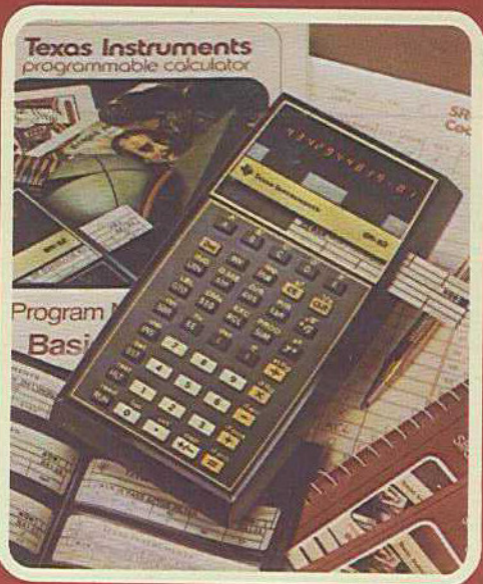


# Texas Instruments

programmable  
slide-rule calculator  
**SR-52**



OPERATING GUIDE



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This manual is designed to serve as a readily available reference which can be carried in the soft case for your calculator. The manual describes in a step-by-step fashion, all the basic operations performed by your calculator. Since this manual is just a guide, refer to your Owner's Manual for details.

## Battery Considerations

- **CAUTION:** Before recharging, check to make sure the battery pack is properly installed in the bottom of the calculator.
- Recharge the battery pack when the display flashes erratically or fades out.
- To prolong operating time before the next recharging, press **CLR** after desired answers have been displayed. Turn your calculator off when not in use.

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## Keyboard Operation

Most of your calculator's keys have dual functions. To execute a function shown on the key, press the desired key.

The first function is printed on the key and the second function is written above the key. To execute a second-function command, press **2nd**, then press the key immediately below the desired second function. For example, to find the natural logarithm of a number, simply press **lnx**. To find the common logarithm of a number, press **2nd** **lnx**. Since this key sequence is visually confusing, it will be shown as **2nd** **log**. First function operations, therefore, are indicated by **[ ]**. Second function operations are indicated by **2nd** **[ ]**. When **2nd** is pressed twice in succession, the calculator returns to the first-function operation.

## Error Indications

Flashing Display—Invalid Operation. Press **CE** to stop flashing display or **CLR** to clear display and internal processing registers. The display will flash for the following reasons:

1. Calculation result (in display or memories) outside the range of the calculator,  $\pm 1 \times 10^{-99}$  to  $\pm 9.999999999 \times 10^{99}$ .
2. Factorial of any number except a positive integer or zero.
3. Inverse of a trigonometric function with an invalid value for the argument, such as  $\sin^{-1} x$  with  $x$  greater than 1.
4. Square root of a negative number.
5. Logarithm of zero or a negative number.
6. Raising a negative number to any power or taking the root of a negative number (the  $y^x$  and  $\sqrt[y]{x}$  functions use the logarithmic routine which is undefined for negative numbers.)
7. Entering more than nine pending parentheses or ten pending operations.
8. Pressing functions keys in succession without entering an operand (Example: **+** **)** or **x** **=**.)
9. Error in reading a magnetic card.
10. Branching to an undefined label or address or to an address outside the range 000 through 223.
11. Writing on a protected card.

## Switches

**On/Off**—Located below display window in upper right corner of calculator. Slide to the right to turn calculator ON. Numbers in display indicate that power is ON. Press **CLR** before proceeding.

**D/R**—Slide to D if angle entered or calculated is to be expressed in degrees. Slide to R if it is to be expressed in radians.

## Data Entry

**Data Keys**— 0 — 9 , .

Enter numbers to a limit of a 10-digit mantissa and a 2-digit exponent. The first of a sequence of data keys will clear the display register before being entered in the right-most digit location. Additional numeric key entries cause the displayed numbers to shift left as the new digits are entered. Only the first decimal point entered in a number entry is effective. When not entered, the decimal point is assumed to be to the right of the least significant digit, which is the last number entered.

**Pi Key**— 2nd  $\pi$

Enters the value of pi ( $\pi$ ) to 12 significant digits (3.14159265359); display indicates value rounded off to 10 significant digits (3.141592654).

**Enter Exponent Key**— EE

The enter exponent key initializes the exponent in the display so that the next digit entered and the change sign key affect only the exponent of the displayed quantity. If INV is pressed before EE, the display is taken out of scientific notation if the absolute value of the display is less than  $10^{10}$  and greater than  $10^{-10}$ .

**Change Sign Key**— +/-




Instructs the calculator to change the sign of the number appearing in the display. When pressed after EE, changes the sign of the exponent.

## Data Control

### Clear Key—

The Clear key is used to clear the calculator. However, neither the contents of the data memories nor the contents of program memory are affected by this key.






### Clear Entry Key—

Clears last numeric entry made with    keys. Stops flashing display without affecting displayed number.

### Clear Memories Key—

Clears all 20 data memory registers ( $R_{00}$  through  $R_{19}$ ).

### Fixed Point Key—

The fixed point key, followed by a number from 0 to 8 sets a corresponding number of digits to be displayed after the decimal point. The right-hand digit is rounded up if the digit to the right of it is 5 or greater. The original number of digits is retained in the display register to maintain accuracy. Pressing   9 or    take the display out of fixed-point operation.

## Inverse Key— **INV**

The inverse key is used to find the inverse of the following keys:

### 1st function

lnx ( $e^x$ )  
sin ( $\sin^{-1}$ )  
cos ( $\cos^{-1}$ )  
tan ( $\tan^{-1}$ )  
SUM (subtract)  
EE (~~EE~~)

### 2nd function

log ( $10^x$ )  
D.MS (Dec. Deg.)  
D/R (R/D)  
P/R (R/P)  
PROD (divide)  
fix (floating)  
dsz (skip if not zero)  
st flg (reset flg)  
if flg (if flg not set)  
if err (if no err)  
if pos (if neg)  
if zro (if not zero)  
read (write)

An inverse instruction may be cancelled by pressing **INV** a second time if no other keys have been pressed.

When used in the calculate mode in conjunction with the second function key, the inverse key can be pressed before or after the second function key is pressed. In a program, the key sequence must be

**INV** **2nd**      or **2nd** **INV** **2nd**      .

## Parentheses Keys— ( )

The parentheses keys are used to alter the order of processing according to standard algebraic rules. Pressing  $\boxed{=}$  will supply all right parentheses which are missing in order to complete a calculation.

The mathematical hierarchy establishes the operational precedence of each calculator function. Your calculator uses algebraic logic and is capable of holding up to ten pending operations and numbers with up to nine pending parentheses. The normal order of processing, omitting parentheses or within parenthetical expressions, is as follows:

1. Powers and roots (excluding square and square root).
2. Multiplication and division.
3. Addition and subtraction.

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## Arithmetic Functions, Roots and Powers, Equals

### Powers and Roots Keys – $y^x$ , $\sqrt[y]{x}$

These functions first complete pending operations of like kind since the last  $($  and then instruct the calculator to hold the entered function as a pending operation. Note  $y \geq 0$ .

### Multiplication and Division Keys – $\times$ , $\div$

These functions first complete any pending  $y^x$   $\sqrt[y]{x}$  operations, then complete any  $\times$  or  $\div$  instruction since the last  $($ . Finally, they instruct the calculator to hold the entered function as a pending operation.

### Addition and Subtraction Keys – $+$ , $-$

These functions first complete any pending  $y^x$  ,  $\sqrt[y]{x}$  operations, then complete any pending  $\times$  ,  $\div$  instruction, then any pending  $+$  or  $-$  instruction since the last  $($ . Finally, they instruct the calculator to hold the entered function as a pending operation.

### Equals Key – $=$

Instructs the calculator to complete all pending operations according to hierarchy and parenthetical levels. Automatically inserts any missing  $)$  entries.

## Memory Functions

Each of the memory function keys with the exception of **CMs** must be followed by a 2-digit decimal number 00-19 to indicate which of the 20 memory registers is being affected. Memory register 00 ( $R_{00}$ ) must be reserved when using **P/R** or **dsz**. The keyboard includes the following memory keys.

### Store Key – **STO** nn

The store key is used to copy the displayed number in the specified memory.

### Recall Key – **RCL** nn

The recall key is used to recall the contents of the specified memory to the display.

### Sum-to-Memory Key – **SUM** nn

The sum-to-memory key is used to add the displayed quantity to the specified memory. When **INV SUM** nn is pressed, the displayed number is subtracted from the specified memory.



### Product-to-Memory Key – **2nd PROD** nn

The product-to-memory key is used to replace the contents of the specified memory register with its original contents multiplied by the contents of the display. The display remains unchanged. When **INV 2nd PROD** nn is pressed, the number of the specified memory is divided by the displayed number and the results are stored in the same memory.

**Exchange Key**—   nn

The exchange key is used to exchange the contents of the specified memory with the display.



## Special Functions

**Square Key**—  



Calculates the square of the number displayed.

**Square Root Key**—  

Calculates the square root of the number displayed.  
 $x \geq 0$ .

**Reciprocal Key**—  

Calculates the reciprocal of the number displayed.  
 $x \neq 0$ .

**Factorial Key**—  

Calculates the factorial of the number displayed,  
where  $0 \leq x \leq 69$ , and  $x$  is an integer.

## Logarithmic Functions

### Natural Logarithm Key— **lnx**

Calculates the natural logarithm (base  $e$ ) of the displayed number,  $x > 0$ . Pressing **INV** **lnx** instructs the calculator to find the value of  $e^x$ , where  $x$  is the displayed number.

### Common Logarithm Key— **2nd** **log**

Calculates the common logarithm (base 10) of the displayed number,  $x > 0$ . Pressing **INV** **2nd** **log** instructs the calculator to find the antilogarithm ( $10^x$ ) of the displayed number.

## Trigonometric Functions

Trigonometric and inverse trigonometric functions use the D/R switch mode selected when accepting an argument or returning a result. The domain of the inverse sine or cosine function is defined for  $-1 \leq y \leq 1$ .

### Sine Key— **sin**

Instructs the calculator to determine the sine of the displayed angle. Pressing **INV** **sin** instructs the calculator to interpret the displayed argument as the sine of an angle and to calculate the angle.

### Cosine Key— **cos**

Instructs the calculator to determine the cosine of the displayed angle. Pressing **INV** **cos** instructs the calculator to interpret the displayed argument as the cosine of an angle and to calculate the angle.

## **Tangent Key—** **[tan]**

Instructs the calculator to determine the tangent of the displayed angle. Pressing **[INV]** **[tan]** instructs the calculator to interpret the displayed argument as the tangent of an angle and to calculate the angle.

## **Conversions**

### **Degrees/Radians Key—** **[2nd]** **[D/R]**

The degrees/radians key instructs the calculator to interpret the displayed number as an angle expressed in decimal degrees and to convert it to radians. Pressing **[INV]** **[2nd]** **[D/R]** instructs the calculator to interpret the displayed number as an angle expressed in radians and to convert to degrees. Operation of the degrees/radians key **is not** dependent on the position of the D/R switch.

### **Degrees, Minutes, Seconds/Decimal Degrees Key—** **[2nd]** **[DMS]**

This key instructs the calculator to interpret the displayed number as an angle expressed in degrees, minutes and seconds and to convert it to its decimal equivalent. Pressing **[INV]** **[2nd]** **[DMS]** instructs the calculator to interpret the displayed number as an angle expressed in decimal degrees and to convert it to its degrees, minutes and seconds equivalent. The format for entering degrees, minutes and seconds is DD.MMSSss.

DD – Enter number of degrees.

• – Enter **[.]**.

MM – Enter two-digit minutes (00-97).

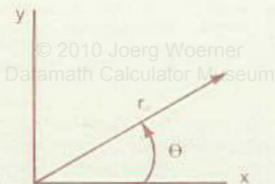
SSss – Enter two-digit seconds (00-97) and decimal fractions of seconds.

Unlike other functions, this conversion operates on only the displayed number. Any digits in the display register that are not displayed, are not used.

## Polar/Rectangular Key— **2nd** **P/R**

The polar-to-rectangular key is used in conjunction with memory register 00 ( $R_{00}$ ). To convert polar coordinates to rectangular coordinates, the magnitude  $r$  of the vector is stored in  $R_{00}$ , and the angle  $\theta$  is entered into the display. Set D/R switch to D when  $\theta$  is entered or desired in degrees, or set to R when working in radians. By pressing **2nd** **P/R** the rectangular conversion is made with the y coordinate in the display and the x coordinate stored in  $R_{00}$ .

To convert from rectangular to polar, the x coordinate is stored in  $R_{00}$  and the y coordinate is entered into the display. Pressing **INV** **2nd** **P/R** transforms the rectangular coordinates to polar form. The angle  $\theta$  appears in the display and the magnitude  $r$  is stored in  $R_{00}$ .



## Program Operation

When your calculator is in the learn mode, you can construct a program using any of the control, data entry, function and data memory keys described earlier and the program control and user-defined keys described in this section. Up to 224 key entries may be programmed in the learn mode. Note that the **2nd** key does not require program space, only the key following **2nd** takes program space.

### **Learn Key—** **LRN**

Pressing this key once puts the calculator in the learn mode of operation. This allows the user to begin writing a program into memory. The display is partitioned into two fields: a 3-digit program counter to the left and a 2-digit numeric key code to the right. A key code chart is located in the back of this manual to correlate keys to key codes and vice versa.

Pressing **LRN** again takes the calculator out of the learn mode and restores the display to its original state. The learn key may not be used as a label or stored in a program.

### **Run Key—** **RUN**

Instructs calculator to execute a program, beginning with present location of program counter.

### **Single Step Key—** **SST**

Causes the program counter to be incremented by one. In the learn mode, pressing this key causes the next storage location to be displayed. When not in the learn mode, pressing this key causes the program to be executed one step at a time. The single step key may not be used as a label or stored in a program.

### **Back Step Key—** **2nd** **bst**

In the learn mode, pressing this key causes the previous storage location to be displayed (program counter is decremented by one). The back step key may not be used as a label or stored in a program.

### Delete Key— **2nd** **DEL**

In the learn mode, pressing this key causes the instruction at the current location to be deleted and shifts all following instructions up one location. The delete key may not be used as a label or stored in a program.

### Insert Key— **INS**

In the learn mode, pressing this key causes the current instruction and all following instructions to be moved down one location and causes a zero instruction to be inserted at the current program location. If an instruction is in the program location (223) it is lost as a result of pressing this key.

### Reset Program Key— **2nd** **RST**

Instructs the calculator to reset the program counter, all user flags (0-4), and the subroutine return-pointer register to zero.

### Label Key — **2nd** **LBL**

While in the learn mode of operation, instructs the calculator to save the next pressed key as a non-executable label. Storing a label requires two program locations; one for **2nd** **LBL** and one for the key designator used as a label. The contents of the program counter are associated with the label in later branch operations. All **except** the following keys may be used as labels: **2nd** , **LRN** , **INS** , **2nd** **DEL** , **SST** , **2nd** **HST** , and **0** through **9** . Note that unidentified keys **2nd** **1** through **2nd** **9** , and **2nd** **INV** may also be used as labels.

A label may be used in a program in place of the 3-digit program address (yyy). A key designator may be used only once as a label in a given program.

**User Defined Keys** — **A** through **E** ,  
**2nd** **A** through **2nd** **E**

These keys instruct the calculator to perform a transfer to the subroutine associated with the key (when previously defined as a label) and automatically begin execution.

**Go To Key** — **GTO** yyy or Label

The go-to key followed by a 3-digit number or label causes the program counter to be set at the called address or label. If the go-to key is used to call a program manually from the keyboard, press **RUN** to execute program.

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**Subroutine Key** — **SBR** yyy or Label Museum

The subroutine key must be followed by a label or a 3-digit address indicating the subroutine the program is to execute next. The calculator is capable of two levels of subroutines. A return (rtn) instruction in a subroutine will automatically return the program to the program address immediately following **SBR** yyy or Label.

**Return Key** — **2nd** **rtn**

The return key stops execution of a subroutine and branches back to the instruction following the last subroutine branch. Program will halt on a return instruction if there is no address in the subroutine return-pointer register, or if the subroutine was called manually from the keyboard.

### **Halt Key—** HLT

The halt key stops the execution of a program.

### **Set Flag Key** 2nd st flg **z**

The set-flag key, followed by a 1-digit number (0-4) indicates which of the five available flags is to be set. The key sequence INV 2nd st flg **z** will reset the specified flag **z** to zero.

### **If Flag Key—** 2nd if flg **z yyy or Label**

The if-flag key must be followed by a 1-digit number to indicate which flag is to be tested. This must be followed by a 3-digit address or label which indicates where the program is to branch if the flag is set. The key sequence INV 2nd if flg **z yyy or Label** causes a branch if the flag is not set. In both cases, the branch address or label is ignored if the flag fails the appropriate test.

### **If Error Key—** 2nd if err **yyy or Label**

The if-error key must be followed by a 3-digit address or label indicating where the program is to branch if an error condition exists at the time of test. The key sequence INV 2nd if err **yyy or Label** causes the program to branch if an error condition does not exist.

### **If Positive Key—** 2nd if pos **yyy or Label**

The if-positive key must be followed by a 3-digit address or label indicating where the program is to branch if the display register is positive or zero. The key sequence INV 2nd if pos **yyy or Label** causes the program to branch if the display register is negative.

### If Zero Key – **2nd** **if zro** yyy or Label

The if-zero key must be followed by a 3-digit address or label indicating where the program is to branch if the display register is zero. The key sequence

**INV** **2nd** **if zro** yyy or Label causes the program to branch if the display register is not zero.

### Decrement and Skip on Zero Key – **2nd** **dsz** yyy or Label

This routine uses memory register 00 ( $R_{00}$ ). User sets up an integer quantity in Register 00 to be decremented to zero. Can be either a positive or negative integer.

The decrement routine will cause the register contents to converge on 0 from either side. The steps in the execution of **2nd** **dsz** yyy or Label are:

1. Decrement  $R_{00}$
2. Test for zero

If contents of  $R_{00} \neq 0$ , branch to yyy or Label.

If contents of  $R_{00} = 0$ , skip yyy or Label and execute next instruction.

If the instruction is **INV** **2nd** **dsz** yyy or Label, execution is the same except branch occurs if  $R_{00} = 0$ .

## Indirect Addressing Key— **2nd** **IND**

The indirect addressing key is used as a prefix to a branching or memory instruction to permit indirect addressing. The indirect addressing key may be used with any of the following functions:

### Memory

**STO** , **RCL** , **SUM** ,

**2nd** **EXC** , **2nd** **PROD**

### Program

**GTO** , **SBR** , **2nd** **if llg** , **2nd** **dsz**

**2nd** **if err** , **2nd** **if pos** , **2nd** **if zro**

When a program instruction is preceded with **2nd** **IND** , a 2-digit memory register number (00-19) must follow the program instruction in place of the normal yyy address or label.

The following examples illustrate some of the ways in which both memory-indirect and program-indirect addressing can be used. The first example uses memory-indirect addressing to add 25 to 15 in memory register 15 ( $R_{15}$ ).

| Enter | Press                               | Display | Comments  |
|-------|-------------------------------------|---------|---|
| 15    | <b>STO</b> 01                       | 15.     | 15 is stored in $R_{01}$ .                        |
|       | <b>2nd</b> <b>IND</b> <b>STO</b> 01 | 15.     | Stores 15 in $R_{15}$                             |
| 25    | <b>2nd</b> <b>IND</b> <b>SUM</b> 01 | 25.     | 25 is indirectly summed to contents of $R_{15}$ . |
|       | <b>2nd</b> <b>IND</b> <b>RCL</b> 01 | 40.     | Contents of $R_{15}$ are indirectly recalled.     |

This example illustrates how program-indirect addressing operates. Notice that in this type of indirect addressing, a location of program memory is addressed by storing it in one of the memory registers. Suppose 123 is stored in memory register 10 ( $R_{10}$ ), and the following program is entered.

| Key | Comments |
|-----|----------|
|-----|----------|

|     |                            |
|-----|----------------------------|
| :   |                            |
| 1   | } Subtract 1 from $R_{02}$ |
| INV |                            |
| SUM |                            |
| 0   |                            |
| 2   |                            |

|     |                   |
|-----|-------------------|
| RCL | } Recall $R_{02}$ |
| 0   |                   |
| 2   |                   |

|          |   |
|----------|---|
| * IND    | } Test displayed number to be $\geq 0$ .<br>If true, branch to program address<br>number (123) stored in $R_{10}$ |
| * If pos |   |
| 1        |   |
| 0        |   |

|     |                     |
|-----|---------------------|
| 1   | } Add 1 to $R_{10}$ |
| SUM |                     |
| 1   |                     |
| 0   |                     |

\* rtn

\*Indicates that key requires **2nd** prefix.

In summary, the program subtracts 1 from the contents of memory register 02 ( $R_{02}$ ) and tests to see if those contents are greater than or equal to zero. If this condition is true, the program branches to location 123 by finding the indirect address in  $R_{10}$ . Notice that if the condition is false, 1 is added to the contents of  $R_{10}$ .

## Optional Printing Unit Control

### List Key –

The list key instructs the calculator to engage the printer (when in the printing unit) and lists the stored program starting at the current program location.

### Print Key –


The print key instructs the printer to print the contents of the display.

### Paper Advance Key –

The paper advance key allows manually advancing the paper in the printer. It advances the paper one line per key stroke.

### Execution Trace

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A trace of instruction execution can be obtained with the optional printer by placing the TRACE switch on the printer in the ON position and stepping through the program using the  key. At each step, the numeric key code and the contents of the display will be printed. This feature is operative in the calculate and run modes.

## Read/Write Operations

**Read/Write Key—** CLR 2nd read (insert card **◀A▶**)

Instructs calculator to read the program data from side A of the card into program-memory locations 000 through 111. Repeating key sequence 2nd read and inserting opposite end (◀B▶) of card will read program data from side B of the card into program memory locations 112 through 223.

To write (store) the contents of program memory on a card, place black self-adhesive tabs over the write-protect windows at the tips of the arrows on the card. Key sequence CLR INV 2nd read (insert card ◀A▶) writes program-memory locations 000 through 111 on side A of the card. Repeating key sequence INV 2nd read and inserting the opposite end of the card (◀B▶) will write program-memory locations 112 through 223 on side B of the card. Remove tabs to prevent accidental recording.

Key sequences CLR 2nd read HLT 2nd read (insert card) or CLR INV 2nd read HLT INV 2nd read (insert card) will instruct the calculator to skip program-memory locations 000 through 111 and to read or write only program-memory locations 112 through 223.

Always read or write both sides of a card to prevent mixing incompatible programs. A flashing display indicates a read error. Repeat entire loading procedure when display flashes. The display is blanked during the actual read or write operations.

NOTE: Location of program counter does not affect the read or write operations.

## APPENDIX

### Conversion Factors

#### English to Metric

| To Find           | Multiply   | By                           |
|-------------------|------------|------------------------------|
| microns           | mils       | <b>25.4</b>                  |
| centimeters       | inches     | <b>2.54</b>                  |
| meters            | feet       | <b>0.3048</b>                |
| meters            | yards      | <b>0.9144</b>                |
| kilometers        | miles      | <b>1.609344</b>              |
| grams             | ounces     | 28.34952313                  |
| kilograms         | pounds     | <b>0.45359237</b>            |
| liters            | gallons    | <b>3.785411784</b>           |
| milliliters (cc)  | fl. ounces | 29.57352956                  |
| sq. centimeters   | sq. inches | <b>6.4516</b>                |
| sq. meters        | sq. feet   | <b>0.09290304</b>            |
| sq. meters        | sq. yards  | <b>0.83612736</b>            |
| milliliters (cc). | cu. inches | <b>16.387064</b>             |
| cu. meters        | cu. feet   | $2.831684659 \times 10^{-2}$ |
| cu. meters        | cu. yards  | 0.764554858                  |

#### Temperature Conversions

$$^{\circ}\text{F} = \frac{9}{5} (^{\circ}\text{C}) + 32$$

$$^{\circ}\text{C} = \frac{5}{9} (^{\circ}\text{F} - 32)$$

Boldface numbers are exact; others are given to ten significant figures.

## General

| To Find                      | Multiply                  | By                     |
|------------------------------|---------------------------|------------------------|
| atmospheres                  | feet of water @4°C        | $2.950 \times 10^{-2}$ |
| atmospheres                  | inches of mercury<br>@0°C | $3.342 \times 10^{-2}$ |
| atmospheres                  | pounds per sq inch        | $6.804 \times 10^{-2}$ |
| BTU                          | foot-pounds               | $1.285 \times 10^{-3}$ |
| BTU                          | joules                    | $9.480 \times 10^{-4}$ |
| cu ft                        | cords                     | <b>128</b>             |
| degree (angle)               | radians                   | 57.2958                |
| ergs                         | foot-pounds               | $1.356 \times 10^7$    |
| feet                         | miles                     | <b>5280</b>            |
| feet of water<br>@4°C        | atmosphere                | 33.90                  |
| foot-pounds                  | horsepower-hours          | $1.98 \times 10^6$     |
| foot-pounds                  | kilowatt-hours            | $2.656 \times 10^6$    |
| foot-pounds<br>per min       | horsepower                | $3.3 \times 10^4$      |
| horsepower                   | foot-pounds<br>per sec    | $1.818 \times 10^{-3}$ |
| inches of<br>mercury<br>@0°C | pounds per sq inch        | 2.036                  |
| joules                       | BTU                       | 1054.8                 |
| joules                       | foot-pounds               | 1.35582                |
| kilowatts                    | BTU per min               | $1.758 \times 10^{-2}$ |
| kilowatts                    | foot-pounds per min       | $2.26 \times 10^{-5}$  |
| kilowatts                    | horsepower                | .745712                |
| knots                        | miles per hour            | 0.86897624             |
| miles                        | feet                      | $1.894 \times 10^{-4}$ |
| nautical miles               | miles                     | 0.86897624             |
| radians                      | degrees                   | $1.745 \times 10^{-2}$ |
| sq. feet                     | acres                     | <b>43560</b>           |
| watts                        | BTU per min               | 17.5796                |

## Values of Fundamental Physical Constants

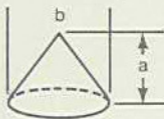
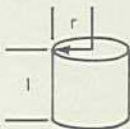
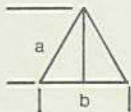
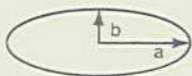
| Constant                                 | Symbol          | Value      | Units                                      |   |
|--|-----------------|------------|--|---|
|  |                 |            | mks  | cgs   |
| 1. Speed of Light                        | $c$             | 2.9979250  | $10^8 \text{ msec}^{-1}$                   | $10^{10} \text{ cmsec}^{-1}$                |
| 2. Electron Charge                       | $e$             | 1.6021917  | $10^{-19} \text{ C}$                       | $10^{-20} \text{ emu}$                      |
| 3. Avogadro Number                       | $N$             | 6.022169   | $10^{26} \text{ kmole}^{-1}$               | $10^{23} \text{ mole}^{-1}$                 |
| 4. Electron Rest Mass                    | $m_e$           | 9.109558   | $10^{-31} \text{ kg}$                      | $10^{-28} \text{ g}$                        |
|  | $m_e$           | 5.485930   | $10^{-4} \text{ amu}$                      | $10^{-4} \text{ amu}$                       |
| 5. Proton Rest Mass                      | $M_p$           | 1.672614   | $10^{-27} \text{ kg}$                      | $10^{-24} \text{ g}$                        |
|  | $M_p$           | 1.00727661 | amu  | amu   |
| 6. Neutron Rest Mass                     | $M_n$           | 1.674920   | $10^{-27} \text{ kg}$                      | $10^{-24} \text{ g}$                        |
|  | $M_n$           | 1.00866520 | amu  | amu   |
| 7. Atomic Mass Unit                      | amu             | 1.660531   | $10^{-27} \text{ kg}$                      | $10^{-24} \text{ g}$                        |
| 8. Ratio of proton to electron rest mass | $M_p/m_e$       | 1836.109   | —  | —   |
| 9. Electron Charge to Mass ratio         | $e/M_e$         | 1.7588028  | $10^{11} \text{ Ckg}^{-1}$                 | $10^7 \text{ emu g}^{-1}$                   |
| 10. Planck Constant                      | $h$             | 6.626196   | $10^{-34} \text{ J-sec}$                   | $10^{-27} \text{ erg-sec}$                  |
| 11. Rydberg Constant                     | $R_\infty$      | 1.09737312 | $10^7 \text{ m}^{-1}$                      | $10^5 \text{ cm}^{-1}$                      |
| 12. Gas Constant                         | $R_0$           | 8.31434    | $10^3 \text{ J-kmole}^{-1} \text{ K}^{-1}$ | $10^7 \text{ erg-mole}^{-1} \text{ K}^{-1}$ |
| 13. Boltzmann Constant                   | $k$             | 1.380622   | $10^{-23} \text{ JK}^{-1}$                 | $10^{-16} \text{ erg K}^{-1}$               |
| 14. Gravitational Constant               | $G$             | 6.6732     | $10^{-11} \text{ N-M}^2 \text{ kg}^{-2}$   | $10^{-8} \text{ dyn-cm}^2 \text{ g}^{-2}$   |
| 15. Electron Volt                        | $\text{eV}$     | 1.6021917  | $10^{-19} \text{ J}$                       | $10^{-12} \text{ erg}$                      |
| 16. Magnetic Flux Quantum                | $\Phi_0$        | 2.0678538  | $10^{-15} \text{ T-m}^2$                   | $10^{-7} \text{ G-cm}^2$                    |
| 17. Bohr Magneton                        | $\mu_B$         | 9.274096   | $10^{-24} \text{ JT}^{-1}$                 | $10^{-21} \text{ erg G}^{-1}$               |
| 18. Electron Magnetic Moment             | $\mu_e$         | 9.284851   | $10^{-24} \text{ JT}^{-1}$                 | $10^{-21} \text{ erg G}^{-1}$               |
| 19. Proton Magnetic Moment               | $\mu_p$         | 1.4106203  | $10^{-26} \text{ JT}^{-1}$                 | $10^{-23} \text{ erg G}^{-1}$               |
| 20. Compton Wavelength of the Electron   | $\lambda_c$     | 2.4263896  | $10^{-12} \text{ m}$                       | $10^{-10} \text{ cm}$                       |
| 21. Compton Wavelength of the Proton     | $\lambda_{c,p}$ | 1.3214409  | $10^{-15} \text{ m}$                       | $10^{-13} \text{ cm}$                       |
| 22. Compton Wavelength of the Neutron    | $\lambda_{c,n}$ | 1.3196217  | $10^{-15} \text{ m}$                       | $10^{-13} \text{ cm}$                       |
| 23. Faraday Constant                     | $F$             | 9.648670   | $10^7 \text{ Ckmole}^{-1}$                 | $10^3 \text{ emu mole}^{-1}$                |

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## Geometric Formulas



**Circumference:** Circle  $2\pi r$

**Area:** Circle  $\pi r^2$   
 Ellipse  $\pi ab$   
 Sphere  $4\pi r^2$   
 Cylinder  $2\pi r[r+l]$   
 Triangle  $\frac{1}{2}ab$

**Volume:** Ellipsoid of revolution  $\frac{4}{3}\pi b^2 a$   
 Sphere  $\frac{4}{3}\pi r^3$   
 Cylinder  $\pi r^2 l$   
 Cone  $\frac{\pi b^2 a}{3}$

**Analytical:** Circle  $\frac{x^2}{r^2} + \frac{y^2}{r^2} = 1$

Ellipse  $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$

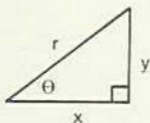
Hyperbola  $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$

Parabola  $y^2 = \pm 2px$

Line  $y = mx + b$

# Mathematical Expressions

## Trigonometric Relations



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

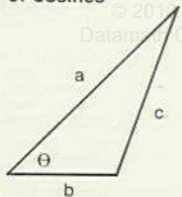
$$\cos \theta = \frac{x}{r}$$

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

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

$$e^{i\theta} = \cos \theta + i \sin \theta \quad i = \sqrt{-1}$$

## Law of Cosines



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

## Laws of Exponents

$$a^x \times a^y = a^{x+y}$$

$$\frac{1}{a^x} = a^{-x}$$

$$(ab)^x = a^x \times b^x$$

$$\frac{a^x}{a^y} = a^{x-y}$$

$$(a^x)^y = a^{xy}$$

$$a^0 = 1$$

## Laws of Logarithms

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

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

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

## Hyperbolic Functions

$$y = \sinh x = \frac{e^x - e^{-x}}{2}$$

$$y = \tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

$$y = \cosh x = \frac{e^x + e^{-x}}{2}$$

# Financial Equations

## Compounded Amounts

$$FV = PV (1 + i)^n$$

$$PV = FV (1 + i)^{-n}$$

$$n = \frac{\ln \left[ \frac{FV}{PV} \right]}{\ln (1 + i)}$$

$$i = \left[ \frac{FV}{PV} \right]^{1/n} - 1$$

where

FV = Future Value

PV = Present Value

n = number of periods

i = interest per period n expressed as a decimal

## Annuities

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$$FV = PMT \left[ \frac{((1 + i)^n - 1)}{i} \right]$$

$$PMT = FV \left[ \frac{i}{((1 + i)^n - 1)} \right]$$

$$n = \frac{\ln \left[ 1 + FV \left[ \frac{i}{PMT} \right] \right]}{\ln (1 + i)}$$

$$PV = PMT \left[ \frac{(1 - (1 + i)^{-n})}{i} \right]$$

$$n = \frac{-\ln \left[ 1 - PV \left[ \frac{i}{PMT} \right] \right]}{\ln (1 + i)}$$

$$PMT = PV \left[ \frac{i}{1 - (1 + i)^{-n}} \right]$$

where

FV = Future Value

PV = Present Value

n = number of periods

i = interest per period n expressed as a decimal

PMT = Payment per period n

## Statistical Functions

### Mean, Variance and Standard Deviation

$$\text{Mean} = \bar{X} = \frac{\sum_{i=1}^N x_i}{N}$$

$$\text{Variance} = \frac{\sum_{i=1}^N (x_i - \bar{X})^2}{N}$$

$$\text{S. Dev.} = \sqrt{\frac{\sum_{i=1}^N (x_i - \bar{X})^2}{N-1}}$$

## Linear Regression

$$y = mx + b$$

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

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

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

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

$\sigma_x^2$  = Variance of the x values

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

## Program Key Codes

| Key         | Key Code | Key         | Key Code | Key        | Key Code      | Key         | Key Code   | Key                  | Key Code |
|-------------|----------|-------------|----------|------------|---------------|-------------|------------|----------------------|----------|
| <b>A</b>    | 16       | <b>B</b>    | 17       | <b>C</b>   | 18            | <b>D</b>    | 19         | <b>E</b>             | 10       |
| <b>A</b>    | 11       | <b>B</b>    | 12       | <b>C</b>   | 13            | <b>D</b>    | 14         | <b>E</b>             | 15       |
| —           | —        | 27*         | log      | 28         | <b>x!</b>     | 29          | <b>1/x</b> | 20                   |          |
| <b>2nd</b>  | —        | <b>INV</b>  | 22       | <b>lnx</b> | 23            | <b>CE</b>   | 24         | <b>CLR</b>           | 25       |
| <b>IND</b>  | 36       | <b>D.MS</b> | 37       | <b>D/R</b> | 38            | <b>P/R</b>  | 39         | <b>√x</b>            | 30       |
| <b>LRN</b>  | —        | <b>sin</b>  | 32       | <b>cos</b> | 33            | <b>tan</b>  | 34         | <b>x√y</b>           | 35       |
| <b>LBL</b>  | 46       | <b>CMs</b>  | 47       | <b>EXC</b> | 48            | <b>PROD</b> | 49         | <b>x²</b>            | 40       |
| <b>GTO</b>  | 41       | <b>STO</b>  | 42       | <b>RCL</b> | 43            | <b>SUM</b>  | 44         | <b>y<sup>x</sup></b> | 45       |
| <b>rtn</b>  | 56       | <b>fix</b>  | 57       | <b>dsz</b> | 58            | <b>π</b>    | 59         | <b>st flg</b>        | 50       |
| <b>SBR</b>  | 51       | <b>EE</b>   | 52       | <b>(</b>   | 53            | <b>)</b>    | 54         | <b>÷</b>             | 55       |
| <b>del</b>  | —        | 67*         | 68*      | 69*        | <b>if flg</b> | 60          |            |                      |          |
| <b>INS</b>  | —        | <b>7</b>    | 07       | <b>8</b>   | 08            | <b>9</b>    | 09         | <b>X</b>             | 65       |
| <b>bst</b>  | —        | 77*         | 78*      | 79*        | <b>if err</b> | 70          |            |                      |          |
| <b>SST</b>  | —        | <b>4</b>    | 04       | <b>5</b>   | 05            | <b>6</b>    | 06         | <b>-</b>             | 75       |
| <b>rsat</b> | 86       | 87*         | 88*      | 89*        | <b>ll pos</b> | 80          |            |                      |          |
| <b>HLT</b>  | 81       | <b>1</b>    | 01       | <b>2</b>   | 02            | <b>3</b>    | 03         | <b>+</b>             | 85       |
| <b>read</b> | 96       | <b>list</b> | 97       | <b>prt</b> | 98            | <b>pap</b>  | 99         | <b>ll rro</b>        | 90       |
| <b>RUN</b>  | 91       | <b>0</b>    | 00       | <b>.</b>   | 93            | <b>+/-</b>  | 94         | <b>=</b>             | 95       |

—Key codes omitted for functions that cannot be stored in a program.

\*Second functions of unmarked keys that may be used as labels; however, first-function numeral keys **may not** be used as labels.

## Program Key Codes

| Key Code | Key       | Key Code | Key            | Key Code | Key        |
|----------|-----------|----------|----------------|----------|------------|
| 00       | 0         | 30       | 2nd $\sqrt{x}$ | 60       | 2nd if flg |
| 01       | 1         | 32       | sin            | 65       | X          |
| 02       | 2         | 33       | cos            | 67*      | 2nd 7      |
| 03       | 3         | 34       | tan            | 68*      | 2nd 8      |
| 04       | 4         | 35       | $x\sqrt{y}$    | 69*      | 2nd 9      |
| 05       | 5         | 36       | 2nd IND        | 70       | 2nd if err |
| 06       | 6         | 37       | 2nd D.MS       | 75       | —          |
| 07       | 7         | 38       | 2nd D/R        | 77*      | 2nd 4      |
| 08       | 8         | 39       | 2nd P/R        | 78*      | 2nd 5      |
| 09       | 9         | 40       | 2nd $x^y$      | 79*      | 2nd 6      |
| 10       | 2nd E     | 41       | GTO            | 80       | 2nd if pos |
| 11       | A         | 42       | STO            | 81       | HLT        |
| 12       | B         | 43       | RCL            | 85       | +          |
| 13       | C         | 44       | SUM            | 86       | 2nd rset   |
| 14       | D         | 45       | $y^x$          | 87*      | 2nd 1      |
| 15       | E         | 46       | 2nd LBL        | 88*      | 2nd 2      |
| 16       | 2nd A'    | 47       | 2nd CMs        | 89*      | 2nd 3      |
| 17       | 2nd B'    | 48       | 2nd EXC        | 90       | 2nd if zro |
| 18       | 2nd C'    | 49       | 2nd PROD       | 91       | RUN        |
| 19       | 2nd D'    | 50       | 2nd st flg     | 93       | .          |
| 20       | 2nd $1/x$ | 51       | SBR            | 94       | +/-        |
| 22       | INV       | 52       | EE             | 95       | =          |
| 23       | In x      | 53       | (              | 96       | 2nd read   |
| 24       | CE        | 54       | )              | 97       | 2nd list   |
| 25       | CLR       | 55       | $\div$         | 98       | 2nd prt    |
| 27*      | 2nd INV   | 56       | 2nd rtn        | 99       | 2nd pap    |
| 28       | 2nd log   | 57       | 2nd fix        |          |            |
| 29       | 2nd $x!$  | 58       | 2nd dsz        |          |            |
|          |           | 59       | 2nd $\pi$      |          |            |

\*Key codes which should only appear as labels.

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