with a "stop" instruction.

5) [2nd] [RST] (reset)

As you've seen, your calculator is able to count steps. When the program is running, the step counter (called "program pointer") travels sequentially from step 00 To step 31. As the calculation is finished at the [R/S] key, you don't want the program pointer going beyond this step, but you want it to return to step 00, to be ready for another calculation. This is the job of the [2nd] [RST] instruction (called "automatic reset") at the end of the program.

6) [LRN]

This second use of the learn key "turns off" the program memory to leave the "learn mode", and go back into "normal calculation mode".

The display now shows a single zero.

7) [2nd] [RST]

Before using the program for the first time, you need to press this key sequence again. Why ? Because the program pointer is still waiting for the next step (step 17) when we leave the learn mode. (If you switch back and forth to learn mode before pressing [2nd] [RST] for the second time you will see the left 2 digits remain at 17.)

We need to return the program pointer to step 00 before we may run (or execute) the program for the first time. This will not be necessary afterwards, as we've included an automatic reset at the end of our program.

To help you better to understand what's going on within the calculator when you run a program, let's take a closer look at the four special programming functions of your calculator. They are shown here as they appear on the keyboard [LRN], [R/S], [2nd] [RST] and one we haven't used yet [SST].

PROGRAMMING KEYS

[LRN] **The Learn Mode Key** - Pressing this key once 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 [LRN] key 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] [ON/C] and then [LRN] for the first time to enter the learn mode, the display changes to a unique format showing two zeros followed by a blank space and then by two other zeros.

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 [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. This will be explained in more detail in the next section.

[R/S] **The Run/Stop Key** - When your calculator is out of learn mode, the [R/S] key is the start/stop switch for any program you may have in the machine. If the program is stopped, pressing [R/S] will start it running. If the program is running, pressing [R/S] will stop it. The [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 [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.

An other way to accomplish this is to switch off your calculator, and then back on. The key sequence is : [OFF] [ON/C] [LRN] , and again, the left two digits are 00. (This is because the [OFF] key automatically resets the program pointer and causes your machine to leave the learn mode.)

[SST] **The Single-Step Key** - If you press this key 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 in the next section. When you press [SST] out of "learn mode", you step through and execute your program one step at a time. We will now see the key codes in detail and then come back to the use of [SST] .

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. The second functions use two program steps, hence they can take the same code as the first corresponding functions without any risk of confusion (if the step preceding a dual function is coded 31 [2nd] , then the following step represents the second function).

Examples :

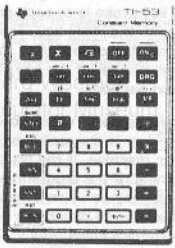
31 (row 3 column 1) is [2nd]

42 (row 4 column 2) is [π]

53 (row 5 column 3) is [8]

65 (row 6 column 5) is [−]

85 (row 8 column 5) is [=]



See page 36 of this manual for a complete list of key codes

The display "00 65" tells you that step 00 is [−] , display "01 74" tells you that step 01 is 3, and so forth.

Note : that [OFF] , [LRN] and [SST] have no code, because these keys cannot be used in a program.

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.

USE OF [SST]

To see the [SST] key in action, we'll use our first example (p. 00). As you might have pressed some keys in the learn mode during the previous explanations, it's advisable to re-enter the program completely. Press [2nd] [ON/C] [LRN] to clear the program memory and enter the learn mode at step 00.

Now re-enter the program :

Press [−] 700 [=] [×] 2 [÷] 9.81 [=] [√x] [R/S] [2nd] [RST] [LRN] [2nd] [RST]

Use of [SST] in learn mode :

In learn mode, [SST] will help us to review each instruction of our program :

Press	Display	Comments
[LRN]	00 65	Enter learn mode and display step 00 : 65 is [−] .
[SST]	01 52	step 01 : 52 is 7
[SST]	02 82	step 02 : 82 is 0
[SST]	03 82	step 03 : 82 is 0
[SST]	04 85	step 04 : 85 is [=] .
[SST]	05 55	step 05 : 55 is [×] .
.	.	.
.	.	.
.	.	.
[SST]	13 13	step 13 : 13 is [√x] .
[SST]	14 81	step 14 : 81 is [R/S] .
[SST]	15 31	step 15 : 31 is [2nd] .
[SST]	16 81	step 16 : 81 is [RST] (because preceding step is [2nd]).
[SST]	17 00	Unprogrammed steps.
[SST]	18 00	

If you continue to press the [SST] key while your calculator is in learn mode, it will go to step 31, then the calculator will automatically leave the learn mode displaying a single zero.

Use of [SST] to execute a program step by step.

[SST] enables you also to execute the program one step at a time. This is particularly useful when finding a mistake in a program which doesn't give the expected result.

Let's step through our program using the first value x = 1000 metres :

Press	Display	Comments
[2nd] [RST]	0	Reset program pointer
1000	1000	enter data
[SST]	1000	step 00 ([−]) pending
[SST]	7	
[SST]	70	
[SST]	700	700 is the result of steps 01 to 03;
[SST]	300	subtraction is completed by step 04 ([=])
[SST]	300	step 05 ([×]) pending
[SST]	2	2 is created by step 06
[SST]	600	multiplication is completed by step 07. division is pending.
[SST]	9	
[SST]	9	
[SST]	9.8	
[SST]	9.81	9.81 is created by steps 08 to 11
[SST]	61.16208	t^2 is calculated by step 12
[SST]	7.8206189	t is calculated by step 13
[SST]	7.8206189	step 14 ([R/S])
[SST]	7.8206189	
[SST]	7.8206189	step 15 and 16 ([2nd] [RST]) executed.

If you press [LRN] now, you will see 00 65 in the display : the program pointer is back at step 00 ready to start a new calculation.

Notes :

1. In fact, after each calculation, the program pointer will stop at step 15. Thus, when you enter new data and press [R/S], the first instruction encountered is [2nd] [RST] and brings the pointer back to the beginning of the program. So, [2nd] [RST] is not executed at the end of a calculation, but at the beginning of the next one. (That's the reason why you have to press [2nd] [RST] before using your program for the first time.)
2. If a running program stops and displays "Error", pressing [ON/C] [LRN] and will show the step number and the code of the illegal operation that produced the error condition.

MODIFYING A PROGRAM

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).

For example, let's modify our skydiver program to pull the ripcord at 600 metres instead of 700 m.

Press	Display	Comments
2nd RST LRN	00 65	Reset and enter learn mode
SST	01 52	this is the step we want to modify to a 6.
6	02 82	The 6 has replaced the 7 in step 01 and the pointer has moved on, showing the contents of step 02.
LRN 2nd RST	0	Leave learn mode and reset, the modification has been completed

Let's use this modified program to compute the new free-fall timings

Press		Display	Comments
1000	R/S	9.0304728	New timing for 1000m
1200	R/S	11.060025	New timing for 1200m
.		.	
.		.	
.		.	
2000	R/S	16.894468	New timing for 2000m

PROGRAMMING EXAMPLES :

Temperature Conversions :

The Celsius scale takes 0°C and 100°C as the temperatures respectively of melting ice and of steam.

The Fahrenheit scale utilises 32°F and 212°F for these 2 points.

Let's write a conversion program. This will convert any temperature measured on one scale into the other.

The conversion formulae have first to be stated : 100°C corresponds to 180°F, so :

$$°C = (°F - 32) \times \frac{100}{180} \quad \text{or} \quad °C = °F \frac{32}{1.8}$$

$$°F = (°C \times \frac{180}{100}) + 32 \quad \text{or} \quad °F = (°C \times 1.8) + 32$$

The program is now straightforward :

Press	Comments
2nd ON/C LRN	Clear program memory, reset and enter learn mode.
− 32 = ÷ 1.8 =	Fahrenheit-Celcius conversion.
R/S	To display the °C result
× 1.8 + 32 =	Celsius-Fahrenheit conversion
R/S	To display the °F result
2nd RST LRN	Reset and leave learn mode
2nd RST	Ready to use the program for the first time.

Example : Convert 86°F into °C.

Press	Display	Comments
86 R/S	30	The result is 30°C
R/S	86	Inverse conversion gives the initial value in °F

But what if you have only °C to °F to convert? This means you only want to use the second part of your program, located after the first R/S. Simply allow the program pointer to go to this first R/S before entering your data. In order to do this, you have only to press R/S once, and then enter the °C figure you want to convert.

Example : Convert 27°C into °F

Press	Display	Comments
R/S	any number	We are now at the first R/S of the program.
27 R/S	80.6	The result is 80.6°F.

Note : If you only use the first conversion (°F into °C), you will have to press [2nd] [RST] after each calculation, because your program contains an "automatic" (programmed) reset only after the second (°C to °F) conversion. You have written two programs in one!

RL circuit :

Let's write a program to compute the impedance Z and the phase angle φ of an RL circuit (circuit with a resistance R and an inductance L in series, powered by an alternating current of frequency f).

The general formulae for Z and φ are :

$$Z = \sqrt{R^2 + \omega^2 L^2}$$

$$\varphi = \text{Arc tan} \left(\frac{\omega L}{R} \right) \quad (\omega = 2 \times f)$$

Let's write $Z = R \sqrt{1 + \left(\frac{\omega L}{R} \right)^2}$ in order to isolate tan φ during the calculation. (This is part of a process known as 'optimising a program'.)

The corresponding program then becomes :

Press	Display	Comments
[2nd] [ON/C] [LRN]	00 00	Clear program memory, reset and enter learn mode.
[STO]	01 00	enter and store R
[x] [(] 1 [+]	05 00	
[(] 2 [x] [π]	09 00	
[x] [R/S]	11 00	stop to enter f
[÷] [RCL] [x] [R/S]	15 00	stop to enter L
[)] [STO]	17 00	store $\frac{\omega L}{R}$ for future use
[x²] [)] [√x] [=]	21 00	compute Z
[R/S]	22 00	stop to display Z
[RCL] [2nd] [tan⁻¹] [R/S]	26 00	compute and stop to display φ
[2nd] [RST]	28 00	automatically reset to step 00
[LRN] [2nd] [RST]	0	leave learn mode and reset before first calculation.

Example :

R = 10 Ω
L = 0.1 H
f = 50 Hz

Press	Display	Comments
10 [R/S]	6.2831853	Enter R and display 2 π
50 [R/S]	31.415927	Enter f and display $\frac{2\pi f}{R}$
.1 [R/S]	32.969083	display Z
[R/S]	72.343213	display φ in degree.

GRAPHING

Graphing a curve can be a tedious job since the function to be plotted must be solved again and again for each value you want to plot. However, if you teach the calculator the keystrokes necessary to solve the equation, you save a lot of time and you won't need to worry about "careless" mistakes. In other words, you are able to concentrate on the problem itself.

For example, let's plot the function :

$f(x) = 2x^3 + 3x^2 - 36x - 20$

from $x = -6$ to $x = +5$

Here is how to program this problem :

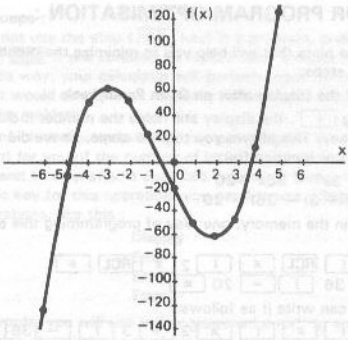
Press	Next step	Comments
2nd ON/C LRN	00 00	Clear program memory, reset and enter learn mode.
1 2nd SUM	03 00	increment (add 1 to
RCL R/S	05 00	the current value of x)
x (x (	09 00	
x 2 + 3)	14 00	
− 36)	18 00	
− 20 = R/S	23 00	f(x) is computed and displayed
2nd RST	25 00	reset automatically for next val.
LRN 2nd RST	0	leave learn mode and reset before first calculation.

Now run the program :

Press	Display	Comments
7 +/− STO	−7	Initialise - store $(x_1 - 1)$ in memory
R/S	−6	first x value
R/S	−128	corresponding f(x) value
R/S	−5	x = −5
R/S	−15	f (−5)
.	.	.
.	.	.
.	.	.
R/S	4	x = 4
R/S	12	f (4) .
R/S	5	x = 5
R/S	125	f (x)

If you want more accuracy, you can easily change the increment of 1 in step 00 by re-writing the program with another value (say 0.5 - the smaller the value, the greater the accuracy).

You can also program in the same way the derivative $f'(x)$ of your function : $f'(x) = 6x^2 + 6x - 36$.



Note: You may have noticed that the program needs to recall the current x value only once. This is because f(x) = x(x(2x + 3) − 36) − 20

Using a special technique (explained in the next section) you need only enter x once.

HINTS FOR PROGRAM OPTIMISATION :

Here are some hints that will help you to minimize the number of programming steps.

1. Content of the Display after an Open Parenthesis :

After pressing [( ] , the display still holds the number it did before pressing this key. This allows you to save steps, as we did when programming our function f(x) :

$f(x) = 2x^3 + 3x^2 - 36x - 20$

$= x(x(2x + 3) - 36) - 20$

If x is stored in the memory, one way of programming this expression is :

[RCL] [x] [(] [RCL] [x] [(] 2 [x] [RCL] [+]
3 [)] [−] 36 [)] [−] 20 [=]

But now you can write it as follows :

[RCL] [x] [(] [x] [(] [x] 2 [+] 3 [)] [−] 36 [)]
[−] 20 [=]

2. Suppresion of close parenthesis ([ )] before [=] key :

The [ )] function is not necessary before [=] because [=] completes all pending operations.

Example : Let's write the shortest possible program to calculate x(x + 1), assuming x is entered into the display.

[x] [(] [+] 1 [=]

This example uses the two features of your calculator we've just described.

3. Absolute value of a number :

You can easily get the absolute value (|x|) of x by using only two steps : [x^2] [$\sqrt{x}$]

4. Integer part of a number :

Here is a program to get the integer part of x (if x in display)

[+] 1 [EE] 10 [−] [EE] [=] [2nd] [EE]

5. Decimal part of a number :

You can get the decimal part of x (in display) using this program :

[−] [(] [+] 1 [EE] 10 [−] [EE] [)] [=] [2nd] [EE]

6. Integer and decimal parts :

If you need both integer and decimal part of x, you will get them using this program (x in display) :

[−] [(] [+] 1 [EE] 10 [−] [EE] [)] [STO] [=] [2nd] [EE]

You will have the decimal part in the display, and the integer part stored in the memory.

7. Finite loops :

If you do not use the stop (R/S key) in a program, ending it only with 2nd RST it will continue to repeat itself without any prompting. In this way, your calculator will perform many calculations in the time it would take you to manually make one or two "loops" through the problem.

Using some clever manoeuvering, you can program the calculator to keep count for you of the number of loops it makes as it works the problem, and to stop after a specified number of loops. As there is no specific key for this operation, you need to use "illegal" or undefined operations, like this :

Press	Display
0 1/x	Error
−1 √x	Error
90 tan	Error

In other words, you will use a "programmed error" to stop your program running at a given point of time. As the only way to clear the error condition is to push the ON/C key, the display will be cleared. So, you need to prepare for this by storing the result you want in the memory.

An example will clarify this : Let's write a program to calculate

$$\sum_{i=1}^{n} x_i = 1 + 2 + 3 + \ldots + (n-1) + n$$

We'll use n as a counter that will be decremented by 1 at each loop. The counter will be "tested" using 1/x, which will give an error condition when the counter is at zero.

The corresponding program is as follows :

Press	Comments
2nd ON/C LRN	Clear program memory, reset and enter learn mode
+	add to the current sum
(RCL − 1)	decrement counter by 1
STO	store new counter value
=	addition is completed
2nd EXC	current sum is put into memory
	counter is recalled into display
1/x	counter is tested
1/x	current counter value is restablished
EE 2nd EE	See note 3 below.
2nd EXC	current sum is back into display
	counter is back into memory
2nd RST	reset to step 00
LRN 2nd RST	leave learn mode and reset before first use.

Use of the program :

Example : n = 5

Press	Display	Comments
5 STO	5	Program starts with n in memory and in display
R/S	(*) Error	program runs and error condition is encountered
ON/C	0	clears error condition
RCL	15	answer is displayed

(*) Program will run for a few seconds before displaying "Error".

Notes : 1. It's necessary to push 2nd RST each time before using this program.

2. The answer can be verified using the formula $\sum_{i=1}^{n} x_i = \frac{1}{2} n (n+1)$.

3. The use of this technique has some limitation as it may generate cumulative rounding errors. This is the purpose of the EE 2nd EE key sequence to avoid such rounding errors.

8. Simulation of 2nd RST when 2 steps are not available at the end of a program :

If your program ends at step 30, you can replace 2nd RST with = in step 31. This will reset the pointer to step 00 in the same way that 2nd RST does.

If your program ends at step 31 (i.e. using 32 steps), the pointer will automatically be reset to step 00 after each loop.

SERVICE INFORMATION

In Case of Difficulty

1. If the battery indicator and digits fail to appear on the display when calculations are not in progress, check for improperly inserted or discharged batteries. See Battery Replacement instructions.
2. If the calculator fails to turn off when OFF is pressed, remove and replace the battery compartment cover to momentarily interrupt power to the calculator. Then, check for normal operation.
3. Review operating instructions to be certain that calculations were performed correctly.
4. When batteries are inserted into the calculator and the display does not reset, pressing OFF , then ON/C should reset the display and prepare the calculator for your use.

User Suggestions

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 us to review any calculator key sequence which you have developed, please include the following in your letter :

"All of the information forward herewith is presented to Texas Instruments on a non confidential, non obligatory 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".

Battery Replacement

Note : Your calculator cannot hold data in its user memory or instructions in its program memory, if the batteries are removed or become discharged.

Two categories of batteries can be used in your calculator :

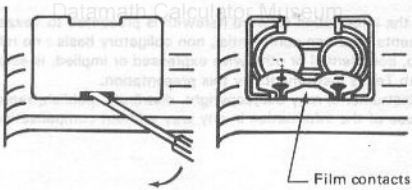
2 Silver Oxide Batteries : Eveready S-76, Mallory 10L14, Ray-O-Vac RW42, UCAR S-76E

or

2 Alkaline Batteries : Ray-O-Vac RW82, Union Carbide A76

Note: Silver oxide batteries have a longer life time than alkaline batteries. Battery life indications which may be found in this manual assume use of silver oxide batteries.

1. Turn the calculator off. Place a small screwdriver, paperclip, or other similar instrument into the slot and gently lift the battery cover.
2. Remove the discharged batteries and install new ones as shown. Be careful not to crease the film contacts while installing the new batteries. Be sure the film contacts are positioned to lay on top of the batteries after they are installed.



3. Replace the cover, top edge first, then gently press until the bottom edge snaps into place.

CONVERSION FACTORS

English to Metric

To Find	Multiply	By
microns	mils	25.4
centimetres	inches	2.54
metres	feet	0.3048
metres	yards	0.9144
kilometres	miles	1.609344
grams	ounces	28.349523
kilograms	pounds	4.5359237×10^{-1}
litres	gallons (U.S.)	3.7854118
litres	gallons (Imp.)	4.546090
millilitres (cc)	fl. ounces	29.573530
sq. centimetres	sq. inches	6.4516
sq. metres	sq. feet	9.290304×10^{-2}
sq. metres	sq. yards	8.3612736×10^{-1}
millilitres (cc)	cu. inches	16.387064
cu. metres	cu. feet	2.8316847×10^{-2}
cu. metres	cu. yards	7.6455486×10^{-1}

Boldface numbers are exact ; others are rounded.

Temperature Conversions

$$°F = \frac{9}{5}(°C) + 32$$

$$°C = \frac{5}{9}(°F - 32)$$

KEY CODES LIST

11	1/x	51	RCL/EXC(*)
12	x^2	52	7
13	$\sqrt{x}$	53	8
15	ON/C	54	9
21	%	55	X
22	sin/$\sin^{-1}$(*)		
23	cos/$\cos^{-1}$(*)	62	4
24	tan/$\tan^{-1}$(*)	63	5
25	DRG	64	6
31	2nd	6.5	−
32	EE/$\overline{EE}$(*)	72	1
33	log/10^x(*)	73	2
34	lnx/e^x(*)	74	3
35	$y^x/\sqrt[y]{}$(*)	75	+
41	STO/SUM(*)	81	R/S /RST(*)
42	π	82	0
43	(	83	•
44	)	84	+/−
45	÷	85	=

* if preceeded by code 31 [2nd]

ONE-YEAR WARRANTY

In case of breakdown or damage, please consult your local Texas Instruments relailer.

1. The terms and conditions set out hereinunder shall not apply where you have purchased this calculator directly from Texas Instruments Ltd. in which case the conditions of sale of Texas Instruments Ltd. shall apply.

2. This electronic calculator (including charger if applicable) from Texas Instruments is warranted to the original purchaser for a period of one (1) year from the original purchase date - under normal use and service - against defective materials or workmanship. For those calculators designed to incorporate batteries, this warranty does not cover damage resulting from any battery leakage. Batteries delivered with calculators are for demonstration purposes only.

   This warranty is void if : the calculator has been damaged by accident or unreasonable use, neglect, improper service or other causes not arising out of defects in material or workmanship.

   During the above one-year period, the calculator or its defective parts will be repaired, adjusted and/or replaced with a reconditioned model of equivalent quality, ("RECONDITIONED") at manufacturer's option without charge to the purchaser when the calculator is returned, by way of the dealer to Texas Instruments with proof-of-purchase date. UNITS RETURNED WITHOUT PROOF-OF-PURCHASE DATE WILL BE REPAIRED AT THE SERVICE RATES IN EFFECT AT THE TIME OF RETURN. In the event of replacement with a reconditioned model, the replacement unit will continue the warranty of the original calculator product or 90 days, whichever is longer.

   THIS CONDITION 2 SHALL NOT AFFECT THE STATUTORY RIGHTS OF A CONSUMER AS DEFINED IN THE CONSUMER TRANSACTIONS (RESTRICTIONS ON STATEMENTS) ORDER 1976 (AS AMENDED).

3. Save as expressly provided in Condition 2, Texas Instruments shall be under no liability of whatsoever kind, howsoever caused whether or not due to the negligence or wilful default of Texas Instruments or its servants or agents arising out of or in connection with this calculator provided that nothing contained in this condition 3 shall exclude or restrict :
   (I) Any liability of Texas Instruments for death or personal injury resulting from the negligence of Texas Instruments or its servants or agents; or
   (II) Any liability of Texas Instruments for loss or damage arising from this calculator proving defective while in consumer use (within the meaning of Sec. 5 (2) (A) Unfair Contract Terms Act. 1977) and resulting from the negligence of Texas Instruments or its servants or agents.

GB **In case of breakdown or damage, please consult your local Texas Instruments retailer.**

D Wenn das Gerät ausfällt oder beschädigt wird, wenden Sie sich bitte an Ihren Texas Instruments-Händler.

F **En cas de panne, veuillez vous adresser à votre revendeur Texas Instruments.**

I In caso di guasto, rivolgersi al proprio rivenditore Texas Instruments.

NL **Gelieve bij moeilijkheden uw wederverkoper te raadplegen.**

S Vid fel eller skada, var vänlig och kontakta din lokala Texas Instruments representant.

DK **Går kalkulatoren i stykker, så kontakt den lokale Texas Instruments forhandler.**

SF Jos laskin on vaurioitunut tai ei toimi ota yhteys paikalliseen Texas Instruments jälleenmyyjään tai suoraan maahantuojaan.

P **Em caso de avaria ou dano, queira por favor consultar o seu agente Texas Instruments.**

E En caso de rotura o avería, por favor consulte al distribuidor local Texas Instruments.

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