TI Programmable 58/59

Master Library

Using the power of your *Solid State Software*™ module

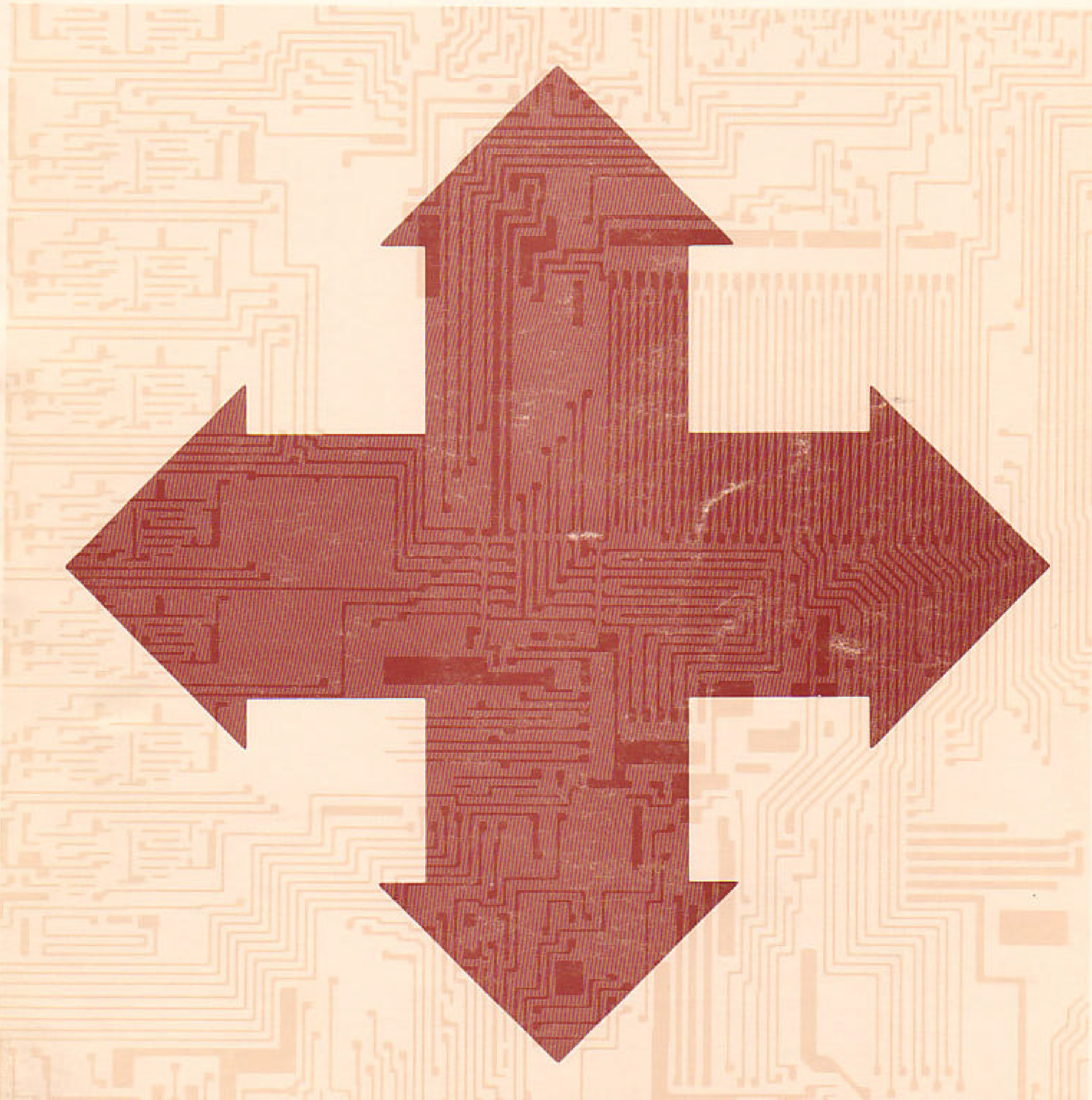


TABLE OF CONTENTS

INTRODUCTION

Your calculator contains a removable *Solid State Software** module which places a large library with a variety of programs at your fingertips the instant you turn the calculator on. Each *Solid State Software* module contains up to 5000 program steps. Within seconds, you can replace the Master Library Module with an optional module, ranging from Applied Statistics to Aviation, to tailor your calculator to solve a series of professional problems with minimal effort. Your *Solid State Software* library does not take up valuable memory space needed for your own programs. In fact, you can call a library program as a subroutine from a program of your own without interruption.

USING THIS MANUAL

After this brief introduction, you will find the description, user instructions, example problems and principal equations (when necessary) for each of the 25 programs in the Master Library. Each program is easily identified by the "ML" number in the upper corner of the page. This number corresponds with the call number you use to tell the calculator which program in the *Solid State Software* module you wish to use.

The primary reference point in this manual for each program is the User Instructions. These user instructions are also available for you in the handy pocket guide furnished with the library. The program description and sample problems should be used when you first run a program, to help you understand its full capabilities and limitations.

When using the *Solid State Software* programs as subroutines to your own programs, you will also want to check Register Contents for the program and check Program Reference Data provided in Appendix A.

RUNNING *SOLID STATE SOFTWARE* PROGRAMS

The Master Library contains a variety of useful programs. To help you get started in using the *Solid State Software* programs, follow through a couple of brief examples with us:

First of all, to eliminate any possibility of having any pending operations or previous results interferring with your current program, turn your calculator off for a couple of seconds, and back on again. This off/on sequence is the assumed starting point for each example problem in this manual. Now press the key sequence [2nd] [Pgm] [0] [1] [SBR] [=] to call and run the *"diagnostic"* program. Notice the display goes blank except for a faint "$\bar{[}$" at the far left which indicates that calculations are taking place. After about 15 seconds, "1." will appear in the display. This displayed number indicates that the Master Library Module is installed in the calculator and that the calculator and module are operating properly. If the display is flashing after the diagnostic, refer to "In Case of Difficulty" in the SERVICE INFORMATION Appendix of the Owner's Manual.

The diagnostic program is a highly specialized one that works internally to check the operation of your software library. Once you're sure things are working, you can continue with another program in the library.

Assume that you have a 6-inch by 8-inch rectangular surface and you need the equivalent dimensions and area in centimeters. Program ML-24 is the appropriate program for this conversion. Look through

*Trademark of Texas Instruments

the nonmagnetic black and gold label cards* and find card ML-24 titled UNIT CONVERSIONS(1). Insert this card in the window above the top row of keys on your calculator. You can now see that the inches to-centimeters (in → cm) conversion is performed by pressing the [A] key. Now to solve the problem:

ENTER	PRESS	DISPLAY	COMMENTS
	[CLR] [2nd] [Pgm] 24	0.	Calls program 24
6	[A]	15.24	Width in centimeters
	[×]	15.24	
8	[A]	20.32	Length in centimeters
	[=]	309.6768	Area in sq. centimeters

Any conversion in this program can be used in the same way by simply pressing the appropriate key as identified on the ML-24 label card. You can manually return the calculator to the main memory that may contain any of your personalized programs by pressing [RST] or [2nd] [Pgm] 00.

If you have the optional PC-100A printer**, a printed record of any problems solved may be obtained with only a few added steps. Most programs in the Master Library will not automatically print entries or results. This prevents unwanted printing when Library programs are used as subroutines in your own programs.) However, Program 01 contains a special print routine which causes each entry and result of a program to be printed.

Using the Calculator Mounting procedure in the PC-100A Owner's Manual, mount your calculator on the PC-100A. The switch called out in step 2 should be set to "OTHER" for your calculator. Always turn the calculator and printer off before mounting or unmounting the calculator. With the calculator properly installed on the printer, the power turned on and the TRACE button in the up position, rerun the conversion problem as follows:

ENTER	PRESS	DISPLAY	PRINT	COMMENTS
	[CLR] [2nd] [Pgm] 01	0.		Call program 01
	24 [STO] 00	24.		Tell print routine to call Program 24
6	[A]	6.	6.	Width in inches
		15.24	15.24	Width in centimeters
	[×]	15.24		
8	[A]	8.	8.	Length in inches
		20.32	20.32	Length in centimeters
	[=]	309.6768		
	[2nd] [Prt]	309.6768	309.6768	Area in sq. centimeters

Note that the automatic print routine is only functional when the user-defined keys are used, but you can manually print any final result by using the [2nd] [Prt] key sequence on the calculator, or the PRINT key on the printer.

*The cards are supplied in a prepunched sheet. Carefully remove the individual cards from the sheet and insert them in the card carrying case for convenient storage.

**Note: The TI Programmable 58 and TI Programmable 59 will not operate on the PC-100 print cradle.

Before you begin using the *Solid State Software* programs on your own, here are a few things to keep clearly in mind until you become familiar with your calculator.

1. Press CLR before running a program if you are not sure of the status of the calculator. (To be completely sure of calculator status, turn it off and on again – but remember that this will clear the program memory.)

2. Some programs will leave the calculator in fix-decimal format (See Appendix A). In that event, you should press INV 2nd Fix before running another program.

3. There is no visual indication of which *Solid State Software* program has been called. If you have any doubts, the safest method is to call the desired program with 2nd Pgm mm, where mm is the two-digit program number. The calculator will remain at this program number until another program is called, RST is pressed or the calculator is turned off.

4. A flashing display normally indicates an improper key sequence or that a numerical limit has been exceeded. When this occurs, always repeat the program sequence and check that each step is performed as directed by the User Instructions. Any unusual limits of a program are given in the User Instructions or related notes. The In Case of Difficulty portion of Appendix A in the Owner's Manual may be helpful in isolating a problem.

5. Some of the *Solid State Software* programs may run for several minutes depending on input data. If you desire to halt a running program, press the RST key. This is considered as an emergency halt operation which returns control to the main memory. A program must be recalled to be run again.

USING *SOLID STATE SOFTWARE* PROGRAMS AS SUBROUTINES

Any of the *Solid State Software* programs may be called as a subroutine to your own program in the main memory. Either of two program sequences may be used: 1) 2nd Pgm mm (User Defined Key) or 2) 2nd Pgm mm SBR (Common Label). Both will send the program control to program mm, run the subroutine sequence, and then automatically return to the main program without interruption. Following 2nd Pgm mm with anything other than SBR or a user-defined key is not a valid key sequence and can cause unwanted results.

It is very important to consider the Program Reference Data in Appendix A for any program called as a subroutine. You must plan and write your own program such that the data registers, flags, subroutine levels, parentheses levels, T-register, angular mode, etc., used by the called subroutine are allowed for in your program. In addition, a Register Contents section of each program description provides a guide to determine where data is or must be located to run the program.

A sample program that calls a *Solid State Software* program as a subroutine is provided in the PROGRAMMING CONSIDERATIONS section of the Owner's Manual.

If you need to examine and study the content of a *Solid State Software* program, you can download as described in the following paragraph.

INTRODUCTION

DOWNLOADING *SOLID STATE SOFTWARE* PROGRAMS

If you need to examine a *Solid State Software* program, it can be downloaded into the main program memory.* This will allow you to single step through a program in or out of the learn mode. It also allows using the program list or trace features of the optional printer. The only requirement for downloading a *Solid State Software* program is that the memory partition be set so there is sufficient space in the main program memory to receive the downloaded program. The key sequence to download a program is [2nd] [Pgm] mm [2nd] [Op] 09, where mm is the program number to be downloaded. This procedure places the requested program into program memory beginning at program location 000. The downloaded program writes over any instructions previously stored in that part of program memory. Remember to press [RST] before running or tracing the downloaded program.

Please note that ML-02 and ML-19 cannot be downloaded in the TI Programmable 58 due to the length of these programs. Also, the partition must be reset from the power-up condition in the TI Programmable 58 for programs ML-03 and ML-06. The key sequence to repartition the main memory for these programs is 2 [2nd] [Op] 17 which must be performed before the downloading sequence.

The partition must be changed from the power-up condition in the TI Programmable 59 for the ML-02 and ML-19 programs. The key sequence to repartition the main memory for ML-02 is [CLR] [2nd] [Op] 17. Since this partition does not leave any data registers, ML-02 cannot be run when in the main memory. The key sequence to repartition for ML-19 is 4 [2nd] [Op] 17.

REMOVING AND INSTALLING MODULES

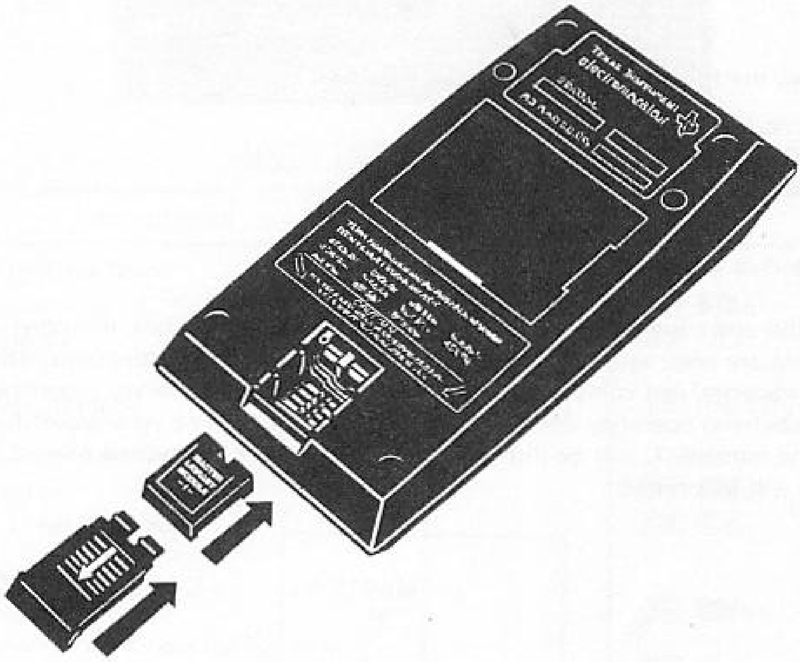
The Master Library module is installed in the calculator at the factory, but can easily be removed or replaced with another. It is a good idea to leave the module in place in the calculator except when replacing it with another module. Be sure to follow these instructions when you need to remove or replace a module.

CAUTION

Be sure to touch some metal object before handling a module to prevent possible damage by static electricity.

1. **Turn the calculator OFF.** Loading or unloading the module with the calculator ON may cause the keyboard or display to lock out. Also, shorting the contacts can damage the module or calculator.
2. Slide out the small panel covering the module compartment at the bottom of the back of the calculator. (See Diagram below).
3. Remove the module. You may turn the calculator over and let the module fall out into your hand.
4. Insert the module, notched end first with the labeled side up into the compartment. The module should slip into place effortlessly.
5. Replace the cover panel, securing the module against the contacts.

*Unless the library is a protected, special-purpose library.



Don't touch the contacts inside the module compartment as damage can result.

MASTER LIBRARY DIAGNOSTIC

This program performs the following functions separately.

1. Diagnostic/Library Module Check
2. Linear Regression Initialization
3. Print Routine

Diagnostic/Library Module Check

This routine checks the operation of your calculator and most of its functions, including conversion and statistics functions that are preprogrammed in the calculator, trigonometric functions, data register operations, program transfers, and comparisons. It also uses other master library programs to verify that the module is connected and operating correctly. If this diagnostic routine runs successfully, in approximately 15 seconds the numeral 1. will be displayed. If the calculator is attached to a PC-100A print cradle, the following will be printed:

```
MASTER
    1.
```

If there is a malfunction in the calculator or the *Solid State Software* module, a flashing number will be displayed. Refer to Appendix A of the Owner's Manual for an explanation of the various procedures to be followed when you have difficulties.

When you simply want to know which of your *Solid State Software* modules is in the calculator without physically looking at it, you can call the Library Module check portion of the routine directly. If the Master Library Module is in the calculator, the number 1. will be displayed. This number is unique to the Master Library (other optional libraries use other identifying digits).

Linear Regression Initialization

This routine initializes the calculator for linear regression by clearing data registers R_{01} through R_{06} and the T-register. It should be used whenever linear regression or other built-in statistics functions are to be started. You can also use the routine at any time to clear these registers selectively without disturbing any other registers.

Print Routine

This routine provides automatic printing of the input and output numbers associated with the user-defined keys for the Master Library programs or any program in the calculator's program memory. That is, whenever you press any of the user-defined keys, the number in the display at that time and the number appearing in the display after the calculation are automatically printed on the PC-100A if it is connected. To assist you in understanding operation of this routine with the various programs, printer results are shown with each of the example problems in this manual.

Solid State Software TI ©1977

MASTER LIBRARY DIAGNOSTIC ML-01

DIAGNOSTIC: SBR =

L.R. INIT: SBR CLR PRINT: mm STO 00

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	Diagnostic/Module Check			
A1	Select Program		2nd Pgm 01	
A2	Run Diagnostic		SBR =	1.[1]
	or			
A3	Library Module Check		SBR 2nd R/S	1.[2]
	Initialize Linear Regression			
B1	Select Program		2nd Pgm 01	
B2	Initialize Linear Regression		SBR CLR	0.
	Print Routine			
C1	Select Program		2nd Pgm 01	
C2	Set calculator to print input and output for user-defined keys of program numbered mm[3].	mm	STO 00	mm
	Now the User Instructions for that program can be followed except that the program need not be called.			

NOTES:

1. This output is obtained if the calculator is operating properly.
2. The number 1 indicates the Master Library.
3. The Master Library programs are numbered 1 through 25. Program number 0 is the calculator's program memory. Do not use print routine with program ML-02, ML-03, ML-07, or ML-10.

Example 1: Diagnostic

PRESS	DISPLAY	OPTIONAL PRINTOUT
[2nd] [Pgm] 01		
[SBR] [=]	1.	MASTER
		1.

Example 2: Library Module Check

PRESS	DISPLAY	OPTIONAL PRINTOUT
[2nd] [Pgm] 01		
[SBR] [2nd] [R/S]	1.	MASTER
		1.

Example 3: Initialize Linear Regression

PRESS	DISPLAY
[2nd] [Pgm] 01	
[SBR] [CLR]	0.

Example 4: Print Routine

Use the print routine with program ML-16, COMBINATIONS, PERMUTATIONS AND FACTORIALS. Find the factorial of 5.

ENTER	PRESS	DISPLAY	PRINT
	[2nd] [Pgm] 01		
16	[STO] 00	16.	
5	[A]	5.	5.
			5.
	[C]		5.
			120.

Register Contents

R_{00}	mm	R_{05}	L.R. Init	R_{10}		R_{15}	
R_{01}	L.R. Init	R_{06}	L.R. Init	R_{11}		R_{16}	
R_{02}	L.R. Init	R_{07}		R_{12}		R_{17}	
R_{03}	L.R. Init	R_{08}		R_{13}		R_{18}	
R_{04}	L.R. Init	R_{09}	Used	R_{14}		R_{19}	

MATRIX INVERSION, DETERMINANTS AND SIMULTANEOUS EQUATIONS

Three operations are performed by this program:

1. Evaluation of the Determinant
2. Matrix Inversion
3. Solution of Linear Simultaneous Equations

First, the determinant, $|A|$, of an n x n matrix A may be evaluated. Then, if the determinant is not zero the inverse of the matrix, A^{-1}, can be found. Also, a system of n linear equations with n unknowns may be solved, provided the determinant of the coefficient matrix is not zero.

An n X n matrix may be described by the following notation:

$$\text{Matrix } A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

The maximum size of the matrix that can be handled depends on the number of data registers available as shown in the following table.

Highest Data Register Required

Matrix Size	Determinant or Inverse	Simultaneous Equations
2 X 2	13	15
3 X 3	19	22
4 X 4	27	31
5 X 5	37	42
6 X 6	49	55
7 X 7	63	70
8 X 8	79	87
9 X 9	97	–

Note: When the calculator is turned on, the number of data registers is automatically set to 30 (R_{00}–R_{29}) for the TI Programmable 58 and 60 (R_{00}–R_{59}) for the TI Programmable 59. The calculator may be repartitioned to allocate a different portion of its memory area to data. This is done in groups of ten data registers using the key sequence R [2nd] [Op] 17 where R is the number of groups of ten data registers. The maximum value of R is 6 (R_{00}–R_{59}) for the TI Programmable 58 and 10 (R_{00}–R_{99}) for the TI Programmable 59. Be sure the partitioning is properly set before attempting to use the program.

Solid State Software				TI ©1977
DETERMINANT, MATRIX, & SIMUL. EQ.				ML-02
$i;\to x_i$	$\to A^{-1}$	$j;\to a_{ij}^{-1}$		$\to \lvert A \rvert, A^{-1}$
n	$j;a_{ij}$	$\to \lvert A \rvert$	$i;b_i$	$\to x$

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 02	
2	Enter order of matrix	n	A	n*
3	Enter elements of matrix A by columns starting with column 1. (To correct an entry in column j, simply enter j and press B. Then reenter the entire column using the R/S key)	1	B	1.
		a_{11}	R/S	a_{11}*
		a_{21}	R/S	a_{21}*
		⋮	⋮	⋮
		a_{n1}	R/S	a_{n1}*
		a_{12}	R/S	a_{12}*
		a_{22}	R/S	a_{22}*
		⋮	⋮	⋮
		a_{nn}	R/S	a_{nn}*
4	Calculate determinant		C	$\lvert A \rvert$*
	If $\lvert A \rvert \neq 0$: Solve Ax = b **(Perform Steps 1-4 first)**			
5	Enter elements of column vector b starting with b_1. (To correct an entry error for b_i, simply enter i and press D. Then reenter b_i using the R/S key.)	1	D	1.
		b_1	R/S	b_1*
		⋮	⋮	⋮
		b_n	R/S	b_n*
6	Calculate x		CLR E	1.
7	Display the elements of x, starting with x_1	1	2nd A'	1.
			R/S	x_1*
			⋮	⋮
			R/S	x_n*
8	To display x_i only	i	2nd A'	i
			R/S	x_i*
	To solve the system for a new vector b′, repeat Steps 5-8 only.			
	If $\lvert A \rvert \neq 0$: Find A^{-1} **(Perform Steps 1-4 first)**			
9	Calculate A^{-1}		CLR 2nd B'	1.
10	Display the elements of A^{-1} by columns starting with column 1: (To display the elements of A^{-1} starting with column j, enter j before pressing 2nd C'). Due to pivoting, A^{-1} may be stored with its columns permuted even though it is displayed in the correct order. Therefore, A^{-1} must be reentered for use in subsequent calculations. Note: A is lost once A^{-1} is calculated.	1	2nd C'	1.
			R/S	a_{11}^{-1}*
			R/S	a_{21}^{-1}*
			⋮	⋮
			R/S	a_{n1}^{-1}*
			R/S	a_{12}^{-1}*
			⋮	⋮
			R/S	a_{nn}^{-1}*
11	To compute $\lvert A \rvert$ and A^{-1} simultaneously, perform Steps 1-3, then perform this step and continue with Step 10 to display A^{-1} if $\lvert A \rvert \neq 0$.		2nd E'	$\lvert A \rvert$*

*These values are automatically printed when the PC-100A Print Cradle is connected.

NOTES:

1. Because of round-off error, this program may not give exact answers for |A|. For example, $\begin{vmatrix} 3 & -2 \\ -9 & 6 \end{vmatrix}$ is evaluated as -9×10^{-12} instead of zero.
2. The inverse of a 3 X 3 matrix is found in approximately 1 minute while a 9 X 9 requires about 12 minutes for computation.
3. This program includes its own print commands and therefore should not be used with the print routine of program ML-01.

Register Contents

R_{00}		R_{05}	Counter	R_{10}		R_{15}
R_{01}	Pointer	R_{06}	Determinant	R_{11}		R_{16}
R_{02}	Pointer	R_{07}	n	R_{12}		R_{17}
R_{03}	Pointer	R_{08}	See note	R_{13}		R_{18}
R_{04}	Counter	R_{09}		R_{14}		R_{19}

Note: R_{08} through R_{n^2+n+7} are used for determinant and inverse matrix; R_{08} through R_{n^2+2n+7} are used for simultaneous equations, where n is the order of the matrix.

Example: Compute the determinant of A where $A = \begin{pmatrix} 4 & 8 & 0 \\ 8 & 8 & 8 \\ 2 & 0 & 1 \end{pmatrix}$. Then, solve Ax = b and Ax′ = b′ where $b = \begin{pmatrix} 4 \\ 4 \\ 6 \end{pmatrix}$ and $b' = \begin{pmatrix} 12 \\ 32 \\ 4 \end{pmatrix}$. Finally, compute A^{-1}.

ENTER	PRESS	DISPLAY	COMMENTS	PRINTOUT*
	2nd Pgm 02		Select program	
3	A	3.	n	3.
1	B	1.	Start with column 1	
4	R/S	4.	a_{11}	4.
8	R/S	8.	a_{21}	8.
2	R/S	2.	a_{31}	2.
8	R/S	8.	a_{12}	8.
8	R/S	8.	a_{22}	8.
0	R/S	0.	a_{32}	0.
0	R/S	0.	a_{13}	0.
8	R/S	8.	a_{23}	8.
1	R/S	1.	a_{33}	1.
	C	96.	$\lvert A \rvert$	96.
1	D	1.	Start with b_1	
4	R/S	4.	b_1	4.
4	R/S	4.	b_2	4.
6	R/S	6.	b_3	6.
	CLR E	1.	Calculate x	
1	2nd A′	1.	Start with x_1	
	R/S	4.	x_1	4.
	R/S	−1.5	x_2	−1.5
	R/S	−2.	x_3	−2.
1	D	1.	Start with b_1'	
12	R/S	12.	b_1'	12.
32	R/S	32.	b_2'	32.
4	R/S	4.	b_3'	4.
	CLR E	1.	Calculate x′	
1	2nd A′	1.	Start with x_1'	
	R/S	1.	x_1'	1.
	R/S	1.	x_2'	1.
	R/S	2.	x_3'	2.
	CLR 2nd B′	1.	Calculate A^{-1}	
1	2nd C′	1.	Start with column 1	
	R/S	.0833333333	a_{11}^{-1}	.0833333333
	R/S	.0833333333	a_{21}^{-1}	.0833333333
	R/S	−.1666666667	a_{31}^{-1}	−.1666666667
	R/S	−.0833333333	a_{12}^{-1}	−.0833333333
	R/S	.0416666667	a_{22}^{-1}	.0416666667
	R/S	.1666666667	a_{32}^{-1}	.1666666667
	R/S	.6666666667	a_{13}^{-1}	.6666666667
	R/S	−.3333333333	a_{23}^{-1}	−.3333333333
	R/S	−.3333333333	a_{33}^{-1}	−.3333333333

*This printout is automatic when the calculator is connected to the PC-100A Print Cradle.

Method Used

The lower upper (LU) decomposition method is used in the calculations. The LU decomposition method is described by the following equations. If $|A| \neq 0$, then $A = LU$ where L is a lower triangular matrix and U is an upper triangular matrix. $U(u_{ij})$ and $L(l_{ij})$ are calculated using the following equations ($l_{kk} = 1$):

$$u_{kj} = a_{kj} - \sum_{p=1}^{k-1} l_{kp} u_{pj} \qquad j = (k, k+1, \cdots, n)$$

$$l_{ik} = \frac{a_{ik} - \sum_{p=1}^{k-1} l_{ip} u_{pk}}{u_{kk}} \qquad i = (k+1, \cdots, n)$$

The determinant of A is found as the product of the diagonal elements of U and the inverse of A is calculated as:

$$A^{-1} = (LU)^{-1} = U^{-1} L^{-1}$$

To complete this equation, if $L^{-1} = Y$ and $U^{-1} = Z$, then $\delta_{ij} = 0$ for $i \neq j$; 1 for $i = j$:

$$y_{ij} = \frac{\delta_{ij} - \sum_{k=j}^{i=1} l_{ik} y_{kj}}{l_{ii}} \qquad i = (j, j+1, \cdots, n)$$

$$z_{ij} = \frac{\delta_{ij} - \sum_{k=i+1}^{j} u_{ik} z_{kj}}{u_{ii}} \qquad i = (j, j-1, \cdots, 1)$$

If b is an n X 1 column vector, then the system $Ax = b$ is solved using the following procedure.

First, $Ly = b$ is solved for y where

$$y_{ij} = \frac{b_i - \sum_{k=1}^{i-1} l_{ik} x_k}{l_{ii}} \qquad i = (1, 2, \cdots, n)$$

Then $Ux = y$ is evaluated by

$$x_{ij} = \frac{b_i - \sum_{k=i+1}^{n} u_{ik} x_k}{u_{ii}} \qquad i = (n, n-1, \cdots, 1)$$

Partial pivoting is performed to improve accuracy.

Reference: *Numerical Methods*, Germund Dahlquist and Ake Bjork, Prentice Hall, 1974.

MATRIX ADDITION AND MULTIPLICATION

Given two m X n matrices A and B and two numbers λ_1 and λ_2, the equation $\lambda_1 A + \lambda_2 B = C$ may be evaluated by this program. The resulting matrix C replaces matrix A in calculator memory.

$$\lambda_1 \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \cdots & \cdots & \cdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} + \lambda_2 \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \cdots & \cdots & \cdots \\ b_{m1} & \cdots & b_{mn} \end{pmatrix} = \begin{pmatrix} c_{11} & \cdots & c_{1n} \\ \cdots & \cdots & \cdots \\ c_{m1} & \cdots & c_{mn} \end{pmatrix}$$

This program may also be used to compute the product AB where A is an m X n matrix and B is an n X p matrix.

$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \cdots & \cdots & \cdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \begin{pmatrix} b_{11} & \cdots & b_{1p} \\ \cdots & \cdots & \cdots \\ b_{n1} & \cdots & b_{np} \end{pmatrix} = \begin{pmatrix} c_{11} & \cdots & c_{1p} \\ \cdots & \cdots & \cdots \\ c_{m1} & \cdots & c_{mp} \end{pmatrix}$$

In matrix multiplication the resulting matrix is computed one column at a time. The procedure requires that matrix A be entered first. Then the first column of matrix B is entered and the first column of matrix C is calculated. The next step is to enter the second column of matrix B to allow computation of the second column of matrix C. This is continued for all columns of the matrix. Matrix A is not disturbed by matrix multiplication.

Data registers $R_1 - R_{(2mn+7)}$ must be available for matrix addition. Matrix multiplication requires registers $R_1 - R_{(mn+n+7)}$. Repartitioning of the memory may be required to provide the needed data registers (See Program ML-02).

Solid State Software			TI ©1977	
MATRIX ADDITION AND MULTIPLICATION				ML-03
$j; c_{ij}$	$i; x_i$	$\rightarrow Ax$	$i; \rightarrow y_i$	
m,n	$j; a_{ij}$	$j; b_{ij}$	λ_1, λ_2	$\lambda_1 A + \lambda_2 B$

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 03	
2a	Enter number of rows in A	m	A	m*
2b	Enter number of columns in A (Steps 2a and 2b must be performed in sequence)	n	A	n*
3	Enter the elements of matrix A starting with column 1. (To correct an entry error in column j, simply enter j and press B. Then reenter the entire column using the R/S key)	1 a_{11} a_{21} ⋮ a_{m1} a_{12} a_{22} ⋮ a_{mn}	B R/S R/S ⋮ R/S R/S R/S ⋮ R/S	1. a_{11}* a_{21}* ⋮ a_{m1}* a_{12}* a_{22}* ⋮ a_{mn}*

*These values are printed automatically if the PC-100A is connected.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	For Matrix Addition:			
4	First Then enter the elements of matrix B using the [R/S] key as in Step 3. (To correct an entry error in column j, simply enter j and press [C]. Then reenter the entire column using the [R/S] key.	1	[C]	1.
5a	Enter λ_1	λ_1	[D]	λ_1*
5b	Enter λ_2 (Steps 5a and 5b must be performed in sequence. These steps are required even if $\lambda_1 = 1$ and/or $\lambda_2 = 1$)	λ_2	[D]	λ_2*
6	Calculate $C = \lambda_1 A + \lambda_2 B$		[CLR] [E]	1.
7	Display the elements of C starting with column 1: To display the elements of C starting with column j, enter j before pressing [2nd] [A']. (To use C as the new A, repeat Steps 4-7. For a new case go to Step 2.	1	[2nd] [A'] [R/S] [R/S] ⋮ [R/S] [R/S] [R/S] ⋮ [R/S]	1. c_{11}* c_{21}* ⋮ c_{m1}* c_{12}* c_{22}* ⋮ c_{mn}*
	For Matrix Multiplication (Perform Steps 1-3 first)			
8	Enter the elements of column j of matrix B starting with b_{1j}. (To correct an entry error for b_{ij}, enter i, press [2nd] [B'] and reenter b_{ij} using the [R/S] key.)	1 b_{1j} ⋮ b_{nj}	[2nd] [B'] [R/S] ⋮ [R/S]	1. b_{1j}* ⋮ b_{nj}*
9	Calculate column j of matrix C		[2nd] [C']	1.
10	Display the elements of column j of matrix C, starting with c_{1j}	1	[2nd] [D'] [R/S] ⋮ [R/S]	1. c_{1j}* ⋮ c_{mj}*
11	To display c_{ij} only	i	[2nd] [D'] [R/S]	i c_{ij}*
12	To compute AB = C, repeat Steps 8-10 for j = 1 to j = p			

NOTE: 1. This program includes its own print commands and should not be used with program ML-01.

*These values are printed automatically if the PC-100A is connected.

Example: Find A − 2B = C and (A − 2B)D = CD = E where:

$$A = \begin{pmatrix} 2 & 3 & 0 \\ 1 & 0 & 5 \end{pmatrix}, \qquad B = \begin{pmatrix} 4 & 0 & -1 \\ 3 & 2 & 6 \end{pmatrix}, \qquad D = \begin{pmatrix} 3 & 1 \\ 0 & 2 \\ 4 & 3 \end{pmatrix}.$$

ENTER	PRESS	DISPLAY	COMMENTS	PRINTOUT*
	[2nd] [Pgm] 03		Select program	
2	[A]	2.	m	2.
3	[A]	3.	n	3.
1	[B]	1.	Start with Column 1	
2	[R/S]	2.	a_{11}	2.
1	[R/S]	1.	a_{21}	1.
3	[R/S]	3.	a_{12}	3.
0	[R/S]	0.	a_{22}	0.
0	[R/S]	0.	a_{13}	0.
5	[R/S]	5.	a_{23}	5.
1	[C]	1.	Start with column 1	
4	[R/S]	4.	b_{11}	4.
3	[R/S]	3.	b_{21}	3.
0	[R/S]	0.	b_{12}	0.
2	[R/S]	2.	b_{22}	2.
1	[+/−] [R/S]	−1.	b_{13}	−1.
6	[R/S]	6.	b_{23}	6.
1	[D]	1.	λ_1	1.
2	[+/−] [D]	−2.	λ_2	−2.
	[CLR] [E]	1.	Compute A − 2B	
1	[2nd] [A']	1.	Start with column 1	
	[R/S]	−6.	c_{11}	−6.
	[R/S]	−5.	c_{21}	−5.
	[R/S]	3.	c_{12}	3.
	[R/S]	−4.	c_{22}	−4.
	[R/S]	2.	c_{13}	2.
	[R/S]	−7.	c_{23}	−7.
1	[2nd] [B']	1.	Start with d_{11}	
3	[R/S]	3.	d_{11}	3.
0	[R/S]	0.	d_{21}	0.
4	[R/S]	4.	d_{31}	4.
	[2nd] [C']	1.	Compute column 1 of E	
1	[2nd] [D']	1.	Start with e_{11}	
	[R/S]	−10.	e_{11}	−10.
	[R/S]	−43.	e_{21}	−43.
1	[2nd] [B']	1.	Start with d_{12}	
1	[R/S]	1.	d_{12}	1.
2	[R/S]	2.	d_{22}	2.
3	[R/S]	3.	d_{32}	3.
	[2nd] [C']	1.	Compute column 2 of E	
1	[2nd] [D']	1.	Start with e_{12}	
	[R/S]	6.	e_{12}	6.
	[R/S]	−34.	e_{22}	−34.

*This printout is automatic if the calculator is connected to the PC-100A Print Cradle.

Register Contents

R_{00}		R_{05}	λ_1	R_{10}		R_{15}	
R_{01}	Pointer	R_{06}	λ_2	R_{11}		R_{16}	
R_{02}	Pointer	R_{07}	Pointer	R_{12}		R_{17}	
R_{03}	m	R_{08}	See note	R_{13}		R_{18}	
R_{04}	n	R_{09}		R_{14}		R_{19}	

Note: For addition and subtraction R_{08} through R_{2mn+7} are used.
For multiplication R_{08} through R_{mn+n+7} are used.

Method Used

In matrix calculations:

If $$C = \lambda_1 A + \lambda_2 B$$

then $$c_{ij} = \lambda_1 a_{ij} + \lambda_2 b_{ij} \qquad (1 \leqslant i \leqslant m,\ 1 \leqslant j \leqslant n)$$

If $$C = AB$$

then $$c_{ij} = \sum_{k=1}^{n} a_{ik} b_{kj} \qquad (1 \leqslant i \leqslant m,\ 1 \leqslant j \leqslant p)$$

COMPLEX ARITHMETIC

For two given complex numbers X = a + bi and Y = c + di, this program calculates the following:

X + Y
X − Y
X x Y
X ÷ Y
Y^x
$\sqrt[x]{Y}$
log X(base Y)

These operations may be chained in the following manner. Initially, two complex numbers are entered with the first number being X and the second number Y. After a function has been performed, the result becomes the new X, and a new Y may be entered. X and Y may be interchanged when necessary.

Also, a result from this program is stored in R_{01} and R_{02} and may be used (without reentering it) as the input for this program or for programs ML-05 and ML-06. In other words, Steps 2a and 2b may be omitted in sequential calculations using these programs.

Solid State Software				TI ©1977
COMPLEX ARITHMETIC				ML-04
Y	→X−Y	→X÷Y	→$\log_Y X$	X⇄Y
X	→X+Y	→X×Y	→Y^x	→$\sqrt[x]{Y}$

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 04	
2a	Enter real part of X	a	A	a
2b	Enter imaginary part of X	b	A	b
	(2a and 2b must be performed in sequence)			
3a	Enter real part of Y	c	2nd A'	c
3b	Enter imaginary part of Y	d	2nd A'	d
	(3a and 3b must be performed in sequence)			
	Perform either Step 4, 5, 6, 7, 8, 9, or 10.			
4	Calculate X + Y		B	real part
			x⇄t	imaginary part
5	Calculate X − Y		2nd B'	real part
			x⇄t	imaginary part
6	Calculate X x Y		C	real part
			x⇄t	imaginary part
7	Calculate X ÷ Y		2nd C'	real part
			x⇄t	imaginary part
8	Calculate Y^X		D	real part
			x⇄t	imaginary part
9	Calculate $\log_Y X$		2nd D'	real part
			x⇄t	imaginary part
10	Calculate $\sqrt[X]{Y}$		E	real part
			x⇄t	imaginary part
	After a calculation, the result becomes the new X.			
11	To swap X and Y		2nd E'	0.

Example:

$$[(2 + 3i)(1 - i)]^{(1+i)}$$

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 04		Select program
1	2	A	2.	a
2	3	A	3.	b
3	1	2nd A'	1.	c
4	1	+/– 2nd A'	–1.	d
5		C	5.	Real(XxY)
		x⇌t	1.	Imag (XxY)
6		2nd E'	0.	X ⇌ Y
7	1	A	1.	a
8	1	A	1.	b
9		D	–1.058423508	Real(Y^X)
		x⇌t	4.049577726	Imag(Y^X)

OPTIONAL PRINTOUT*

REF.	PRINT
1	2.
	2.
2	3.
	3.
3	1.
	1.
4	–1.
	–1.
5	–1.
	5.
6	1.
	0.
7	1.
	1.
8	1.
	1.
9	1.
	–1.058423508

*The printout shown is obtained by using the print routine of Pgm 01.

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	a	R_{06}		R_{11}		R_{16}	
R_{02}	b	R_{07}		R_{12}		R_{17}	
R_{03}	Used	R_{08}		R_{13}		R_{18}	
R_{04}	Used	R_{09}		R_{14}		R_{19}	

Method Used

$$X = a + bi \qquad Y = c + di$$

$$X + Y = (a + c) + (b + d)i$$

$$X - Y = (a - c) + (b - d)i$$

$$X \times Y = (ac - bd) + (ad + bc)i$$

$$X \div Y = \frac{ac + bd}{c^2 + d^2} + \frac{bc - ad}{c^2 + d^2} i$$

$$Y^X = e^{X \ln Y}, \; Y \neq 0$$

$$\sqrt[X]{Y} = e^{\frac{\ln Y}{X}}, \; X \neq 0, \; Y \neq 0$$

$$\log X(\text{base } Y) = \frac{\ln X}{\ln Y}, \; X \neq 0, \; Y \neq 0$$

For calculation of e^X, ln X, and 1/X for complex numbers, see program ML-05.

COMPLEX FUNCTIONS

The following functions are calculated for the complex number X = a + bi.

Polar representation (r,θ) of X
X^2
$\sqrt{X}$
1/X
e^x
ln X

After a function has been performed, the result is stored in R_{01} and R_{02} and becomes the new X. Therefore, a result may be used without reentering it in this program and in programs ML-04 and ML-06.

Solid State Software				TI ©1977
COMPLEX FUNCTIONS				ML-05
→ ln X	→ e^x			
X	→ r, θ	→ X^2	→ $\sqrt{X}$	→ 1/X

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 05	
2a	Enter real part of X	a	A	a
2b	Enter imaginary part of X (2a and 2b must be performed in sequence)	b	A	b
3	Calculate polar form of X, if desired		B x⇄t	r θ
	Perform either Step 4, 5, 6, 7, or 8			
4	Calculate X^2		C x⇄t	real part imaginary part
5	Calculate $\sqrt{X}$		D x⇄t	real part imaginary part
6	Calculate 1/X		E x⇄t	real part imaginary part
7	Calculate ln X		2nd A' x⇄t	real part imaginary part
8	Calculate e^X		2nd B' x⇄t	real part imaginary part
	After a calculation, the result becomes the new X.			

Example: Find $\ln X^2$

if $X = 2 + 3i$

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 05		Select program
1	2	A	2.	a
2	3	A	3.	b
3		C	–5.	Real(X^2)
		x:t	12.	Imag(X^2)
4		2nd A'	2.564949357	Real($\ln X^2$)
		x:t	1.965587446	Imag($\ln X^2$)

OPTIONAL PRINTOUT*

REF.	PRINT
1	2. 2.
2	3. 3.
3	3. –5.
4	12. 2.564949357

* The printout shown is obtained by using the print routine of Program 01.

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	a	R_{06}		R_{11}		R_{16}	
R_{02}	b	R_{07}		R_{12}		R_{17}	
R_{03}	Used	R_{08}		R_{13}		R_{18}	
R_{04}	Used	R_{09}		R_{14}		R_{19}	

Method Used

$$X = a + bi$$

$$\text{Magnitude of } X = r = \sqrt{a^2 + b^2}$$

$$\text{Angle of } X \text{ (radians)} = \theta, \text{ where } -\frac{\pi}{2} \leqslant \theta \leqslant \frac{3\pi}{2}^{**}$$

$$\theta = \begin{cases} \tan^{-1} b/a & \text{if } a \neq 0 \\ \pi/2 & \text{if } a = 0, b > 0 \\ -\pi/2 & \text{if } a = 0, b < 0 \end{cases}$$

$$X^2 = r^2 (\cos 2\theta + i \sin 2\theta)$$

$$\sqrt{X} = \sqrt{r}\,(\cos \frac{\theta}{2} + i \sin \frac{\theta}{2})$$

$$\frac{1}{X} = \frac{1}{a + bi}$$

$$e^X = e^a \cos b + i e^a \sin b$$

$$\ln X = \ln r + i\theta, \; X \neq 0$$

**See page V-31 of Owner's Manual.

COMPLEX TRIGONOMETRIC FUNCTIONS

This program calculates the value of trigonometric functions for a complex number X = a + bi. The following functions are evaluated:

$\sin X$
$\cos X$
$\tan X$
$\sin^{-1} X$
$\cos^{-1} X$
$\tan^{-1} X$

The result of any function is stored in R_{01} and R_{02} and becomes the new value of X. Therefore a result may be used without reentering it in this program and in programs ML-04 and ML-05.

Solid State Software			TI ©1977	
COMPLEX TRIG FUNCTIONS				ML-06
	→ sin⁻¹X	→ cos⁻¹X	→ tan⁻¹X	
X	→ sin X	→ cos X	→ tan X	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 06	
2a	Enter real part of X	a	[A]	a
2b	Enter imaginary part of X (2a and 2b must be performed in sequence)	b	[A]	b
	Perform either Step 3, 4, 5, 6, 7, or 8			
3	Calculate sin X		[B] [x:t]	real part imaginary part
4	Calculate cos X		[C] [x:t]	real part imaginary part
5	Calculate tan X		[D] [x:t]	real part imaginary part
6	Calculate $\sin^{-1}$ X		[2nd] [B'] [x:t]	real part imaginary part
7	Calculate $\cos^{-1}$ X		[2nd] [C'] [x:t]	real part imaginary part
8	Calculate $\tan^{-1}$ X		[2nd] [D'] [x:t]	real part imaginary part

NOTES:
1. After a calculation, the result becomes the new X.
2. X is expressed in radians. Program leaves calculator in radian mode.

Example: Find sin X
if X = 2 + 3i

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		[2nd] [Pgm] 06		Select program	1	2.
1	2	[A]	2.	a		2.
2	3	[A]	3.	b	2	3.
3		[B]	9.154499147	Real(sin X)		3.
		[x⇄t]	−4.168906696	Imag(sin X)	3	3.
						9.154499147

*The printout shown is obtained by using the print routine of Program 01.

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	a	R_{06}		R_{11}		R_{16}	
R_{02}	b	R_{07}		R_{12}		R_{17}	
R_{03}	Used	R_{08}		R_{13}		R_{18}	
R_{04}	Used	R_{09}		R_{14}		R_{19}	

Method Used

The functions are evaluated using the following formulas:

$$\sin X = \frac{e^{iX} - e^{-iX}}{2i}$$

$$\cos X = \frac{e^{iX} + e^{-iX}}{2}$$

$$\tan X = \sin X/\cos X$$

$$\sin^{-1} X = \sin^{-1} B + i \ln [A + (A^2 - 1)^{½}]$$

$$\cos^{-1} X = \cos^{-1} B - i \ln [A + (A^2 - 1)^{½}]$$

where

$$A = \frac{1}{2}[(a+1)^2 + b^2]^{½} + \frac{1}{2}[(a-1)^2 + b^2]^{½}$$

$$B = \frac{1}{2}[(a+1)^2 + b^2]^{½} - \frac{1}{2}[(a-1)^2 + b^2]^{½}$$

$$\tan^{-1} X = \frac{1}{2}\tan^{-1}\left[\frac{2a}{1 - a^2 - b^2}\right] + \frac{i}{4}\ln\left[\frac{a^2 + (b+1)^2}{a^2 + (b-1)^2}\right]$$

Note: X is in radians.

ML-07

POLYNOMIAL EVALUATION

This program evaluates the polynomial

$$P(x) = a_0 + a_1x + a_2x^2 + \cdots + a_nx^n$$

for any real number x where $a_0, a_1, \ldots, a_n$ are known real numbers.

The maximum value of n is limited by the number of data registers available. The number of registers available must be equal to or greater than the value (n + 6). With the normal power-up partitioning the TI Programmable 58 will evaluate 24th degree polynomials and the TI Programmable 59 will handle 54th degree. These limits will suffice for most applications, but can be increased by repartitioning as described in program ML-02, if necessary.

Solid State Software			TI ©1977	
POLYNOMIAL EVALUATION				ML-07
n	i ; a_i	x → P(x)		

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 07	
2	Enter n[1]	n	A	n*
3	Enter all coefficients[2] starting with a_0 (To correct a_i, enter i, press B and reenter a_i with the R/S key.)	0 a_0 a_1 ⋮ a_n	B R/S R/S ⋮ R/S	0. a_0* a_1* ⋮ a_n*
4	Enter x and compute P(x)	x	C	P(x)*
5	For a new value of x repeat Step 4			

NOTES:
1. Number of data registers available ≥ n + 6.
2. Even if a coefficient is zero, it must be entered.
3. This program contains print commands and should not be used with program ML-01.

*These values are printed automatically if the calculator is connected to the PC-100A Print Cradle.

Register Contents

R_{00}		R_{05}	See note	R_{10}		R_{15}	
R_{01}	Pointer	R_{06}		R_{11}		R_{16}	
R_{02}	Counter	R_{07}		R_{12}		R_{17}	
R_{03}	x	R_{08}		R_{13}		R_{18}	
R_{04}	n	R_{09}		R_{14}		R_{19}	

Note: The coefficients of the polynomial are stored starting with a_0 in R_{05}.

Example: Let $P(x) = 2 - 3 + x^2$

Find P(2) and P(−1)

ENTER	PRESS	DISPLAY	COMMENTS	PRINTOUT*
	[2nd] [Pgm] 07		Select program	
2	[A]	2.	n	2.
0	[B]	0.	Start with a_0	
2	[R/S]	2.	a_0	2.
3	[+/−] [R/S]	−3.	a_1	−3.
1	[R/S]	1.	a_2	1.
2	[C]	0.	P(2)	2.
				0.
1	[+/−] [C]	6.	P(−1)	−1.
				6.

*This printout is automatic when the calculator is connected to the PC-100A Print Cradle.

Method Used

If $P(x) = a_0 + a_1x + a_2x^2 + \cdots + a_nx^n$, then P(c) is evaluated as follows:

$$b_n = a_n$$

$$b_{n-1} = a_{n-1} + b_nc = a_{n-1} + a_nc$$

$$b_{n-2} = a_{n-2} + b_{n-1}c = a_{n-2} + (a_{n-1} + a_nc)c$$

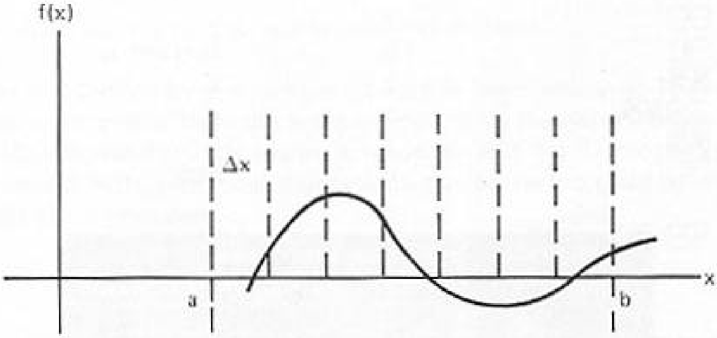
$$\vdots$$

$$b_0 = a_0 + b_1c$$

Then $P(c) = b_0$

ZEROS OF FUNCTIONS

Using the graphical bisection method, this program calculates the roots of a function defined by the user.



The values of a and b, the lower and upper limits for evaluation, must be supplied whereas the sampling increment Δx, if not specified by the user, defaults to $b - a$. The degree of accuracy (error limit) defaults to 0.01 if not specified by the user.

The method used will find only one root in a subinterval (Δx). To find all the roots, the selected sampling increment (Δx) must be small enough to ensure that the function changes sign only once in any subinterval.

If there are no roots in the overall interval evaluated, or after all the roots have been found, the display will flash 9.9999999 99. If the display flashes another number, the number flashed may be a root. In this case the flashing is triggered when an undefinable point is encountered while evaluating the function (1/x evaluated at 0, for example).

Solid State Software				TI ©1977
ZEROS OF FUNCTIONS				ML-08
a	b	Δx	ϵ	→x

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Initialize		RST	0.
2	Select learn mode		LRN	000 00
3	Use A' as label		2nd Lbl 2nd A'	001 00 002 00
4	Enter f(x) as a series of keystrokes. Do not use = or CLR. Do not use registers 0-8.			
5	End f(x) with INV SBR		INV SBR	xxx 00
6	Leave learn mode		LRN	0.
7	Select program		2nd Pgm 08	
8	Enter lower limit	a	A	a
9	Enter upper limit	b	B	b
10	Enter sampling increment[1]	Δx	C	Δx
11	Enter maximum error[2]	ϵ	D	ϵ
12	Calculate roots. Repeat this step until flashing 9's display is obtained which indicates all roots in [a,b) have been found.		E	root
13	To use a different interval, Δx, or ϵ, repeat Steps 8-12.			

NOTES:
1. If Δx is not entered, b – a is assumed.
2. If ϵ is not entered, .01 is assumed.
3. Evaluate expressions using parentheses only.
4. [a,b) is a notation which means that a is included in the interval but b is not.
5. Program may run for several minutes, depending on input data.

Example: Let f(x) = 4 sin x + 1 – x. Determine the zeros of f(x) in the interval from –3 to 3, using Δx = 0.5 and ϵ = 0.01, when x is expressed in radians.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		RST	0.	
		LRN	000 00	
		2nd Lbl	001 00	
		2nd A'	002 00	
		(STO 10	005 00	Key in f(x)
		2nd sin ×	007 00	
		4 + 1	010 00	
		– RCL 10	013 00	
		) INV SBR	015 00	
		LRN	0.	
		2nd Pgm 08	0.	Select program
		2nd Rad	0.	Select rad mode
1	3	+/– A	–3.	a
2	3	B	3.	b
3	.5	C	0.5	Δx
4	.01	D	0.01	ϵ
5		E	–2.20703125	root 1
6		E	–0.33984375	root 2
7		E	2.69921875	root 3
8		E	9.9999999 99	No more roots

OPTIONAL PRINTOUT*

REF.	PRINT
1	–3. –3.
2	3. 3.
3	0.5 0.5
4	0.01 0.01
5	0.01 –2.20703125
6	–2.20703125 –0.33984375
7	–0.33984375 2.69921875
8	2.69921875 9.999999999 99?

*The printout shown is obtained with the print routine of Program 01.

Register Contents

R_{00}		R_{05}	b_k	R_{10}		R_{15}	
R_{01}	a, a + Δx	R_{06}	c_k	R_{11}		R_{16}	
R_{02}	b	R_{07}	m_k	R_{12}		R_{17}	
R_{03}	Δx	R_{08}	Used	R_{13}		R_{18}	
R_{04}	a_k	R_{09}	ϵ	R_{14}		R_{19}	

Method Used

A function defined as a series of keystrokes in program memory is evaluated over a given interval [a, b)* at a sampling increment (step size) of Δx. First, endpoints of subintervals are examined to find where the function changes sign. When a sign change is detected, the subinterval in which it occurs is successively halved until its length is less than the specified error limit. The midpoint of this smaller interval is a root of the function within the accuracy or error limit.

*[a, b) is a symbolic notation which means that a is included in the interval but b is not.

SIMPSON'S APPROXIMATION (CONTINUOUS)

This program may be used to approximate the integral, I, of a function defined by the user, over an interval x_0 to x_n, using Simpson's Rule.

$$I = \int_{x_0}^{x_n} f(x)dx$$

The function f(x) must be expressed as a sequence of keystrokes in the user program memory.

Solid State Software			TI ©1977	
SIMPSON'S APPROXIMATION (CONTINUOUS)			ML-09	
x_0	x_n	n	→I	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Initialize		[RST]	0.
2	Select learn mode		[LRN]	000 00
3	Use A′ as label		[2nd] [Lbl] [2nd] [A′]	001 00 002 00
4	Enter f(x) as a series of keystrokes. Do not use [=] or [CLR]. Do not use registers 0-5.			
5	End f(x) with [INV] [SBR]		[INV] [SBR]	xxx 00
6	Leave learn mode		[LRN]	0.
7	Select program		[2nd] [Pgm] 09	
8	Enter lower limit	x_0	[A]	x_0
9	Enter upper limit	x_n	[B]	x_n
10	Enter n(n = 2, 4, 6, · · ·, display flashes if not legal entry)	n	[C]	h
11	Compute integral		[D]	I
12	For a new interval or a new n, repeat Steps 7-11.			

NOTE:
1. Evaluate expressions using parentheses only.
2. Running time is dependent on input data.

Example:

Evaluate $\int_0^{\pi/2} \frac{1}{\cos x + 2} dx$ using two subintervals.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		RST	0.	
		LRN	000 00	
		2nd Lbl	001 00	
		2nd A'	002 00	
		2nd Rad	003 00	
		(2nd cos	005 00	Key in f(x)
		+ 2)	008 00	
		1/x INV SBR	010 00	
		LRN	0.	
		2nd Pgm 09	0.	Select program
1	0	A	0.	x_0
		2nd π ÷	3.141592654	
2	2	= B	1.570796327	x_2 $(\pi/2)$
3	2	C	.7853981634	h
4		D	0.604998903	I

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	1.570796327 1.570796327
3	2. .7853981634
4	.7853981634 0.604998903

* The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}	n	R_{10}		R_{15}	
R_{01}	x_0	R_{06}		R_{11}		R_{16}	
R_{02}	x_n	R_{07}		R_{12}		R_{17}	
R_{03}	h	R_{08}		R_{13}		R_{18}	
R_{04}	I	R_{09}		R_{14}		R_{19}	

Method Used

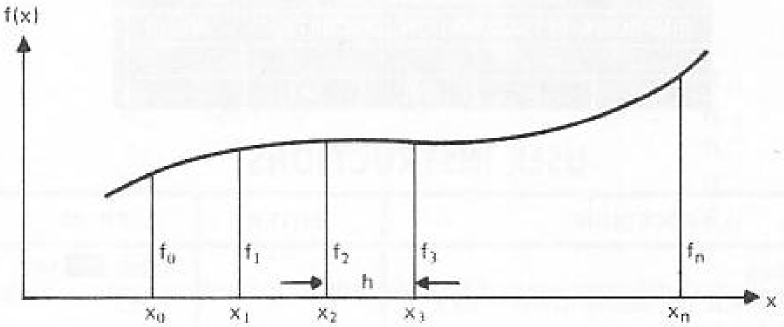
Calculations are based on Simpson's rule:

$$\int_{x_0}^{x_n} f(x)dx \approx \frac{h}{3}(f_0 + 4f_1 + 2f_2 + 4f_3 + 2f_4 + \cdots + 2f_{n-2} + 4f_{n-1} + f_n)$$

where:

$$h = \frac{x_n - x_0}{n}, \; x_n > x_0$$

n = number of subintervals = 2, 4, 6, 8, · · ·



SIMPSON'S APPROXIMATION (DISCRETE)

This program may be used to approximate the integral, I,

where:

$$I = \int_{x_0}^{x_n} f(x)dx$$

using Simpson's Rule. The value of f(x) must be known at n + 1 equally spaced points (f_0 – f_n). The number of subintervals is limited by the number of available data registers.

Solid State Software			TI ©1977	
SIMPSON'S APPROXIMATION (DISCRETE)			ML-10	
n	h	i, f_i	→I	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 10	
2	Enter n(n = 2, 4, 6, ···, display flashes if not a legal entry). See note 2.	n	[A]	n*
3	Enter h	h	[B]	h*
4	Enter function values starting with f_0	0 f_0 f_1 ⋮ f_n	[C] [R/S] [R/S] ⋮ [R/S]	0. f_0* f_1* ⋮ f_n*
5	Calculate integral		[D]	I*

NOTES: 1. This program contains print commands, and should not be used with program ML-01.

2. n + 7 ≤ No. of data registers.

*These values are printed automatically if the calculator is connected to the PC-100A Print Cradle.

Example: Find the area under the curve where: n = 4, h = 1 and f_0 = 1, f_1 = 8, f_2 = 27, f_3 = 64, f_4 = 125.

ENTER	PRESS	DISPLAY	COMMENTS	PRINTOUT
	2nd Pgm 10		Select program	
4	A	4.	n	4.
1	B	1.	h	1.
0	C	0.	Start with f_0	
1	R/S	1.	f_0	1.
8	R/S	8.	f_1	8.
27	R/S	27.	f_2	27.
64	R/S	64.	f_3	64.
125	R/S	125.	f_4	125.
	D	156.	I	156.

Register Contents

R_{00}		R_{05}	n	R_{10}		R_{15}	
R_{01}	Pointer	R_{06}	See note	R_{11}		R_{16}	
R_{02}	Counter	R_{07}		R_{12}		R_{17}	
R_{03}	h	R_{08}		R_{13}		R_{18}	
R_{04}	I	R_{09}		R_{14}		R_{19}	

Note: R_{06} through R_{n+6} are used for storing the values of f(x) starting with f_0 in R_{06}.

Method Used

The integral is evaluated using Simpson's Rule:

$$\int_{x_0}^{x_n} f(x)\,dx \approx \frac{h}{3}(f_0 + 4f_1 + 2f_2 + 4f_3 + 2f_4 + \cdots 2f_{n-2} + 4f_{n-1} + f_n)$$

where:

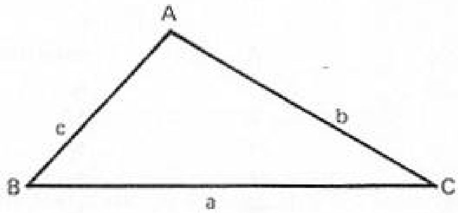
$$h = \frac{x_n - x_0}{n}, \quad x_n > x_0$$

n = number of subintervals = 2, 4, 6, 8, · · ·

$n + 7 \leqslant$ number of data registers available

TRIANGLE SOLUTION (1)

Given three elements of a triangle (SSS, SSA, or SAS), the remaining angles and sides are calculated.



This program will perform the following:

Knowing SSS (sides a, b, c), compute angles A, B, C.
Knowing SSA (sides a, b, angle A), compute angles B, C, side c.
Knowing SAS (sides a, b, angle C), compute angles A, B, side c.

See program TRIANGLE SOLUTION (2), ML-12, for more combinations.

Reference: *Standard Mathematical Tables*, Samuel M. Selby, CRC Press, 1974.

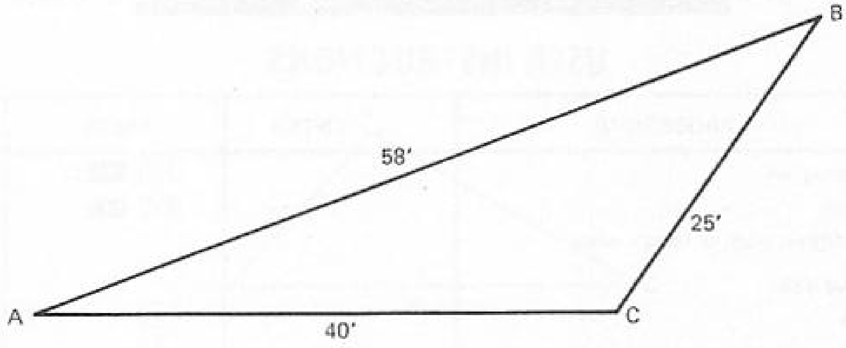
Solid State Software			TI ©1977	
TRIANGLE SOLUTION (1)				ML-11
SSS ∠A'	∠B'	∠C' ∠A'		INIT
a	b	c, ∠A, ∠C	SSA c'	SAS c'

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 11	
2	Initialize		2nd E'	0.
3	Select degree, grad, or radian mode			
	Knowing SSS			
4	Enter a	a	A	a
5	Enter b	b	B	b
6	Enter c	c	C	c
7	Calculate ∠A		2nd A'	∠A'
8	Calculate ∠B		2nd B'	∠B'
9	Calculate ∠C		2nd C'	∠C'
	Knowing SSA			
10	Enter a	a	A	a
11	Enter b	b	B	b
12	Enter ∠A	∠A	C	∠A
13	Calculate c		D	c'
14	Calculate ∠B		2nd B'	∠B'
15	Calculate ∠C		2nd C'	∠C'
	Knowing SAS			
16	Enter a	a	A	a
17	Enter b	b	B	b
18	Enter ∠C	∠C	C	∠C
19	Calculate c		E	c'
20	Calculate ∠B		2nd B'	∠B'
21	Calculate ∠A		2nd C'	∠A'

NOTES:
1. Input data must be reentered following each set of calculations.
2. A flashing display indicates there is no triangle satisfying the input data.
3. All inputs should be entered in the sequence shown, all outputs should be calculated in the order shown. Do not omit any steps except output steps which follow the last part in question.

Example 1:



The sides of a triangle are 25 ft, 40 ft, and 58 ft. What is the measure of each angle in degrees?

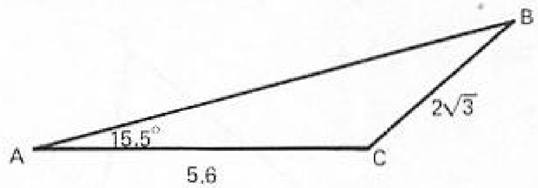
REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 11		Select program
		2nd Deg		Degree mode
1		2nd E'	0.	Initialize
2	25	A	25.	side a
3	40	B	40.	side b
4	58	C	58.	side c
5		2nd A'	20.75095402	angle A
6		2nd B'	34.53367939	angle B
7		2nd C'	124.7153666	angle C

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	25. 25.
3	40. 40.
4	58. 58.
5	58. 20.75095402
6	20.75095402 34.53367939
7	34.53367939 124.7153666

*The printout shown is obtained using the print routine of Program 01.

Example 2:



If side a is $2\sqrt{3}$, side b is 5.6, and angle A is 15.5° as shown, find side c and angles B and C.

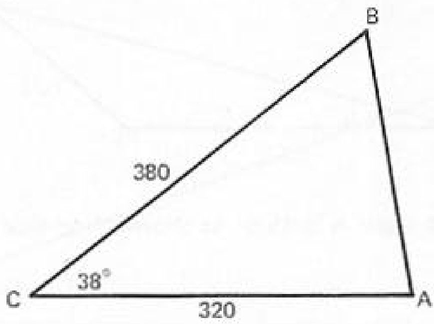
REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 11		Select program
		[2nd] [Deg]		Degree mode
1		[2nd] [E']	0.	Initialize
	2	[×]	2.	
2	3	[√x] [=] [A]	3.464101615	side a
3	5.6	[B]	5.6	side b
4	15.5	[C]	15.5	angle A
5		[D]	8.520491749	side c
6		[2nd] [B']	25.59534103	angle B
7		[2nd] [C']	138.904659	angle C

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	3.464101615 3.464101615
3	5.6 5.6
4	15.5 15.5
5	15.5 8.520491749
6	8.520491749 25.59534103
7	25.59534103 138.904659

*The printout shown is obtained using the print routine of Program 01.

Example 3:



Given side a = 380, side b = 320, and angle C = 38°; calculate side c and angles B and A.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 11		Select program
		2nd Deg		Degree mode
1		2nd E'	0.	Initialize
2	380	A	380.	side a
3	320	B	320.	side b
4	38	C	38.	angle C
5		E	234.8526873	side c
6		2nd B'	57.02134388	angle B
7		2nd C'	84.97865612	angle A

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	380. 380.
3	320. 320.
4	38. 38.
5	38. 234.8526873
6	234.8526873 57.02134388
7	57.02134388 84.97865612

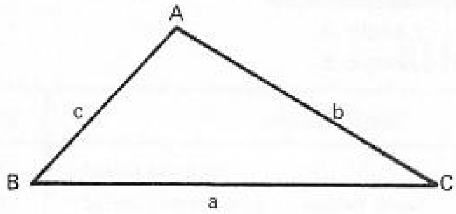
*The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}	Used	R_{10}		R_{15}	
R_{01}	b	R_{06}	a	R_{11}		R_{16}	
R_{02}	c	R_{07}		R_{12}		R_{17}	
R_{03}	Used	R_{08}		R_{13}		R_{18}	
R_{04}	Used	R_{09}		R_{14}		R_{19}	

Method Used

The following equations are used in the calculations



$$A + B + C = 180^\circ \text{ (or equivalent)}$$

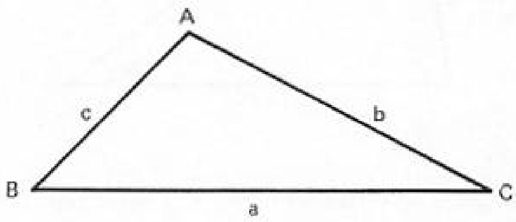
$$c^2 = a^2 + b^2 - 2ab \cos C \qquad a, b, c > 0$$

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

TRIANGLE SOLUTION (2)

A continuation of ML-11, TRIANGLE SOLUTION (1), this program will compute the following:

Knowing ASA (angles B, C, side a), compute sides b, c, angle A.
Knowing SAA (side a, angles A, C), compute sides b, c, angle B.
The area of any triangle knowing its three sides.



Reference: *Standard Mathematical Tables*, Samuel M. Selby,
CRC Press, 1974.

Solid State Software				TI ©1977
TRIANGLE SOLUTION (2)				ML-12
ASA ∠A'	SAA ∠B'	AREA		
a	∠A, ∠B	∠C	b	c

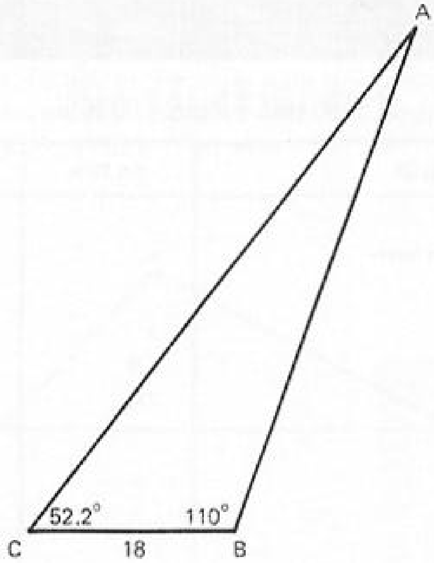
USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 12	
2	Select degree, grad, or radian mode			
	Knowing ASA			
3	Enter a	a	[A]	a
4	Enter ∠B	∠B	[B]	∠B
5	Enter ∠C	∠C	[C]	∠C
6	Calculate ∠A		[2nd] [A']	∠A
7	Calculate b		[D]	b
8	Calculate c		[E]	c
	Knowing SAA			
9	Enter a	a	[A]	a
10	Enter ∠A	∠A	[B]	∠A
11	Enter ∠C	∠C	[C]	∠C
12	Calculate ∠B		[2nd] [B']	∠B
13	Calculate b		[D]	b
14	Calculate c		[E]	c
	Calculate Area			
15	Calculate area of triangle. Sides b, c, a must have been previously computed and consequently reside in R_{01}, R_{02}, and R_{07}, respectively. If not, they can be manually placed there.		[2nd] [C']	Area

NOTES:

1. Input data must be reentered after each set of calculations.
2. For a triangle solution in program ML-11, the area may be calculated by pressing [2nd] [Pgm] 12, [RCL] 06, [STO] 07, [2nd] [C'] without reentering the data.
3. All inputs should be entered in the sequence shown, all outputs should be calculated in the order shown. Do not omit any steps except those which follow the last part in question.

Example 1:



Given side a = 18, angle B = 110°, and angle C = 52.2°, calculate angle A and sides b and c.

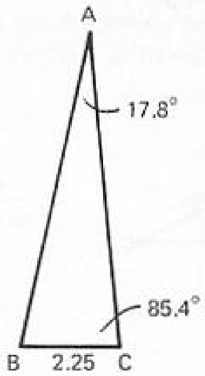
REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 12		Select program
		2nd Deg		Degree mode
1	18	A	18.	side a
2	110	B	110.	angle B
3	52.2	C	52.2	angle C
4		2nd A'	17.8	angle A
5		D	55.33113169	side b
6		E	46.52603423	side c

OPTIONAL PRINTOUT*

REF.	PRINT
1	18. 18.
2	110. 110.
3	52.2 52.2
4	52.2 17.8
5	17.8 55.33113169
6	55.33113169 46.52603423

*The printout shown is obtained using the print routine of Program 01.

Example 2:



Given side a = 2.25, angle A = 17.8°, angle C = 85.4°, find angle B and sides b and c. Also calculate the area of this triangle.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 12		Select program
		2nd Deg		Degree mode
1	2.25	A	2.25	side a
2	17.8	B	17.8	angle A
3	85.4	C	85.4	angle C
4		2nd B'	76.8	angle B
5		D	7.165803648	side b
6		E	7.336561734	side c
7		2nd C'	8.035561939	area

OPTIONAL PRINTOUT*

REF.	PRINT
1	2.25 2.25
2	17.8 17.8
3	85.4 85.4
4	85.4 76.8
5	76.8 7.165803648
6	7.165803648 7.336561734
7	7.336561734 8.035561939

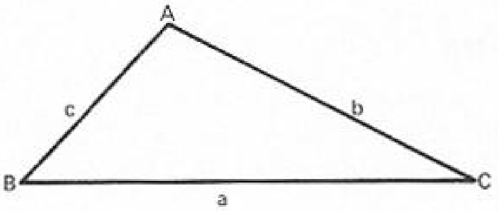
*The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}	Used	R_{10}		R_{15}	
R_{01}	b	R_{06}	Used	R_{11}		R_{16}	
R_{02}	c	R_{07}	a	R_{12}		R_{17}	
R_{03}	Used	R_{08}		R_{13}		R_{18}	
R_{04}	Used	R_{09}		R_{14}		R_{19}	

Method Used

The following equations are used in the calculations.



$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

$$A + B + C = 180^\circ \text{ (or equivalent)}$$

$$c^2 = a^2 + b^2 - 2ab \cos C \qquad a, b, c > 0$$

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

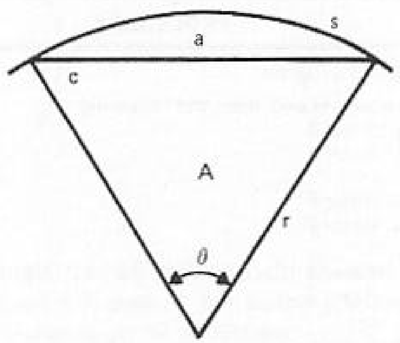
where:

$$s = \frac{a + b + c}{2}$$

CURVE SOLUTION

For an arc of a circle, this program calculates the remaining parameters when certain pairs are given. One of the following pairs of parameters must be supplied as input:

θ,r
θ,s
θ,c
r,s
r,c



θ – Central angle ($<\pi$ radians)
r – Radius
s – Arc length
c – Chord length
A – Sector area
a – Segment area

Solid State Software				TI ©1977
CURVE SOLUTION				ML-13
θ'	r'	s'	c'	a'
θ	r	s	c	A'

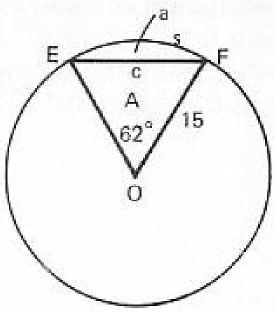
USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 13	
2	Enter one pair from the following			
	a. Enter θ	θ	A	θ
	a. Enter r	r	B	r
	or			
	b. Enter θ	θ	A	θ
	b. Enter s	s	C	s
	or			
	c. Enter θ	θ	A	θ
	c. Enter c	c	D	c
	or			
	d. Enter r	r	B	r
	d. Enter s	s	C	s
	or			
	e. Enter r	r	B	r
	e. Enter c	c	D	c
3	See Note 1			
4	Calculate θ		2nd A'	θ'
5	Calculate r		2nd B'	r'
6	Calculate s		2nd C'	s'
7	Calculate c		2nd D'	c'
8	Calculate A		E	A'
9	Calculate a		2nd E'	a'

NOTES:

1. All steps 4 through 9 must be performed in sequence. Values entered in Step 2 may be omitted.
2. θ is expressed in radians. Program leaves calculator in radian mode.

Example:



The radius of a circle is 15 inches and the measure of the angle formed by two radii OE and OF is 62°. Calculate the length of the intercepted arc, the length of chord EF, area of the sector and area of the segment. *Remember: the formula used requires the angular measure to be in radians.*

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 13		Select program
	62	[÷]	62.	
	180	[×] [2nd] [π]	3.141592654	
1		[=] [A]	1.082104136	θ (radians)
2	15	[B]	15.	r
3		[2nd] [C']	16.23156204	s(arc length)
4		[2nd] [D']	15.45114225	c(chord length)
5		[E]	121.7367153	A(sector area)
6		[2nd] [E']	22.40511113	a(segment area)

OPTIONAL PRINTOUT*

REF.	PRINT
1	1.082104136 1.082104136
2	15. 15.
3	15. 16.23156204
4	16.23156204 15.45114225
5	15.45114225 121.7367153
6	121.7367153 22.40511113

*The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	θ	R_{06}		R_{11}		R_{16}	
R_{02}	r	R_{07}		R_{12}		R_{17}	
R_{03}	s	R_{08}		R_{13}		R_{18}	
R_{04}	c	R_{09}		R_{14}		R_{19}	

ML-13

Method Used

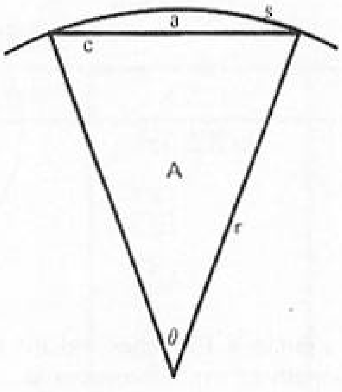
The following formulas are used in the calculations:

Arc length, $s = r\theta$

Chord length, $c = 2r \sin\frac{\theta}{2}$

Sector area, $A = \frac{sr}{2}$

Segment area, $a = \frac{sr}{2} - \frac{cr}{2}\cos\frac{\theta}{2}$



where:

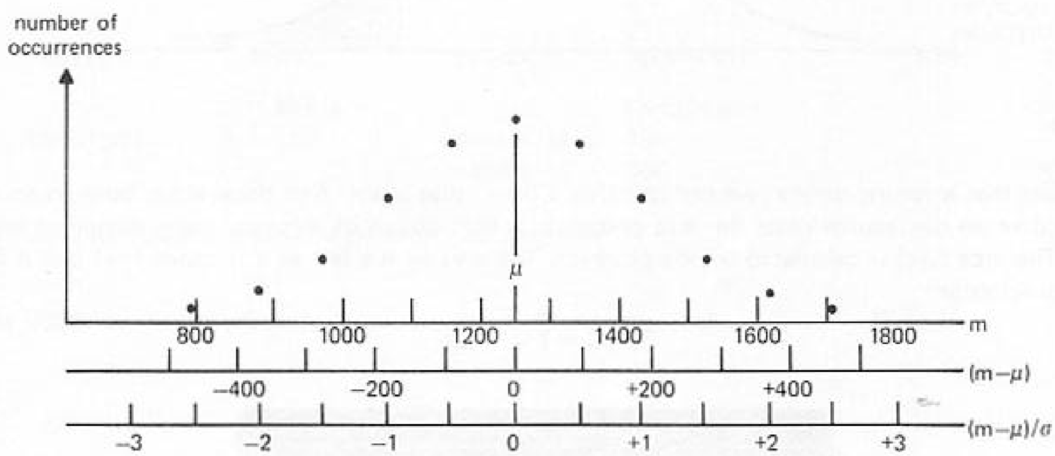
θ = central angle in radians ($<\pi$)

r = radius

Reference: *Standard Mathematical Tables,* Samuel M. Selby, CRC Press, 1974.

NORMAL DISTRIBUTION

In many circumstances the set of numbers which measure some characteristic of a set of objects under study are said to be *normally* distributed. That is, a plot of these numbers against their number of occurrences would follow the normal curve, with the peak at the mean (average value) of these numbers. For example, consider a plot of battery lifetimes (used in the example problem). Look first at the upper horizontal scale.

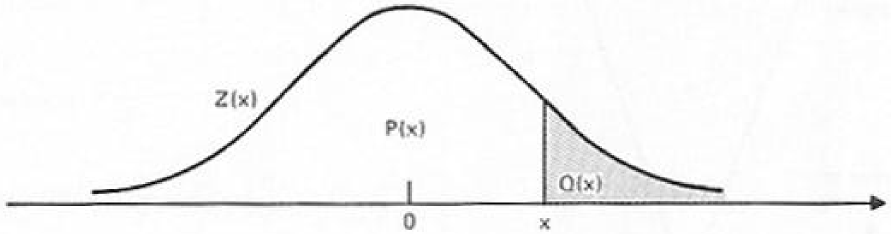


A plot using this scale would not be very useful for analyzing data in general, because it would be limited to this particular example situation only. If we assume the numbers to be symmetric about the mean, each of the numbers could be replaced by its distance from the mean $(m-\mu)$, where m is the number and μ is the mean. This is shown on middle scale. This measure would be useful for any set of numbers having the same spread, or deviation from the mean. Now, if we replace $(m-\mu)$ with $(m-\mu)/\sigma$, where σ is the standard deviation of the set of numbers, our "standard" unit becomes the number of standard deviations away from the mean, and the plot (or curve if we connect the points) is useful for all sets of numbers that are normally distributed. This is the scale factor we call x, so remember $x = (m-\mu)/\sigma$.

Now that we have a "standard" normal distribution, what can it tell us? Consider that the area under the curve contains information on the number of occurrences of each number. The total area under the curve would contain all the numbers and could be assigned a value of 1. What we frequently want to know is *what fraction of the total are numbers larger or smaller than a certain limit.* It is easy to see that half of the numbers (0.5) are equal to or larger than the mean. For the less obvious cases, the calculator comes into use.

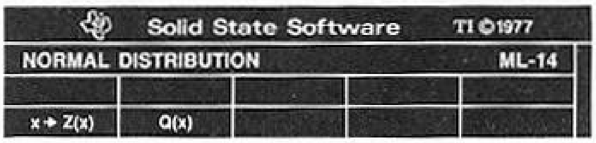
Mathematicians long ago determined the equation for the standard normal distribution curve:

$$Z(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2} \qquad x = \frac{m - \mu}{\sigma}$$



This means that knowing only x, we can calculate Z(x) at that point. And because we have an equation for the curve we can approximate the area needed to a high degree of accuracy using numerical techniques. The area Q(x) is calculated by the program. The area to the left of x is called P(x) and is found using the equation:

$$P(x) = 1 - Q(x)$$



USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 14	
2	Enter data and calculate Z(x)	x[1]	A	Z(x)
3	Calculate Q(x)		B	Q(x)

NOTES:
1. $|x| \leq 15.11$, display will flash for x outside this range.
2. Z(x) must be calculated before Q(x).
3. $Z(-x) = Z(x)$ and $Q(-x) = 1 - Q(x)$.
4. $P(x) = 1 - Q(x)$.

Example: A study showed that the lifetimes of a certain type of automobile battery are normally distributed with a mean of 1248 days and a standard deviation of 185 days. If the manufacturer wishes to guarantee the battery for 36 months (1080 days), what percentage of the batteries will have to be replaced under the guarantee?

$$P(x \leq 1080) = 1 - Q\left(\frac{1080 - 1248}{185}\right) = 1 - Q(-.9081081081)$$

where Q(x) is found using the program. Then:

$$(1 - .8180894772) = .1819105228 \text{ or } 18.19\%$$

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		2nd Pgm 14		Select program	1	−.9081081081 .2641419314
1	.9081081081	+/− A	.2641419314	Z(x)		
2		B	.8180894772	Q(x)	2	.2641419314 .8180894772

*The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	Z(x)	R_{06}		R_{11}		R_{16}	
R_{02}	t	R_{07}		R_{12}		R_{17}	
R_{03}	x	R_{08}		R_{13}		R_{18}	
R_{04}		R_{09}		R_{14}		R_{19}	

Method Used

Q(x) is calculated using the following polynomial expansion:

$$Q(x) = Z(x)(b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5) + \epsilon(x)$$

where:

$$t = \frac{1}{1 + px}$$

$$|\epsilon(x)| < 7.5 \times 10^{-8}$$

$$p = .2316419$$

$$b_1 = .319381530$$

$$b_2 = -.356563782$$

$$b_3 = 1.781477937$$

$$b_4 = -1.821255978$$

$$b_5 = 1.330274429$$

Reference: *Handbook of Mathematical Functions,* Abramowitz and Stegun, National Bureau of Standards, 1964.

RANDOM NUMBER GENERATOR

This program generates sequences of uniformly or normally distributed random numbers. A seed number (0 to 199017) selected by the user is to initiate the sequences. As an additional feature the program compiles statistical data to allow computation of the mean and standard deviation of the generated numbers.

For normally distributed random numbers, the seed, desired mean $\overline{x}$, and desired standard deviation must be entered by the user.

For uniformly distributed random numbers, the lower limit A, upper limit B, and the seed are entered.

Uniformly distributed random numbers on the interval (0,1) may be generated at any time without entering upper and lower limits. Mean and standard deviation statistics are not collected for these numbers.

Solid State Software				TI ©1977
RANDOM NUMBER GENERATOR				ML-15
		No. ($\bar{x}$,σ)		INIT
A, $\bar{x}$	B, σ	No. (A,B)		SEED

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 15	
2	Initialize		2nd E'	0.
3	Enter random number seed (0 ≤ seed ≤ 199017)	seed	E	seed
	For Uniform Distribution			
4	Enter lower limit	A	A	A
5	Enter upper limit	B	B	B
6	Generate random number (Repeat as needed)		C	Random No.
	For Normal Distribution			
7	Enter desired mean	$\overline{x}$	A	Desired $\overline{x}$
8	Enter desired standard deviation	σ	B	Desired σ
9	Generate random number (Repeat as needed)		2nd C'	Random No.
	For Either Distribution			
10	Compute actual mean of generated numbers		2nd $\overline{x}$	Actual $\overline{x}$
11	Compute actual standard deviation of generated numbers		INV 2nd $\overline{x}$	Actual σ
12	Display number of generated numbers		RCL 03	N
	For Range of (0,1)			
13	Generate random number (Repeat as needed)		SBR 2nd D.MS	Random No.

NOTE: 1. Five significant digits of the originally generated number are retained for further calculations. Therefore, no more than the first five significant digits of the generated numbers may be considered to be random.

Example 1: Generate five uniformly distributed random numbers on the interval (1,10) using .32 as the seed.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 15		Select program
1		[2nd] [E']	0.	Initialize
2	.32	[E]	0.32	Seed
3	1.	[A]	1.	Lower limit
4	10.	[B]	10.	Upper limit
5		[C]	5.87341	Random number
6		[C]	7.34635	Random number
7		[C]	3.5911	Random number
8		[C]	1.63531	Random number
9		[C]	9.05329	Random number

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	0.32 0.32
3	1. 1.
4	10. 10.
5	10. 5.87341
6	5.87341 7.34635
7	7.34635 3.5911
8	3.5911 1.63531
9	1.63531 9.05329

*The printout shown is obtained using the print routine of Program 01.

Example 2: Generate five normally distributed random numbers with desired mean 5.84 and standard deviation 2.12 using 1 as the seed. Determine the actual mean and standard deviation of the generated numbers and recall the number of random numbers generated.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 15		Select program
1		[2nd] [E']	0.	Initialize
2	1	[E]	1.	Seed
3	5.84	[A]	5.84	Desired $\bar{x}$
4	2.12	[B]	2.12	Desired σ
5		[2nd] [C']	7.8171433	Random number
6		[2nd] [C']	7.290557451	Random number
7		[2nd] [C']	3.075542923	Random number
8		[2nd] [C']	5.109539381	Random number
9		[2nd] [C']	3.323206704	Random number
		[2nd] [$\bar{x}$]	5.323197952	Actual $\bar{x}$
		[INV] [2nd] [$\bar{x}$]	2.190196047	Actual σ
		[RCL] [0] [3]	5.	N

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	1. 1.
3	5.84 5.84
4	2.12 2.12
5	2.12 7.8171433
6	7.8171433 7.290557451
7	7.290557451 3.075542923
8	3.075542923 5.109539381
9	5.109539381 3.323206704

*The printout shown is obtained using the print routine of Program 01.

Method Used

Uniformly distributed numbers are generated using the linear congruential method. The following relationship exists between the generated numbers:

$$x_{n+1} = (ax_n + c) \bmod m$$

where:

x_0 = seed ($0 \leq$ seed ≤ 199017)	c = 99991
a = 24298	m = 199017

The generated sequence is of period m and each x_i is adjusted to the range (A, B) by the following:

$$x_i' = (x_i/m)(B - A) + A$$

Normally distributed random numbers are generated using the direct method. First a pair of uniformly distributed random numbers are generated on the interval (0, 1). Then, using these numbers (u_1 and u_2), a value x is calculated from

$$x = \sqrt{-2 \ln u_1} \cos(2\pi u_2)$$

This normal deviate with zero mean and unit variance is adjusted to mean $\overline{x}'$ and standard deviation σ' by

$$x' = \sigma' x + \overline{x}'$$

Register Contents

R_{00}		R_{05}	Σx^2	R_{10}	A, $\overline{x}$	R_{15}	
R_{01}	Σy	R_{06}	Σxy	R_{11}	B, σ	R_{16}	
R_{02}	Σy^2	R_{07}	Used	R_{12}		R_{17}	
R_{03}	N	R_{08}	Used	R_{13}		R_{18}	
R_{04}	Σx	R_{09}	Seed	R_{14}		R_{19}	

Reference: *The Art of Computer Programming,* Donald E. Knuth,
Addison-Wesley Publishing Co., 1969

COMBINATIONS, PERMUTATIONS AND FACTORIALS

This program performs three functions.

Factorial: Calculates the factorial (n!) of a positive integer ($0 \leqslant n \leqslant 69$).

$$n! \equiv (n)(n-1)(n-2) \cdot \ldots \cdot (3)(2)(1), \quad (0! = 1).$$

Permutations: Calculates the number of possible permutations of n items taken r at a time.

$$P\binom{n}{r} = n!/(n-r)! = (n)(n-1) \cdot \ldots \cdot (n-r+1), \quad (P\binom{n}{0} = 1).$$

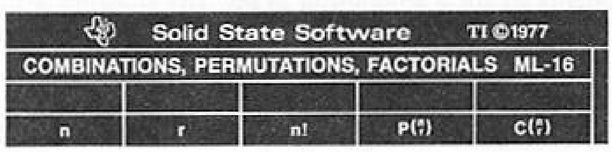
Limit: $P\binom{n}{r} \leqslant 69!$

Combinations: Calculates the number of possible combinations of n items taken r at a time.

$$C\binom{n}{r} = n!/r!(n-r)! = (n/r)(n-1/r-1) \cdot \ldots \cdot (n-r+1/1), \quad (C\binom{n}{0} = 1).$$

Limit: $C\binom{n}{r} \leqslant 69!$

Reference: International Dictionary of Applied Mathematics, Van Nostrand.



USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 16	
2a	Enter n	n	A	Integer |n|
2b	Enter r ($0 \leqslant r \leqslant n$) (2a must precede 2b)	r	B	Integer |r|
	Factorial			
3	Calculate factorial of n ($0 \leqslant n \leqslant 69$)		C	n!
	Permutations			
4	Calculate number of possible permutations		D	$P\binom{n}{r}$
	Combinations			
5	Calculate number of possible combinations		E	$C\binom{n}{r}$

NOTES:
1. For r > n the display flashes 9.9999999 99.
2. The display flashes 9.9999999 99 for overflow in the calculation.
3. For negative entries of either n or r, the absolute values are used and the display flashes the result.
4. For non-integer values of either n or r, only the integer values are used and the display flashes the results.
5. Step 2 must be repeated for each calculation.
6. Running time is dependent upon input data.

Example 1: The individual books of a four-volume set of Shakespeare are placed next to each other on a shelf at random. How many possible orderings are there?

This problem may be solved by finding the number of possible permutations of 4 items taken 4 at a time:

$$P\binom{4}{4} = 4!/(4-4)! = 4!/0! = 4!/1 = 4!.$$

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		2nd Pgm 16		Select program		
1	4	A	4.	n	1	4. 4.
2		C	24.	n!	2	4. 24.

*The printout shown is obtained using the print routine of Program 01.

Example 2: Twenty-five students sit for a scholarship exam. The students with the top 3 scores are to be awarded scholarships of $8,000, $5,000, and $2,000 respectively. How many different results are possible?

The number of possible results is found by determining the number of possible permutations of 25 items taken 3 at a time.

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		2nd Pgm 16		Select program		
1	25	A	25.	n	1	25. 25.
2	3	B	3.	r	2	3. 3.
3		D	13800.	$P\binom{n}{r}$	3	3. 13800.

*The printout shown is obtained using the print routine of Program 01.

Example 3: If a player is dealt 4 cards from a 52-card deck, how many possible hands can he receive?

By calculating the number of possible combinations of 52 items taken 4 at a time the number of possible hands is found.

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		2nd Pgm 16		Select program		
1	52	A	52.	n	1	52. 52.
2	4	B	4.	r	2	4. 4.
3		E	270725.	$C\binom{n}{r}$	3	4. 270725.

*The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	n	R_{06}		R_{11}		R_{16}	
R_{02}	r	R_{07}		R_{12}		R_{17}	
R_{03}	Used	R_{08}		R_{13}		R_{18}	
R_{04}	n!, P, C	R_{09}		R_{14}		R_{19}	

MOVING AVERAGES

This program calculates the moving average of the n most recent values in a sequence of variables. For example, the three-day moving average of maximum temperatures would contain the following values:

$$\text{day 3:}\quad \frac{m_1 + m_2 + m_3}{3}$$

$$\text{day 4:}\quad \frac{m_2 + m_3 + m_4}{3}$$

$$\text{day 5:}\quad \frac{m_3 + m_4 + m_5}{3}\text{, etc.}$$

The values for this type of sequence may be expressed as:

$$\frac{1}{n}\left(m_k + m_{k+1} + \cdots + m_{k+n-1}\right) \qquad k = 1,2,\ldots$$

Reference: Mathematics Dictionary, James/James.

Solid State Software				TI ©1977
MOVING AVERAGES				ML-17
				INIT
NUMBER	m→AVG			

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 17	
2	Initialize		2nd E'	0.
3	Enter number of values to be averaged	n[3]	A	n
4	Enter value to be averaged	m	B	average[2]
	Repeat for each value.			

NOTES:
1. Error conditions:
   For n ≤ 0 or n non-integer, the display will flash 9.9999999 99.
2. An average will be taken for all values entered below the nth value. Once the nth value is entered, the concept of moving averages begins.
3. The number of data registers available must be greater than or equal to n + 5.

Example: Determine a moving average of 3 on the number of traffic accidents resulting in injuries per month in a certain city. Records show the following sequence: 45, 50, 57, 65, 73, 81, 84, 84, 78, 68, 56, 48

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 17		Select program
1		2nd E'	0.	Initialize
2	3	A	3.	n
3	45	B	45.	
4	50	B	47.5	
5	57	B	50.66666667	
6	65	B	57.33333333	
7	73	B	65.	
8	81	B	73.	
9	84	B	79.33333333	
10	84	B	83.	
11	78	B	82.	
12	68	B	76.66666667	
13	56	B	67.33333333	
14	48	B	57.33333333	

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	3. 3.
3	45. 45.
4	50. 47.5
5	57. 50.66666667
6	65. 57.33333333
7	73. 65.
8	81. 73.
9	84. 79.33333333
10	84. 83.
11	78. 82.
12	68. 76.66666667
13	56. 67.33333333
14	48. 57.33333333

*The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}	New term	R_{10}	R_{15}
R_{01}	Pointer	R_{06}	See note	R_{11}	R_{16}
R_{02}	n	R_{07}		R_{12}	R_{17}
R_{03}	# Operands	R_{08}		R_{13}	R_{18}
R_{04}	Total sum	R_{09}		R_{14}	R_{19}

Note: R_{06} through R_{n-5} are used for storing entries.

COMPOUND INTEREST

In many investment situations involving interest, the interest earned is compounded to the principal for each interest period. In this manner, the interest earned in one period becomes principal and will earn interest during the following period.

The mathematical relationship that gives you a future value (FV) based on a present value (PV), or principal, compounded for N periods at an interest rate of I% per period is:

$$FV = PV\ (1 + I/100)^N$$

Given any three of these four factors as input data, this program solves for the remaining factor in this equation. The forms of the equation used in solving for each of the factors are shown in Methods Used.

The program can be used to solve compound interest problems using either the nominal annual rate method (U.S. method) or yearly effective rate method (European method). The two interest rates may be defined as follows:

$$\text{Nominal Annual Rate} = I \times N_c$$

$$1 + (YER/100) = 1(1 + I/100)^{N_c}$$

where

N_c is the number of compounding period per year

YER is the yearly effective rate.

Given FV, PV, and N, the program solves for the periodic interest rate, I, which is the same for either method. The nominal annual rate is found by simple multiplication by the number of periods per year as shown. To find YER, the term 1+(YER/100) is solved for using the program and YER is determined manually.

If the nominal annual interest rate is given, dividing this value by N_c provides I for input to the program. However, if the yearly effective interest rate is the known factor, the periodic rate I must be computed first using the program. This value can then be used without reentering in further calculations.

To simplify using the program for either method, two separate User Instructions are provided. Examples are given to demonstrate operation of the program for both methods.

Annuity Formulas

The four following basic annuity formulas are also accessible in this program to allow generation of annuity tables. See Program ML-19 for discussion of annuities.

Sinking Fund

$$s_{\overline{n}|i} = [(1 + i)^N - 1]/i$$

Ordinary Annuity/PV

$$a_{\overline{n}|i} = [1 - (1 + i)^{-N}]/i$$

Annuity Due/FV

$$(1 + i)s_{\overline{n}|i} = [(1 + i)^{N+1} - (1 + i)]/i$$

Annuity Due/PV

$$(1 + i)a_{\overline{n}|i} = [(1 + i) - (1 + i)^{1-N}]/i$$

Solid State Software				TI ©1977
COMPOUND INTEREST				ML-18
$S_{\overline{n}\rceil i}$	$(1+i)S_{\overline{n}\rceil i}$	$a_{\overline{n}\rceil i}$	$(1+i)a_{\overline{n}\rceil i}$	INIT
N	%I	PV	FV	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	U.S. Method			
1	Select program		2nd Pgm 18	
2	Initialize		2nd E'	0.00
3	Enter three of the following four variables in any order:			
	Number of periods	N	A	N
	Interest rate (percent per period)	%I	B	%I
	Present value	PV	C	PV
	Future value	FV	D	FV
4	Calculate the remaining variable			
	Number of periods	0	A	N
	Interest rate (percent per period)	0	B	%I
	Present value	0	C	PV
	Future value	0	D	FV
	Annuity Formulas			
	(See Note 1 below and Notes on Annuity Formulas)			
5	Solve for $S_{\overline{n}\rceil i}$		2nd A'	$S_{\overline{n}\rceil i}$
6	Solve for $(1+i)\,S_{\overline{n}\rceil i}$		2nd B'	$(1+i)S_{\overline{n}\rceil i}$
7	Solve for $a_{\overline{n}\rceil i}$		2nd C'	$a_{\overline{n}\rceil i}$
8	Solve for $(1+i)\,a_{\overline{n}\rceil i}$		2nd D'	$(1+i)a_{\overline{n}\rceil i}$

NOTE: 1. Steps 5-8 assume the following:
N is stored in R_{01}
$I \div 100$ is stored in R_{08}
$(I \div 100) + 1$ is stored in R_{09}

Example 1: What is the value of $500 after 24 months with interest compounded monthly, if the nominal annual interest rate is 5.75%?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 18		Select program
1		2nd E'	0.00	Initialize
2	24	A	24.00	Periods
	5.75	÷	5.75	I(annual)
3	12	= B	0.48	I(period)
4	500	C	500.00	PV
5	0	D	560.78	FV

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.00
2	24.00 24.00
3	0.48 0.48
4	500.00 500.00
5	0.00 560.78

*The printout shown was obtained using the print routine of Program 01.

Example 2: Compare the investment of $1000 for one year at the nominal annual interest rate of 5.75% compounded daily with the amount invested at 6% compounded quarterly.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 18		Select program
1		2nd E'	0.00	Initialize
2	365	A	365.00	Periods
	5.75	÷	5.75	I(annual)
3	365	= B	0.02	I(period)
4	1000	C	1000.00	PV
5	0	D	1059.18	FV
6	4	A	4.00	Periods
	6	÷	6.00	I(annual)
7	4	= B	1.50	I(period)
8	0	D	1061.36	FV

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.00
2	365.00 365.00
3	0.02 0.02
4	1000.00 1000.00
5	0.00 1059.18
6	4.00 4.00
7	1.50 1.50
8	0.00 1061.36

*The printout shown was obtained using the print routine of Program 01.

Note that it was not necessary to enter 1000 for the present value the second time.

Solid State Software TI ©1977

COMPOUND INTEREST				ML-18
$S_{\overline{n}\vert i}$	$(1+i)S_{\overline{n}\vert i}$	$a_{\overline{n}\vert i}$	$(1+i)a_{\overline{n}\vert i}$	INIT
N	%I	PV	FV	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	European Method			
1	Select program		2nd Pgm 18	
2	Initialize		2nd E'	0.00
	If annual interest rate is known			
3	Solve for I_{eff} per period			
3A	Enter periods per year	N_c	A	N_c
3B	Enter 1 as PV	1	C	1.00
3C	Enter $(1 + I_{ann}/100)$ as FV	$1 + I/100$	D	FV
3D	Solve for I_{eff} per period	0	B	I_{eff}
4	Enter two of the following three variables in any order:			
	Number of periods	N	A	N
	Present value	PV	C	PV
	Future value	FV	D	FV
5	Calculate the remaining variable:			
	Number of periods	0	A	N
	Present value	0	C	PV
	Future value	0	D	FV
	To solve for I_{ann}, given PV, FV, N			
6	Number of periods	N	A	N
7	Present value	PV	C	PV
8	Future value	FV	D	FV
9	Solve for I per period	0	B	I(period)
10	Solve for annual interest rate (I_{ann})			
10A	Periods per year (N_c)	N_c	A	N_c
10B	Enter 1 for PV	1	C	1.00
10C	$FV = 1 + I_{ann}/100$	0	D	$1 + I_{ann}/100$
10D	Subtract 1 and multiply by 100		−	
		1	= ×	
		100	=	I_{ann}

Example 3: (European Method) What is the value of $500 after 24 months with interest compounded monthly, if the yearly effective interest rate is 5.75%?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 18		Select program
1		[2nd] [E']	0.00	Initialize
2	12	[A]	12.00	N per yr for I_{eff}
3	1	[C]	1.00	PV for I_{eff}
4	1.0575	[D]	1.06	FV for I_{eff}
5	0	[B]	0.47	I_{eff}
6	24	[A]	24.00	N
7	500	[C]	500.00	PV
8	0	[D]	559.15	FV

OPTIONAL PRINTOUT*

REF.	PRINT
1	0.00 0.00
2	12.00 12.00
3	1.00 1.00
4	1.06 1.06
5	0.00 0.47
6	24.00 24.00
7	500.00 500.00
8	0.00 559.15

Example 4: (European Method) What is the interest rate per period and the yearly effective interest rate for a savings account which increased in value from $1234.00 to $1300.00 in 13 months if the interest was compounded monthly?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 18		Select program
1		[2nd] [E']	0.00	Initialize
2	13	[A]	13.00	N
3	1234	[C]	1234.00	PV
4	1300	[D]	1300.00	FV
5	0	[B]	0.40	I
6	12	[A]	12.00	N per yr for I_{eff}
7	1	[C]	1.00	PV for I_{eff}
8	0	[D] [−]	1.05	FV for I_{eff}
	1	[=] [×]	0.05	
	100	[=]	4.93	I_{eff} (annual)

OPTIONAL PRINTOUT*

REF.	PRINT
1	0.00 0.00
2	13.00 13.00
3	1234.00 1234.00
4	1300.00 1300.00
5	0.00 0.40
6	12.00 12.00
7	1.00 1.00
8	0.00 1.05

Notes on Annuity Formulas

The purpose of the annuity formulas accessed by user-defined keys A', B', C', and D' is to allow you to generate your own annuity tables or to write your own programs using these functions as subroutines.

The decimal periodic interest rate must be stored in R_{08} and this quantity plus one in R_{09}. This is done by user-defined key B in Program 18. N is stored in R_{01} by A in Program 18.

The following example shows how to access the ordinary annuity routine and use it to generate an annuity table. First key in the following sequence of instructions.

PRESS	DISPLAY	PRESS	DISPLAY
RST	0.	B	011 00
LRN	000 00	2nd Prt	012 00
2nd Lbl	001 00	INV SBR	013 00
A	002 00	2nd Lbl	014 00
STO	003 00	C	015 00
0 1	004 00	2nd Pgm	016 00
2nd Prt	005 00	1 8	017 00
INV SBR	006 00	2nd C'	018 00
2nd Lbl	007 00	2nd Prt	019 00
B	008 00	INV SBR	020 00
2nd Pgm	009 00	LRN	0.
1 8	010 00		

Now use this program to generate an ordinary annuity table for I = 8 and N = 1, 2, 3, ···, 10. Press INV 2nd Fix. If the PC-100A is available, all of the displayed values will be printed.

ENTER	PRESS	DISPLAY
8	B	8.
1	A	1.
	C	.9259259259
2	A	2.
	C	1.783264746
3	A	3.
	C	2.577096987
4	A	4.
	C	3.31212684
5	A	5.
	C	3.992710037
6	A	6.
	C	4.622879664
7	A	7.
	C	5.206370059
8	A	8.
	C	5.746638944
9	A	9.
	C	6.246887911
10	A	10.
	C	6.710081399

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	N	R_{06}		R_{11}		R_{16}	
R_{02}	I	R_{07}		R_{12}	$[(I \div 100) + 1]^N$	R_{17}	
R_{03}	PV	R_{08}	$I \div 100$	R_{13}		R_{18}	
R_{04}	FV	R_{09}	$(I \div 100) + 1$	R_{14}		R_{19}	

Method Used

The compound interest equation is used in the following forms.

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

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

$$I = [(FV/PV)^{1/N} - 1] \times 100$$

$$N = \ln(FV/PV)/\ln(1 + i)$$

ANNUITIES

An annuity is a series of equal payments made at regular intervals of time. The time intervals between payments are called payment periods. An annuity is a compound interest situation with periodic payments. When the payments are made at the ends of the payment periods, the annuity is called an **ordinary annuity**. When the payments are made at the beginning of the payment periods, the annuity is called an **annuity due.**

There are many money situations that involve not only a series of payments, but also a payment at termination that is larger or smaller than the regular payments. These are called balloon payments and can be for a loan you decide to pay off before its normal duration is complete or for situations like the ownership of property from which you have received a steady flow of rent, then decided to sell, producing a large impulse of income at the end of the investment. A balloon payment is equal to the remaining principal balance at that time.

This program handles four types of annuities:

Sinking Fund
Annuity Due/FV
Ordinary Annuity/PV
Annuity Due/PV

Sinking Fund

In simple terms a sinking fund is a savings fund designed to accumulate a definite amount of money on a specified date. This amount is the future value of an ordinary annuity and can be calculated from:

$$FV = PMT \times \frac{(1 + i)^N - 1}{i}$$

where

FV = future value
PMT = payment
i = I/100
I = interest rate per period in %
N = number of periods

Given any three of the four variables, the program will calculate the remaining variable.

Annuity Due/FV

This type of annuity situation is most easily described as the future value of a savings account with equal deposits being made at the beginning of each period. The future value is calculated from:

$$FV = PMT \times (1 + i) \times \frac{(1 + i)^N - 1}{i}$$

where the variables are defined as for sinking fund. The program will calculate any one of the variables, given the other three as inputs.

Ordinary Annuity/PV

A loan such as a home mortgage is a prime example of this annuity situation in which a sum of money is to be repaid with interest by certain payments for a fixed number of periods. A balloon payment is sometimes associated with this type of annuity. The present value is calculated as:

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

where BAL = balloon payment (may equal zero)
The other variables are defined as for Sinking Fund.

Given four of the five variables, the program will solve for the fifth.

Annuity Due/PV

Rent or lease situations are common examples of this type of annuity. In other words, what is the present value of a lease which will involve fixed payments for a certain number of periods if the interest rate requirement of the lessor is known. A balloon payment at the end of the term may be involved. The present value is:

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

The program will calculate any one of the variables, given the other four as inputs.

Solid State Software				TI ©1977
ANNUITIES				ML-19
Sinking Fund	Ann Due/FV	Ord Ann/PV	Ann Due/PV	INIT
N	%I	PMT	PV/FV	B. PMT

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 19	
2	Initialize		2nd E'	0.
3	Select type of routine:			
	Sinking Fund		2nd A'	0.
	Annuity Due/FV		2nd B'	0.
	Ordinary Annuity/PV		2nd C'	0.
	Annuity Due/PV		2nd D'	0.
4	Enter the known variables in any order			
	Number of Periods	N	A	N
	Interest Rate (percent per period)	%I	B	%I
	Payment per Period	PMT	C	PMT
	PV or FV	PV or FV	D	PV or FV
	Balloon Payment[1]	BAL	E	BAL
5	Solve for the unknown variable			
	Number of Periods	0	A	N
	Interest Rate (percent per period)	0	B	%I
	Payment per Period	0	C	PMT
	PV or FV	0	D	PV or FV
	Balloon Payment	0	E	BAL
6	To solve another problem of the same type, go to Step 4 (See Note 2). For a problem of a different type, go to Step 2.			

NOTES: 1. If balloon payment does not apply, **DO NOT** enter zero. Merely skip the step.

2. If balloon payment was non-zero in the previous problem and is zero in the new problem, go to Step 2.

Register Contents

R_{00}		R_{05}	B.PMT	R_{10}	Used	R_{15}	
R_{01}	N	R_{06}	Used	R_{11}	Used	R_{16}	
R_{02}	%I	R_{07}	Used	R_{12}	Used	R_{17}	
R_{03}	PMT	R_{08}	I ÷ 100	R_{13}	Used	R_{18}	
R_{04}	PV/FV	R_{09}	(I ÷ 100) + 1	R_{14}	Used	R_{19}	

Example 1: Sinking Fund

At the end of each month, a corporation will deposit $25 in a fund to provide for the replacement of a certain machine at the end of a 10-year period. If the fund accumulates at the rate of 5¼%, compounded monthly, how much is in the fund: a) at the end of 4½ years; b) at the end of 10 years?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 19		Select program
1		2nd E'	0.	Initialize
2		2nd D'	0.	Sinking Fund
	4.5	×	4.5	
3	12	= A	54.	N
	5.25	÷	5.25	
4	12	= B	0.4375	%I
5	25	C	25.00	PMT
6	0	D	1519.08	FV
	10	×	10.00	
7	12	= A	120.	N
8	0	D	3934.42	FV

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	0. 0.
3	54. 54.
4	0.4375 0.4375
5	25.0000 25.00
6	0.00 1519.08
7	120.00 120.
8	0. 3934.42

*The printout shown is obtained using the print routine of Program 01.

Example 2: Annuity Due/FV

Sam wants to be able to save $10,000 over the next 10 years so he can pay off his home mortgage. If he can put $50 at the beginning of each month into a savings plan, what monthly interest rate must it have for him to accumulate the $10,000 by the end of the tenth year?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 19		Select program
1		2nd E'	0.	Initialize
2		2nd C'	0.	Annuity due/FV
3	10000	D	10000.00	FV
4	50	C	50.00	PMT
	10	×	10.00	
5	12	= A	120.	N
6	0	B 1	0.7869	I(monthly)

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	0. 0.
3	10000. 10000.00
4	50.00 50.00
5	120. 120.
6	0. 0.7869

*The printout shown is obtained using the print routine of Program 01.

Example 3: Ordinary Annuity/PV

Calculate the monthly payments on a 30-year basis for a $32,000 loan at an 8.75% annual interest rate. Also calculate the payments for this loan on a 20-year basis.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 19		Select program
1		[2nd] [E']	0.	Initialize
2		[2nd] [C']	0.	Ordinary annuity
	8.75	[÷]	8.75	
3	12	[=] [B]	0.7292*	I(monthly)
4	32000	[D]	32000.00	PV
	30	[×]	30.00	
5	12	[=] [A]	360.	N(30-yr)
6	0	[C]	251.74	PMT(30-yr)
	20	[×]	20.00	
7	12	[=] [A]	240.	N(20-yr)
8	0	[C]	282.79	PMT(20-yr)

OPTIONAL PRINTOUT**

REF.	PRINT
1	0. 0.
2	0. 0.
3	.7291666667 0.7292
4	32000.0000 32000.00
5	360.00 360.
6	0. 251.74
7	240.00 240.
8	0. 282.79

*Display is rounded to 4 places; however, full results of the division are used in the calculation.

** The printout shown is obtained using the print routine of Program 01.

Example 4: Annuity Due/PV

A copier company leases its high-volume copier costing $45,000 for 2 years for $2000 per month payable on the first of each month. The company expects to sell the copier for $10,000 after the 2-year period. What yield can be expected?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 19		Select program
1		[2nd] [E']	0.	Initialize
2		[2nd] [D']	0.	Annuity due/PV
3	45000	[D]	45000.00	PV
4	2000	[C]	2000.00	PMT
5	10000	[E]	10000.00	BAL
	2	[×]	2.00	
6	12	[=] [A]	24.	N
7	0	[B] [×]	1.9638	I(monthly)
	12	[=]	23.5651	I(annual)

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.
2	0. 0.
3	45000. 45000.00
4	2000.00 2000.00
5	10000.00 10000.00
6	24.00 24.
7	0. 1.9638

*The printout shown is obtained using the print routine of Program 01.

The yield will be 1.9638%/month or 23.5651%/year.

Method Used

The following equations are used to solve for the variables shown in the various annuity situations.

Sinking Fund

$$FV = PMT \times \frac{(1 + i)^N - 1}{i}$$

$$N = \ln\left(\frac{FV \times i}{PMT} + 1\right) \Big/ \ln(1 + i)$$

$$PMT = FV \times i/[(1 + i)^N - 1]$$

I is determined by the Newton-Raphson method.

Annuity Due/FV

$$FV = PMT \times (1 + i) \times \frac{(1 + i)^N - 1}{i}$$

$$N = \ln\left[\frac{FV}{PMT} \times i + (1 + i)\right] \Big/ \ln(1 + i) - 1$$

$$PMT = FV \Big/ \left[(1 + i) \times \frac{(1 + i)^N - 1}{i}\right]$$

I is determined by the Newton-Raphson method.

Ordinary Annuity/PV

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

$$N = \ln[(PMT - i\,BAL)/(PMT - i\,PV)]/\ln(1 + i)$$

$$PMT = [PV - BAL(1 + i)^{-N}] \Big/ \left[\frac{1 - (1 + i)^{-N}}{i}\right]$$

I is determined by the Newton-Raphson method.

$$BAL = \left(PV - PMT \times \frac{1 - (1 + i)^{-N}}{i}\right) \Big/ (1 + i)^{-N}$$

Annuity Due/PV

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

$$N = \ln\left[\left(\frac{PMT(1 + i)}{i} - BAL\right) \Big/ \left(\frac{PMT(1 + i)}{i} - PV\right)\right] \Big/ \ln(1 + i)$$

$$PMT = \left[PV - BAL \times (1 + i)^{-N}\right] \Big/ \left[(1 + i) \times \frac{1 - (1 + i)^{-N}}{i}\right]$$

I is determined by the Newton-Raphson method.

$$BAL = \left[PV - PMT \times (1 + i) \times \left(\frac{1 - (1 + i)^{-N}}{i}\right)\right] \Big/ (1 + i)^{-N}$$

where:

N = number of payment periods

PV = present value

FV = future value

BAL = balloon payment

I = periodic interest

i = I ÷ 100

DAY OF THE WEEK
DAYS BETWEEN DATES

This program calculates the number of days between any two calendar dates after the year 1582. It also determines the day of the week for any date after the year 1582. The calculations are based on the Gregorian calendar.

Note that the dates are entered in the order: month, day, year using the format MMDD.YYYY.

The days of the week are represented by single digits 0 through 6 for Saturday through Friday, respectively.

Solid State Software			TI ©1977	
DAY OF WEEK, DAYS BETWEEN DATES				ML-20
(M M D D.Y Y Y Y)				
DATE 1	DATE 2	No. DAYS	D → D of W	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 20	
	Days Between Dates			
2	Enter first date	MMDD.YYYY	A	0.
3	Enter second date	MMDD.YYYY	B	0.
4	Calculate number of days between given dates		C	No. of days
	Day of the Week			
5	Enter date and calculate day of week *0 – Sat 4 – Wed 1 – Sun 5 – Thurs 2 – Mon 6 – Fri 3 – Tues	MMDD.YYYY	D	Day of week*

NOTES:
1. Date must be entered in the order: month day year
2. Error conditions
   - a. negative inputs
   - b. DD > 31
   - c. MM > 12
   - d. YYYY < 1582

Example 1: Days Between Dates

How many days are between June 1, 1960 and October 31, 1976? How many days are between October 1, 1976 and October 31, 1976?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 20		Select program
1	601.1960	A	0.	First date
2	1031.1976	B	0.	Second date
3		C	5996.	No. of days
4	1001.1976	A	0.	New date
5		C	30.	No. of days

OPTIONAL PRINTOUT* REF.	PRINT
1	601.196 0.
2	1031.1976 0.
3	0. 5996.
4	1001.1976 0.
5	0. 30.

*The printout shown is obtained using the print routine of Program 01.

Example 2: Day of the Week

On what day of the week was December 7, 1941?

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 20		Select program
1	1207.1941	D	1.*	Day of week

OPTIONAL PRINTOUT** REF.	PRINT
1	1207.1941 1.

*0 – Saturday, 1 – Sunday, 2 – Monday, 3 – Tuesday, 4 – Wednesday, 5 – Thursday, 6 – Friday

**The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}	FACTOR 2	R_{10}		R_{15}	
R_{01}	MM	R_{06}		R_{11}		R_{16}	
R_{02}	DD	R_{07}		R_{12}		R_{17}	
R_{03}	YYYY	R_{08}		R_{13}		R_{18}	
R_{04}	FACTOR 1	R_{09}		R_{14}		R_{19}	

Method Used

The number of days between two dates is found by calculating the FACTOR for each date, then finding the difference between the FACTORS.

For January and February:

$$\text{FACTOR} = 365(\text{YYYY}) + \text{DD} + 31(\text{MM} - 1) + \text{INT}\,[(\text{YYYY} - 1)/4] - \text{INT}(\tfrac{3}{4}[\text{INT}[((\text{YYYY} - 1)/100) + 1]])$$

For March through December:

$$\text{FACTOR} = 365(\text{YYYY}) + \text{DD} + 31(\text{MM} - 1) - \text{INT}(.4\text{MM} + 2.3) + \text{INT}(\text{YYYY}/4) - \text{INT}(\tfrac{3}{4}[\text{INT}(\text{YYYY}/100) + 1])$$

In these formulas INT indicates using only the integer portion of the expression.

The day of the week for any date is determined from the FACTOR for that date as follows:

$$\text{Day of Week} = \text{FACTOR} + [\text{INT}(-\text{FACTOR}/7) \times 7]$$

where the day of the week is represented by a single digit 0 through 6 for Saturday through Friday, respectively.

HI-LO GAME

In addition to recreational diversion, this program serves as a nontechnical demonstration of the library module. The game is easy to play, permitting almost immediate hands-on experience for any user.

The object of the game is to guess a secret number (whole numbers only) from 1 to 1023 that has been generated in the calculator. The calculator responds with a "too high," "too low," or "correct" indication to each of your guesses. Your score (number of guesses) is tallied by the calculator.

Also, you may select a number in the range 1 to 1023 and the calculator will attempt to guess this number as you supply proper responses to each of its guesses. When the calculator has found the number you selected, its score will be displayed.

An exercise which often casts doubt on the "man over machine" axiom is to have the calculator guess the same number that it generated for you to guess. Now, follow the User Instructions and see if you can uphold the superiority of man.

Solid State Software			TI ©1977	
HI-LO GAME				ML-21
M INIT	M LO	M HI	M CORR	
INIT	GO	GUESS	SCORE	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 21	
	You Guess			
2	Key in a number (0 to 1)*	Number	A	0.
3	Generate secret number		B	0.
4	Enter your guess (1 to 1023) Clue: −1. if guess was low 1. if guess was high flashing 0. if your guess was correct	Guess	C	Clue
5	Repeat Step 4 as required			
6	Display score		D	Score
7	For a new number, go to Step 3			
	Calculator Guesses			
8	Select a number (1 to 1023)			
9	Display calculator's first guess		2nd A'	Calc. guess
10	If calculator's guess is:			
	Low		2nd B'	Calc. guess
	High		2nd C'	Calc. guess
	Correct		2nd D'	Calc. guess
11	Repeat Step 10 as required			
12	For a new game, go to Step 8			

*Each number you select will produce a different game.

Example: User challenges the machine by first attempting to guess its secret number (530). He then chooses a number (848) and the machine guesses it in only six tries.

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	OPTIONAL PRINTOUT* PRINT
		2nd Pgm 21		Select program		
1	.12345	A	0.12345	Initialize	1	0.12345 0.12345
2		B	0.	Machine selects no.	2	0.12345 0.
3	200	C	−1.	200 is low	3	200. −1.
4	600	C	1.	600 is high	4	600. 1.
5	400	C	−1.	400 is low	5	400. −1.
6	500	C	−1.	500 is low	6	500. −1.
7	550	C	1.	550 is high	7	550. 1.
8	525	C	−1.	525 is low	8	525. −1.
9	530	C	flashing 0.	530 is correct	9	530. 0.?
10		D	7.	7 tries	10	0.? 7.
11		2nd A'	512.	low	11	7. 512.
12		2nd B'	768.	low	12	512. 768.
13		2nd B'	896.	high	13	768. 896.
14		2nd C'	832.	low	14	896. 832.
15		2nd B'	864.	high	15	832. 864.
16		2nd C'	848.	correct	16	864. 848.
17		2nd D'	6.	6 tries	17	848. 6.

*The printout shown is obtained using the print routine of Program 01.

Register Contents

R_{00}		R_{05}	User's Guess	R_{10}		R_{15}	
R_{01}	M Guess	R_{06}		R_{11}		R_{16}	
R_{02}	Guesses Left	R_{07}		R_{12}		R_{17}	
R_{03}	Machine's No.	R_{08}		R_{13}		R_{18}	
R_{04}	No. Guesses	R_{09}	Seed	R_{14}		R_{19}	

CHECKING/SAVINGS ACCOUNT MANAGEMENT

This program will determine the current balances on checking and savings accounts when given the starting balances as inputs. In addition to accepting checking and savings deposits and withdrawals (checks), the program will add savings interest when given the interest rate and the number of compounding periods. The resulting balances may be carried forward on a magnetic card (TI Programmable 59 only) or may be written down and keyed in the next time the program is used.

The savings balance is adjusted for interest using the classical compound interest equation:

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

where

FV = future value (new balance)
PV = present value (current balance)
i = periodic interest rate (decimal)
N = number of periods

Note that this formula must be applied to periods when PV has not been altered by deposits or withdrawals. Therefore, an active account having daily compounding periods will require several applications of this formula (once for each deposit or withdrawal).

Solid State Software			TI ©1977	
CHECKING/SAVINGS ACCOUNT				ML-22
Checking	Savings	I%/Yr	Periods/Yr	
Balance	Deposit	Withdrawal	No. Periods	New Bal.

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 22	
2	Load data registers from card[1] or			
	Enter checking balance	C. Bal	2nd A' E	C. Bal.
	Enter savings balance	S. Bal	2nd B' E	S. Bal.
3	Select checking mode		2nd A'	
4	Enter deposit amount	Dep. amt.	B	New Bal.
5	Enter check amount	Chk. amt.	C	New Bal.
6	Repeat 4 and 5 as necessary			
7	Select savings mode		2nd B'	
8	To add interest:			
	Enter annual interest rate (%)	%I/yr	2nd C'	%I/yr
	Enter compounding periods per year	P	2nd D'	%I/per.
	Enter number of periods	N	D	New Bal.
9	To add savings deposit	Dep. amt.	B	New Bal.
10	To subtract savings withdrawal	Withdr. amt.	C	New Bal.
11	To display checking balance		2nd A' A	Chk. Bal.
12	To display savings balance		2nd B' A	Sav. Bal.
13	Optional: Record data registers on card[1]			

NOTE: 1. For TI Programmable 59 only.

Register Contents

R_{00}		R_{05}	Checking Bal.	R_{10}	Ind. Bal. Pointer	R_{15}	
R_{01}	N	R_{06}	Savings Bal.	R_{11}		R_{16}	
R_{02}	I	R_{07}	I	R_{12}		R_{17}	
R_{03}	PV	R_{08}	$I \div 100$	R_{13}		R_{18}	
R_{04}	FV	R_{09}	$(I \div 100) + 1$	R_{14}		R_{19}	

Example: Mr. Smith decides to balance his checking and savings accounts at the end of April. His bank pays 5% interest (annual rate) on savings accounts, credited daily. His savings balance at the end of March was $1732.84 while his checking balance was $231.70. Activity for the month was as follows:

Checking deposits: $231.60, $50.00
Checks: $43.10, $18.73, $103.79, $10.36
Savings deposits: $304.00, $428.00 (on 10th and 14th)
Savings withdrawals: $1000.00 (on 20th)

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		2nd Pgm 22		Select program
1		2nd A'	0.00	Checking mode
2	231.70	E	231.70	Checking balance
3	231.60	B	463.30	Deposit
4	50.00	B	513.30	Deposit
5	43.10	C	470.20	Check
6	18.73	C	451.47	Check
7	103.79	C	347.68	Check
8	10.36	C	337.32	Final checking balance
9		2nd B'	337.32	Savings mode
10	1732.84	E	1732.84	Savings balance
11	5	2nd C'	5.00	I(annual)
12	365	2nd D'	0.01	I(daily)
13	10	D	1735.22	Balance on 10th
14	304	B	2039.22	Deposit
15	4	D	2040.33	Balance on 14th
16	428	B	2468.33	Deposit
17	6	D	2470.36	Balance on 20th
18	1000	C	1470.36	Withdrawal
19	10	D	1472.38	Final savings balance

OPTIONAL PRINTOUT*

REF.	PRINT
1	0. 0.00
2	231.70 231.70
3	231.60 463.30
4	50.00 513.30
5	43.10 470.20
6	18.73 451.47
7	103.79 347.68
8	10.36 337.32
9	337.32 337.32
10	1732.84 1732.84
11	5.00 5.00
12	365.00 0.01
13	10.00 1735.22
14	304.00 2039.22
15	4.00 2040.33
16	428.00 2468.33
17	6.00 2470.36
18	1000.00 1470.36
19	10.00 1472.38

*The printout shown is obtained using the print routine of Program 01.

DMS OPERATIONS

Addition or subtraction of two numbers in degree-minute-second format (dd.mmss) can be accomplished using this program. Also, a number in degree-minute-second format can be multiplied or divided by a scalar.

The program can also be used for time calculations with the values in hour-minute-second format (hh.mmss).

Solid State Software			TI ©1977	
DMS OPERATIONS				ML-23
(dd.mmss)				
n	±p→n±p	a→n×a	a→n÷a	

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		[2nd] [Pgm] 23	
2	Enter number n (dd.mmss)	n	[A]	n(dec. deg.)
	For Addition or Subtraction			
3	For addition, enter number p(dd.mmss)	p	[B]	(n + p)
4	For subtraction, enter number p(dd.mmss)	p	[+/-] [B]	(n − p)
	For Multiplication or Division			
5	For multiplication, enter scalar a	a	[C]	(n × a)
6	For division, enter scalar a	a	[D]	(n ÷ a)

NOTES:
1. Display is in Fix 4 format after any of the four operations is performed.
2. For chained operations, the result of an operation should be used directly as the entered number in Step 2. This will minimize rounding errors.

Register Contents

R_{00}		R_{05}		R_{10}		R_{15}	
R_{01}	n	R_{06}		R_{11}		R_{16}	
R_{02}		R_{07}		R_{12}		R_{17}	
R_{03}		R_{08}		R_{13}		R_{18}	
R_{04}		R_{09}		R_{14}		R_{19}	

Example 1: Mr. Smith's flight will leave at 8:00 a.m. and is scheduled for 3 hours, 20 minutes. At what time will he arrive at his destination?

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		[2nd] [Pgm] 23		Select program	1	8. 8.
1	8	[A]	8.	Decimal hours		
2	3.2	[B]	11.2000	Sum(hh.mmss)	2	3.2 11.2000

*The printout shown is obtained using the print routine of Program 01.

Example 2: Subtract from angle 47°00'31" angle 24°43'35".

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		[2nd] [Pgm] 23		Select program	1	47.0031 47.00861111
1	47.0031	[A]	47.00861111	Decimal degrees		
2	24.4335	[+/-] [B]	22.1656	Difference(dd.mmss)	2	-24.4335 22.1656

*The printout shown is obtained using the print routine of Program 01.

Example 3: What is twice 20°30'45"?

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		[2nd] [Pgm] 23		Select program	1	20.3045 20.5125
1	20.3045	[A]	20.5125	Decimal degrees		
2	2	[C]	41.0130	Product(dd.mmss)	2	2. 41.0130

*The printout shown is obtained using the print routine of Program 01.

Example 4: What is half of 160°89'77"?

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		[2nd] [Pgm] 23		Select program	1	160.8977 161.5047222
1	160.8977	[A]	161.5047222	Decimal degrees		
2	2	[D]	80.4509	Quotient(dd.mmss)	2	2. 80.4509

*The printout shown is obtained using the print routine of Program 01.

UNIT CONVERSIONS (1)

This program provides length conversions through the user-defined keys as follows:

Key	Conversion	Operation
A	inches to centimeters	multiples by 2.54
2nd A'	centimeters to inches	divides by 2.54
B	feet to meters	multiplies by 0.3048
2nd B'	meters to feet	divides by 0.3048
C	yards to meters	multiplies by 0.9144
2nd C'	meters to yards	divides by 0.9144
D	statute miles to kilometers	multiplies by 1.609344
2nd D'	kilometers to statute miles	divides by 1.609344
E	statute miles to nautical miles (Int.)	multiplies by 0.86897624
2nd E'	nautical miles (Int.) to statute miles	divides by 0.86897624

Area conversions may be obtained by pressing the conversion key twice. Volume conversions may be obtained by pressing the conversion key three times.

Solid State Software				TI ©1977
UNIT CONVERSIONS (1)				ML-24
cm→in	m→ft	m→yd	km→mi	n mi→mi
in→cm	ft→m	yd→m	mi→km	mi→n mi

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 24	
2	To convert:			
	inches to centimeters	inches	A	cm
	centimeters to inches	cm	2nd A'	inches
	feet to meters	feet	B	meters
	meters to feet	meters	2nd B'	feet
	yards to meters	yards	C	meters
	meters to yards	meters	2nd C'	yards
	miles to kilometers	miles	D	km
	kilometers to miles	km	2nd D'	miles
	miles to nautical miles	miles	E	nau. miles
	nautical miles to miles	nau. miles	2nd E'	miles

Example 1: Convert the following:

2 inches to centimeters
6 feet to meters
20 yards to meters
1000 kilometers to miles
100 meters to feet

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		2nd Pgm 24		Select program	1	2. 5.08
1	2	A	5.08	in to cm		
2	6	B	1.8288	ft to m	2	6. 1.8288
3	20	C	18.288	yd to m	3	20. 18.288
4	1000	2nd D'	621.3711922	km to mi	4	1000. 621.3711922
5	100	2nd B'	328.0839895	m to ft	5	100. 328.0839895

*The printout shown is obtained using the print routine of Program 01.

Example 2: Find the volume in cubic centimeters of a rectangular tank that is 12 inches by 6 inches by 4 inches.

REF.	ENTER	PRESS	DISPLAY	COMMENTS	OPTIONAL PRINTOUT* REF.	PRINT
		2nd Pgm 24		Select program	1	288. 731.52
	12	×	12.			731.52 1858.0608
	6	×	72.			1858.0608 4719.474432
	4	=	288.	cubic inches		
1		A A A	4719.474432	cubic cm		

*The printout shown is obtained using the print routine of Program 01.

Register Contents

No registers used.

UNIT CONVERSIONS (2)

This program provides volume, weight, and temperature conversions through the user-defined keys as follows:

Key	Conversion	Operation
A	°F to °C	$C = \frac{5}{9}(F - 32)$
2nd A'	°C to °F	$F = \frac{9}{5}C + 32$
B	fluid ounces to liters	multiplies by 0.0295735296
2nd B'	liters to fluid ounces	divides by 0.0295735296
C	gallons (U.S.) to liters	multiplies by 3.785411784
2nd C'	liters to gallons (U.S.)	divides by 3.785411784
D	ounces (av.) to grams	multiplies by 28.34952313
2nd D'	grams to ounces (av.)	divides by 28.34952313
E	pounds (av.) to kilograms	multiplies by 0.45359237
2nd E'	kilograms to pounds (av.)	divides by 0.45359237

The output of one conversion may be used as input to another by simply leaving the answer in the display and pressing another user-defined key.

Solid State Software				TI ©1977
UNIT CONVERSIONS (2)				ML-25
°C→°F	lit→oz	lit→US gal	gm→oz	kg→lb
°F→°C	oz→lit	US gal→lit	oz→gm	lb→kg

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Select program		2nd Pgm 25	
2	To convert:			
	°F to °C	°F	A	°C
	°C to °F	°C	2nd A'	°F
	fluid ounces to liters	fl. oz.	B	liters
	liters to fluid ounces	liters	2nd B'	fl. oz.
	U.S. gallons to liters	gallons	C	liters
	liters to U.S. gallons	liters	2nd C'	gallons
	ounces to grams	ounces	D	grams
	grams to ounces	grams	2nd D'	ounces
	pounds to kilograms	pounds	E	kg
	kilograms to pounds	kg	2nd E'	pounds

Example 1: Convert the following:

410°F to °C
10 fluid ounces to liters
35 ounces to grams
122 pounds to kilograms
100 kilograms to pounds

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 25		
1	410	[A]	210.	°F to °C
2	10	[B]	0.295735296	fl. oz. to liters
3	35	[D]	992.2333096	oz to grams
4	122	[E]	55.33826914	lb to kg
5	100	[2nd] [E']	220.4622622	kg to lb

OPTIONAL PRINTOUT*

REF.	PRINT
1	410. 210.
2	10. 0.295735295
3	35. 992.2333096
4	122. 55.33826914
5	100. 220.4622622

*The printout shown is obtained using the print routine of Program 01.

Example 2: Convert 6.2 pounds per gallon to kilograms per liter.

REF.	ENTER	PRESS	DISPLAY	COMMENTS
		[2nd] [Pgm] 25		
1	6.2	[E]	2.812272694	kg per gallon
2		[2nd] [C']	.7429238494	kg per liter

OPTIONAL PRINTOUT*

REF.	PRINT
1	6.2 2.812272694
2	2.812272694 .7429238494

*The printout shown is obtained using the print routine of Program 01.

Register Contents

No registers used.

APPENDIX A: PROGRAM REFERENCE DATA

Program Number	Title	No. of Steps	Data Reg. Used	Flags Used	SBR. Levels	Paren. Levels	Calls Pgm.	Special Functions Used	x ≷ t	ABS. Address.	Fix Decimal	EE*	=	Angular Mode	Program Number
01	Diagnostic	189	0-6, 9		1	4	15	N/A	CP		9			Deg	01
02	Determinant, Matrix, Simultaneous Equations	898	1-15 min.		2	1			X	X			Used		02
03	Matrix Addition and Multiplication	274	1-7 min.		1	1			X				Used		03
04	Complex Arithmetic	167	1-4		3	2	5	P/R	X					Rad	04
05	Complex Functions	119	1-4		2	2	4	P/R	X					Rad	05
06	Complex Trig Functions	250	1-4		2	4	4,5	P/R	X			X		Rad	06
07	Polynomial Evaluation	78	1-4		0	1			X						07
08	Zeros of Functions	144	1-8		1	1	00		X						08
09	Simpson's Approximation (Continuous)	118	1-5		1	1	00		X						09
10	Simpson's Approximation (Discrete)	123	1-9 min.		0	1			X						10
11	Triangle Solution (1)	195	1-6	0-3	0	2						X			11
12	Triangle Solution (2)	155	1-7	0	0	2									12
13	Curve Solution	188	1-4	0,1	1	3			CP					Rad	13
14	Normal Distribution	143	1-3	1	0	2			CP						14
15	Random Number Generator	136	1-11		1	3	1	Σ+	CP					Rad	15
16	Combinations, Permutations, Factorials	132	1-4	1	1	0			X						16
17	Moving Averages	117	1-7 min.	1	0	1			X						17
18	Compound Interest	171	1-4, 8, 9, 12		2	3			CP		2				18
19	Annuities	589	1-14	1-4	3	3	18		X	X	2,4,9				19
20	Day of the Week, Days Between Dates	191	1-5		1	5			X						20
21	Hi-Lo	95	1-5, 9		1	4	15		X						21
22	Checking/Savings Acct.	94	1-10		1	1	18		CP		2				22
23	DMS Operations	52	1		1	5		DMS			4				23
24	Unit Conversions (1)	96	–		1	1									24
25	Unit Conversions (2)	124	–		1	2									25
	Pointers & Counters	162													

*Does not run in ENG format

NOTES

NOTES

TEXAS INSTRUMENTS
INCORPORATED
DALLAS TEXAS

Printed in U.S.A.

1014984-11