HEWLETT-PACKARD

HP-67

Standard Pac

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Introduction

The HP-67 Standard Pac provides an excellent nucleus from which to build your program library. The programs address topics common to business, science, and engineering as well as providing enjoyable programs such as *Arithmetic Teacher, Follow Me, and Moon Rocket Lander.*

No knowledge of programming is required to use the programs in Standard Pac. However, familiarity with sections one through five of the Owner's Handbook (or previous HP calculator experience) is assumed. If this is your first encounter with programmability, be sure to read ''Running a Program'' on pages iv to xi of this manual. This detailed description is designed to help you become more familiar with your calculator. It is most effective when you perform all operations as they are described.

For each program the Standard Pac provides a description, user instructions, keystrokes for example problems, a prerecorded magnetic card (in the plastic card case) and program listings (at the back of this manual). There is also a diagnostic program for checking calculator operation, a head cleaning card which can be used occasionally to clean the magnetic card read/write head, and blank magnetic cards which may be used to record the programs you write.

Standard Pac differs from optional HP-67/97 application pacs in that it contains explanations of important programming techniques. The titles and page numbers of these explanations may be found opposite page 15-03 of this manual.

We hope you find Standard Pac useful in your daily calculations.

NOTES

CONTENTS

RUNNING A PROGRAM

Loading A Program

Select the *Curve Fitting* card, SD-03A, from the card case supplied with this application pac.

Set W/PRGM-RUN switch to RUN.

Turn the calculator ON. You should see 0.00.

Gently insert either end of the card (printed side up) in the reader slot as shown in figure 1.

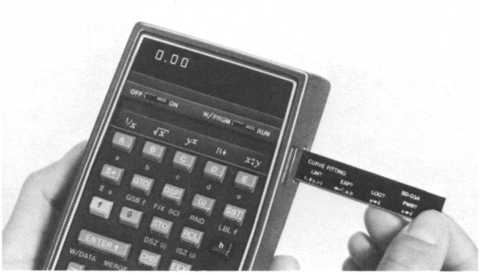


Figure 1.

When the card is part way in, a motor engages and passes it out the side of the calculator. Sometimes the motor engages but does not pull the card in. If this happens, push the card a little farther into the machine. Do not impede or force the card; let it move freely.

The display will show ''Error'' if the card reads improperly. In this case, press CL x and reinsert the card.

Since *Curve Fitting* is longer than 112 steps, the display now shows ''Crd'' indicating that a second card pass is necessary to load the remaining steps. With the writing still visible to you, insert the *opposite* end of the card (figure 2) and pass the card through the card reader again.

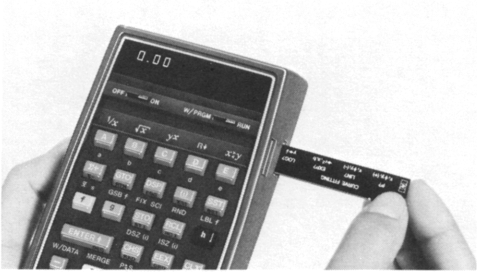


Figure 2.

When the motor stops, remove the card from the side of the calculator and insert it in the ''window slot'' of the calculator (see figure 3).

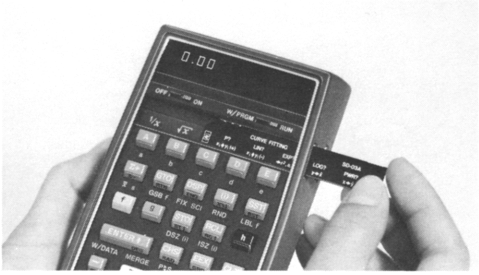


Figure 3.

The program has now been stored in the calculator. It will remain stored until another program is loaded or the calculator is turned off.

MAGNETIC CARD

Instructions On The Magnetic Card

Look at the card that you just inserted in the window slot of the calculator. The mnemonics on the card can help you run the program. The most important thing to note is that the mnemonics are associated with the user-definable keys A – E. For instance ''LOG?'' and ''y →x̂'' are associated with the D key.

Following is a table of the important types of symbols and conventions used in this pac. The table is provided as a reference until you become familiar with the symbols on the magnetic cards.

Symbols And Conventions

SYMBOL OR CONVENTION	INDICATED MEANING
White mnemonic: x A	White mnemonics are associated with the user-definable key they are above when the card is inserted in the calculator's window slot. In this case the value of x could be input by keying it in and pressing A.
Gold mnemonic: y x f E	Gold mnemonics are similar to white mnemonics except that the gold f key must be pressed before the user-definable key. In this case y could be input by pressing f E.
x ↑ y A	↑ is the symbol for ENTER↑. In this case ENTER↑ is used to separate the input variables x and y. To input both x and y you would key in x, press ENTER↑, key in y and press A.
$\boxed{x}$ A	The box around the variable x indicates input by pressing STO A.
(x) A	Parentheses indicate an option. In this case, x is not a required input but could be input in special cases.
→x A	→ is the symbol for calculate. This indicates that you may calculate x by pressing key A.
→x, y, z A	This indicates that x, y, and z are calculated by pressing A once. The values would be sequentially displayed in x, y, z order.

SYMBOL OR CONVENTION	INDICATED MEANING
➡x; y; z A	The semi-colons indicate that after x has been calculated using A, y and z may be calculated in turn by pressing R/S and then again R/S.
➡"x ",y A	The quote marks indicate that the x value will be "paused" or held in the display for one second. The pause will be followed by the display of y.
↔ x A	The two-way arrow ↔ indicates that x may be either output or input when the associated user-definable key is pressed. If numeric keys have been pressed between user-definable keys, x is stored. If numeric keys have not been pressed, the program will calculate x.
P? A	The question mark indicates that this is a mode setting, while the mnemonic indicates the type of mode being set. In this case a pause mode is controlled. Mode settings typically have a 1.00 or 0.00 indicator displayed after they are executed. If 1.00 is displayed, the mode is on. If 0.00 is displayed, it is off.
START A	The word START is an example of a command. The start function should be performed to begin or start a program. It is included when initialization is necessary.
DEL A	This special command indicates that the last value or set of values input may be deleted by pressing A.

FORMAT OF USER INSTRUCTIONS

The completed User Instruction Form—which accompanies each program—is your guide to operating the programs in this Pac.

The form is composed of five labeled columns. Reading from left to right, the first column, labeled STEP, gives the instruction step number.

The INSTRUCTIONS column gives instructions and comments concerning the operations to be performed.

The INPUT-DATA/UNITS column specifies the input data, and the units of data if applicable. Data input keys consist of 0 to 9 and decimal point (the numeric keys), EEX (enter exponent), and CHS (change sign).

The KEYS column specifies the keys to be pressed after keying in the corresponding input data.

The OUTPUT-DATA/UNITS column specifies intermediate and final outputs and their units, where applicable.

The following illustrates the User Instruction Form for *Curve Fitting,* SD-03A.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Optional: Select pause input			
	mode.		f A	1.00/0.00
3	Select type of regression:			
	for linear fit		f B	1.00
	for exponential fit		f C	1.00
	for logarithmic fit		f D	1.00
	for power fit		f E	1.00
4	Input x value*.	x_i	ENTER↑	x_i
5	Input y value.	y_i	A	$i + 1$
6	Repeat steps 4 and 5 for all data			
	pairs**.			
7	Compute and output coefficient			
	of determination r^2 and a and b.		C	r^2, a, b
8	Optional: Make projections			
	based on a known y value.	y	D	$\hat{x}$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
9	Optional: Make projections			
	based on a known x value.	x	E	$\hat{y}$
10	For a new case go to step 3.			
	*Note that this step may be skip-			
	ped if the x value equals the dis-			
	played counter (i + 1).			
	**The last set of data pairs may			
	be deleted by pressing h R↓			
	then B. Any set of data pairs			
	may be deleted by entering them			
	as in steps 4 and 5 and			
	pressing B.			

Since you loaded this program in ‘‘Loading A Program’’ on page iv, step 1 is already done and we can move to step 2. (If you turned your calculator off, you must reload the program.)

Step 2 is optional. It is primarily intended for printer control on the HP-97 printing programmable calculator. On your HP-67 calculator, print commands are interpreted as pause commands. That is, the calculator stops and displays the X-register value for one second and then continues with program execution.

In this particular application the print mode provides a permanent record of input data on the HP-97 printing calculator. On the HP-67 pocket calculator the input values are displayed for review if the print input mode is selected.

To select this ‘‘print/pause’’ mode, you would press f A as shown in the KEYS column of the User Instruction Form. Go ahead and press f A now. You should see a 1.00 in the display as indicated in the OUTPUT DATA/UNITS column. Successive presses of f A will cause 0.00 and 1.00 to be displayed alternately, indicating that the print/pause mode is off (0.00) or on (1.00). Try this, but leave 0.00 displayed (print/pause mode off) before moving to step 3.

In step 3 the type of curve fit is selected. There are four options listed, and you must select one. For example, to select exponential curve fit, refer to the *KEYS* column of the same line and press f C. Do this. The number 1.00 should be displayed, as shown in the OUTPUT-DATA/UNITS column.

The magnetic card gives short mnemonic hints about the four possible modes that may be selected. Printed in gold above the C key is ''EXP?'' indicating that the exponential mode is set by pressing f C.

To do a curve fit, you must input a number of data pairs (x_i and y_i). Steps 4, 5 and 6 give the input instructions. First key in x_i as indicated under INPUT-DATA/UNITS. Then press ENTER↑ to tell the calculator that you have completed building the number x. Then key in the value for y_i and press A. The number of data pairs plus one ($i + 1$) will appear in the display. Repeat the procedure for all data pairs. Try it for this data set:

x_i	1	3	7
y_i	2.7	20	1100

The keystrokes you should use are 1 ENTER↑ 2.7 A 3 ENTER↑ 20 A 7 ENTER↑ 1100 A. If you make a mistake, look at the second note at the bottom of the User Instructions. It describes procedures for correcting errors. If the last input pair was in error, you could press h R↓ B and eliminate it. Don't do this. Instead eliminate the (3,20) pair and replace it with (4,60). The keystrokes are 3 ENTER↑ 20 B 4 ENTER↑ 60 A.

Now that you know how the program works, the mnemonics on the magnetic card will prompt you on data input and data correction.

When all data have been keyed into the calculator, the regression coefficients can be calculated. Step 7 of the User Instructions says press C to do this.

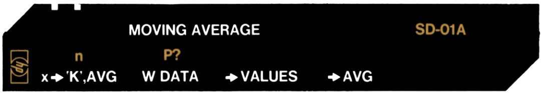
Three values will be displayed in the order listed in the comments column of the user instructions. First, the coefficient of determination (r^2 here equal to 1.00) will be displayed. Then the regression coefficients, a (1.02) and b (1.00), will be displayed. Go ahead and press C. When execution stops (after all three values have been displayed), you may review the values by pressing C again.

If you wish to have more time to observe a value during a pause, press R/S during the pause. This stops program execution leaving the value displayed. To restart the calculator, press R/S again. Try this. Press C, then stop the calculator during the first pause by pressing R/S. Press R/S again to restart program execution. Stop the calculator during the second pause and see 1.02. Press R/S again to complete the calculation. Note that during an output pause, the decimal point flashes. This signifies that program execution has not terminated and will resume automatically.

Now try a projection. Step 9 instructs you to key in an x value, press E and see a projected $\hat{y}$ value. Try an x value of 10. You should see a projected $\hat{y}$ result of 22926.17. You can also estimate an x value $\hat{x}$ using a known y value. Leave the value of 22926.17 in the display and press D. The value 10.00 should be displayed again.

If your answers agree with ours, you are ready to try other programs in Standard Pac. If your answers did not agree with ours, try the procedure again.

MOVING AVERAGE



In a moving average, a specified number of data points are averaged. When there is a new piece of input data, the oldest piece of data is discarded to make room for the latest input. This replacement scheme makes the moving average a valuable tool in following trends. The fewer the number of data points, the more trend sensitive the average becomes. With a large number of data points, the average behaves more like a regular average, responding slowly to new input data.

This program allows for a moving average span of 1 to 22 units. The number of units, n, must be specified before any data input begins by keying it in and pressing f A. Then the data is input by keying in each value, x_k, and pressing A in turn. The calculator will display the current input number, k, until at least n values have been entered. After the n^{th} value (and for all succeeding values), the calculator will flash the current input number before halting with the moving average, AVG, in the display.

In many applications moving averages are calculated daily, weekly, monthly, or even yearly. In such cases it is necessary to store the register contents on a magnetic card for future use. To do this, press B for WRITE DATA and insert one side of the blank card. If the display says ''Crd'' after the first card pass, insert the other end of the card. If the display is unchanged after the first pass, all data has been recorded on the first pass and you may proceed to other calculations. When the recorded data is required again, insert the data card. If ''Crd'' appears after the first pass, load the other end of the card. The original data has been returned to the storage registers and you are ready to continue the moving average at the point you left off.

The value of the average may be displayed at any time by pressing D. This feature allows the average to be calculated before n data points have been input. The average is based on the number of inputs or n, whichever is smaller.

Remarks:

Attempts to input a value larger than 22.00 or smaller than 1.00 for n will result in a flashing display which can be cleared by pressing R/S.

All data storage registers are used.

Moving averages of 10.00 or more units require two passes of the data card to record or store the values.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	If data from a previous calculation is stored on a magnetic card, insert the magnetic card and skip to step 5.			
3	Input number of points in average (1 ≤ n ≤ 22)	n	f A	n
4	Optional: Select pause input mode.		f B	1.00/0.00
5	Input data point and compute moving average.*	x_k	A	"k", AVG
6	Go to step 5 for next input.			
7	Optional: To store data on magnetic card for future use, press B and insert card in reader.		B	Crd
8	Optional: Output values in newest to oldest order.		C	Values
9	Optional: Display average at any time.		D	AVG
	For a new case go to step 2.			
	*If you make an error on data input, you must start over unless you previously recorded data on a magnetic card. If data was previously recorded, load the data card and start with the first value input after recording the card.			

Example 1:

A six-period moving average is used to project monthly sales. The first 6 months of sales are as follows:

Month	1	2	3	4	5	6
Sales	125	183	207	222	198	240

Compute the moving average. Also compute the average after month three.

Keystrokes:	**Outputs:**	
6 f A →	6.00	
125 A →	1.00	
183 A →	2.00	
207 A →	3.00	
D →	171.67	(average after month three)
222 A →	4.00	
198 A →	5.00	
240 A →	"6.00",	195.83

Now record the data for example 2.

B → Crd

Insert a blank magnetic card in the card reader.

Now turn the calculator off and assume a month has passed. Turn the calculator back on and load both sides of *Moving Average*.

Example 2:

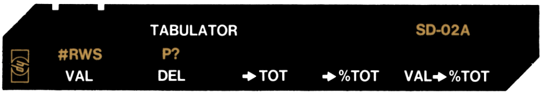
The actual sales for the seventh month totaled 225 units. Compute a new moving average with this data. Also, output the values in the average.

Load the magnetic data card recorded at the end of example 1.

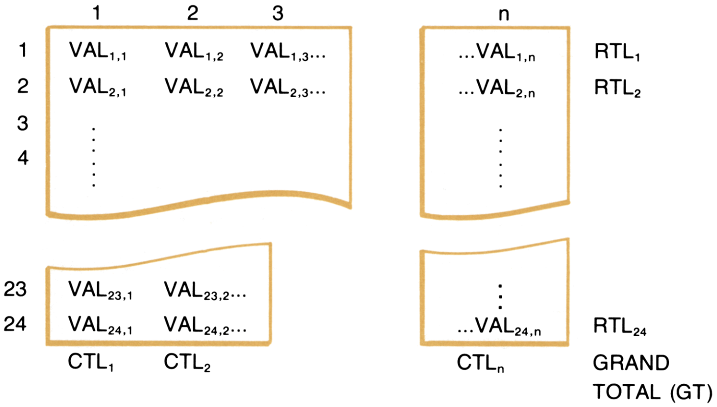
Keystrokes:	**Outputs:**	
225 A →	"7.00",	212.50
C →	225.00 ***	(current moving
	240.00 ***	average values
	198.00 ***	in newest to
	222.00 ***	oldest order)
	207.00 ***	
	183.00 ***	
	6.00	

NOTES

TABULATOR



This program is designed to be of aid in tabulating applications such as accounting and estimating. It can be used to add single columns containing up to 24 values (VAL), remember each value, and find the percent of total of each value. (The first example problem shows this type of use.) The program can also be used to total any number of columns and find row totals, the percent of total for each row total, and the grand total for a table of values. The total of each column is displayed as soon as the column is completed.



	1	2	3	n	
1	$VAL_{1,1}$	$VAL_{1,2}$	$VAL_{1,3}$...	...$VAL_{1,n}$	RTL_1
2	$VAL_{2,1}$	$VAL_{2,2}$	$VAL_{2,3}$...	...$VAL_{2,n}$	RTL_2
3	⋮			⋮	
4					
23	$VAL_{23,1}$	$VAL_{23,2}$...		⋮	
24	$VAL_{24,1}$	$VAL_{24,2}$...		...$VAL_{24,n}$	RTL_{24}
	CTL_1	CTL_2		CTL_n	GRAND TOTAL (GT)

Column totals (CTL) are output when the column is complete.

Figure 1

Equations:

$$\% \text{ of Total}_i = \frac{\text{Row Total}_i}{\text{Grand Total}} \times 100$$

Remarks:

If the last value input was in error, it may be deleted by pressing **B**. This subtracts the value from both column and row totals and resets the indices.

Attempts to specify more than 24 or less than 1 for the number of rows will result in flashing input which can be cleared by pressing R/S.

All data storage registers are used.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Key in number of rows (1 to 24)			
	and initialize*.	ROWS	f A	0.00
3	Optional: Select pause input			
	mode		f B	1.00/0.00
4	Input value	VAL	A	VAL (or CTL)
5	If your last data input was in			
	error execute this step to return			
	to prior status:		B	
6	Go to step 4 until all values have			
	been input.			
7	Obtain outputs:			
	Output row totals and grand total.		C	ROWS
	or			
	Output % of grand total for each			
	row total.		D	ROW %
8	Optional: Compute percentage			
	of grand total for any number.	NUMBER	E	% of GT
9	For new case go to step 2.			
	*Flashing input indicates an			
	input less than one or greater			
	than 24. Clear with R/S.			

02-03

Example 1:

The following list of unit sales figures are to be totaled and converted to monthly percentages.

January: 1012
February: 1235
March: 895
April: 1123
May: 1502
June: 1073
July: 973
August: 1250
September: 1051
October: 1244
November: 1127
December: 977

```
Keystrokes:                                      Output:
12 f A ----------------------------------------> 0.00
1012 A 1235 A 895 A 1123 A --------------------> 1123.00
1502 A 1073 A 973 A 1250 A --------------------> 1250.00
1051 A 1244 A 1127 A 977 A --------------------> 13462.00
D ---------------------------------------------> 7.52 ***      (Percents)
                                                 9.17 ***
                                                 6.65 ***
                                                 8.34 ***
                                                 11.16 ***
                                                 7.97 ***
                                                 7.23 ***
                                                 9.29 ***
                                                 7.81 ***
                                                 9.24 ***
                                                 8.37 ***
                                                 7.26 ***

                                                 100.00 ***
C ---------------------------------------------> 1012.00 *** (row totals)
                                                 1235.00 ***
                                                 895.00 ***
                                                 1123.00 ***
                                                 1502.00 ***
                                                 1073.00 ***
                                                 973.00 ***
                                                 1250.00 ***
                                                 1051.00 ***
                                                 1244.00 ***
                                                 1127.00 ***
                                                 977.00 ***

                                                 13462.00***
```

Example 2:

The following table is to be totaled (both rows and columns). Also, find the percent of total sales for each booklet.

BOOKLET SALES DATA

	JAN	FEB	MARCH	APRIL	MAY
BOOK 1	273	284	303	244	252
BOOK 2	1093	847	1222	1027	978
BOOK 3	423	654	683	540	570
BOOK 4	118	255	453	755	805

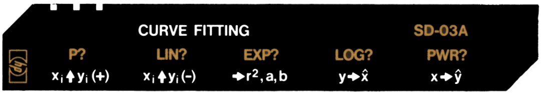
Keystrokes:		Outputs:	
4 f A	→	0.00	
273 A 1093 A 423 A 118 A	→	1907.00	(Jan total)
284 A 847 A 654 A 255 A	→	2040.00	(Feb total)
303 A 1222 A 683 A 453 A	→	2661.00	(Mar total)
244 A 1027 A 540 A 755 A	→	2566.00	(Apr total)
252 A 978 A 570 A 805 A	→	2605.00	(May total)
C	→	Row totals	
D	→	% of row totals	

BOOKLET SALES DATA

	JAN	FEB	MARCH	APRIL	MAY	TOTALS	PERCENTS
BOOK 1	273	284	303	244	252	1356	11.51%
BOOK 2	1093	847	1222	1027	978	5167	43.87%
BOOK 3	423	654	683	540	570	2870	24.37%
BOOK 4	118	255	453	755	805	2386	20.26%
TOTALS	1907	2040	2661	2566	2605	11779.00	100.00%

03-01

CURVE FITTING



This program can be used to fit data to:

1. Straight lines (linear regression); $y = a + bx$,
2. Exponential curves; $y = ae^{bx}$ $(a > 0)$,
3. Logarithmic curves; $y = a + b \ln x$,
4. Power curves; $y = ax^b$ $(a > 0)$.

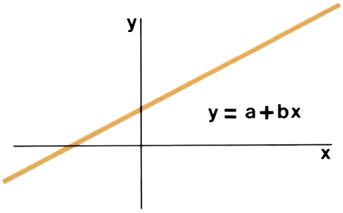
The type of curve fit must be determined before data input begins. To select linear regression, you would press the f B keys. To select exponential curve fit, press f C. To select logarithmic curve fit, press f D. To select power curve fit, press f E. Do not attempt to change from one type of fit to another after data input has begun because the summation registers are cleared when the type of curve fit is selected. Restarting can be accomplished by repeating the curve fit selection process.

Data pairs (x_i and y_i) are input by keying in x_i, pressing ENTER↑, keying in y_i and pressing the A key. Any number of data pairs may be input. If, after pressing the A key, you discover a data pair was incorrect, wait until execution stops, press h R↓, then the B key. This will eliminate the errant data pair. If you wish to eliminate any data pair previously input, key it in (x ENTER↑ y) and press B.

After all data pairs have been input, press C. This initiates calculation and output of the coefficient of determination r^2, and the regression coefficients a and b. The coefficient of determination indicates the quality of fit achieved by the regression. Values of r^2 close to 1.00 indicate a better fit than values close to zero. The regression coefficients a and b define the curve generated, according to the equations at the beginning of this discussion.

After the regression coefficients have been calculated, projections may be made based on the curve fit. Key in a known x value, press E and see an estimated y value, $\hat{y}$, or key in a known y value, press D and see an estimated x value, $\hat{x}$.

Linear Regression

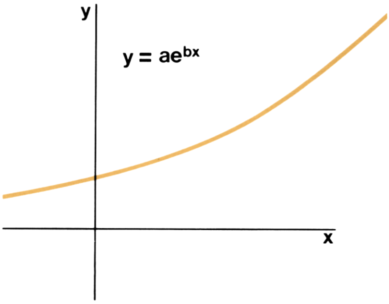


$$b = \frac{\Sigma x_i y_i - \frac{\Sigma x_i \ \Sigma y_i}{n}}{\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}}$$

$$a = \left[\frac{\Sigma y_i}{n} - b \frac{\Sigma x_i}{n} \right]$$

$$r^2 = \frac{\left[\Sigma x_i y_i - \frac{\Sigma x_i \ \Sigma y_i}{n} \right]^2}{\left[\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n} \right] \left[\Sigma y_i^2 - \frac{(\Sigma y_i)^2}{n} \right]}$$

Exponential Curve Fit

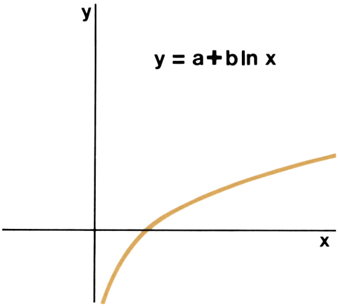


$$b = \frac{\Sigma x_i \ \ln y_i - \frac{1}{n} (\Sigma x_i)(\Sigma \ln y_i)}{\Sigma x_i^2 - \frac{1}{n} (\Sigma x_i)^2}$$

$$a = \exp\left[\frac{\Sigma \ln y_i}{n} - b\,\frac{\Sigma x_i}{n}\right]$$

$$r^2 = \frac{\left[\Sigma x_i \ln y_i - \frac{1}{n}\Sigma x_i\,\Sigma \ln y_i\right]^2}{\left[\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}\right]\left[\Sigma(\ln y_i)^2 - \frac{(\Sigma \ln y_i)^2}{n}\right]}$$

Logarithmic Curve Fit

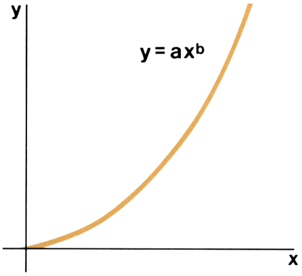


$$b = \frac{\Sigma y_i \ln x_i - \frac{1}{n}\Sigma \ln x_i\;\Sigma y_i}{\Sigma(\ln x_i)^2 - \frac{1}{n}(\Sigma \ln x_i)^2}$$

$$a = \frac{1}{n}(\Sigma y_i - b\,\Sigma \ln x_i)$$

$$r^2 = \frac{\left[\Sigma y_i \ln x_i - \frac{1}{n}\Sigma \ln x_i\;\Sigma y_i\right]^2}{\left[\Sigma(\ln x_i)^2 - \frac{1}{n}(\Sigma \ln x_i)^2\right]\left[\Sigma y_i^2 - \frac{1}{n}(\Sigma y_i)^2\right]}$$

Power Curve Fit



$$b = \frac{\Sigma(\ln x_i)(\ln y_i) - \frac{(\Sigma \ln x_i)(\Sigma \ln y_i)}{n}}{\Sigma(\ln x_i)^2 - \frac{(\Sigma \ln x_i)^2}{n}}$$

$$a = \exp\left[\frac{\Sigma \ln y_i}{n} - b\frac{\Sigma \ln x_i}{n}\right]$$

$$r^2 = \frac{\left[\Sigma(\ln x_i)(\ln y_i) - \frac{(\Sigma \ln x_i)(\Sigma \ln y_i)}{n}\right]^2}{\left[\Sigma(\ln x_i)^2 - \frac{(\Sigma \ln x_i)^2}{n}\right]\left[\Sigma(\ln y_i)^2 - \frac{(\Sigma \ln y_i)^2}{n}\right]}$$

Remarks:

Negative and zero values of x_i will cause a machine error for logarithmic curve fits. Negative and zero values of y_i will cause a machine error for exponential curve fits. For power curve fits both x_i and y_i must be positive, non-zero values.

Registers R_0–R_9 are available for user storage.

It is not necessary to key in the x value if it corresponds to the counter returned to the display (see example 1).

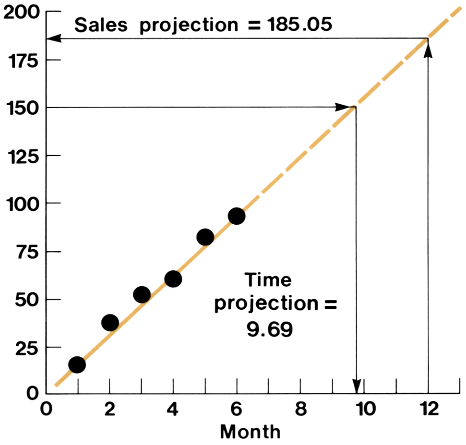
As the differences between x and/or y values become small, the accuracy of the regression coefficients will decrease.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Optional: Select pause input			
	mode.		f A	1.00/0.00
3	Select type of regression:			
	for linear fit		f B	1.00
	for exponential fit		f C	1.00
	for logarithmic fit		f D	1.00
	for power fit		f E	1.00
4	Input x value*.	x_i	ENTER↑	x_i
5	Input y value.	y_i	A	i + 1
6	Repeat steps 4 and 5 for all data			
	pairs**.			
7	Compute and output coefficient			
	of determination r^2 and a and b.		C	r^2, a, b
8	Optional: Make projections			
	based on a known y value.	y	D	$\hat{x}$
9	Optional: Make projections			
	based on a known x value.	x	E	$\hat{y}$
10	For a new case go to step 3.			
	*Note that this step may be skip-			
	ped if the x value equals the dis-			
	played counter (i + 1).			
	**The last set of data pairs may			
	be deleted by pressing h R↓			
	then B. Any set of data pairs may			
	be deleted by entering them as in			
	steps 4 and 5 and pressing B.			

Example 1:

Below is the sales data for the first 6 months of a product's life. According to a linear projection, what should the sales be after 12 months? When would sales reach the 150 unit per month mark assuming constant linear growth.

Month	1	2	3	4	5	6
Sales	15	37	52	59	83	92



Keystrokes:	Outputs:	
f B →	1.00	
15 A 37 A 52 A 59 A 83 A 92 A →	7.00	
C →	0.98 ***	(r^2)
	3.33 ***	(a)
	15.14 ***	(b)
12 E →	185.05	units
150 D →	9.69	months

Example 2:

The velocity of a particle experiencing constant acceleration is expressed by

$$v = v_o + \alpha t$$

where v is the velocity, v_0 is the initial velocity, α is the acceleration and t is the time since $v = v_0$.

The following time velocity data was experimentally obtained for a particle:

t (sec)	V(m/sec)
5	140
6	149
7	159
9	175

What was the velocity at t = 0? What will the velocity be when t = 20? Note that the equation for velocity

$$v = v_0 + \alpha t$$

is the equation of a straight line and is analogous to

$$y = a + bx$$

Therefore use linear regression with v substituted for y, v_0 for a, α (acceleration) for b and t for x.

Keystrokes:	Outputs:	
f B	1.00	
5 ENTER↑ 140 A 6 ENTER↑ 149 A		
7 ENTER↑ 159 A	4.00	
9 ENTER↑ 175 A C	1.00 ***	(r^2)
	96.54 ***	(a, v_0)
	8.77 ***	(b, acceleration)
20 E	271.97	(m/sec)

Example 3:

Many compression processes can be correlated using the power curve

$$p = av^{-b}$$

where b is the polytropic constant of the process.

Pressure-volume data for a compression process is shown below. Run a power curve fit to determine the polytropic constant, −b. What is the pressure when v is 15?

v	p
10	210
30	40
50	12
70	9
90	6.8

Keystrokes:	**Outputs:**
f E	1.00
10 ENTER↑ 210 A 30 ENTER↑ 40 A	
50 ENTER↑ 12 A	4.00
70 ENTER↑ 9 A 90 ENTER↑ 6.8 A C	0.99 *** (r^2)
	8599.81 *** (a)
	–1.62 *** (–b)
15 E	108.35

CALENDAR FUNCTIONS

For the period March 1, 1900 through February 28, 2100, this program interchangeably solves for dates and days. Given two dates, the number of days between them can be calculated. Given one date and a specified number of days, a second date can be found. The program will also work in terms of weeks between dates or compute the day of the week given the date. After input of a date, its Julian Day number* is displayed.

A date must be input in mm.ddyyyy format. For instance, June 3, 1975 is keyed in as 6.031975. It is important that the zero between the decimal point and the day of the month be included when the day of the month is less than 10. Weeks are input and output as WKS.DYS. Seven weeks, three days would be 7.3. The day of the week is represented by the digits 0 through 6 where zero is Sunday.

Equations:

To compute the day number from the date:

Julian Day number = INT (365.25 y′) + INT (30.6001 m′) + d + 1,720,982

where

$$y' = \begin{cases} \text{year} - 1 & \text{if } m = 1 \text{ or } 2 \\ \text{year} & \text{if } m > 2 \end{cases}$$

$$m' = \begin{cases} \text{month} + 13 & \text{if } m = 1 \text{ or } 2 \\ \text{month} + 1 & \text{if } m > 2 \end{cases}$$

Then days between dates is found by

$$\text{Days} = \text{Day number}_2 - \text{Day number}_1$$

To compute the date from a day number:

$$\text{Day \#} = \text{Julian Day Number} - 1{,}720{,}982$$

$$y' = \text{INT}\left[\frac{\text{Day \#} - 122.1}{365.25}\right]$$

*The Julian Day number is an astronomical convention representing the number of days since January 1, 4713 B.C.

$$m' = \text{INT}\left[\frac{\text{Day \#} - \text{INT}(365.25\ y')}{30.6001}\right]$$

$$\begin{aligned}\text{Day of the month} = \text{Day \#} &- \text{INT}\left[365.25\ y'\right] \\ &- \text{INT}\left[30.6001\ m'\right]\end{aligned}$$

$$\text{Month} = m = \begin{cases} m' - 13 \text{ if } m' = 14 \text{ or } 15 \\ m' - 1 \text{ if } m' < 14 \end{cases}$$

$$\text{Year} = \begin{cases} y' & \text{if } m > 2 \\ y' + 1 & \text{if } m = 1 \text{ or } 2 \end{cases}$$

To compute the day of the week:

$$\text{Day of the week} = 7 \times \text{FRAC}\left[(\text{Day \#} + 5)/7\right]$$

Remarks:

No checking is done to determine if input data represents valid dates.

In this program the calculator uses flag 3 to decide what to do after A, B, C or D is pressed. If the numeric keys have been pressed, flag 3 is on. This causes the value in the display to be stored as an input when the user-definable key is pressed. If no numeric keys have been touched, the program will calculate the value associated with the user-definable key. Thus, it is important not to touch the numeric keys between the last input and the attempt to calculate a result.

Registers R_0–R_2, R_B, R_D, R_E and R_{S0}–R_{S9} are available for user storage.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	For day of the week calculations			
	go to step 6.			
3	Input two of the following:			
	First date (mm.ddyyyy)	DT_1	A	Day $\#_1$
	Second date (mm.ddyyyy)	DT_2	B	Day $\#_2$
	Days between dates	DAYS	C	Days
	or weeks between dates*	WKS. DYS	D	Days

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
4	Calculate one of the following:			
	First date		A	DT_1
	Second date		B	DT_2
	Days between dates		C	Days
	Weeks between dates		D	WKS. DYS
5	For a new case go to step 2.			
6	Input date and calculate day			
	of the week (0 = Sunday,			
	6 = Saturday).	DT	E	DOW
7	For a new case go to step 2.			
	*Either days between dates or			
	weeks between dates, but not			
	both, may be input in step 3.			

Example 1:

Senior Lieutenant Yuri Gagarin flew Vostok I into space on April 12, 1961. On July 21, 1969 Neil Armstrong set foot on the moon. How many days had passed between the first manned space flight and the moon landing? How many weeks and days? On what day of the week did each event take place?

Keystrokes:		**Outputs:**	
4.121961 A 7.211969 B C	→	3022.	(days)
D	→	431.5	(weeks.days)
4.121961 E	→	3.	(Wednesday)
7.211969 E	→	1.	(Monday)

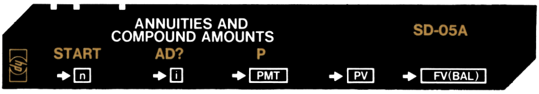
Example 2;

A short term note is due in 200 days. If the issue date is June 11, 1976, what is the maturity date?*

Keystrokes:	**Outputs:**	
6.111976 A 200 C B →	12.281976	(December 28, 1976)

*Some securities use a 30/360 day calendar while this program performs all calculations using the actual number of days. Do not use the program for financial purposes unless you are sure that actual calendar days are correct.

ANNUITIES AND COMPOUND AMOUNTS



This program can be used to solve a variety of problems involving money, time and interest. The following variables can be inputs or outputs:

- n, which is the number of compounding periods. (For a 30 year loan with monthly payments, n = 12 × 30 = 360.)
- i, which is the periodic interest rate expressed as a percent. (For other than annual compounding, divide the annual percentage rate by the number of compounding periods in a year; i.e. 8% annual interest compounded monthly equals 8/12 or 0.667%.)
- PMT, which is the periodic payment.
- PV, which is the present value of the cash flows or compound amounts.
- FV, which is the future value of a compounded amount or a series of cash flows.
- BAL, which is the balloon or remaining balance at the end of a series of payments.

The program accommodates payments which are made at the end of compounding periods or at the beginning. Payments made at the end of compounding periods (ordinary annuity) are common in direct reduction loans and mortgages while payments at the beginning of compounding periods (annuity due) are common in leasing. When the program is loaded into the calculator or when the START function f A is executed, the calculator is set in ordinary annuity mode. Pressing f B sets the calculator in annuity due mode and displays 1.00 indicating that the annuity due mode is set. Pressing f B again returns the machine to ordinary annuity mode and displays 0.00. Successive use of f B will alternately display 1.00 and 0.00 indicating that the annuity due mode is on or off, respectively.

In this program STO A is used to input n, STO B to input i, STO C to input PMT, STO D to input PV and STO E to input FV or BAL. After all inputs are stored it is possible to calculate the unknown value by pressing the appropriate user-definable key. For instance, you would press B to calculate interest.

The START function (f A) performs two functions:

1. It sets PMT, PV, and BAL to zero (n and i are not affected).
2. It sets the ordinary annuity mode.

START provides a safe, convenient, easy to remember method of preparing the calculator for a new problem. It is not necessary to use START between problems containing the same combination of variables. For instance, any number of n, i, PMT, FV problems involving different numbers and/or different combinations of knowns could be done in succession without using START. Only the values which change from problem to problem would have to be keyed in. To change the combination of variables without using START, simply input zero for any variable which is no longer applicable. To go from n, i, PMT, PV problems to n, i, PV, FV problems, a zero would be stored (0 STO C) in place of PMT. Table 1 summarizes these procedures. START should always be used immediately after loading *Annuities and Compound Amounts.*

Table I

Possible Solutions Using *Annuities and Compound Amounts*

Allowable Combination of Variables	Applications		Initial Procedure
	Ordinary Annuity	Annuity Due	
n, i, PMT, PV (Input any three and calculate the fourth.)	Direct reduction loan Discounted notes Mortgages	Leases	Use START or set BAL to zero.
n, i, PMT, PV, BAL (Input any four and calculate the fifth.)	Direct reduction loan with balloon Discounted notes with balloon	Leases with residual values	None
n, i, PMT, FV (Input any three and calculate the fourth.)	Sinking fund	Periodic savings insurance	Use START or set PV to zero.
n, i, PV, FV (Input any three and calculate the fourth.)	Compound amount Savings (Annuity mode is not applicable and has no effect)		Use START or set PMT to zero.

Equations:

$$PV = \pm \frac{PMT}{i} A \left[1 - (1+i)^{-n}\right] + (BAL \text{ or } FV)(1+i)^{-n}$$

where

$$A = \begin{cases} 1 & \text{ordinary annuity} \\ (1+i) & \text{annuity due.} \end{cases}$$

The sign is plus if FV is zero and minus if PV is zero.

Remarks:

The calculator must be in FIX display mode to solve for i when payments are involved.

The equation above is solved for i using Newton's method where:

$$i_n = i_{n-1} - \frac{f\,(i_{n-1})}{f'(i_{n-1})}$$

This is why solutions involving PMT and i take longer than other solutions. The algorithm works best for positive input values and for interest rates between zero and 100%. It is quite possible to define problems which cannot be solved by this technique. Such problems usually result in an error message but may simply continue to run indefinitely.

Iterative interest solutions are accurate to the number of significant figures of the display setting. It is possible to obtain more significant figures by changing the display setting from DSP 2 to DSP 3, DSP 4, DSP 5, etc. However, time for solution increases as accuracy is improved.

Problems with negative balloon payments may have more than one mathematically correct answer (or no answer at all). While this program may find one of the answers, it has no way of finding or indicating other possibilities.

RCL A, RCL B, RCL C, RCL D and RCL E may be used to review associated values at any time.

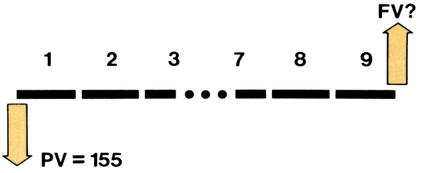
Registers R_0–R_2 and R_{S0}–R_{S9} are available for user storage.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Initialize		f A	0.00
3	If payments occur at the begin-			
	ning of the period set annuity			
	due mode*.		f B	1.00/0.00
4	Input the known values:			
	Number of periods	n	STO A	n
	Periodic interest rate	i (%)	STO B	i (%)
	Periodic payment	PMT	STO C	PMT
	Present value	PV	STO D	PV
	Future value, balloon or balance	FV, (BAL)	STO E	FV, (BAL)

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
5	Calculate the unknown value.			
	Number of periods		A	n
	Periodic interest rate		B	i (%)
	Periodic payment		C	PMT
	Present value		D	PV
	Future value, balloon or balance		E	FV, (BAL)
6	Output values in n, i, PMT, PV,			
	FV-BAL order.		f C	Values
7	For a new case, go to step 4			
	and change appropriate values.			
	Input zero for any value not			
	applicable in the new case.			
	*One or zero will be displayed			
	alternately after pressing f B,			
	indicating that the annuity			
	due mode is on or off.			

Example 1:

If $155 is placed in a savings account paying 5¾% compounded monthly, what sum of money will be in the account at the end of 9 years?



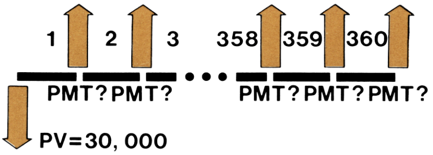
Keystrokes:	**Outputs:**
f A 155 STO D	155.00
5.75 ENTER↑ 12 ÷ STO B	0.48
9 ENTER↑ 12 × STO A	108.00
E	259.74

If the interest is changed to 6%, what is the sum?

6 ENTER↑ 12 ÷ STO B →	0.50
E →	265.62

Example 2:

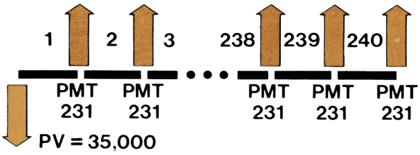
What is the monthly payment required to fully amortize a 30 year, $30,000 mortgage if the annual percentage rate is 9%? After solving the problem, review the values.



Keystrokes:	**Outputs:**
f A 30 ENTER↑ 12 × STO A →	360.00
30000 STO D →	30000.00
9 ENTER↑ 12 ÷ STO B →	0.75
C →	241.39
f C →	360.00 *** (n)
	0.75 *** (i)
	241.39 *** (PMT)
	30000.00 ***(PV)
	0.00 *** (FV)

Example 3:

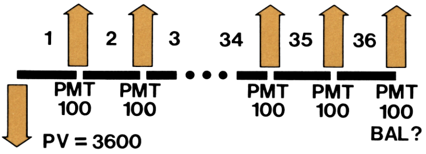
A fixed term annuity is available which requires a $35,000 initial deposit. In return the depositor will receive monthly payments of $231 for 20 years. What annual interest rate is being applied?



Keystrokes:	Outputs:	
f A 35000 STO D →	35000.00	
231 STO C →	231.00	
20 ENTER↑ 12 × STO A →	240.00	
B →	0.42	(0.42% monthly)
12 × →	5.00	(5% annual interest rate)

Example 4:

Two individuals are constructing a loan with a balloon payment. The loan amount is $3,600 and it is agreed that the annual interest rate will be 10% with 36 monthly payments of $100. What balloon payment amount, to be paid coincident with the 36th payment, is required to fulfill the loan agreement?

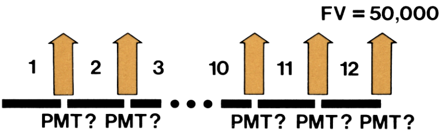


Keystrokes:	Outputs:
f A 3600 STO D 10 ENTER↑ 12 ÷ STO B 36 STO A 100 STO C E →	675.27

(Note that the final payment is $675.27 + $100.00 = $775.27 since the final payment falls at the end of the last period.)

Example 5:

A corporation has determined that a certain piece of equipment costing $50,000 will be required in 3 years. Assuming a fund paying 7% compounded quarterly is available, what quarterly payment must be placed in the fund in order to cover this cost if savings are to start at the end of this quarter?



Keystrokes: **Outputs:**

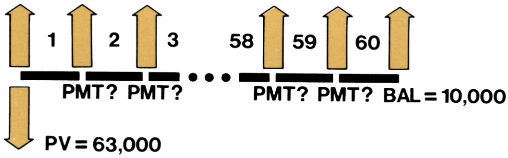
f A 50000 STO E 3 ENTER↑ 4 ×
STO A 7 ENTER↑ 4 ÷ STO B C → 3780.69

What single amount, invested immediately, would provide the same effect?

0 STO C D → 40602.89

Example 6:

A "third party" leasing firm is considering the purchase of a mini-computer priced at $63,000 and intends to achieve a 13% annual yield by leasing the computer to a customer for a 5-year period. Ownership is retained by the leasing firm, and at the end of the lease they expect to be able to sell the equipment for at least $10,000. What should they establish as the monthly payments in order to realize their desired yield? (Since lease payments occur at the start of the periods, this is an annuity due problem.)



Keystrokes: **Outputs:**

f A f B 63000 STO D 13 ENTER↑ 12 ÷
STO B 5 ENTER↑ 12 × STO A
10000 STO E C → 1300.16

If the price increased to $70,000, what should the payments be?

70000 STO D C → 1457.73

If the payments were increased to $1500 what would the yield be?

1500 STO C B → 1.18 (% per month)
12 × → 14.12 (% per year)

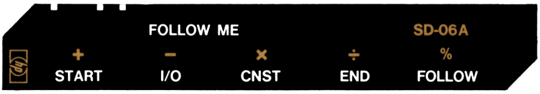
For more accuracy in calculation of the interest rate, change the display setting to five places and calculate the interest rate.

DSP 5 B → 1.17700
12 × → 14.12399

Return display to two places.

DSP 2 → 14.12

FOLLOW ME



This program allows the calculator to learn a simple set of keystrokes and repeat them over and over with different data. The allowable functions are plus, minus, times, divide, percent, constant and input-output halt. Up to 23 operations may be included in a sequence. Constants count as two operations each.

To run the program you would press A to start. Then do the first of the desired calculations using the +, −, ×, ÷, and % functions on the card. Any constants that repeat between problems should be followed by the C key so they will be automatically introduced at the proper times. Where intermediate answers or inputs are required, press B for an I/O halt. To signify the end of the sequence press D.

After the sequence has been learned by the calculator, only variables need be keyed in at I/O halts. The E key is used to start execution after I/O halts.

If an error is made while running a sequence, press D to start over. If an error is made while teaching the calculator a sequence, press A for a restart.

FOLLOW ME INSTRUCTION SET

Program Control	Action
START	Clears program from *Follow Me* memory and prepares for a new program sequence.
END	Defines the end of a sequence of keystrokes and resets program counter to the beginning of *Follow Me* memory.
FOLLOW	Starts halted program.
Programmable Operations	
+	Adds content of X register and Y register leaving result in X register.
−	Subtracts content of X register from Y register leaving result in X register.

Program Control	Action
×	Multiplies content of X register by content of Y register leaving result in X register.
÷	Divides content of Y register by content of X register leaving result in X register.
%	Multiplies content of Y register by content of X register divided by 100, replaces X register content with result and leaves content of Y register undisturbed.
CNST	Recalls constant to X register (requires two steps).
I/O	Input or output halt causes *Follow Me* to stop for display of calculated results and/or input of variables.

Remarks:

All four registers of the operational stack are available for input and output of data. By using all four registers the need for I/O halts can be minimized. Keyboard functions other than +, −, ×, ÷ and % may be used during I/O halts, but cannot be incorporated in a *Follow Me* program.

All data storage registers are used.

A flashing 24 results if more than 23 operations are attempted. This error condition may be cleared by pressing **R/S**.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Initialize.		**A**	0.00
3	Perform first string calculation by pressing **B** at each point where a halt for input or output is desired, **C** after each constant, **f** **A** for each addition, **f** **B** for each subtraction, **f** **C** for each multiplication, **f** **D** for each division and **f** **E** for percent operations. 23 steps are allowed (constants count as two steps).			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
4	End calculation		D	0.00
5	Key in variable(s) and initiate			
	execution	VAR	E	OUTPUT
6	If an error was made in step 5			
	go to step 4 and restart.			
7	Go to step five until calculation			
	is complete.			
8	For a new calculation of the			
	same type, go to step 5.			
9	For a new type of calculation,			
	go to step 2.			

Example 1:

Using *Follow Me,* program

$$y = 3(P + Q)$$

and calculate y for the following data:

P	Q
6	4
5	8
9	11

A solution:

Keystrokes: **Outputs:**

(Start)
A → 0.00
(I/O) (I/O) (+) (×)
3 B 6 B 4 f A f C → 30.00
(End)
D → 0.00
3 E 5 E 8 E → 39.00
3 E 9 E 11 E → 60.00

A better solution:

Keystrokes:	Outputs:
A	0.00
(CNST)	
3 C 6 ENTER↑ 4 B f A f C	30.00
D	0.00
E 9 ENTER↑ 11 E	60.00

Best solution (uses least amount of *Follow Me* memory):

Keystrokes:	Outputs:
A	0.00
6 ENTER↑ 4 f A 3 C f C	30.00
D	0.00
5 ENTER↑ 8 E	39.00
9 ENTER↑ 11 E	60.00

Example 2:

A company determines the retail price of its products by adding the fixed cost of assembly and distribution to a variable parts cost then multiplying by 2.7. The company sets the wholesale price at 50% of the retail price. Use *Follow Me* to determine the retail and wholesale prices for the parts cost list below.

PARTS COST LIST

PART #	PARTS COST
0001	$17.35
0002	$21.18
0003	$26.07
0004	$28.75
0005	$33.15

Retail cost = [Parts + Fixed] × 2.7
Wholesale cost = 50% of retail cost
Fixed cost = $25/unit

Keystrokes:	**Outputs:**	
Teach the sequence to the calculator and compute results for the first part #.		
A 17.35 ENTER↑ 25 C f A 2.7 C f		
C B →	114.35	(Retail)
50 C f E →	57.17	(Wholesale)
D →	0.00	
Compute prices for other parts.		
21.18 E →	124.69	
E →	62.34	
26.07 E →	137.89	
E →	68.94	
28.75 E →	145.13	
E →	72.56	
33.15 E →	157.01	
E →	78.50	

Example 3:

Use *Follow Me* to help evaluate the following formula using the data below.

$$y = 0.75\ A\ e^{0.63t}$$

A	2.3	2.8	3.7	6.4
t	1.0	2.0	4.5	6.0

Keystrokes:	**Outputs:**
A 1 ENTER↑ .63 C f C B g e^x 2.3	
ENTER↑ .75 C f C f C →	3.24
D →	0.00
2.0 E g e^x 2.8 E →	7.40
4.5 E g e^x 3.7 E →	47.26
6.0 E g e^x 6.4 E →	210.32

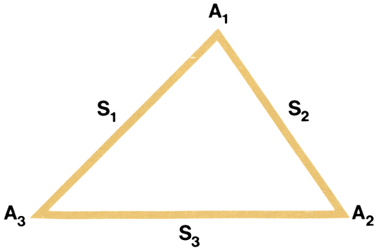
Any keyboard function may be used during I/O halts.

NOTES

07-01

TRIANGLE SOLUTIONS

This program can be used to find the area, the dimensions of the sides (S_1, S_2, S_3) and the angles (A_1, A_2, A_3) of a triangle.



Simply key in three known values and press the corresponding user definable key. The calculator will successively display the values of the sides, the angles, and the area. The order of output is determined by the order of input. If input values are selected in a clockwise order around the triangle, the outputs will also follow a clockwise order around the triangle. The order is as follows:

First side input	(S_1)
Adjacent angle	(A_1)
Adjacent side	(S_2)
Adjacent angle	(A_2)
Adjacent side	(S_3)
Adjacent angle	(A_3)

Area

After calculation has ended, the area will be in the display, S_1 in R_9, A_1 in R_A, S_2 in R_B, A_2 in R_C, S_3 in R_D, and A_3 in R_E.

Equations:

S_1, S_2, S_3 (all sides of triangle are known)

$$A_3 = 2 \cos^{-1} \sqrt{\frac{P(P - S_2)}{S_1 \, S_3}}$$

where $P = (S_1 + S_2 + S_3)/2$

$$A_2 = 2 \cos^{-1} \sqrt{\frac{P(P - S_1)}{S_2\ S_3}}$$

$$A_1 = \cos^{-1} \left(-\cos (A_3 + A_2)\right)$$

A_3, S_1, A_1 (Two angles and the included side are known)

$$A_2 = \cos^{-1} \left(-\cos (A_3 + A_1) \right)$$

$$S_2 = S_1 \frac{\sin A_3}{\sin A_2}$$

$$S_3 = S_1 \cos A_3 + S_2 \cos A_2$$

S_1, A_1, A_2 (side and following two angles known)

$$A_3 = \cos^{-1} \left(-\cos (A_1 + A_2) \right)$$

Problem has been reduced to the A_3, S_1, A_1 configuration.

S_1, A_1, S_2 (Two sides and included angle are known)

$$S_3 = \sqrt{S_1^2 + S_2^2 - 2\ S_1\ S_2 \cos A_1}$$

The problem has been reduced to the S_1, S_2, S_3 configuration.

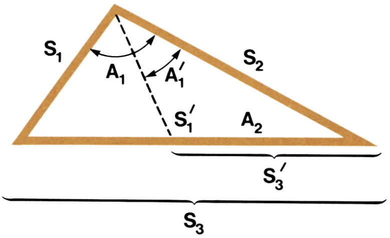
S_1, S_2, A_2 (Two sides and the adjacent angle known)

$$A_3 = \sin^{-1} \left[\frac{S_2}{S_1} \sin A_2 \right]^*$$

$$A_1 = \cos^{-1} \left[-\cos (A_2 + A_3) \right]$$

The problem has been reduced to the A_3, S_1, A_1 configuration.

*Note that two possible solutions exist if S_2 is greater than S_1 and A_3 does not equal 90°. Both possible answer sets are calculated.



Area = 1/2 S_1 S_3 sin A_3

Remarks:

Registers R_0 - R_6, R_{S0} - R_{S9} and I are available for user storage.

Angles must be in units corresponding to the angular mode of the machine. Degrees mode is set when the program is loaded.

Note that the triangle described by the program does not conform to standard triangle notation; i.e., A_1 is not opposite S_1.

Angles must be entered as decimals. The H.MS→ conversion can be used to convert degrees, minutes, and seconds to decimal degrees.

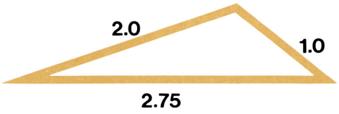
Accuracy of solution may degenerate for triangles containing extremely small angles.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Find applicable case in the list			
	below and input indicated			
	values:			
	All sides known	S_1	ENTER↑	S_1
		S_2	ENTER↑	S_2
		S_3	A	S_1, A_1, S_2...
	Two angles and included side			
	known	A_3	ENTER↑	A_3
		S_1	ENTER↑	S_1
		A_1	B	S_1, A_1, S_2...

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	Two angles and adjacent side			
	known	S_1	ENTER↑	S_1
		A_1	ENTER↑	A_1
		A_2	C	S_1, A_1, S_2...
	Two sides and included angle			
	known	S_1	ENTER↑	S_1
		A_1	ENTER↑	A_1
		S_2	D	S_1, A_1, S_2...
	Two sides and adjacent angle			
	known	S_1	ENTER↑	S_1
		S_2	ENTER↑	S_2
		A_2	E	S_1, A_1, S_2...
3	After step 2, the values of the			
	sides and angles of the triangle			
	are successively displayed. The			
	first value output is the first			
	side input. The next five outputs			
	are the remaining angles and			
	sides. The last output is the			
	triangle's area. For the last case			
	(S_1, S_2, A_2), two possible			
	solutions may exist and both			
	will be output.			

Example 1:

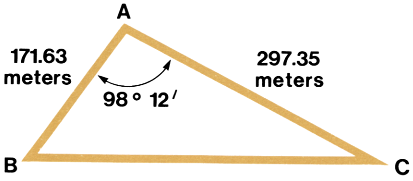
Find the angles and the area for the following triangle.



Keystrokes:	Outputs:	
2 ENTER↑ 1 ENTER↑ 2.75 A	2.00 ***	
	129.84 ***	(A_1)
	1.00 ***	
	33.95 ***	(A_2)
	2.75 ***	
	16.21 ***	(A_3)
	0.77 ***	(Area)
RCL 9	2.00	
RCL A	129.84	
RCL B	1.00	
RCL C	33.95	
RCL D	2.75	
RCL E	16.21	

Example 2:

A surveyor is to find the area and dimensions of a triangular land parcel. From point A, the distances to B and C are measured with an electronic distance meter. The angle between AB and AC is also measured. Find the area and other dimensions of the triangle.



This is a side-angle-side problem where:

$$S_1 = 171.63, \ A_1 = 98°12' \text{ and } S_2 = 297.35.$$

Keystrokes: **Outputs:**

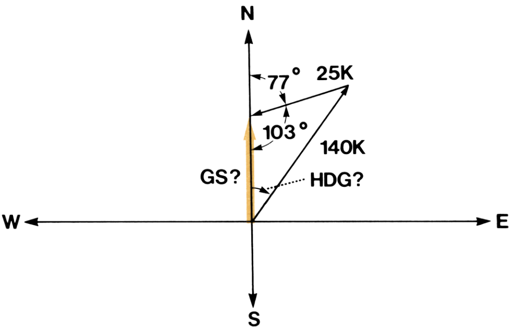
171.63 ENTER↑ 98.12 f H.MS→

297.35 D →

```
171.63 ***   (AB)
98.20 ***    (∠ A)
297.35 ***   (AC)
27.83 ***    (∠ C)
363.91 ***   (CB)
53.97 ***    (∠ B)
25256.21 ***(Area)
```

Example 3:

A pilot wishes to fly due north. The wind is reported as 25 knots at 77°. Because winds are reported opposite to the direction they blow, this is interpreted as 77 + 180 or 257°. The true airspeed of the aircraft is 140 knots. What heading (HDG) should be flown? What is the ground speed (GS)?



By subtracting the wind direction from 180 (yielding an angle of 103°), the problem reduces to a S_1, S_2, A_2 triangle.

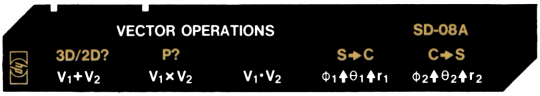
Keystrokes: **Outputs:**

140 ENTER↑ 25 ENTER↑ 103 E →

```
140.00 ***   (TAS)
66.98 ***
25.00 ***    (Wind velocity)
103.00 ***
132.24 ***   (GS)
10.02 ***    (HDG)
1610.64 ***
```

Thus, the pilot should fly a heading 10.02° east of due north. His ground speed equals 132.24 knots.

VECTOR OPERATIONS


VECTOR OPERATIONS
SD-08A
3D/2D?
P?
S→C
C→S
V_1+V_2
$V_1 \times V_2$
$V_1 \cdot V_2$
$\Phi_1 \uparrow \theta_1 \uparrow r_1$
$\Phi_2 \uparrow \theta_2 \uparrow r_2$

This program performs the basic vector operations of addition, cross product, and dot or scalar product. It also allows conversion between spherical and cartesian coordinates and can find the angle between two vectors.

Either two-dimensional or three-dimensional space may be selected using the f A keys. The machine is set in two-dimensional mode when the program is loaded. The first press of f A yields a display of 3.00 indicating three-dimensional space. Repeatedly pressing f A will yield alternate displays of 2.00 and 3.00 indicating the mode of the machine. Be sure the mode is correct before input of data.

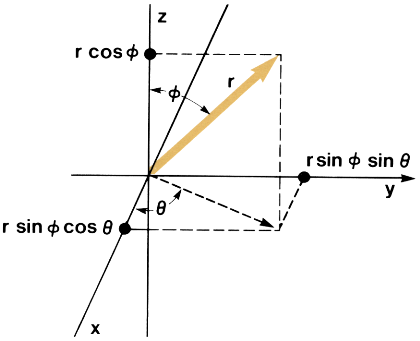
Another available option allows review of input values. Pressing f B causes a 1.00 to be displayed alternately indicating that the pause input mode is on or off. A print stack command is used to successively display the inputs in the following format:

Vector number (1.00 or 2.00)	T
ϕ (or $\pi \div 2$ for 2D vectors)	Z
θ	Y
r	X

Vector outputs are displayed in the following order:

POLAR FORM		RECTANGULAR FORM (S→C only)	
0.00	T	0.00	T
ϕ	Z	z	Z
θ	Y	y	Y
r	X	x	X

Equations:



Coordinate conversions:

$$x = r \sin \phi \cos \theta \qquad r = \sqrt{x^2 + y^2 + z^2}$$

$$y = r \sin \phi \sin \theta \qquad \theta = \tan^{-1} (y/x)$$

$$z = r \cos \phi \qquad \phi = \cos^{-1} \left(z/\sqrt{x^2 + y^2 + z^2} \right)$$

Vector addition:

$$\vec{V}_1 + \vec{V}_2 = (x_1 + x_2)\,\vec{i} + (y_1 + y_2)\,\vec{j} + (z_1 + z_2)\,\vec{k}$$

Cross product:

$$\vec{V}_1 \times \vec{V}_2 = (y_1 z_2 - z_1 y_2)\,\vec{i} + (z_1 x_2 - x_1 z_2)\,\vec{j} + (x_1 y_2 - y_1 x_2)\,\vec{k}$$

Dot or scalar product:

$$\vec{V}_1 \cdot \vec{V}_2 = x_1 x_2 + y_1 y_2 + z_1 z_2$$

Angle between vectors:

$$\gamma = \cos^{-1} \frac{\vec{V}_1 \cdot \vec{V}_2}{|\vec{V}_1|\ |\vec{V}_2|}$$

Remarks:

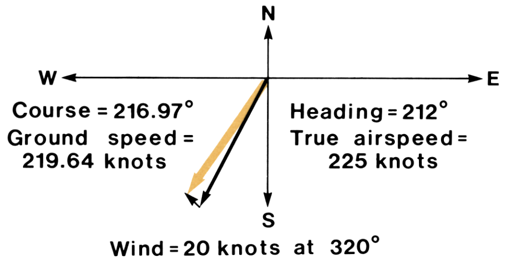
Registers $R_0 - R_6$ and $R_{S0} - R_{S9}$ are available for user storage.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and 2.			
2	Select mode for 2-dimensional			
	or 3-dimensional vectors.		f A	3.00/2.00
3	Optional: Select pause input			
	mode.		f B	1.00/0.00
4	If coordinate conversion			
	needed:			
	Spherical to Cartesian-go to			
	step 8.			
	Cartesian to spherical-go to			
	step 10.			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
5	Input vectors one and two:			
	Co-latitude (skip for 2D)	(ϕ_1)	ENTER↑	(ϕ_1)
	Longitude	θ_1	ENTER↑	θ_1
	Magnitude	r_1	D	1.00
	Co-latitude (skip for 2D)	(ϕ_2)	ENTER↑	(ϕ_2)
	Longitude	θ_2	ENTER↑	θ_2
	Magnitude	r_2	E	2.00
6	Perform vector operation:			
	Add vectors		A	$0, \phi, \theta, r$
	Cross product		B	$0, \phi, \theta, r$
	Dot product		C	$\vec{V}_1 \cdot \vec{V}_2, \gamma$
7	For a new case go to steps 2, 3, 4 or 5.			
8	Input spherical coordinates: (converts to Cartesian)			
	Co-latitude (skip for 2D)	(ϕ)	ENTER↑	(ϕ)
	Longitude	θ	ENTER↑	θ
	Magnitude	r	f D	x
9	For a new case go to steps 2, 3, 4 or 5.			
10	Input Cartesian coordinates (converts to spherical)			
	z—distance (skip for 2D)	(z)	ENTER↑	(z)
	y—distance	y	ENTER↑	y
	x—distance	x	f E	r
11	For a new case go to steps 2, 3, 4 or 5.			

Example 1:

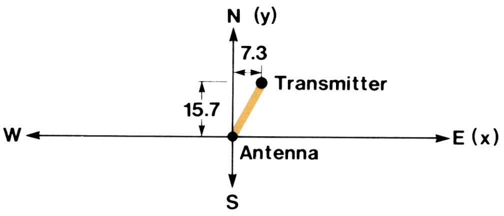
An aircraft flies a heading of 212 degrees at 225 knots. The wind is reported at 20 knots and 140 degrees (which translates to 20 knots and 320 degrees since winds are reported opposite to the direction they blow). What is the course of the aircraft? What is the ground speed?



Keystrokes:	**Outputs:**	
f A f A	2.00	
212 ENTER↑ 225 D	1.00	
320 ENTER↑ 20 E	2.00	
A	0.00 ***	T
	90.00 ***	Z
	216.97 ***	Y (degrees)
	219.64 ***	X (knots)

Example 2:

A microwave antenna is to be pointed at a transmitter which is 15.7 kilometers north, 7.3 kilometers east and 0.76 kilometers below. Use the cartesian to spherical conversion to find the total distance and the direction to the transmitter.

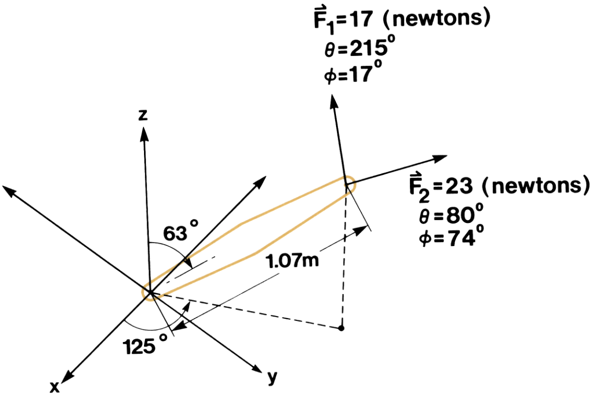


Keystrokes:	**Outputs:**
f A	3.00
.76 CHS ENTER↑ 15.7 ENTER↑	

7.3 f E →	17.33	(distance)
h R↓ →	65.06	(θ from east)
h R↓ →	92.51	(ϕ from vertical)
h R↓ →	0.00	
h R↓ →	17.33	(back to distance)

Example 3:

What is the moment at the origin of the lever shown below? What is the component of force along the lever? What is the angle between the resultant of the force vectors and the lever?



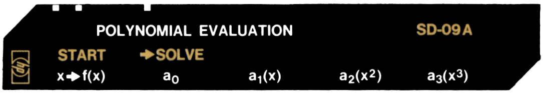
Keystrokes:	**Outputs:**	
First, add $\vec{F}_1$ and $\vec{F}_2$		
f A →	3.00	(3D mode)
17 ENTER↑ 215 ENTER↑ 17 D →	1.00	
74 ENTER↑ 80 ENTER↑ 23 E →	2.00	
A →	0.00 ***	T
	39.34 ***	Z
	90.70 ***	Y
	29.47 ***	X (newtons)

Keystrokes:	**Outputs:**	
Take cross product for moment, $\vec{M} = \vec{r} \times \vec{F}$		
E →	2.00	
63 ENTER↑ 125 ENTER↑ 1.07 D →	1.00	
B →	0.00 ***	T
	124.34 ***	Z
	55.37 ***	Y
	18.02 ***	X

Take dot product to resolve force along the lever.

Keystrokes:	**Outputs:**	
63 ENTER↑ 125 ENTER↑ 1 D →	1.00	
C →	24.19 ***	(newtons)
	34.85 ***	(degrees)

POLYNOMIAL EVALUATION



This program may be used to find the roots of the following equations:

Cubic equation (3 roots)

$$f(x) = a_0 + a_1x + a_2x^2 + a_3x^3 = 0$$

Quadratic equation (2 roots)

$$f(x) = a_0 + a_1x + a_2x^2 = 0$$

Linear equation (1 root)

$$f(x) = a_0 + a_1x = 0$$

where a_0, a_1, a_2 and a_3 are the polynomial coefficients input by the user. Both real and imaginary roots can be extracted. When imaginary roots are found, a −1. is displayed followed by imaginary and real parts. Real roots are displayed without the −1. indicator. Example 3 involves imaginary roots and should make this clear.

Polynomials may also be evaluated for arbitrary values of x. This is of aid in plotting polynomials and using data correlations based on polynomials. Example 2 demonstrates this type of use.

Equations:

Cubic Equation:

$$Q = \frac{3a_1 - a_2^2/a_3}{9a_3}$$

$$R = \frac{9a_2a_1/a_3 - 27a_0 - 2a_2^3/a_3^2}{54a_3}$$

$$S = \sqrt[3]{R + \sqrt{Q^3 + R^2}}$$

$$T = \sqrt[3]{R - \sqrt{Q^3 + R^2}}$$

If $$Q^3 + R^2 \geqslant 0,$$

then $$x_3 = S + T - \frac{a_2}{3a_3}$$

If $$Q^3 + R^2 < 0,$$

then $$x_3 = 2\sqrt{-Q}\cos\left[\frac{1}{3}\cos^{-1}(R/\sqrt{-Q^3})\right] - \frac{a_2}{3a_3}$$

After x_3 is found, synthetic division is performed to reduce the cubic equation to a quadratic equation.

$$a_2' = 1.00$$

$$a_1'/a_2' = x_3 + a_2/a_3$$

$$a_0'/a_2' = x_3(x_3 + a_2/a_3) + a_1/a_3$$

Quadratic equation:

$$x_1 = \begin{cases} -\dfrac{a_1}{2a_2} - \sqrt{(a_1/2a_2)^2 - (a_0/a_2)} & \text{If } -a_1/2a_2 < 0 \\ -\dfrac{a_1}{2a_2} + \sqrt{(a_1/2a_2)^2 - (a_0/a_2)} & \text{If } -a_1/2a_2 \geqslant 0 \end{cases}$$

$$x_2 = \frac{a_0}{a_2 x_1}$$

Linear equation:

$$x = -\frac{a_0}{a_1}$$

Remarks:

Registers R_0, $R_5 - R_9$, and $R_{S0} - R_{S9}$ are available for user storage.

Accuracy degenerates if the real root of the cubic equation is extremely small.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Initialize		f A	0.00
3	Input coefficients of Polynomial:			
	Constant	a_0	B	1.00
	x coefficient	a_1	C	2.00
	x^2 coefficient	a_2	D	3.00
	x^3 coefficient	a_3	E	4.00
4	To evaluate polynomial for			
	various values of x go to step 7.			
5	Find the roots of the polynomial.			
	(Imaginary roots will be output			
	in imaginary, real order preced-			
	ed by a negative one).		f B	roots
6	Go to step 8.			
7	Input x and see f(x)	x	A	f(x)
8	For a new case of same or high-			
	er degree, go to step 3 and			
	change appropriate coefficients.			
	For a lower degree go to step 2.			

Example 1:

A ball is thrown straight up at a velocity of 20 meters per second, from a height of 2 meters. At what time, neglecting air resistance, will it reach the ground? The acceleration of gravity is 9.81 meters per second. From physics:

$$f(t) = x = x_0 + v_0 t + \frac{1}{2} a t^2 = 0$$

$$= 2 + 20t + (-9.81/2)t^2 = 0$$

Keystrokes: **Outputs:**

f A ——→ 0.00

2 B 20 C 9.81 ENTER↑		
2 ÷ CHS D f B →	4.18 ***	(seconds)
	−0.10 ***	(seconds)

The answer is 4.18 seconds. The second root of −0.10 is a legitimate root of the equation but is not relevant to this problem.

Example 2:

The standard heat of formation of ammonia (NH_3) is given as a function of Kelvin temperature by:

$$\Delta H^\circ_T = -9140 - 7.596\ T + 4.243 \times 10^{-3}\ T^2 - 0.742 \times 10^{-6}\ T^3\ \text{(cal)}$$

Determine the heat of formation for temperatures of 400 K, 600 K, and 800 K.

Keystrokes:	**Outputs:**	
f A →	0.00	
9140 CHS B 7.596 CHS C →	2.00	
4.243 EEX CHS 3 D .742		
CHS EEX CHS 6 E →	4.00	
400 A →	−11547.01	(cal)
600 A →	−12330.39	(cal)
800 A →	−12881.18	(cal)

Example 3:

Find the roots of the following equation.

$$x^3 - 4x^2 + 8x - 8 = 0$$

Keystrokes:	**Outputs:**	
f A 8 CHS B 8 C		
4 CHS D 1 E f B →	2.00 ***	(real root)
	−1.	(indicator)
	1.73 ***	(imaginary part)
	1.00 ***	(real part)

The real root is 2.00. The imaginary roots are 1.00 + 1.73i and 1.00 − 1.73i. The −1. (which is not followed by asterisks) indicates that the last two outputs will be imaginary and real parts rather than real roots.

3 × 3 MATRIX OPERATIONS

3X3 MATRIX OPERATIONS
SD-10A
→DET
→INV
→MULT
$a_1 \uparrow a_2 \uparrow a_3$
$b_1 \uparrow b_2 \uparrow b_3$
$c_1 \uparrow c_2 \uparrow c_3$
$d_1 \uparrow d_2 \uparrow d_3$
MAT P

This program can be used to find the determinant or generate the inverse of a 3 × 3 matrix. It can also multiply a 3 × 3 matrix by a column matrix. By using the matrix inverse function in combination with the matrix multiply function, it is possible to solve three linear equations in three unknowns.

Equations:

$$\text{Matrix A} = \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{bmatrix}$$

$$\text{Matrix D} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix}$$

Determinant of matrix A

$$\begin{aligned} \text{Det} &= a_1 b_2 c_3 + b_1 c_2 a_3 + c_1 b_3 a_2 \\ &\quad - c_1 b_2 a_3 - c_2 b_3 a_1 - c_3 a_2 b_1 \end{aligned}$$

Inverse of matrix A

$$A^{-1} = \begin{bmatrix} \alpha_1 & \beta_1 & \gamma_1 \\ \alpha_2 & \beta_2 & \gamma_2 \\ \alpha_3 & \beta_3 & \gamma_3 \end{bmatrix}$$

$$\alpha_1 = (b_2 c_3 - b_3 c_2)/\text{Det}$$

$$\alpha_2 = (a_3 c_2 - a_2 c_3)/\text{Det}$$

$$\alpha_3 = (a_2 b_3 - a_3 b_2)/\text{Det}$$

$$\beta_1 = (b_3 c_1 - b_1 c_3)/\text{Det}$$

$$\beta_2 = (a_1 c_3 - a_3 c_1)/\text{Det}$$

$$\beta_3 = (a_3 b_1 - a_1 b_3)/\text{Det}$$

$$\gamma_1 = (b_1\, c_2 - b_2\, c_1)/\text{Det}$$
$$\gamma_2 = (a_2\, c_1 - a_1\, c_2)/\text{Det}$$
$$\gamma_3 = (a_1\, b_2 - a_2\, b_1)/\text{Det}$$

Matrix multiplication

$$A \cdot D = \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{bmatrix} \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix}$$

$$= \begin{bmatrix} a_1d_1 + b_1d_2 + c_1d_3 \\ a_2d_1 + b_2d_2 + c_2d_3 \\ a_3d_1 + b_3d_2 + c_3d_3 \end{bmatrix}$$

Remarks:

During matrix inversion, A^{-1} replaces A in storage. If you wish to save matrix A, store it on a magnetic card before starting the inversion process.

Two by two matrix operations can be performed with this program (see example 2). A 2 × 2 matrix should be input in the following form:

$$A = \begin{bmatrix} a_1 & b_1 & 0 \\ a_2 & b_2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The corresponding column vector is:

$$D = \begin{bmatrix} d_1 \\ d_2 \\ 0 \end{bmatrix}$$

If the determinant of a matrix is zero, the inverse cannot be found.

Registers R_{S0}–R_{S9} are available for user storage.

Matrices may be output at any time by pressing **E**. The order of output is a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2, c_3, d_1, d_2, d_3.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Input 3 × 3 matrix:			
	Column 1	a_1	ENTER↑	a_1
		a_2	ENTER↑	a_2
		a_3	A	a_3
	Column 2	b_1	ENTER↑	b_1
		b_2	ENTER↑	b_2
		b_3	B	b_3
	Column 3	c_1	ENTER↑	c_1
		c_2	ENTER↑	c_2
		c_3	C	c_3
3	For solution of simultaneous			
	equations or multiplication of			
	the 3 × 3 matrix by a column			
	matrix, input column matrix.	d_1	ENTER↑	d_1
		d_2	ENTER↑	d_2
		d_3	D	d_3
4	To find a determinant go to step			
	5. To find the inverse or solve a			
	3 × 3 system, go to step 8. To			
	perform multiplication, go to			
	step 10.			
5	Find the determinant of the			
	3 × 3 matrix.		f A	$\|A\|$
6	For a new case,go to step 2.			
	Change any or all of the columns			
	in step 3.			
7	If you wish to save the 3 × 3			
	matrix for future use, record it			
	on a magnetic card.			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
8	Find the inverse.		f B	0.00
9	For a solution of a 3 × 3 system			
	go to step 10. For a new case go			
	to step 2. The original 3 × 3			
	matrix has been replaced in			
	storage by its 3 × 3 inverse.			
10	Multiply the 3 × 3 matrix by the			
	column matrix. (The resulting			
	column matrix is output in x, y, z			
	order).		f C	x, y, z
11	For multiplication by another			
	column matrix, perform step 3,			
	then press f C. For a new			
	case go to step 2.			

Example 1:

Find the determinant and inverse of the following matrix; then multiply by the column matrix.

$$\begin{bmatrix} 23 & 15 & 17 \\ 8 & 11 & -6 \\ 4 & 15 & 12 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

Keystrokes:	**Outputs:**
23 ENTER↑ 8 ENTER↑ 4 A →	4.00
15 ENTER↑ 11 ENTER↑ 15 B →	15.00
17 ENTER↑ 6 CHS ENTER↑ 12 C →	12.00
1 ENTER↑ 1 ENTER↑ 1 D →	1.00

f A	4598.00	(determinant)
f B	0.00	(inverse found)
E	0.05 ***	(α_1)
	−0.03 ***	(α_2)
	0.02 ***	(α_3)
	0.02 ***	(β_1)
	0.05 ***	(β_2)
	−0.06 ***	(β_3)
	−0.06 ***	(γ_1)
	0.06 ***	(γ_2)
	0.03 ***	(γ_3)
	1.00 ***	(d_1)
	1.00 ***	(d_2)
	1.00 ***	(d_3)
	(results of multiplication)	
f C	4.349717270 −03 ***	
	0.08 ***	
	−0.02 ***	

Example 2:

Find the determinant and the inverse of the 2 × 2 matrix below. After the inverse has been found, multiply by the column matrix.

$$\begin{bmatrix} 14 & -8 \\ -8 & 12 \end{bmatrix} \quad \begin{bmatrix} 20 \\ 5 \end{bmatrix}$$

First transform the matrices to three dimensions as specified in the remarks section:

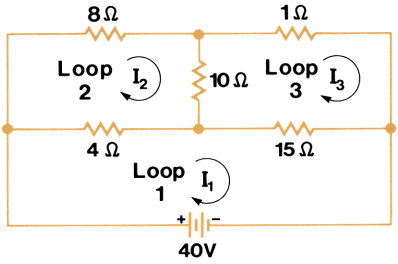
$$\begin{bmatrix} 14 & -8 & 0 \\ -8 & 12 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 20 \\ 5 \\ 0 \end{bmatrix}$$

Keystrokes:	Outputs:
14 ENTER↑ 8 CHS ENTER↑ 0 A	0.00
8 CHS ENTER↑ 12 ENTER↑ 0 B	0.00
0 ENTER↑ 0 ENTER↑ 1 C	1.00
20 ENTER↑ 5 ENTER↑ 0 D	0.00

f A →	104.00	(determinant)
f B →	0.00	(inverse has been found)
E →	0.12 ***	(α_1)
	0.08 ***	(α_2)
	0.00 ***	(α_3)
	0.08 ***	(β_1)
	0.13 ***	(β_2)
	0.00 ***	(β_3)
	0.00 ***	(γ_1)
	0.00 ***	(γ_2)
	1.00 ***	(γ_3)
	20.00 ***	(d_1)
	5.00 ***	(d_2)
	0.00 ***	(d_3)
f C →	2.69 ***	(results of multiplication)
	2.21 ***	
	0.00 ***	

Example 3:

Solve for the loop currents in the following circuit.



The three loop equations are:

Loop 1 $\quad 4I_1 - 4I_2 + 15\ I_1 - 15\ I_3 - 40 = 0$

Loop 2 $\quad 4\ I_2 - 4\ I_1 + 8\ I_2 + 10\ I_2 - 10\ I_3 = 0$

Loop 3 $\quad 10\ I_3 - 10\ I_2 + 1\ I_3 + 15\ I_3 - 15\ I_1 = 0$

or

$$19\ I_1 - 4\ I_2 - 15\ I_3 = 40$$
$$-4\ I_1 + 22\ I_2 - 10\ I_3 = 0$$
$$-15\ I_1 - 10\ I_2 + 26\ I_3 = 0$$

or in matrix form

$$\begin{bmatrix} 19 & -4 & -15 \\ -4 & 22 & -10 \\ -15 & -10 & 26 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 40 \\ 0 \\ 0 \end{bmatrix}$$

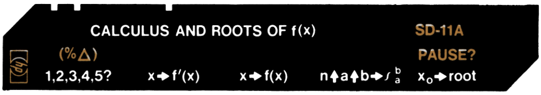
and

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 19 & -4 & -15 \\ -4 & 22 & -10 \\ -15 & -10 & 26 \end{bmatrix}^{-1} \begin{bmatrix} 40 \\ 0 \\ 0 \end{bmatrix}$$

Keystrokes:		Outputs:	
19 ENTER↑ 4 CHS ENTER↑ 15 CHS A	→	-15.00	
4 CHS ENTER↑ 22 ENTER↑ 10 CHS B	→	-10.00	
15 CHS ENTER↑ 10 CHS ENTER↑ 26 C	→	26.00	
40 ENTER↑ 0 ENTER↑ 0 D	→	0.00	
f B	→	0.00	(inverse has been found)
f C	→	7.86 ***	(I_1)
		4.23 ***	(I_2)
		6.16 ***	(I_3)

NOTES

CALCULUS AND ROOTS OF f(X)



This program incorporates four routines for numerical analysis of user specified functions. Suppose figure 1 represents a known function of x called f(x).

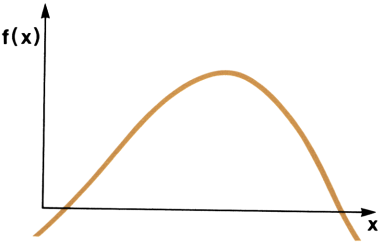


Figure 1

If the formula for f(x) can be keyed into program memory in less than 112 steps (including LBL and RTN), this program can be used to find the value of f(x) at any point x, the derivative of f(x) at any point x, the integral of f(x) over a specified interval and the real roots of f(x). There may be up to five different f(x) functions in program memory at one time. They must be labeled from 1 to 5. The function to be evaluated is selected by keying in 1, 2, 3, 4 or 5 and pressing A.

Only side 1 of *Calculus and Roots of f(x)* is used for the program. Side 2 of *Calculus and Roots of f(x)* has three functions recorded on it. These will be used in the example problems to show various applications of the program. You may wish to record functions you use frequently on blank magnetic cards. Once recorded, the functions can be linked to *Calculus and Roots of f(x)* by the following sequence of operations:

1. Load side 1 of *Calculus and Roots of f(x)*.
2. Press GTO . 1 1 2.
3. Press g MERGE.
4. Load your magnetic card.

Once a function is defined and selected, keying in a value of x and pressing the C key will result in the evaluation of f(x) (see figure 2).

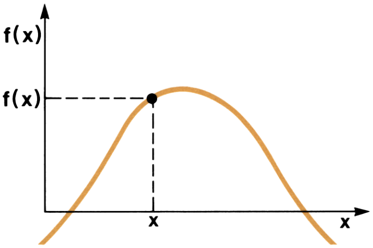


Figure 2

Similarly, the value of the slope of f(x) at a particular point x can be calculated by keying in x and pressing the B key (see figure 3). The slope of f(x) is determined using an approximation to the differential:

$$f'(x) = \frac{f(x + \Delta x/2) - f(x - \Delta x/2)}{\Delta x}$$

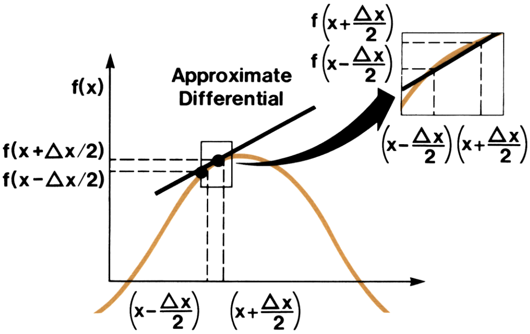

f(x)
Approximate Differential
f(x+Δx/2)
f(x−Δx/2)
$f\left(x+\frac{\Delta x}{2}\right)$
$f\left(x-\frac{\Delta x}{2}\right)$
$\left(x-\frac{\Delta x}{2}\right)$ $\left(x+\frac{\Delta x}{2}\right)$
$\left(x-\frac{\Delta x}{2}\right)$ $\left(x+\frac{\Delta x}{2}\right)$

Figure 3

The value of Δx used to approximate the differential is assumed to be 0.01% of x ($10^{-4} \times x$) unless a % Δ is specified by the user. That is:

$$\Delta x = \frac{\%\Delta}{100} \cdot x$$

In the special case where x = 0, Δx is set equal to %Δ.

For most applications, the assumed value of 0.01% should be adequate. In some cases more accurate results can be obtained using a smaller value of

%Δ. However, care must be taken to assure that the calculator can accurately resolve the difference between f(x − Δx/2) and f(x + Δx/2).

The D key may be used to approximate the integral or area under a curve.

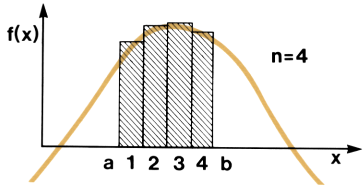


Figure 4

You specify the end points of the interval (a and b) and the number of rectangles (n) the interval should be broken into (see figure 4). The calculator computes the sum of the areas of the rectangles. The more rectangles used the closer this value is to the actual area under the curve. However, more rectangles mean more computation time. Experience with a particular function should lead to a balance between accuracy and execution time.

Root finders are used to solve equations which are difficult or impossible to solve explicitly. An example of such an equation is

$$f(x) = \ln x + 3x - 10.8074 = 0$$

which is solved in example 4.

The root finder incorporated in this program uses a secant method of approximation. You must supply the routine with an initial guess of the root. Based on this guess, it will attempt to make better and better approximations of the root by the following formula:

$$x_{i+1} = x_i - f(x_i)\left[\frac{(x_i - x_{i-1})}{f(x_i) - f(x_{i-1})}\right]$$

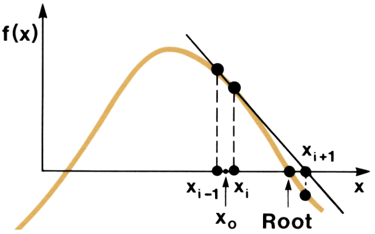


Figure 5

The display is automatically set to fix mode during the root finder portion of the program. When the last approximation is accurate to the number of places specified by the display setting of the calculator, the routine halts and displays the root.

Since the root finder starts its search based on your guess, care should be exercised in guess selection. A bad guess will cause long execution times and could result in a machine status error halt (overflow, division by zero, log of a negative number, etc.). If this happens, simply try another guess. Practice will make the pitfalls more obvious and easier to avoid.

A special feature of the iterative routine is the pause function. This feature allows the program to pause at one point in each iteration to display the current approximation of the root. The pause option may be turned off and on by pressing f E. The pause allows you to watch the routine converge (or diverge) without interrupting the program. This can be a helpful tool when the iterative routine fails to converge. By watching each successive approximation of the root, the reasons for failure of convergence can usually be determined.

Remarks:

The value of x is stored in R_0 by the program. It is also in the X register when control transfers to the function subroutine.

Registers R_1-R_8, and R_{S0}-R_{S9} are available for use in f(x) or for other user storage.

User-specified functions may use one level of subroutine nesting.

The secant method does not guarantee convergence to a root.

Given one guess, the root finder will find, at most, one root of an equation. Other real roots, if they exist, may be found by modifying the initial guess.

In order to compute f′(x), the function f(x) must be continuous on the interval $(x + \Delta x/2, x - \Delta x/2)$.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1.			
2	Load subroutine(s) (either key			
	them in or link from program			
	step 112).			
3	Select function label number.	i(1-5)	A	i
4	Store any constants necessary			
	to subroutine(s) loaded in			
	step 2.			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
5	For differentiation, go to step 6. For evaluation of a function, go to step 9. For integration of a function, go to step 11. To find a root, go to step 15.			
6	Optional: Key in percent delta.	%Δ	f A	%Δ
7	Key in x and calculate derivative at x.	x	B	$f_i'(x)$
8	For new x, go to step 7. For a new case, go to step 2, 3, 4, 5 or 6.			
9	Key in x and evaluate function.	x	C	$f_i(x)$
10	For new x, go to step 9. For a new case, go to step 2, 3, 4, or 5.			
11	Input the number of intervals.	n	ENTER↑	n
12	Input the lower limit.	a	ENTER↑	a
13	Input the upper limit and calculate the integral.	b	D	$\int f_i(x)\,dx$
14	For new limits or interval, go to step 11. For a new case, go to step 2, 3, 4 or 5.			
15	Optional: Key in percent delta.	%Δ	f A	%Δ
16	Optional: Toggle pause mode.		f E	1.00/0.00
17	Key in guess and calculate root.	GUESS	E	x
18	For a new guess go to step 17. For a new case go to step 2, 3, 4 or 5.			

Example 1:

Numerical integration provides the only solution to the complete elliptic integral of the first kind:

$$u = \int_0^{\pi/2} \frac{d\theta}{\sqrt{1 - K^2 \sin\theta^2}}$$

Find the value of u for limits of integration of 0.0 to $\pi/2$. Let K be 0.5 and store it in register 1 for access by the program. Use 3 and then 10 for the number of intervals. The formula for the integral is recorded under label three on side two of the magnetic card. If either example 2 or example 3 has just been run, skip the first three lines under keystrokes.

Keystrokes:	**Outputs:**
Load side 1 only	
GTO • 112 g MERGE	
Load side 2	
Select label 3	
3 A →	3.00
0.50 STO 1 →	0.50
Integrate using 3 intervals	
DSP 9 3 ENTER↑ 0 ENTER↑	
h π 2 ÷ D →	1.685750251
Integrate using 10 intervals	
10 ENTER↑ 0 ENTER↑ h π 2 ÷ D →	1.685750355

Example 2:

In the design of gear teeth, it is frequently necessary to calculate x for a given value of the involute:

$$INV(x) = \tan x - x$$

or restated

$$f(x) = \tan x - x - INV(x) = 0$$

If the involute of x is 0.0049819, what is x?

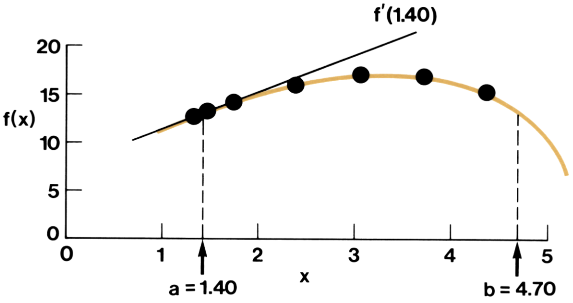
This problem requires an iterative solution since the equation cannot be explicitly solved for x. Use 0.21 radians as your initial guess. The equation for f(x) is recorded under label 2 on side 2 of the magnetic card. Use the pause feature to watch the routine converge. Skip the first three lines under keystrokes if Example 1 or 3 has been run. Store the involute (.0049819) in R_2 for access by the function.

Keystrokes:	**Outputs:**	
Load side 1 only		
GTO · 112 g MERGE		
Load side 2		
Select label 2		
2 A →	2.00	
Set pause		
DSP 2 f E →	1.00	
.0049819 STO 2 .21 E →	"0.25"	
	"0.24"	
	"0.24"	
	0.24	(rad)

Example 3:

In many instances, a function is represented graphically. This program can be of use in integration and, in some cases, differentiation of such graphs. Label 1 of side 2 of the prerecorded magnetic card is designed for this purpose. It returns x values to the display. You must find f(x) from the graph, key it in and press R/S.

For the function below find the integral from a to b using 5 intervals. Then find the derivative at a, using 10% for %Δ. After the problem is complete, return %Δ to 0.01%.



If either Example 1 or Example 2 was run previously, skip the first three lines under keystrokes.

Keystrokes:	Outputs:	
Load side 1 only		
GTO • 112 g MERGE		
Load side 2		
Select Label 1		
1 A	1.00	
Key in integration limits and return first x value		
5 ENTER↑ 1.40 ENTER↑ 4.70 D	1.73	(x)
From the graph, f(x) at x = 1.73 equals 14.2. Key 14.2 in and press R/S. The next value of x will be displayed.		
14.2 R/S	2.39	
f (2.39) = 16		
16 R/S	3.05	
f (3.05) = 17		
17 R/S	3.71	
f (3.71) = 16.9		
16.9 R/S	4.37	
f (4.37) = 15.3		
15.3 R/S	52.40	(Answer)
To find the derivative at point a		
10 f A 1.40 B	1.33	$\left(x - \frac{\Delta x}{2}\right)$
f (1.33) = 12.7		
12.7 R/S	1.47	$\left(x + \frac{\Delta x}{2}\right)$
f (1.47) = 13.3		
13.3 R/S	4.29	(Slope)
Return %Δ to 0.01%		
.01 f A	0.01	

Example 4:

Find the root of ln x + 3x − 10.8074 = 0. Determine the slope at the root.

This equation is not recorded on the magnetic card. It must be manually keyed into program memory starting at step 112. Use R_1 to store the 3 and R_2 to store 10.8074.

Keystrokes:	Outputs:
Load side 1 only	
GTO • 112	
Switch to W/PRGM	112 35 22
f LBL 1	31 25 01

```
f LN ──────────────────────────→ 114 31 52   (lnx)
RCL 1 ─────────────────────────→ 115 34 01
RCL 0 ─────────────────────────→ 116 34 00
× ─────────────────────────────→ 117    71
+ ─────────────────────────────→ 118    61   (lnx + 3x)
RCL 2 ─────────────────────────→ 119 34 02
− ─────────────────────────────→ 120    51   (lnx + 3x −
                                               10.8074)
h RTN ─────────────────────────→ 121 35 22
Switch to Run
Select LBL 1
1 A ───────────────────────────→ 1.00
3 STO 1 ───────────────────────→ 3.00
10.8074 STO 2 ─────────────────→ 10.81
Make a guess of 5.0
5 E ───────────────────────────→ 3.21        (ROOT)
Find the derivative
B ─────────────────────────────→ 3.31        f′ (3.21)
```

NOTES

ENGLISH-SI CONVERSIONS

This card provides the more common conversions between English and SI (metric) units. Side one of the card provides length, volume, force and mass conversions. Side two provides temperature, energy, pressure, density and power conversions. Only one side of the card may be loaded into program memory at any time.

Conversion Factors:

Side 1 of magnetic card

1 inch (in) = 25.4* millimeters (mm)
1 foot (ft) = 0.3048* meters (m)
1 U.S. liquid gallon (gal) = 3.785411784* liters (ℓ)
1 pound force avoirdupois (lbf) = 4.448221615 newtons (N)
1 pound mass avoirdupois (lbm) = 0.45359237* kilograms (kg)

Side 2 of magnetic card

Degrees Fahrenheit (°F) are related to degrees Celsius (°C) by the following formula:

$$°C = (°F - 32)/1.8$$

1 International Steam Table British thermal unit (Btu) = 1055.055853 joules (J)
1 pound per square inch (psi) = 6894.7572 newtons/square meters (N/m^2)
1 pound per cubic foot (lb/ft^3) = 16.018463 kilograms per cubic meter (kg/m^3)
1 horsepower (550 ft-lbf/sec) = 745.69987 watts (W)

Remarks:

Only one side of the card may be in program memory at a time.

All data registers (R_0 – I) are available for user storage. The T register of the operational stack is lost during conversions. The LAST X register contains the input value for all conversions except temperature conversions.

*By definition.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	For length, volume, force or mass conversion, load side 1. For temperature, energy, pressure, density, or power conversion, go to step 4.			
2	To convert inches to millimeters	in	A	mm
	or millimeters to inches	mm	f A	in
	or feet to meters	ft	B	m
	or meters to feet	m	f B	ft
	or gallons to liters	gal	C	ℓ
	or liters to gallons	ℓ	f C	gal
	or pounds to newtons	lbf	D	N
	or newtons to pounds	N	f D	lbf
	or pounds to kilograms	lbm	E	kg
	or kilograms to pounds	kg	f E	lbm
3	For a new case, go to step 2.			
4	Load side 2.			
5	To convert Fahrenheit to Celsius	°F	A	°C
	or Celsius to Fahrenheit	°C	f A	°F
	or Btu to joules	Btu	B	J
	or joules to Btu	J	f B	Btu
	or psi to N/m^2	psi	C	N/m^2
	or N/m^2 to psi	N/m^2	f C	psi
	or lb/ft^3 to kg/m^3	lb/ft^3	D	kg/m^3
	or kg/m^3 to lb/ft^3	kg/m^3	f D	lb/ft^3
	or horsepower to watts	hp	E	W
	or watts to horsepower	W	f E	hp
6	For a new case, go to step 5.			

Example 1:

Convert ⅜ of an inch to millimeters and round to an integer value.

Keystrokes:	**Output:**	
Load side one		
3 ENTER↑ 8 ÷ A	9.53	(mm)
DSP 0 f RND	10.	(mm)
DSP 2	10.00	(mm)

Example 2:

Convert 212°F to °C. Convert 0°C to °F.

Keystrokes:	**Outputs:**
Load side two	
212 A	100.00
0 f A	32.00

Example 3:

Convert 75 Btu/hr-ft^2 to joules/hr-m^2. (Since ft^2 is in the denominator, the sense of the conversion is reversed.)

Keystrokes:	**Output:**	
Side 1		
75 f B f B	807.29	(Btu/hr-m^2)
Side 2		
B	851739.50	(J/hr-m^2)

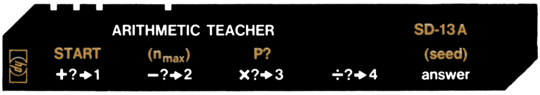
Example 4:

Convert six pounds per gallon to kilograms per liter.

Keystrokes:	**Outputs:**	
Side 1		
6 E f C	0.72	(kg/ ℓ)

NOTES

ARITHMETIC TEACHER



Preschool and elementary school students may use this program to help them learn addition, subtraction, multiplication, and division. The program generates and displays problems in the following form:

x .y

Where x is one variable and y is the other variable. The child mentally computes the answer (x + y, x − y, x × y, or x ÷ y depending on the lesson), keys it in, and presses the answer key E . If the answer is correct, the calculator poses a new problem. If the answer is incorrect, the calculator returns the problem until a correct response is given.

One lesson consists of 20 problems. After problem 20, the calculator outputs number correct, number tried, and percent correct.

As the child progresses, the maximum size of the numbers, n_{max}, may be modified. For example, keying in 3 and pressing f B would set the maximum number size to 3 for addition and multiplication, 3 + 3 for subtraction, and 3^2 for division. For more advanced students, n_{max} might be set to 15. If the value is not specified by the user, the program assumes a value of 9.

Remarks:

The type of problem to be solved (+, −, ×, ÷) can be changed at any time during the lesson. When the problem type is selected, a code number is displayed for a moment before a new problem is posed. The digit 1 indicates addition, 2 indicates subtraction, 3 indicates multiplication, and 4 indicates division.

If the student realizes that a wrong answer has been keyed in before the E key is pressed, the h R↓ keys can be used to eliminate the error and return the problem to the display.

Any attempt to use the calculator to solve the problem will result in an error necessitating a restart of the program.

The number generator incorporated in this program will always give the same sequence of numbers unless n_{max} is changed or a ''seed'' is input. The seed can be any number between 0 and 1. To input a seed, simply key it in and press f E .

Registers R_0 - R_6 and R_{S0} - R_{S9} are available for user storage.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2.			
2	Start program.		f A	0.00
3	Optional: Input a seed (any			
	number between 0 and 1).*	SEED	f E	0.00
4	Optional: Select maximum			
	number size (default is 9).	^{n}max	f B	0.00
5	Optional: Select print lesson			
	mode.		f C	1.00/0.00
6	Select arithmetic mode:* *			
	Addition		A	problem
	Subtraction		B	problem
	Multiplication		C	problem
	Division		D	problem
7	Let student key in answer and			
	press E.	answer	E	problem
8	Repeat step 7 for 20 problems.			
	After problem 20 the calculator			
	will output number correct,			
	number attempted and %			
	correct.			
9	For another session go to step 7.			
	To change arithmetic mode go			
	to step 6. To select print lesson			
	mode go to step 5. To sleect a			
	new maximum number size go			
	to step 4.			

* See page L13-01 for description of algorithm and comments on optional seed selection.

* After an arithmetic mode is selected a code is output to indicate which mode was set: 1 addition, 2 subtraction, 3 multiplication and 4 division.

Example 1:

A child is to practice multiplication of the numbers one through eight.

Keystrokes:	Outputs:
f A	0.00
Select maximum number size of 8.	
8 f B	8.0 ***
Select lesson type	
C	3.0 ***
	6.8
48 E	1.4
4 E	7.3
21 E	8.8
64 E	7.7
49 E	7.4
28 E	7.6
40 E	
45 E	
42 E	4.2
8 E	8.6
48 E	8.8
64 E	8.7
56 E	8.6
48 E	5.8
40 E	6.7
40 E	
42 E	5.8
40 E	8.4
32 E	4.6
24 E	7.4
28 E	4.4
16 E	4.7
28 E	18.0 ***
	20.
	90.0 ***

The calculator displays the first problem of the next set.

Example 2:

The child of example 1 now wishes to practice division for numbers 1 through 10.

Keystrokes:	Outputs:
10 f B	10.0 ***
D	4.0 ***
	30.06
5 E	70.07
10 E	30.06
5 E	28.04
7 E	32.08
4 E	6.06
1 E	80.10
8 E	40.04
10 E	16.04
4 E	80.08
10 E	70.10
7 E	80.08
10 E	42.07
6 E	81.09
9 E	7.07
1 E	10.05
2 E	60.06
6 E	
10 E	56.08
7 E	56.07
8 E	70.10
7 E	19.00 ***
	20.
	95.00 ***

MOON ROCKET LANDER

Imagine for a moment the difficulties involved in landing a rocket on the moon with a strictly limited fuel supply. You're coming down tail-first, freefalling toward a hard rock surface. You'll have to ignite your rockets to slow your descent; but if you burn too much too soon, you'll run out of fuel 100 feet up, and then you'll have nothing to look forward to but cold eternal moon dust coming faster every second. The object, clearly, is to space your burns just right so that you will alight on the moon's surface with no downward velocity.

The game starts off with the rocket descending at a velocity of 50 feet/second from a height of 500 feet. The velocity and altitude are shown in a combined display as –50.0500, the altitude appearing to the right of the decimal point and the velocity to the left, with a negative sign on the velocity to indicate downward motion. Then the remaining fuel is displayed and a rocket fire count down begins "3", "2", "1", "0",. Exactly at zero you may key in a fuel burn. You only have one second, so be ready. A zero burn, which is very common, is accomplished by doing nothing. However, if you miss the one second "fire window" and then try to key in a burn, your engine will die and you will have to restart by pressing B. This automatically uses 5 fuel units and gives no thrust. After a burn the sequence is repeated unless:

1. You have successfully landed—flashing zeros.
2. You have smashed into the lunar surface—flashing crash velocity.

You must take care, however, not to burn more fuel than you have; for if you do you will free-fall to your doom! The final velocity shown will be your inpact velocity (generally rather high). You have 60 units of fuel initially.

Equations:

We don't want to get too specific, because that would spoil the fun of the game; but rest assured that the program is solidly based on some old friends from Newtonian physics:

$$x = x_0 + v_0t + \frac{1}{2}at^2 \qquad v = v_0 + at \qquad v^2 = v_0^2 + 2ax$$

where x, v, a, and t are distance, velocity, acceleration, and time.

Remarks:

Only integer values for fuel burn are allowed.

R/S can be used to stop *Moon Rocket Lander* at any time.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1.			
2	Assume manual control.		A	"V.ALT"
				"FUEL"
				"3"
				"2"
				"1"
3	Key in burn*.	BURN		"V.ALT"
				"FUEL"
				"3"
				"2"
				"1"
4	Go to step 3 until you land			
	(flashing zeros) or crash (flash-			
	ing impact velocity).			
5	If you survived last landing			
	attempt, go to step 2 for			
	another try.			
	*If you miss the burn window and			
	flameout, press B for a new			
	engine start.		B	

DIAGNOSTIC PROGRAM

This program can be used to test the calculator and diagnose calculator malfunctions. Simply insert the card and press A. After approximately two seconds, the calculator should pause displaying:

57.0

If the calculator does not pause with this number, there is a malfunction in executing and returning from a subroutine, finding Label 0, program storage, the display, the magnetic card, the PAUSE command or the card reader. After the pause, the calculator should continue to run about one-and-one-half minutes more and then print the three lines shown:

```
    -888.9-90
    -8.889-88
-8.888888888-88
```

This output indicates that printing and display formatting are working correctly. If the calculator stops before displaying ***-8.888888888-88***, a code number corresponding to a function or operation malfunction will be displayed. For instance, if the calculator stopped with ***36.0*** in the display, an error in tangent or arctangent would be indicated. The sole exception is a failure in primary register 0. The calculator will stop execution of the program with the erroneous contents of R_0 displayed.

DIAGNOSTIC CODES

Function or Operation or Register Indicated	Code
STO i, RCL i, R_0, GTO 0, LBL 0, $x=y$, $x \neq y$	0
ISZ I, R_1	1
R_2	2
R_3	3
R_4	4
R_5	5
R_6	6
R_7	7
R_8	8
R_9	9
R_{S0}	10
R_{S1}	11
R_{S2}	12

Remarks:

If this program runs correctly, it strongly suggests that the calculator is operating correctly. However, the diagnosis is by no means complete or exhaustive. The diagnostic can be made to repetitively loop by changing step 224 from ''R/S'' to ''GTO A''. This may aid in detection of intermittent failures. The program relies on the status of the flags to be correctly set by the card. If a flag error occurs, re-insert the diagnostic card and verify repeatability of failure.

ERROR CODES

Malfunction	Code	Malfunction	Code
R_1	1	y^x, LAST x, 1/x	30
R_2	2	$\sqrt{x}$, x^2	31
R_3	3	LN, e^x	32
R_4	4	LOG, 10^x	33
R_5	5	→H.MS, H.MS→, RND	34
R_6	6	→P, →R	35
R_7	7	TAN, TAN^{-1}	36
R_8	8	COS, COS^{-1}	37
R_9	9	DEG, SIN, SIN^{-1}	38
R_{S0}	10	FLAG 2, test cleared	39
R_{S1}	11	FLAG 1, set; LBL9	40
R_{S2}	12	FLAG 2, set; LBL8	41
R_{S3}	13	FLAG 0, clear	42
R_{S4}	14	FLAG 3, test cleared	43
R_{S5}	15	FLAG 0, set by card; LBL7	44
R_{S6}	16	FLAG 3, set by card; LBL6	45
R_{S7}	17	FLAG 1, cleared by card	46
R_{S8}	18	FLAG 2, cleared by card	47
R_{S9}	19	$x>0$, true; LBL4	48
R_A	20	$x<0$, false	49
R_B	21	$x=0$, false	50
R_C	22	$x\neq0$, true; LBL3	51
R_D	23	I-REGISTER	52
R_E	24	$x\leq y$, true; LBL1	53
EEX, %	25	$x=y$, false	54
D→R, R→D	26	$x>y$, false	55
FRC, INT	27	ENTER↑, R↓, R↑, x⇌y, STACK (X, Y, Z, T)	56
×, ÷	28	Subroutine execution and return, CLREG,	see text
+, −	29	P⇌S; LBL0	

Function or Operation or Register Indicated	Code
Flag 3, off	48
Flag 0, on	49
Flag 1, on	50
Flag 2, on	51
Flag 3, on	52

Remarks:

If this program runs correctly, it strongly suggests that the calculator is operating correctly. However, the diagnostic is by no means complete or exhaustive.

All data storage registers are used.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Start diagnostic		A	-7.777777770-77
3	See documentation for description of outputs.			

PROGRAM LISTINGS* AND PROGRAMMING TECHNIQUES

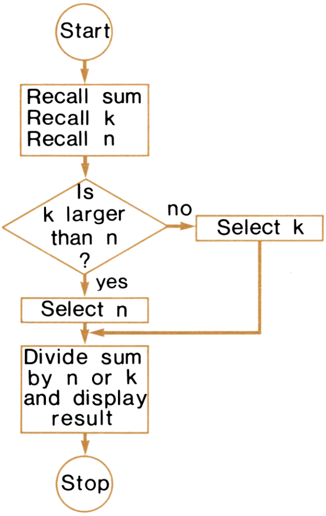
*Keycodes for program steps may be found in Appendix E of your Owner's Handbook.

COMPARISON

Subroutine D of *Moving Average* computes the moving average when the D key is pressed from the keyboard.

```
LBL D
RCL 0
RCL E
RCL D
x≤y?
x⇄y
R↓
÷
RTN
```

Generally, the average is calculated based on the summation of input values, Σ (stored in R_0) and the requested number of units, n (stored in R_D) in the moving average. However, if less than n values have been input, the average must be calculated based on the current number of inputs (k). The value of k is stored in R_E. The flowchart for this calculation might look like this:



Subroutine D begins by recalling the sum from R_0, k from R_E and n from R_D. After these recalls the operational stack is as follows:

Unknown value	T
Sum	Z
k	Y
n	X

The comparison step $x \leq y$ (if x is less than or equal to y) causes program execution to *skip* the next step when the conditions of the comparison are *not met*. If the conditions of the comparison are met, the*following step is executed*. This is the "*DO* if *TRUE*" rule. For instance, if $k = y = 15$ and $n = x = 6$ the comparison would be true or satisified (since x is less than y) and the next step, x≷y (x exchange y), would be executed. If k were less than 6, say 4, the x≷y command would be skipped. The stack contents for both cases are shown below:

BEFORE COMPARISON

Unknown value	T	Unknown value	T
Sum	Z	Sum	Z
15	Y	4	Y
6	X	6	X

AFTER COMPARISON AND NEXT STEP

Unknown value		T	Unknown value		T
Sum		Z	Sum		Z
6	switched	Y	4	not switched	Y
15		X	6		X

The next step rolls the stack down removing the unwanted value from the X-register.

15 (Unwanted value)	T	6 (Unwanted value)	T
Unknown value	Z	Unknown value	Z
Sum	Y	Sum	Y
6	X	4	X

The last step divides the sum by the value in the X-register to complete the calculation.

Moving Average

```
001  *LBLa
002   CLRG       Clear registers.
003   P⇄S
004   CLRG       ------------------------
005      1       If 1 ≤ n ≤ 22 continue,
006   X>Y?       otherwise go to label 1.
007   GTO1
008   CLX
009    - 2
010      2
011   X⇄Y
012   X>Y?
013   GTO1       ------------------------
014   STOD
015      1       Store n in R_D and
016      %       (n + n/100) in R_I.
017      +
018   STOI
019   INT
020   RTN
021  *LBL1       ------------------------
022   R↓         Flash input error.
023  *LBL4
024   PSE
025   GTO4       ------------------------
026  *LBLA       Increment k by one. Print
027   F0?        space, k, and input if flag 0
028   SPC        is set.
029   RCLE
030      1
031      +
032   F0?
033   PRTX
034   X⇄Y
035   F0?
036   PRTX       ------------------------
037   RCLi       Remove oldest value from
038   ST-0       sum and add input.
039   X⇄Y
040   STOi
041   ST+0       ------------------------
042   R↓         Store k.
043   X⇄Y
044   STOE       ------------------------
045   RCLD       If n ≤ k,GTO 0 and
046   X≤Y?       calculate average.
047   GSB0       ------------------------
048   DSZI       If I is not zero, GTO 5 for
049   GTO5       display
050   RCLI       ------------------------
051      1
052      0       Reset index for another
053      1       loop.
054      ×
055   STOI       ------------------------
056  *LBL5       Display average or n.
```

```
057   R↓
058   RTN
059  *LBL6       If print mode is off pause
060   X⇄Y        for display of n.
061   F0?
062   GTO0
063   PSE
064  *LBL0       ------------------------
065   RCL0       Compute average.
066   RCLD
067      ÷       ------------------------
068   ENT↑       Output and set for display.
069   F0?
070   PRTX       ------------------------
071   RTN        Write data.
072  *LBLE
073   WDTA
074   RTN        ------------------------
075  *LBLb
076   F0?        Print/pause mode toggle.
077   GTO6
078      1
079   SF0
080   RTN
081  *LBL6
082      0
083   CF0
084   RTN        ------------------------
085  *LBLC
086   SPC        Output values in newest
087      0       to oldest order.
088  *LBL3
089   RCLD
090   X=Y?
091   RTN
092      1
093      %
094      +
095   RCLI
096   X=Y?
097   FRC
098   STOI
099   ISZI
100   RCLi
101   PRTX
102   R↑
103      1
104      +
105   GTO3       ------------------------
106  *LBLD
107   RCL0       Compute average at any
108   RCLE       time.
109   RCLD
110   X≤Y?
111   X⇄Y
112   R↓
```

REGISTERS

0 Σ	1 used	2 used	3 used	4 used	5 used	6 used	7 used	8 used	9 used
S0 used	S1 used	S2 used	S3 used	S4 used	S5 used	S6 used	S7 used	S8 used	S9 used

A used	B used	C used	D n	E k	I control

```
113      ÷         -24
114      RTN        24
115      R/S        51
```

LABELS					FLAGS	SET STATUS		
A x→"k," Avg	B W DATA	C →VAL	D →AVG	E	0 print	FLAGS	TRIG	DISP
a n	b P?	c	d	e	1	ON OFF 0 □ ☒ 1 □ ☒ 2 □ ☒ 3 □ ☒	DEG ☒ GRAD □ RAD □	FIX ☒ SCI □ ENG □ n 2
0 used	1 error	2	3 print	4 error	2			
5 display	6	7	8	9	3			

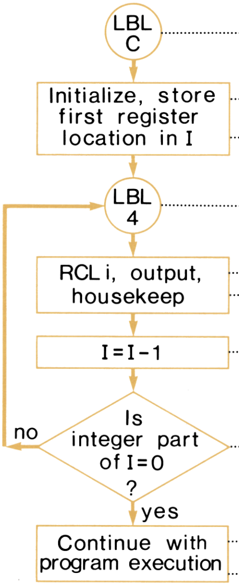
L02-01

DECREMENT AND SKIP ON ZERO (DSZI) LOOP IN COMBINATION WITH INDIRECT RECALL (RCLi)

One of the most powerful features of your calculator is its ability to do indirect recalls. That is, recall a register which is specified by a value stored in the I register. For instance, if the contents of I were 3.0 and an indirect recall (RCLi) command were encountered, the contents of R_3 would be recalled. When the content of I is changed, the action of the RCLi is also changed. Because of this relationship, it is possible to access all 26 data storage registers with only one RCLi command.

DSZI (Decrement and Skip on Zero) was designed to help take full advantage of RCLi and other indirect capabilities. A DSZI command causes 1.00 to be subtracted from the contents of I. After the subtraction, the content of I is automatically compared to zero. If the integer part of the value is zero, the calculator skips the step following the DSZI command. If the integer part is non-zero, the following step is executed. This automatic test capability makes DSZI a valuable looping tool.

Steps 102–130 of *Tabulator* illustrate a typical use of DSZI and RCLi. The task is to recall the values of the row totals, in order, and output them. Below are the flowchart and the commented code which performs the task.


LBL C
Initialize, store first register location in I
LBL 4
RCL i, output, housekeep
I=I-1
Is integer part of I=0 ?
no
yes
Continue with program execution

```
LBL C
CF 1
LBL 6
SPACE     }
RCL I     }
FRAC      }
EEX       }  Store position
4         }  of first register
%         }  location in I
X⇄I       }
DSP 2
LBL 4
RCL i        Indirect recall
F 1?      }  Compute % of grand
GSB E     }  total if flag is set
PRINT X      Output
R↓           Eliminate value from stack
DSZ I        Subtract 1.0 and test
GTO 4        Loop again if I ≠ 0
SPACE     }
RCL 0     }
F 1?      }
GSBE      }  Complete output.
PRINT X   }
R↓        }
STO I     }
R↑
CF 1
RTN
```

NOTES

Tabulator

001	*LBLa		057	*LBL1	Clear stack except for last input.
002	CF2	Clear flag 2 and registers.	058	0	
003	CLRG		059	ENT↑	
004	P⇄S		060	ENT↑	
005	CLRG		061	R↑	
006	INT		062	RTN	
007	1	If the value input for number of rows is not in the range of 1 to 24, reject the value.	063	*LBLB	If column just changed GTO 1.
008	X>Y?		064	F2?	
009	GTO2		065	GTO1	
010	CLX		066	ISZI	Restore counter. Subtract display from totals.
011	2		067	-	
012	4		068	LSTX	
013	X⇄Y		069	ST-0	
014	X≤Y?		070	ST-i	
015	GTO0		071	F0?	Print space to indicate deletion.
016	GTO7		072	SPC	
017	*LBL0		073	RTN	
018	1	Store # registers + # registers/100 in I.	074	*LBL1	Reset index to previous column, last value.
019	%		075	R↑	
020	+		076	RCLI	
021	STOI		077	FRC	
022	0		078	1	
023	ENT↑	Clear stack.	079	+	
024	ENT↑		080	STOI	
025	ENT↑		081	R↓	Subtract display from totals.
026	RTN		082	-	
027	*LBLA	If flag 2 is set clear stack.	083	LSTX	
028	F2?		084	ST-0	
029	GSB1		085	ST-i	
030	ST+i	Add input to row.	086	F0?	Print space to indicate deletion.
031	ST+0	Add input to GT.	087	SPC	
032	X⇄Y		088	RTN	
033	R↓	Add input to column total.	089	*LBLb	
034	+		090	F0?	Toggle print/pause flag.
035	LSTX		091	GTO0	
036	F0?	Print input?	092	SF0	
037	PRTX		093	CLX	
038	DSZI	Stop if I is not 0.	094	SPC	
039	RTN		095	1	
040	F0?		096	RTN	
041	SPC	Set flag 2 for new stack total.	097	*LBL0	
042	SF2		098	CF0	
043	RCLI	Reset index for next loop.	099	CLX	
044	EEX		100	0	
045	4		101	RTN	
046	%		102	*LBLC	
047	+		103	CF1	Clear % flag.
048	STOI		104	*LBL6	
049	CLX	Print or display column total and stop.	105	SPC	Set index to begin at first row total.
050	ENT↑		106	RCLI	
051	R↑		107	FRC	
052	F0?		108	EEX	
053	PRTX		109	4	
054	F0?		110	%	
055	SPC		111	X⇄I	
056	RTN		112	DSP2	

REGISTERS

0 GT	1 used	2 used	3 used	4 used	5 used	6 used	7 used	8 used	9 used
S0 used	S1 used	S2 used	S3 used	S4 used	S5 used	S6 used	S7 used	S8 used	S9 used

A used	B used	C used	D used	E used	I index

113	*LBL4	
114	RCLi	Recall and output values. If flag 1 is set, convert values to % before output.
115	F1?	
116	GSBE	
117	PRTX	
118	R↓	
119	DSZI	If I ≠ 0 loop again.
120	GTO4	
121	SPC	Output grand total or % of grand total if flag 1 is set.
122	RCL0	
123	F1?	
124	GSBE	
125	PRTX	
126	R↓	Return original index to I.
127	STOI	
128	R↑	
129	CF1	Clear flag 1 and stop.
130	RTN	
131	*LBLD	
132	SF1	Output % of total values using LBL C.
133	GTO6	
134	*LBLE	
135	RCL0	
136	÷	Compute % of total for any input value.
137	EEX	
138	2	
139	×	
140	RTN	
141	*LBL2	
142	R↓	Error flash loop.
143	*LBL7	
144	PSE	
145	GTO7	
146	R/S	

LABELS					FLAGS
A Val	B Del	C →Tot	D → % Tot	E Val→ % Tot	0 print
a #rows	b P?	c	d	e	1 %
0 used	1 Col Chg	2 error	3	4 Tot	2 Col Chg
5	6 % Tot	7 error	8	9	3

SET STATUS				
FLAGS			TRIG	DISP
	ON	OFF		
0	□	☒	DEG ☒	FIX ☒
1	□	☒	GRAD □	SCI □
2	□	☒	RAD □	ENG □
3	□	☒		n 2

PRIMARY EXCHANGE SECONDARY REGISTERS

The data storage of your calculator is comprised of 26 registers. Sixteen of these registers are directly accessible at all times through store and recall commands. The remaining 10 secondary registers R_{S0}–R_{S9} are not directly addressable but may be exchanged with primary registers R_0–R_9 at any time. The P⇄S command can be used to do this. Figure 1 represents the action of P⇄S. After execution of the command, the value originally stored in R_{S0} is found in R_0, and the value originally in R_0 is in R_{S0}. A similar exchange would occur between R_1–R_9 and R_{S1}–R_{S9}, respectively.

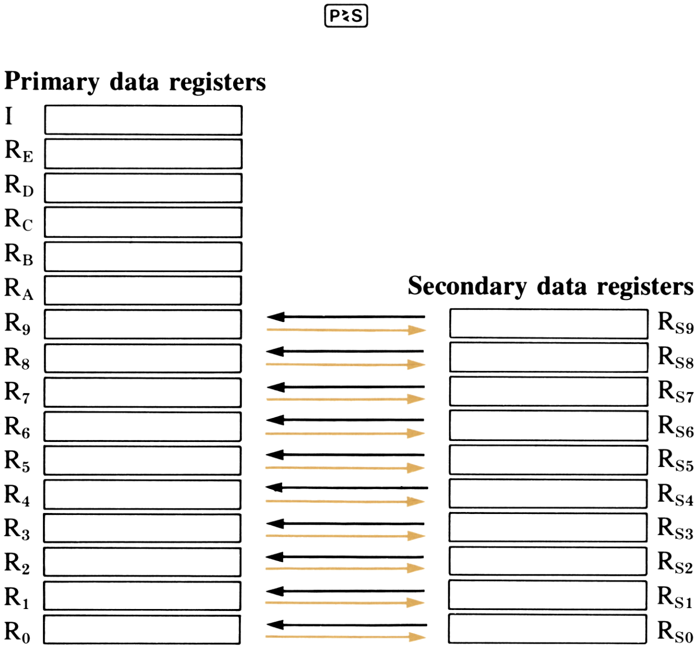


Figure 1.

In *Curve Fitting*, the Σ+ command is used to automatically accumulate the necessary sums in the registers indicated below:

$$\Sigma x \longrightarrow R_{S4}$$
$$\Sigma x^2 \longrightarrow R_{S5}$$
$$\Sigma y \longrightarrow R_{S6}$$
$$\Sigma y^2 \longrightarrow R_{S7}$$
$$\Sigma xy \longrightarrow R_{S8}$$
$$\Sigma n \longrightarrow R_{S9}$$

Before starting to accumulate the sums, registers R_{S4}–R_{S9} must be cleared. Since the clear registers command only operates on the primary registers, a P⇄S command is necessary. The code from *Curve Fitting* which prepares the secondary registers for summation is shown below:

P⇄S	Exchange primary and secondary registers.
CL REG	Clear primary registers.
P⇄S	Return cleared registers to secondary status, ready to accumulate sums.

Note that this sequence has no effect on the original, primary registers R_0–R_9. They still contain exactly what they contained before the sequence. This allows R_0–R_9 to be used for user storage during execution of *Curve Fitting*.

After the sums are accumulated, they must be accessed to calculate the regression coefficients a, b and r^2. However, since the sums are in the secondary registers, they are not directly accessible by the store and recall commands. This necessitates use of P⇄S again. Label C (steps 68–113) of *Curve Fitting* performs the calculation. P⇄S is found at the beginning and the end of the Label C routine. The first P⇄S allows the values to be accessed directly. The second P⇄S returns the registers to their original configuration.

LBL C	
P⇄S	Exchanges primary and secondary registers for access by STO and RCL.
⋮	
P⇄S	Exchanges primary and secondary registers returning
RTN	calculator to original status.

L03-03

Curve Fitting

001	*LBLa		057	X⇄Y	
002	0	Toggle print/pause mode flag.	058	PRTX	
003	F2?		059	X⇄Y	
004	RTN		060	PRTX	
005	1		061	SF2	
006	SF2		062	RTN	
007	RTN		063	*LBLE	
008	*LBLb	Clear flags and registers for linear regression.	064	SF3	Set Σ− flag.
009	CF0		065	F2?	Print delete indicator if flag is set.
010	CF1		066	GSB3	
011	P⇄S		067	GTO8	Delete inputs.
012	CLRG		068	*LBLC	Switch to secondary registers.
013	P⇄S		069	P⇄S	
014	1		070	SPC	Compute b.
015	RTN		071	RCL8	
016	*LBLc	Call LBL b, then set exponential flag.	072	RCL4	
017	GSBb		073	RCL6	
018	SF1		074	×	
019	RTN		075	RCL9	
020	*LBLd	Call LBL b, then set logarithmic flag.	076	÷	
021	GSBb		077	−	
022	SF0		078	ENT↑	
023	RTN		079	ENT↑	
024	*LBLe	Call LBL d, then set flag for power curve fit.	080	RCL4	
025	GSBd		081	X^2	
026	SF1		082	RCL9	
027	RTN		083	÷	
028	*LBLA	Clear Σ− flag.	084	RCL5	
029	CF3		085	X⇄Y	
030	*LBL8		086	−	
031	F2?	Print if flag 2 is set.	087	÷	
032	GSB9		088	STOB	
033	STOD		089	×	Compute r^2.
034	F1?	ln y if flag 1 set.	090	RCL6	
035	LN		091	X^2	
036	X⇄Y	ln x if flag 0 is set.	092	RCL9	
037	STOC		093	÷	
038	F0?		094	CHS	
039	LN		095	RCL7	
040	F3?	If flag 3, then Σ−.	096	+	
041	GTO0		097	÷	
042	Σ+	Compute sums.	098	PRTX	
043	*LBL7	Calculate i + 1.	099	RCL6	Compute a.
044	ENT↑		100	RCL4	
045	1		101	RCLB	
046	+		102	×	
047	RCLC	Set inputs in stack positioned for possible deletion.	103	−	
048	X⇄Y		104	RCL9	
049	RCLD		105	÷	
050	X⇄Y		106	F1?	
051	RTN		107	e^x	
052	*LBL0	Subtract from sums.	108	STOA	
053	Σ−		109	PRTX	Output a and b.
054	GTO7		110	RCLB	
055	*LBL9	Print inputs and reset print flag.	111	PRTX	
056	SPC		112	P⇄S	Switch registers.

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0 0	S1 0	S2 0	S3 0	S4 Σx	S5 Σx^2	S6 Σy	S7 Σy^2	S8 Σxy	S9 n
A a	B b	C x_i	D y_i	E x,y	I 0				

L03-04

```
113    RTN
114  *LBLE     Position coefficients in stack
115   STOE     for use by projection
116   RCLA     routines.
117   RCLB
118   RCLE
119    F1?     If flag 1 is set, power or
120   GTO1     exp projection.
121    F0?
122     LN     Logarithmic?
123      ×
124      +     Linear or logarithmic
125    F2?     projection.
126   GTO9     Print?
127    RTN
128  *LBL1     Stop
129    F0?     If flag 0 is set, do power fit.
130   GTO2
131      ×     Do exponential projection.
132     eˣ
133      ×
134    F2?     Print?
135   GTO9
136    RTN     Stop
137  *LBL2
138    X⇄Y     Do power projection.
139     Yˣ
140      ×
141    F2?
142   GTO9     Print?
143    RTN     Stop.
144  *LBL3     Print −1 indicator.
145    SPC
146      1
147    CHS
148   PRTX
149    SF2
150     R↓
151    RTN
152  *LBLD     Position coefficients in stack
153   STOE     for use by projection
154   RCLB     routine.
155    1/X
156   RCLA
157   RCLE
158    X⇄Y
159    F1?     Power or exp?
160   GTO1
161      -     Linear and log projection.
162      ×
163    F0?     Logarithmic.
164     eˣ
165    F2?     Print?
166   GTO9
167    RTN     Stop.
168  *LBL1
```

```
169      ÷     Power exp calc.
170    F0?     For power GTO 1
171   GTO1
172     LN     Exponential projection.
173      ×
174    F2?
175   GTO9     Print?
176    RTN     Stop
177  *LBL1
178    X⇄Y     Power projection.
179     Yˣ
180    F2?     Print?
181   GTO9     Stop.
182    RTN
183    R/S
```

LABELS					FLAGS
A $x_i \uparrow y_i$ (+)	B $x_i \uparrow y_i$ (−)	C →r², a, b	D $y \rightarrow \hat{x}$	E $x \rightarrow \hat{y}$	0 Log
a P?	b LIN?	c EXP?	d LOG?	e PWR?	1 Exp
0 Σ−	1 used	2 power	3 print	4	2 print
5	6	7 display	8 Σ−	9 print	3 Σ−

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	□	☒	DEG	☒	FIX	☒
1	□	☒	GRAD	□	SCI	□
2	□	☒	RAD	□	ENG	□
3	□	☒			n	2

L04-01

MULTIPLE STORAGE IN REGISTERS

In *Calendar Functions* the date is input in mm.ddyyyy format. This allows three pieces of information (the day, the month, and the year) to be carried in one register. In *Calendar Functions* this provides a convenient means of displaying the date. In other programs a similar technique could be used to store more than 26 values in the 26 addressable registers.

When multiple storage techniques are used, two types of code are usually required. The first type breaks a combined number into its individual components. The second type assembles the individual components into a single number.

Steps 83 through 97 of *Calendar Functions* break the date into its individual components.

PROGRAM STEPS	X REGISTER CONTENT	
ENT↑	mm.ddyyyy	(combined form)
INT	mm.000000	
STO7	mm.000000	(months)
—	.ddyyyy	
EEX		
2	100.000000	
X	dd.yyyy00	
ENT↑	dd.yyyy00	
INT	dd.000000	
STO8	dd.000000	(days)
—	.yyyy00	
EEX		
4	10000.000000	
X	yyyy.000000	
STO9	yyyy.000000	(years)

Steps 54 through 78 of *Calendar Functions* assemble the three values into one number for display. However, other operations are being performed which obscure the technique being used. Below is a sample program which could be used to build a date in mm.ddyyyy format if m were stored in R_7, d in R_8, and y in R_9.

L04-02

PROGRAM STEPS	X REGISTER CONTENTS
RCL7	mm.000000
RCL8	dd.000000
EEX	
2	100.000000
÷	0.dd0000
+	mm.dd0000
RCL9	yyyy.000000
EEX	
6	1000000.000000
÷	0.00yyyy
+	mm.ddyyyy

Calendar Functions

001	*LBLA	Calculate Δ days and put control 3 in display.
002	RCL4	
003	RCLC	
004	-	
005	3	
006	GTO0	
007	*LBLB	Calculate Δ days and put control 4 in display.
008	RCL3	
009	RCLC	
010	+	
011	4	
012	*LBL0	Store control code.
013	STOI	
014	R↓	Store constants.
015	3	
016	6	
017	5	
018	.	
019	2	
020	5	
021	STO5	
022	3	
023	0	
024	.	
025	6	
026	0	
027	0	
028	1	
029	STO6	
030	R↓	Return Δ days to display.
031	R↓	
032	F3?	If data input, GTO 1.
033	GTO1	
034	STOi	Store Δ days according to control code.
035	1	
036	2	
037	2	Calculate y′.
038	.	
039	1	
040	-	
041	RCL5	
042	÷	
043	INT	
044	STO9	Calculate m′.
045	RCL5	
046	×	
047	INT	
048	RCLi	
049	-	
050	CHS	
051	STOA	
052	RCL6	
053	÷	
054	INT	
055	STO7	Calculate day of month.
056	RCLA	
057	X⇄Y	
058	RCL6	
059	×	
060	INT	
061	-	
062	STO8	
063	RCL7	Build (m′ − 1). dd part of display.
064	1	
065	RCL8	
066	÷	
067	-	
068	-	
069	RCL7	Correct m′ − 1 and y′ to m and y.
070	1	
071	4	
072	÷	
073	GSB2	
074	RCL9	Finish building mm.ddyyyy result and display final answer.
075	EEX	
076	6	
077	÷	
078	+	
079	DSP6	
080	RTN	
081	*LBL1	Break date input into the individual components of mm, dd, yyyy.
082	R↓	
083	ENT↑	
084	INT	
085	STO7	
086	-	
087	EEX	
088	2	
089	×	
090	ENT↑	
091	INT	
092	STO8	
093	-	
094	EEX	
095	4	
096	×	
097	STO9	
098	RCL7	m + 1
099	1	
100	+	
101	ENT↑	m + 1 → m′
102	1/X	
103	.	
104	7	y → y′
105	+	
106	CHS	
107	GSB2	
108	RCL6	Compute day number.
109	×	
110	INT	
111	RCL9	
112	RCL5	

REGISTERS

0	1	2	3 Day #1	4 Day #2	5 365.25	6 30.6001	7 m	8 d	9 y
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A used	B	C Δ days	D	E	I control

113	×		169	X⇄Y	
114	INT		170	FRC	
115	+		171	1	
116	RCL8		172	0	
117	+		173	×	
118	STOi		174	+	
119	1	Compute Julian day number for output.	175	STOC	
120	7		176	RTN	
131	2		177	*LBLE	Calculate day number.
122	0		178	SF3	
123	9		179	RCL5	
124	6		160	5	
125	2		191	GSB0	
126	+		182	RCLi	Change day number to modulo 7 number.
127	DSP0		183	5	
128	RTN		184	+	
129	*LBL2	If input to this routine has absolute value 1 or greater: y = y ± 1 m = m ± 12	185	GSB3	
130	INT		186	LSTX	
131	ST+9		197	1	
132	1		188	0	
133	2		189	×	
134	×		190	RTN	
135	−	(+ for plus input)	191	R/S	
136	RTN				
137	*LBLC	Store input.			
138	DSP0				
139	STOC				
140	F3?	If input flag, stop.			
141	RTN				
142	RCL4	Calculate Δdays and stop.			
143	RCL3				
144	−				
145	STOC				
146	RTN				
147	*LBLD	If input GTO 4.			
148	F3?				
149	GTO4				
150	GSBC	Compute Δdays.			
151	DSP1				
152	*LBL3	Convert to Δ weeks.days format.			
153	7				
154	÷				
155	INT				
156	LSTX				
157	FRC				
158	.				
159	7				
160	×				
161	+				
162	RTN				
163	*LBL4	Convert Δ weeks.days to days and store.			
164	DSP0				
165	ENT↑				
166	INT				
167	7				
168	×				

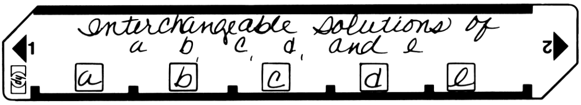
LABELS					FLAGS	SET STATUS		
A ↔DT_1	B ↔DT_2	C ↔ΔDays	D ↔ΔWks. Days	E DT → DOW	0	FLAGS	TRIG	DISP
a	b	c	d	e	1	ON OFF 0 □ ☒ 1 □ ☒ 2 □ ☒ 3 □ ☒	DEG ☒ GRAD □ RAD □	FIX ☒ SCI □ ENG □ n 2
0 calc	1 DT → days	2 m − 12	3 mod 7	4 Δwk → Δday	2			
5	6	7	8	9	3 input			

L05-01

INTERCHANGEABLE SOLUTIONS

In programs like *Annuities and Compound Amounts,* it is necessary to be able to calculate any value given the other values. While there are many ways to do these interchangeable solutions, two methods are designed into your calculator. The method used in *Annuities and Compound Amounts* takes advantage of the STO A through STO E commands. The other method, used in *Calendar Functions,* takes advantage of the keyboard sensing flag (flag 3).

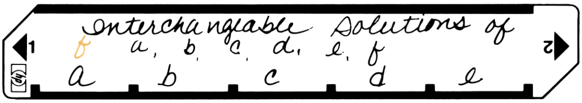
An interchangeable solution requires a method for storage and calculation. It is also desirable to associate inputs and outputs with the mnemonics on the magnetic cards. The STO A through STO E commands accommodate the storage of up to five values in the A through E registers and associate these values with the user definable keys which can be used to initiate calculation. Below is a diagram representing these relationships.



A	B	C	D	E
LBL A	LBL B	LBL C	LBL D	LBL E
C	C	C	C	C
A	A	A	A	A
L	L	L	L	L
C	C	C	C	C
U	U	U	U	U
L	L	L	L	L
A	A	A	A	A
T	T	T	T	T
E	E	E	E	E
a	b	c	d	e
STO A	STO B	STO C	STO D	STO E
RTN	RTN	RTN	RTN	RTN

To store a, press STO A; to calculate a, press A. Note that after any value is calculated, it is automatically stored just before the RTN command stops execution. This eliminates the need to reinput calculated values in subsequent calculations.

The keyboard sensing flag allows up to ten variables to be interchangeably input. It also allows more versatility in storage register selection and allows input processing of data. However, it is slightly more complicated, requires extra steps and may seem mysterious to the uninitiated program user. The diagram below shows the relationships between the magnetic card and the keyboard sensing code.



	A	B	C	D	E
LBL f A	LBL A	LBL B	LBL C	LBL D	LBL E
STO 0	STO 1	STO 2	STO3	STO 4	STO 5
F3?	F3?	F3?	F3?	F3?	F3?
RTN	RTN	RTN	RTN	RTN	RTN
C	C	C	C	C	C
A	A	A	A	A	A
L	L	L	L	L	L
C	C	C	C	C	C
U	U	U	U	U	U
L	L	L	L	L	L
A	A	A	A	A	A
T	T	T	T	T	T
E	E	E	E	E	E
f	a	b	c	d	e
STO 0	STO 1	STO 2	STO 3	STO 4	STO 5
RTN	RTN	RTN	RTN	RTN	RTN

To input the value a, key it in and press A. To calculate a, press A. Pressing A for both input and output works because Flag 3 is set when the digit entry keys are pressed. When Flag 3 is set, the value is stored and execution stops at the first RTN. If the flag is not set (no digit keys were pressed), the program skips the first return and continues through the calculate portion of the program.

L05-03

Annuities and Compound Amounts

001	*LBLA	Store dummy 0 for n.	057	STO5	(1 + i) in R_5.
002	0		058	STO7	Store (1 + i) in R_7.
003	STOA		059	RCLA	
004	GSB0	Calculate subroutine.	060	CHS	Calculate $(1 + i)^{-n}$ and store in R_8.
005	RCLE		061	Y^x	
006	LSTX	Solve for n and store it in R_A.	062	STO8	
007	-		063	RCLE	FV $(1 + i)^{-n}$
008	RCLD		064	×	
009	LSTX		065	1	Calculate $[1 - (1 + i)^{-n}]$ and store in R_4.
010	-		066	RCL8	
011	÷		067	-	
012	LN		068	STO4	Calculate ± (PMT/i). Use – if FV flag is set. Store in R_3.
013	RCL7		069	RCLC	
014	LN		070	RCL9	
015	÷		071	÷	
016	STOA		072	F1?	
017	RTN		073	CHS	
018	*LBLC	Store dummy 1 for PMT.	074	STO3	
019	1		075	RCL5	Calculate $\frac{+PMT}{i}[1 - (1 + i)^{-n}]\ R_5$.
020	STOC		076	×	
021	GSB0	Calculate subroutine.	077	×	
022	1/X		078	RTN	
023	RCLD	Solve for PMT and store it in R_C.	079	*LBLa	Start by clearing PMT, PV, FV (BAL) registers and annuity due flag.
024	R↑		080	CLX	
025	-		081	STOC	
026	×		082	STOD	
027	STOC		083	STOE	
028	RTN		084	CF0	
029	*LBLD	Store dummy 1 for PV.	085	RTN	
030	1		086	*LBLb	Annuity due flag toggle.
031	STOD		087	F0?	
032	GSB0	Calculate subroutine.	088	GTO1	
033	+	Solve for PV and store in R_D.	089	1	
034	STOD		090	SF0	
035	RTN		091	RTN	
036	*LBLE	Calculate subroutine.	092	*LBL1	
037	GSB0		093	0	
038	RCLD	Solve for FV (or BAL) and store in R_E.	094	CF0	
039	X⇄Y		095	RTN	
040	-		096	*LBLB	Clear R_B for sum of i terms.
041	RCL8		097	0	
042	÷		098	STOB	Store address of R_B in R_I for indirect access.
043	STOE		099	2	
044	RTN		100	1	
045	*LBL0	Clear FV flag.	101	STOI	
046	CF1		102	RCLE	Recall FV, n, and PMT.
047	RCLD		103	RCLA	
048	X=0?	If PV = 0 set FV flag.	104	RCLC	If PMT = 0, GTO n, i, PV, FV solution.
049	SF1		105	X=0?	
050	1	Set annuity due mode off (R_5 = 1).	106	GTO8	Start guess of i. n PMT + BAL.
051	STO5		107	×	
052	RCLB		108	+	
053	%	Convert i to decimal and store in R_9.	109	RCLD	If PV = 0, GTO FV guess.
054	STO9		110	X=0?	
055	+	Calculate (i + 1).	111	GTO3	
056	F0?	If AD flag is set store	112	-	PV guess for i.

REGISTERS

0	1	2	3 ±PMT/i	4 $[1-(1+i)^{-n}]$	5 1 or 1 + i	6 $n(1+i)^{-n-1}$	7 (1 + i)	8 $(1 + i)^{-n}$	9 i/100
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A n	B i	C PMT	D PV	E FV (BAL)	I 21

113	RCLA	$\frac{nPMT + BAL - PV}{n}$ and recall PV.
114	÷	
115	RCLD	
116	GTO4	
117	*LBL3	FV guess for i numerator: 2(FV − nPMT)
118	RCLE	
119	LSTX	
120	-	
121	ENT↑	
122	+	and denominator: $(n-1)^2$ PMT + FV
123	RCLA	
124	1	
125	-	
126	X²	
127	RCLC	
128	×	
129	RCLE	
130	+	
131	*LBL4	Guess for i.
132	÷	
133	.	If guess is less than −0.9 use −0.9 for guess.
134	9	
135	CHS	
136	X≤Y?	
137	X⇄Y	
138	GSB5	Store guess as a %.
139	X=0?	If guess = 0 stop.
140	RTN	
141	*LBL6	Calculate f(i).
142	GSB0	
143	+	
144	F1?	
145	CHS	
146	RCLD	
147	-	
148	RCL8	Calculate f′(i).
149	RCLA	
150	RCL7	
151	÷	
152	×	
153	F1?	
154	CLX	
155	STO6	
156	F1?	
157	R↓	
158	F1?	
159	LSTX	
160	RCL4	
161	RCL9	
162	÷	
163	-	
164	RCL5	
165	×	
166	F0?	
167	RCL4	
168	F0?	

169	+	
170	RCLC	
171	×	
172	RCL9	
173	÷	
174	RCL6	
175	RCLE	
176	×	
177	-	
178	÷	f(i)/f′(i)
179	CHS	
180	GSB5	Subtract f(i)/f′(i) from current i value.
181	RCLB	
182	÷	
183	RND	If value is not = to zero, loop again.
184	X≠0?	
185	GTO6	
186	RCLB	Stop and display.
187	RTN	
188	*LBL8	Compute i for n, i, PV, FV problem.
189	RCLE	
190	RCLD	
191	÷	
192	RCLA	
193	1/X	
194	Yˣ	
195	1	
196	-	
197	*LBL5	
198	EEX	Convert i to % and add to content of R_B.
199	2	
200	×	
201	ST+i	
202	RTN	
203	*LBLc	Output n, i, PMT, PV and FV or BAL.
204	SPC	
205	RCLA	
206	PRTX	
207	RCLB	
208	PRTX	
209	RCLC	
210	PRTX	
211	RCLD	
212	PRTX	
213	RCLE	
214	PRTX	
215	RTN	
216	R/S	

LABELS					FLAGS
A n	B i	C PMT	D PV	E FV (BAL)	0 AD
a start	b AD	c print	d	e	1 PV = 0
0 calc	1 AD	2	3 FV guess	4 guess	2
5 i → %	6 loop	7	8 FV,PV-i	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	□	☒	DEG	☒	FIX	☒
1	□	☒	GRAD	□	SCI	□
2	□	☒	RAD	□	ENG	□
3	□	☒			n	2

INDIRECT GTO

The GTO function is used to cause program execution to transfer from the location of the GTO to the label specified. The label may be specified in one of two ways:

1. As a direct branch such as GTO 1, GTO A, GTO f C, etc.
2. As an indirect branch GTOi which causes execution to transfer to the label specified by the content of the I register.

In *Follow Me* the content of the I register is used to specify the operation to be performed. The operation codes are:

CODE	OPERATION
1	+
2	−
3	×
4	÷
5	%
6	I/O HALT
7	Constant

The first time a problem is done using *Follow Me* these codes are stored starting in R_D and ending in R_1. The calculator accesses these codes in subsequent calculations and performs the operations indicated by them.

The GTOi instruction at step 083 actually selects the next operation. The RCLi and X⇆I commands directly above the GTOi place the operation code in the I register. The GTOi command transfers control to one of seven labels corresponding to the operation code stored in the I register. For instance, if 3 is stored in I, the GTOi command will transfer control to LBL3 and the multiply at step 108 will be performed.

NOTES

L06-03

Follow Me

001	*LBLA	Clear registers and set index at 24 to begin sequence.
002	CLRG	
003	P⇄S	
004	CLRG	
005	2	
006	4	
007	STOI	
008	CLX	
009	RTN	
010	*LBLa	Perform addition and put addition code of 1 in display register.
011	+	
012	1	
013	GTO0	
014	*LBLb	Perform subtraction and put 2 in display, then transfer to LBL 0.
015	-	
016	2	
017	GTO0	
018	*LBLc	Perform multiplication and put 3 in display.
019	×	
020	3	
021	GTO0	
022	*LBLd	Perform division and put 4 in the display.
023	÷	
024	4	
025	*LBL0	Decrement step count.
026	DSZI	
027	GTO1	GTO function store.
028	GTO9	GTO error.
029	*LBL1	Store function code and return operation result.
030	STOi	
031	R↓	
032	RTN	
033	*LBLe	Perform %, store display register value, and put 5 code in display.
034	%	
035	STOE	
036	CLX	
037	5	
038	GTO8	
039	*LBLB	I/0 halt code of 6 put in display after storing display register value.
040	STOE	
041	CLX	
042	6	
043	GTO8	
044	*LBLC	Constant code of 7 put in display after display value is stored.
045	STOE	
046	CLX	
047	7	
048	DSZI	If I is non zero after decrement, store code.
049	GTO1	
050	*LBL9	Flash 24 indicating that too many operations have been attempted.
051	CLX	
052	2	
053	4	
054	PSE	
055	GTO9	
056	*LBL1	Store constant code and recall constant value.
057	STOi	
058	CLX	
059	RCLE	
060	*LBL8	If I is non zero after dec store cd.
061	DSZI	
062	GTO1	
063	GTO9	GTO error.
064	*LBL1	Store code and return display to proper status.
065	STOi	
066	CLX	
067	RCLE	
068	RTN	
069	*LBLD	Store 24 in I to reset counter and store zero code in R_0 for auto reset at end of sequence.
070	CLX	
071	2	
072	4	
073	STOI	
074	CLX	
075	STO0	
076	RTN	
077	*LBLE	Store display value, access code after dec, put code in I, transfer to LBL corresponding to code.
078	STOE	
079	R↓	
080	DSZI	
081	RCLi	
082	X⇄I	
083	GTOi	
084	*LBL0	Reset to start new sequence by setting I to 24 and returning output to display.
085	CLX	
086	2	
087	4	
088	STOI	
089	CLX	
090	RCLE	
091	RTN	
092	*LBL1	Perform addition and return to LBL E for next instruction.
093	X⇄I	
094	CLX	
095	RCLE	
096	+	
097	GTOE	
098	*LBL2	Perform subtraction.
099	X⇄I	
100	CLX	
101	RCLE	
102	-	
103	GTOE	
104	*LBL3	Perform multiplication.
105	X⇄I	
106	CLX	
107	RCLE	
108	×	
109	GTOE	
110	*LBL4	Perform division.
111	X⇄I	
112	CLX	

REGISTERS

0	1	2	3	4	5	6	7	8	9
0	used	used	used	used	used	used	used	used	used

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
used	used	used	used	used	used	used	used	used	used

A	B	C	D	E	I
used	used	used	used	temp store	step count

L06-04

```
113  RCLE
114    ÷
115  GTOE     ------------
116  *LBL5    Perform %.
117   X⇄I
118   CLX
119  RCLE
120    %
121  GTOE
122  *LBL6    ------------
123   X⇄I     Halt for I/0.
124   CLX
125  RCLE
126   RTN     ------------
127  *LBL7    Recall constant.
128   X⇄I
129   CLX
130  RCLE
131  DSZI
132  RCLi
133  GTOE
134   R/S
              ------------
```

LABELS					FLAGS	SET STATUS		
A Start	B I/O	C Const	D End	E Follow	0	FLAGS	TRIG	DISP
a +	b –	c x	d ÷	e %	1	ON OFF 0 □ ☒ 1 □ ☒ 2 □ ☒ 3 □ ☒	DEG ☒ GRAD □ RAD □	FIX ☒ SCI □ ENG □ n 2
0 used	1 +	2 –	3 x	4 ÷	2			
5 %	6 I/O	7 const	8	9 error	3			

VARIABLE INPUT

In many instances, it is desirable to input more than one value per user definable key. In *Triangle Solutions,* the lengths of all three sides of a triangle are input with one press of A. Before A is pressed the values of S_1, S_2, and S_3 must be keyed into the operational stack. The sequence to do this is:

S_1 ENTER↑ S_2 ENTER↑ S_3

After this sequence is completed, the operational stack contains the values in the following positions:

T: Unknown value
Z: S_1
Y: S_2
X: S_3

The X, or display register, shows S_3.

To operate successfully, *Triangle Solutions* must store S_1 in R_9, S_2 in R_B and S_3 in R_D. Since S_3 is in the X-register, it can be stored in R_D with a STO D command (step 002). The value of S_2 must now be moved to the X-register so that they can be stored. A R↓ function (step 003) is used for this purpose. It moves the Y value to X, the Z value to Y, the T value to Z and the X value to T. After the R↓, STO B is performed placing S_2 in R_B. The operational stack is left as follows:

T: S_3
Z: Unknown value
Y: S_1
X: S_2

Both S_3 and S_2 are stored in the correct registers. After R↓ and STO 9, S_1 is correctly stored. The final stack contents are as follows:

T: S_2
Z: S_3
Y: Unknown value
X: S_1

The complete input sequence is:

```
LBL A
STO D  (store $S_3$)
R↓
STO B  (store $S_2$)
R↓
STO 9  (store $S_1$)
```

Up to four values may be input per user definable key using this type of technique.

L07-03

Triangle Solutions

001	*LBLA	Store lengths of sides S_3, S_2, S_1.
002	STOD	
003	R↓	
004	STOB	
005	R↓	
006	STO9	
007	R↓	
008	R↓	$P=(S_1+S_2+S_3)/2$
009	+	
010	+	
011	2	
012	÷	
013	STO7	
014	X²	
015	LSTX	
016	RCLB	
017	×	
018	-	$A_3=2\cos^{-1}\sqrt{\frac{P(P-S_2)}{S_1S_3}}$
019	RCL9	
020	RCLD	
021	×	
022	÷	
023	√X	
024	COS⁻¹	
025	2	
026	×	
027	STOE	
028	SIN	
029	RCL9	$h=S_1 \sin A_3$
030	×	
031	STO8	
032	RCL7	
033	X²	
034	LSTX	
035	RCL9	
036	×	
037	-	
038	RCLB	
039	÷	$A_2=2\cos^{-1}\sqrt{\frac{P(P-S_1)}{S_2S_3}}$
040	RCLD	
041	÷	
042	√X	
043	COS⁻¹	
044	2	
045	×	
046	STOC	
047	RCLE	GSB third angle routine.
048	GSB0	
049	STOA	GTO print.
050	GTO1	
051	*LBLB	Store A_1, S_1, and A_3.
052	STOA	
053	R↓	
054	STO9	
055	R↓	
056	STOE	
057	RCLA	GSB third angle
058	GSB0	
059	STOC	$Y = S_1 \sin A_3$.
060	RCLE	
061	RCL9	$X = S_1 \cos A_3$.
062	→R	
063	X⇄Y	
064	STO8	$h = X$.
065	RCLC	$Y = \sin A_2$.
066	1	$X = \cos A_2$.
067	→R	
068	R↓	$S_2=S_1 \sin A_3/\sin A_2$.
069	÷	
070	STOB	
071	R↑	$S_3=S_1 \cos A_3 + S_2 \cos A_2$.
072	×	
073	+	
074	STOD	
075	GTO1	GTO print.
076	*LBLC	Store A_2, A_1, and S_1.
077	STOC	
078	R↓	
079	STOA	
080	R↓	
081	STO9	
082	RCLC	GSB third angle routine.
083	RCLA	
084	GSB0	
085	RCL9	Set stack for A_3, S_1, A_1 solution.
086	RCLA	
087	GTOB	
088	*LBLD	Store S_2, A_1, and S_1.
089	STOB	
090	R↓	
091	STOA	
092	R↓	
093	STO9	
094	RCLA	
095	RCLB	$S_3{}^2 = S_1{}^2 + S_2{}^2 - 2S_1S_2 \cos A_1$.
096	→R	
097	RCL9	
098	-	
099	→P	
100	STOD	
101	RCL9	Recall S_1, S_2, and S_3 and GTO A.
102	RCLB	
103	RCLD	
104	GTOA	
105	*LBLE	Store A_2, S_2, and S_1.
106	STOC	
107	R↓	
108	STOB	
109	R↓	
110	STO9	
111	RCLC	
112	SIN	

REGISTERS

0	1	2	3	4	5	6	7 used	8 h	9 S_1
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A A_1	B S_2	C A_2	D S_3	E A_3	I

```
113   RCLB     A3 = sin-1 (S2/S1 sin A2)
114      x
115   RCL9
116      ÷
117   SIN-1
118   STOE
119   RCLC     GSB third angle.
120   GSB0
121   STOA     Recall A3, S1, and A1 and
122   RCLE     GSB B.
123   RCL9
124   RCLA
125   GSBB
126   RCL9     Stop if this is the only
127   RCLB     solution.
128   X≤Y?
129   GTO9
130   RCLE     Find secondary angle for
131    COS     alternate solution.
132    CHS
133   COS-1
134   STOE
135   RCLC     GSB third angle.
136   GSB0
137   STOA     Recall A3, S1, and A1 and
138   RCLE     GSB B.
139   RCL9
140   RCLA
141   GTOB
142  *LBL0     Third angle =
143      +     cos-1 [-cos (A + B)]
144    COS
145    CHS
146   COS-1
147    RTN
148  *LBL1
149    SPC     Print values starting with S1.
150    SPC
151   RCL9
152   PRTX
153   RCLA
154   PRTX
155    SPC
156   RCLB
157   PRTX
158   RCLC
159   PRTX
160    SPC
161   RCLD
162   PRTX
163   RCLE
164   PRTX
165    SPC
166   RCL8     Calculate and print area =
167   RCLD     (S1 S3 sin A3)/2.
168      x
```

```
169      2
170      ÷
171   PRTX
172    RTN
173  *LBL9     Area.
174     R↓
175     R↓
176    RTN
177    R/S
```

LABELS					FLAGS
A S_1, S_2, S_3	B A_3, S_1, A_1	C S_1, A_1, A_2	D S_1, A_1, S_2	E S_1, S_2, A_2	0
a	b	c	d	e	1
0 3rd angle	1 print	2	3	4	2
5	6	7	8	9 Area	3

SET STATUS

FLAGS			TRIG	DISP
	ON	OFF		
0	□	☒	DEG ☒	FIX ☒
1	□	☒	GRAD □	SCI □
2	□	☒	RAD □	ENG □
3	□	☒		n 2

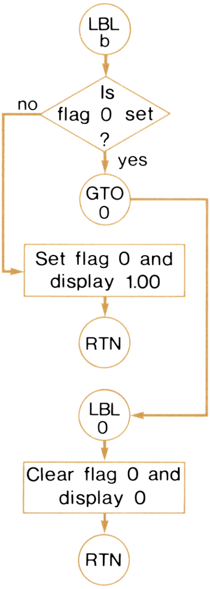
FLAG SET, CLEAR AND TEST—COMMAND CLEARING FLAGS

Review of the input values for *Vector Operations* is an option available to the user. When the program is loaded, the non-review status is automatically set. The user can change this status by pressing f B. Each time the f B keys are pressed, the status is changed and 1.00 or 0.00 is displayed to indicate whether or not the input values will be reviewed. The 1.00 indicates review and the 0.00 indicates no review.

Flag 0 and flag 1 are command clearing flags. That is, once they are set they remain set until a clear flag command is encountered. Testing them has no effect on their on/off status.

Flag 0 is used to control the review of the input values in *Vector Operations*. Lines 064, 090 and 112 contain PRST (print stack).* Preceding each of these statements is F0? (test flag 0). If flag 0 is set the PRST commands will be executed, reviewing the input values. If flag 0 is not on, the PRST commands are skipped. Below is the code used to change the flag status.

If flag 0 is off, this code sets flag 0 on and displays 1.00. If flag 0 is on, this code turns flag 0 off and displays 0.00.



```
LBL  b
F0?
GTO  0
SF0
 1
RTN
LBL  0
CF0
  0
RTN
```

*The HP-67 interprets PRST as pause stack. The values contained in the T, Z, Y, and X registers will be displayed for approximately 3 seconds each. The decimal point will flash, indicating program execution will resume automatically.

NOTES

Vector Operations

```
001  *LBLa
002    F1?     Toggle two and three di-
003   GTO0     mensional modes.
004    SF1
005      3
006    RTN
007  *LBL0
008      2
009    CF1
010    RTN
011  *LBLb     Toggle print/pause mode.
012    F0?
013   GTO0
014    SF0
015      1
016    RTN
017  *LBL0
018    CF0
019      0
020    RTN
021  *LBLD     Store magnitude and input
022   STO7     1 code.
023      1
024   GTO0
025  *LBLE     Store magnitude and input
026   STO8     2 code.
027      2
028  *LBL0
029    SF2     GSB S→C routine.
030   GSB5
031   GTOi     GTO storage routine.
032  *LBL1
033   STO9     Storage for vector 1.
034     R↓
035   STOA
036     R↓
037   STOB
038      1
039    RTN
040  *LBL2     Storage for vector 2.
041   STOC
042     R↓
043   STOD
044     R↓
045   STOE
046      2
047    RTN
048  *LBLd     Keyboard S→C begins.
049      0
050  *LBL5
051   STOI     Store code.
052     R↑
053    F1?
054   GTO0     If 3D mode is set, skip π/2
055    CLX     substitution for Z register
056      1
```

```
057   SIN⁻¹    content.
058  *LBL0
059     R↓     Put vector code in T.
060    CLX
061   RCLI
062     R↓
063    F0?     Print input?
064   PRST
065    X⇄Y     Convert S→C.
066      1
067     →R
068     R↑
069     R↑
070     →R
071    X⇄Y
072     R↑
073    X⇄Y
074      ×
075   LSTX
076     R↑
077      ×
078   GTO2     Begin C→S.
079  *LBLe     If 2D, set content of Z
080     R↓     register to zero.
081     R↓
082    F1?
083   GTO0
084    CLX
085  *LBL0
086     R↓     Set T to zero.
087    CLX
088     R↓
089    F0?     Print input?
090   PRST
091  *LBL6
092     →P     Convert C→S.
093    X⇄Y
094   X<0?
095   GSB3
096     R↓
097    X⇄Y
098    F1?
099   GTO0
100    CLX
101  *LBL0
102     →P
103     R↑
104    X⇄Y
105  *LBL2
106     R↑     Put zero in T register.
107    CLX
108     R↓
109    F2?     Return if GSB.
110    RTN
111    F0?     Print result?
112   PRST
```

REGISTERS

0	1	2	3	4	5	6	7 r_1	8 r_2	9 x_1
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A y_1	B z_1	C x_2	D y_2	E z_2	I code

```
113     RTN
114   *LBL3      Convert negative angles to
115       1      positive angles 0° – 360°.
116     CHS
117    COS⁻¹
118       +
119    LSTX
120       +
121     RTN
122   *LBLA      Add V⃗1 and V⃗2 and con-
123    RCLB      vert back to spherical
124    RCLE      coordinates.
125       +
126    RCLD
127    RCLA
128       +
129    RCLC
130    RCL9
131       +
132     SF2
133    GSB6
134    PRST
135     RTN
136   *LBLB      Take cross product.
137    RCL9
138    RCLD
139       x
140    RCLA
141    RCLC
142       x
143       -
144    RCLB
145    RCLC
146       x
147    RCL9
148    RCLE
149       x
150       -
151    RCLB
152    RCLD
153       x
154    STOI
155     CLX
156    RCLA
157    RCLE
158       x
159    RCLI
160       -
161      →P      Convert back to spherical.
162     X⇄Y
163    X<0?
164    GSB3
165      R↓
166     X⇄Y
167      →P
168      R↑
```

```
169     X⇄Y
170      R↑
171     CLX
172      R↓
173    PRST
174     RTN
175   *LBLC      Take dot product.
176     SPC
177    RCL7
178    RCL8
179       x
180     1/X
181    RCL9
182    RCLC
183       x
184    RCLA
185    RCLD
186       x
187       +
188    RCLB
189    RCLE
190       x
191       +
192    PRTX      Compute angle between
193       x      vectors.
194    LSTX
195     X⇄Y
196    COS⁻¹
197    PRTX
198     RTN
199     R/S
```

LABELS					FLAGS
A $\vec{V}_1 + \vec{V}_2$	B $\vec{V}_1 \times \vec{V}_2$	C $\vec{V}_1 \cdot \vec{V}_2$	D $\phi_1 \uparrow \theta_1 \uparrow r_1$	E $\phi_2 \uparrow \theta_2 \uparrow r_2$	0 PRINT?
a 3D/2D?	b P?	c	d S→C	e C→S	1 3D/2D?
0 used	1 $\vec{V}_1$	2 $\vec{V}_2$, print	3 0° – 360°	4	2 S→C
5 S→C	6 C→S	7	8	9	3

SET STATUS				
FLAGS			TRIG	DISP
	ON	OFF		
0	□	☒	DEG ☒	FIX ☒
1	□	☒	GRAD □	SCI □
2	□	☒	RAD □	ENG □
3	□	☒		n 2

L09-01

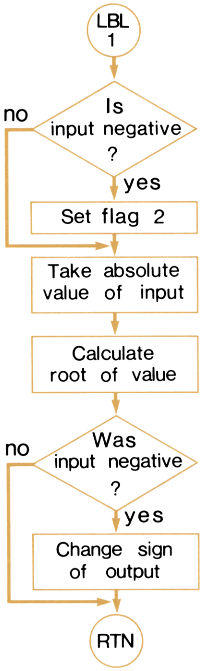
FLAG SET, CLEAR AND TEST-TEST CLEARING FLAG

Flag 2 and flag 3* are test clearing flags. Each time they are tested, they are automatically cleared. This makes them especially useful in many programming situations.

In *Polynomial Evaluation,* flag 2 is used twice. At step 62 it is used to decide whether to add or subtract; and at step 145, it is used to determine whether a result should be positive or negative. The following discussion details the use in the latter case.

Label 1 calculates the cube root of a number. This would be very simple if y^x were defined for the case where y is negative and x is a non-integer. However, if we tried to find the cube root of –8 (which is –2) directly, we would obtain an error message. The following flow chart and code yield the desired result:

Flow chart



Code	X register (Positive 8)	X register (Negative 8)
LBL 1	8	-8
x<0	8	-8
SF2	8	-8
ABS	8	8
3 1/x y^x	3 0.333... 2	3 0.333... 2
F2?	2	2
CHS	2	-2
RTN	2	-2

*When using flag 3, you must be aware that it is set whenever the numeric keys are pressed.

NOTES

Polynomial Evaluation

001	*LBLa	Store zero for degree to initialize.
002	0	
003	STOE	
004	RTN	
005	*LBLB	Store a_0 and set degree indicator (= degree + 1) to 1.
006	STO1	
007	1	
008	RTN	
009	*LBLC	Store a_1 and set indicator to 2.
010	STO2	
011	2	
012	GTO0	
013	*LBLD	Store a_2 and set indicator to 3.
014	STO3	
015	3	
016	GTO0	
017	*LBLE	Store a_3 and set indicator to 4.
018	STO4	
019	4	
020	*LBL0	Sort to find and retain largest indicator.
021	X⇄Y	
022	X=0?	
023	RTN	
024	X⇄Y	
025	RCLE	
026	X⇄Y	
027	X>Y?	
028	STOE	
029	X⇄Y	
030	R↓	
031	RTN	
032	*LBLb	Start polynomial solution.
033	SPC	
034	RCLE	
035	STOI	Put degree code in I for control.
036	÷	
037	RCLi	
038	STOA	Divide all coef. by coef. of highest deg.
039	1/X	
040	GSB5	
041	RCL1	Select proper deg solution.
042	CHS	
043	RCL2	
044	GTOi	
045	*LBL3	Begin quadratic equation.
046	RCL1	
047	*LBL9	Calculate $-\frac{a_1}{2a_2}$
048	STOB	
049	X⇄Y	
050	CHS	
051	2	
052	÷	
053	X<0?	Set flag to det sol order.
054	SF2	
055	ENT↑	$(a_1/2a_2)^2-(a_0/a_2)$
056	X^2	

057	RCLB	
058	-	
059	X<0?	Imaginary roots?
060	GTO0	
061	√X	Compute x_1 (the root of largest absolute value).
062	F2?	
063	CHS	
064	+	Compute x_2.
065	÷	
066	LSTX	
067	GTO6	
068	*LBL0	Compute imaginary part.
069	ABS	
070	√X	
071	1	Output img code.
072	CHS	
073	PRTX	
074	R↓	Img part to X.
075	*LBL6	Output x_2 or img part.
076	PRTX	
077	*LBL2	Output x_1 or real part.
078	X⇄Y	
079	PRTX	
080	RCLA	
081	*LBL5	Return equation to original form.
082	ST×4	
083	ST×3	
084	ST×2	
085	ST×1	
086	R↓	Stop and display.
087	CF2	
088	RTN	
089	*LBL4	Start 3rd degree solution by computing Q.
090	3	
091	÷	
092	RCL3	
093	X^2	
094	9	
095	÷	
096	-	
097	STOD	Compute Q^3.
098	3	
099	Y^X	
100	STOC	Compute R.
101	RCL3	
102	RCL2	
103	×	
104	RCL1	
105	3	
106	×	
107	-	
108	6	
109	÷	
110	RCL3	
111	3	
112	Y^X	

REGISTERS

0	1	2	3	4	5	6	7	8	9
	a_0	a_1	a_2	a_3					
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
a_{high}	R, X, a_0/a_2	Q^3	Q	degree	control

L09-04

Step	Key	Comment
113	2	
114	7	
115	÷	
116	-	
117	STOB	
118	X²	$Q^3 + R^2$ decision.
119	+	
120	X<0?	
121	GTO0	
122	√X	Compute x_3 using $x_3 = S + T - \frac{a_2}{3a_3}$
123	RCLB	
124	X⇄Y	
125	-	
126	LSTX	
127	RCLB	
128	+	
129	GSB1	
130	X⇄Y	
131	GSB1	
132	+	
133	RCL3	
134	3	
135	÷	
136	-	
137	GTO8	
138	*LBL1	Cube root of a number.
139	X<0?	
140	SF2	
141	ABS	
142	3	
143	1/X	
144	Yˣ	
145	F2?	
146	CHS	
147	RTN	
148	*LBL0	Compute x_3 using $x = 2\sqrt{-Q}\ \cos(M) - \frac{a_2}{3a_3}$ Where $M = \frac{1}{3}\cos^{-1}(R/\sqrt{-Q^3})$
149	RCLB	
150	RCLC	
151	CHS	
152	√X	
153	÷	
154	COS⁻¹	
155	3	
156	÷	
157	COS	
158	RCLD	
159	CHS	
160	√X	
161	×	
162	ENT↑	
163	+	
164	RCL3	
165	3	
166	÷	
167	-	
168	*LBL8	
169	PRTX	Output x_3 and begin synthetic division.
170	SPC	
171	STOB	
172	RCL3	
173	+	
174	ENT↑	
175	ENT↑	
176	RCLB	
177	×	
178	RCL2	
179	+	
180	GTO9	
181	*LBLA	
182	ENT↑	Set up for polynomial evaluation.
183	ENT↑	
184	ENT↑	
185	RCLE	
186	STOI	
187	CLX	
188	RCLi	
189	DSZI	
190	GTOd	
191	RTN	Degree one check.
192	*LBLd	
193	×	
194	RCLi	Evaluate f(x).
195	+	
196	DSZI	
197	GTOd	
198	RTN	
199	R/S	Stop and display.

LABELS

A x→f(x)	B a_0	C a_1	D a_2	E a_3
a Start	b →Solve	c	d	e
0 used	1 cube root	2 output x_1	3 deg 2	4 deg 3
5 divide	6 output x_2	7 used	8 syn div	9 deg 2

FLAGS

0	
1	
2	sign
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	□	☒	DEG	☒	FIX	☒
1	□	☒	GRAD	□	SCI	□
2	□	☒	RAD	□	ENG	□
3	□	☒			n	2

SUBROUTINES AND INDIRECT RECALLS

LBL a (lines 22 through 49) of *Matrix Operations* calculates the determinant of the 3 × 3 matrix stored in registers R_1 through R_9.

$$\begin{vmatrix} R_1 & R_2 & R_3 \\ R_4 & R_5 & R_6 \\ R_7 & R_8 & R_9 \end{vmatrix} = (R_5R_9 - R_6R_8)\,R_1 - (R_4R_9 - R_6R_7)\,R_2 + (R_4R_8 - R_5R_7)\,R_3$$

$$= -(R_6R_8R_1 + R_4R_9R_2 + R_5R_7R_3) + R_3R_8R_4 + R_1R_9R_5 + R_2R_7R_6$$

The following keystroke procedure will perform the calculation:

RCL 6 RCL 8 $\underline{\text{RCL 1}}$ × × RCL 4 RCL 9 $\underline{\text{RCL 2}}$ × × + RCL 5

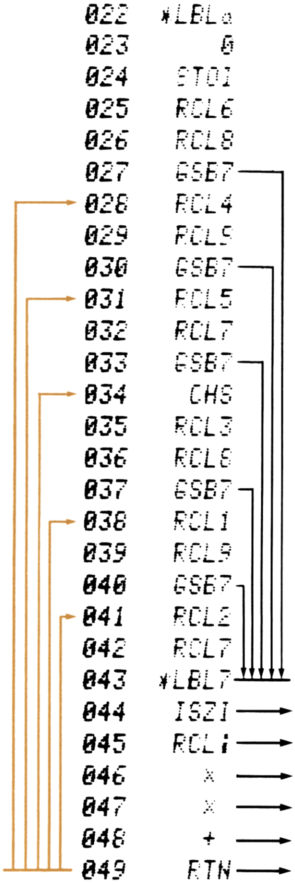
RCL 7 $\underline{\text{RCL 3}}$ × × + CHS RCL 3 RCL 8 $\underline{\text{RCL 4}}$ × × + RCL 1

RCL 9 $\underline{\text{RCL 5}}$ × × + RCL 2 RCL 7 $\underline{\text{RCL 6}}$ × × +

There are two patterns in the above procedure which can be exploited to reduce the number of program steps necessary for solution:

1. × × + appears repeatedly.
2. The values recalled immediately before × × +, are recalled from consecutive registers (note underlined RCL instructions in keystrokes above).

A subroutine can be used to take advantage of item one, while indirect recalls in combination with the ISZ command can be used to recall values consecutively. Let's examine the code that does this.



```
022  *LBLa
023      0
024   STOI
025   RCL6
026   RCL8
027   GSB7
028   RCL4
029   RCL9
030   GSB7
031   RCL5
032   RCL7
033   GSB7
034    CHS
035   RCL3
036   RCL8
037   GSB7
038   RCL1
039   RCL9
040   GSB7
041   RCL2
042   RCL7
043  *LBL7
044   ISZI
045   RCLi
046      ×
047      ×
048      +
049    RTN
```

Here is what happens on the first, second and sixth time the subroutine is executed.

ISZI	I = 1	I = 2	I = 6
RCLi	RCL 1	RCL 2	RCL 6
×	$R_8 \times R_1$	$R_9 \times R_2$	$R_7 \times R_6$
×	$R_6 \times R_8 \times R_1$	$R_4 \times R_9 \times R_2$	$R_2 \times R_7 \times R_6$
+	$0 + R_6 \times R_8 \times R_1$	Subtotal	Total
RTN	Return to call	Return to call	Stop

Each time the GSB 7 command is encountered, the calculator goes to LBL 7, executes the ISZ command, which adds one to the contents of register I, and recalls the contents of the register specified by the contents of register I (R_1 through R_6). After this, the × × + is done and execution continues at the step following the GSB 7 call.

L10-03

Matrix Operations

Set 0 in display for indirect store.

```
001  *LBLA
002      0
003   GTO5
```

Set 3 in display for indirect store.

```
004  *LBLB
005      3
006   GTO5
```

Set 6 in display for indirect store.

```
007  *LBLC
008      6
009   GTO5
```

Set 19 in display for indirect store.

```
010  *LBLD
011      1
012      9
```

Store code in I.

```
013  *LBL5
014   STOI
```

Store three input values in proper registers according to code.

```
015   GSB6
016   GSB6
017  *LBL6
018     R↑
019   ISZI
020   STOi
021    RTN
```

Calculate determinant.

```
022  *LBLa
023      0
024   STOI
025   RCL6
026   RCL8
027   GSB7
028   RCL4
029   RCL9
030   GSB7
031   RCL5
032   RCL7
033   GSB7
034    CHS
035   RCL3
036   RCL8
037   GSB7
038   RCL1
039   RCL9
040   GSB7
041   RCL2
042   RCL7
043  *LBL7
044   ISZI
045   RCLi
046      ×
047      ×
048      +
049    RTN
```

Calculate reciprocal of determinant.

```
050  *LBLb
051   GSBa
052    1/X
```

Calculate inverse.

```
053   RCL1
054   RCL9
055      ×
056   RCL3
057   RCL7
058   GSB3
059   STOD
060    CLX
061   RCL3
062   RCL4
063      ×
064   RCL1
065   RCL6
066   GSB3
067   STOE
068    CLX
069   RCL2
070   RCL7
071      ×
072   RCL1
073   RCL8
074   GSB3
075   STOI
076    CLX
077   RCL1
078   RCL5
079      ×
080   RCL2
081   RCL4
082   GSB3
083   STO0
084    CLX
085   RCL3
086   RCL6
087      ×
088   RCL2
089   RCL9
090   GSB3
091   STO1
092    CLX
093   RCL2
094   RCL6
095      ×
096   RCL3
097   RCL5
098   GSB3
099   STO3
100    CLX
101   RCL5
102   RCL9
103      ×
104   RCL6
105   RCL8
106   GSB3
107   STO2
108    CLX
109   RCL6
110   RCL7
111      ×
112   RCL4
```

REGISTERS

0	1	2	3	4	5	6	7	8	9
γ_3	a_1, α_1	a_2, α_2	a_3, α_3	b_1, β_1	b_2, β_2	b_3, β_3	c_1, γ_1	c_2, γ_2	c_3, γ_3
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
d_1	d_2	d_3	β_2	β_3	control

```
113   RCL9
114   GSB3
115   ST06
116    CLX
117   RCL4
118   RCL8
119     x
120   RCL5
121   RCL7
122   GSB3
123   RCLI      ------------
124   RCL0      Store inverse values in
125   GSBC      proper registers.
126   RCL2
127   RCL1
128   RCL3
129   GSBA
130   RCL6
131   RCLD
132   RCLE
133   GSBB
134    CLX      ------------
135    RTN      Stop and display 0.
136  *LBL3      ------------
137     x       Inverse subroutine.
138     -
139     x       ------------
140    RTN
141  *LBLE      Initialize output loop.
142    SPC
143      1
144   STOI
145  *LBL2      ------------
146   RCLi      Output registers R1 through
147   PRTX      R9.
148      9
149   RCLI
150   X=Y?
151   GTO0
152      3
153      ÷
154    FRC
155   X=0?
156    SPC
157   RCLI
158   ISZI
159   GTO2
160  *LBL0      ------------
161    SPC      Output registers RA
162   RCLA      through RC.
163   PRTX
164   RCLB
165   PRTX
166   RCLC
167   PRTX
168    RTN      ------------
```

```
169  *LBLc
170    SPC      First value from
171      1      multiplication.
172   STOI
173   GSB1      ------------
174   STOD      Second value from
175      2      multiplication.
176   STOI
177   GSB1
178   STOE      ------------
179      3      Third value from
180   STOI      multiplication.
181   GSB1
182   STO0      ------------
183      0      Put values in stack for
184   RCLD      display.
185   RCLE
186   RCL0
187    RTN      ------------
188  *LBL1      Multiplication.
189      0
190   RCLA
191   GSB4
192   RCLB
193   GSB4
194   RCLC
195   GSB4
196   PRTX
197    RTN      ------------
198  *LBL4      Multiplication subroutine.
199   RCLi
200     x
201     +
202   ISZI
203   ISZI
204   ISZI
205    RTN      ------------
206    R/S
```

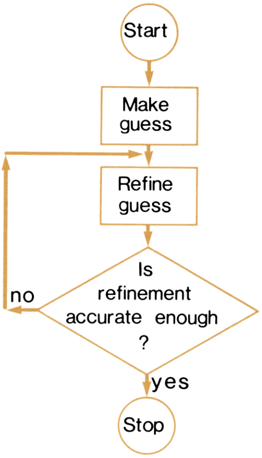
LABELS					FLAGS	SET STATUS		
A a_1, a_2, a_3	B b_1, b_2, b_3	C c_1, c_2, c_3	D d_1, d_2, d_3	E Print	0	FLAGS	TRIG	DISP
a →Det	b →Inv	c →Mult	d	e	1	ON OFF 0 □ ☒ 1 □ ☒ 2 □ ☒ 3 □ ☒	DEG ☒ GRAD □ RAD □	FIX ☒ SCI □ ENG □ n 2
0 print	1 mult	2 print	3 inv	4 mult	2			
5 code	6 input	7 det	8	9	3			

ITERATIVE TEST AND LOOP

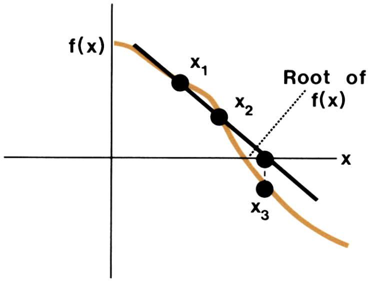
Some equations cannot be solved explicitly. That is, it is impossible to separate a particular variable from the rest of the equation. Solution of this type of equation requires a repetitive technique. In general, such techniques are composed of three basic operations.

1. An initial guess is made.
2. This guess is refined.
3. The refined guess is tested for accuracy. If the accuracy is satisfactory, the result is displayed. If the result is not satisfactory, the refinement process is repeated.

In flow chart form, the process might look like this:



In *Calculus And Roots Of f(x),* LBL E (steps 83 through 112) performs a general interative solution for user-specified functions. The initial guess supplied by the user is refined using the secant method. The secant method evaluates the function f(x) at two points and generates a third refined point. Graphically, this can be represented by the sketch below:



By defining a straight line using x_1 and x_2, x_3 can be found. Subsequently, x_2 and x_3 can be used to generate x_4 etc.

The equation defining the secant method is as follows:

$$x_{i+1} = x_i - f(x_i)\left(\frac{(x_i - x_{i-1})}{f(x_i) - f(x_{i-1})}\right)$$

It is evaluated repeatedly by steps 88 through 103. Each time these steps are repeated, the value of x is refined.

Steps 104 through 110 (excluding steps 105 and 106) test to determine whether the guess has been refined to the desired accuracy. If another loop is required, control is transferred to LBL 6. If the value is sufficiently accurate, the program stops, displaying the result at step 112.

The display setting, in combination with the RND function, is used to determine the accuracy of the result. If the amount of change in x_i divided by x_{i+1} rounds to zero, the condition for convergence is met and x_{i+1} is displayed as the answer. If the rounded value is not zero, another iteration is required. For instance, if $x_i = 10$, the change in x_i is 0.1 and the display is set at two decimal places, the test value would be calculated as follows:

$$\begin{aligned}\text{Test value} &= \text{RND}(0.1/(10-0.1)) = \text{RND}(0.01010101)\\ &= 0.01\end{aligned}$$

Since the value is not zero, another loop is required. If, on the next loop, the refinement were 0.01, and x_i were 9.9, the test value would be calculated as follows:

$$\begin{aligned}\text{Test value} &= \text{RND}(0.01/(9.9-0.01)) = \text{RND}(0.001011122)\\ &= 0.00\end{aligned}$$

Since the value is zero, x_{i+1} would be displayed as the result ($x_{i+1} = 9.89$). Note that, if the display had been set to three decimal places, another loop would be required since the RND function is display dependent.

Calculus and Roots of f(x)

```
001  *LBLA      Store function number.
002   STOI
003    RTN
                ------------------------
004  *LBLe      Pause toggle.
005    F0?
006   GTO0
007    SF0
008      1
009    RTN
010  *LBL0
011      0
012    CF0
013    RTN
                ------------------------
014  *LBLa      Store %Δ and set flag.
015    SF1
016   STOE
017    RTN
                ------------------------
018  *LBLE      Choose default %Δ or use
019    EEX      0.01%?
020    CHS
021      2
022   RCLE
023    F1?
024    X⇄Y
025     R↓
                ------------------------
026      %      If x=0 use %Δ rather than
027    X=0?     % of x as Δx.
028   LSTX
029   STOC
                ------------------------
030      2
031      ÷      f(x − Δx/2).
032      -
033   STOA
034   STO0
035   GSBi
036   STOD
                ------------------------
037   RCLA
038   RCLC      f(x + Δx/2).
039      +
040   STO0
041   GSBi
                ------------------------
042   STOB      f(x+Δx/2)−f(x−Δx/2)
043   RCLD      -------------------
044      -              Δx
045   RCLC
046      ÷
047    RTN
                ------------------------
048  *LBLC      f(x).
049   STO0
050   GSBi
051    RTN
                ------------------------
052  *LBLD      Store a.
                ------------------------
053    X⇄Y
054   STO0      b−a.
055      -
                ------------------------
056    X⇄Y      Store n.
```

```
057   STOB
058      ÷
                ------------------------
059   STOC      (b − a)/n
060      2
                ------------------------
061      ÷      b − a
062   ST+0      -----
                 2n
                ------------------------
063      0      Set integral sum at 0.
064   STO9
                ------------------------
065   RCLB      Put number of intervals
066    X⇄I      in I.
                ------------------------
067  *LBL7
068    X⇄I      Return function number
069   STOB      to I and n to R_B.
070   RCL0
                ------------------------
071   GSBi      F'(R0)
072   RCLC
                ------------------------
073   ST+0      R0 + (b − a)/n
                ------------------------
074      x      Add f(R0) (b − a)/n
075   ST+9
                ------------------------
076   RCLB      Decrement n and save
077    X⇄I      function in display.
078   DSZI
                ------------------------
079   GTO7      Store function number.
080   STOI
                ------------------------
081   RCL9      Display result of
082    RTN      integration.
                ------------------------
083  *LBLE      Use numerical differential
084    FIX      to generate x_i from user
085   GSBB      guess.
086   RCLB
087   GTO0
                ------------------------
088  *LBL6      Evaluate f(x_i)
089   RCL0
090   GSBi
091   STOB
092  *LBL0
                ------------------------
093   RCLA      Secant method calculates
094   RCL0      correction for x value
095   STOA      and sets values for next
096      -      loop.
097   RCLD
098   RCLB
099   STOD
100      -
101      ÷
102      x
                ------------------------
103   ST-0      Subtract correction.
                ------------------------
104   RCL0      Pause and display root if
105    F0?      flag set?
106    PSE
                ------------------------
107      ÷      RND (change/x_(i+1))
108    RND
                ------------------------
109    X≠0?     Accurate to display?
110   GTO6
                ------------------------
111   RCL0      If it is, display result.
112    RTN
```

REGISTERS

0 x	1	2	3	4	5	6	7	8	9 integral
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A x_{i-1}	B $f(x_i)$	C Δx	D $f(x_{i-1})$	E %Δ	I function

L11-04

```
001  *LBL1
002    R/S
003    RTN
004  *LBL2
005    RAD
006    TAN
007   LSTX
008      -
009   RCL2
010      -
011    DEG
012    RTN
013  *LBL3
014    RAD
015    SIN
016   RCL1
017      x
018     X²
019      1
020    X⇄Y
021      -
022     √X
023    1/X
024    DEG
025    RTN
```

Graphical evaluation subroutine.

$f(x) = \tan(x) - \text{Inv}(x) - x$

$$f(\theta) = \frac{1}{\sqrt{1 - k^2 \sin^2 \theta}}$$

LABELS					FLAGS
A Function #	B x→f'(x)	C x→f(x)	D n↑a↑b→∫	E x₀→root	0 Pause
a %Δ	b	c	d	e pause	1 %Δ
0 used	1	2	3	4	2
5	6 iterate	7 integrate	8	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	□	☒	DEG	☒	FIX	☒
1	□	☒	GRAD	□	SCI	□
2	□	☒	RAD	□	ENG	□
3	□	☒			n	2

L12-01

English—SI Conversions (Metric Conversions)

001	*LBLa	Set millimeter inch flag.
002	SF2	
003	*LBLA	Input conversion constant.
004	2	
005	5	
006	.	
007	4	
008	F2?	in. to mm or mm to in?
009	1/X	
010	X⇄Y	Set stack for LST x
011	×	Convert.
012	RTN	
013	*LBLb	Feet-meter conversion.
014	SF2	
015	*LBLB	
016	.	
017	3	
018	0	
019	4	
020	8	
021	F2?	
022	1/X	
023	X⇄Y	
024	×	
025	RTN	
026	*LBLc	Gallon-liter conversion.
027	SF2	
028	*LBLC	
029	3	
030	.	
031	7	
032	8	
033	5	
034	4	
035	1	
036	1	
037	7	
038	8	
039	4	
040	F2?	
041	1/X	
042	X⇄Y	
043	×	
044	RTN	
045	*LBLd	Pound force-newton conversion.
046	SF2	
047	*LBLD	
048	4	
049	.	
050	4	
051	4	
052	8	
053	2	
054	2	
055	1	
056	6	
057	1	
058	5	
059	F2?	
060	1/X	
061	X⇄Y	
062	×	
063	RTN	
064	*LBLe	Pound mass-kilogram conversion.
065	SF2	
066	*LBLE	
067	.	
068	4	
069	5	
070	3	
071	5	
072	9	
073	2	
074	3	
075	7	
076	F2?	
077	1/X	
078	X⇄Y	
079	×	
080	RTN	
081	R/S	

REGISTERS

0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

L12-02

```
001  *LBLA
002      3
003      2
004      -
005      1        °C = (°F − 32)/1.8
006      .
007      8
008      ÷
009    RTN        ------------
010  *LBLa
011      1
012      .        °F = 1.8°C + 32
013      8
014      x
015      3
016      2
017      +
018    RTN        ------------
019  *LBLb
020    SF2        British thermal unit to joule
021  *LBLB        conversion.
022      1
023      0
024      5
025      5
026      .
027      0
028      5
029      5
030      8
031      5
032      3
033    F2?
034    1/X
035    X⇄Y
036      x
037    RTN        ------------
038  *LBLc
039    SF2
040  *LBLC        Pound per square inch to
041      6        newton per square metre
042      8        conversion.
043      9
044      4
045      .
046      7
047      5
048      7
049      2
050    F2?
051    1/X
052    X⇄Y
053      x
054    RTN        ------------
055  *LBLd
056    SF2
```

```
057  *LBLD
058      1        Pound mass per cubic foot
059      6        to kilogram per cubic metre
060      .        conversion.
061      0
062      1
063      8
064      4
065      6
066      3
067    F2?
068    1/X
069    X⇄Y
070      x
071    RTN
072  *LBLe        ------------
073    SF2
074  *LBLE        Horsepower to watt
075      7        conversion.
076      4
077      5
078      .
079      6
080      9
081      9
082      9
083      8
084      7
085    F2?
086    1/X
087    X⇄Y
088      x
089    RTN        ------------
090    R/S
```

LABELS					FLAGS
A in-mm	B ft-m	C gal-1	D lbf-N	E lbm-kg	0
°F − °C	Btu-J	psi-N/m^2	lb/ft^3 − kg/m	hp-W	1
0	1	2	3	4	2 reverse
5	6	7	8	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	□	☒	DEG	☒	FIX	☒
1	□	☒	GRAD	□	SCI	□
2	□	☒	RAD	□	ENG	□
3	□	☒			n	2

PSEUDORANDOM NUMBER GENERATOR

Arithmetic Teacher incorporates a pseudorandom number generator. This generator supplies a sequence of numbers between zero and one which are converted into the problems displayed by the program.

The term ''Pseudorandom'' implies that the sequence of numbers is predictable from the algorithm and the initial value or seed used for the generator. A truly random device, such as a fair roulette wheel, is totally unpredictable. However, pseudorandom generators can be used to model random events provided they yield uniformly distributed numbers (i.e., as many values fall between 0.00 and 0.10 as fall between 0.10 and 0.20 etc.) and they do not repeat the same sequence of values during the simulation.

The pseudorandom number generator incorporated in *Arithmetic Teacher* is very simple but quite good. It uses the multiplicative linear congruential method:

$$u_{i+1} = \text{fractional part of } (997u_i)$$

$$\text{where } i = 0, 1, 2, \ldots$$

$$u_0 = 0.5284163^{*} \text{ (seed)}$$

The period of this generator has a length of 500,000 numbers and the generator passes the frequency test (chi square) for uniformity, the serial test and the run test. The most significant digits (the left hand digits) are the most random digits. The right most digits are significantly less random.

In *Arithmetic Teacher* the initial seed of .5284163 is stored at step 022. Label 5 (steps 084-096) actually generates the digits for each arithmetic problem. However, pseudorandom number generation occupies only the first six steps of label 5. These six steps and the corresponding x register contents are as follows:

STEPS	X REGISTER
LBL 5	
RCL E	old seed
9	
9	
7	997
x	seed × 997

*Other seeds may be selected but the quotient of (seed × 10^7) divided by two or five must not be an integer. Also, it would be wise to statistically test other seeds before using them.

```
  FRC     fractional part of (seed × 997)
STO E     pseudorandom number is stored
   ·      to act as seed for next loop.
   .
   .
```

Arithmetic Teacher

Step	Key	Comment	Step	Key	Comment
001	*LBLa	Store initial constants and default constants.	057	SPC	Output operation code.
002	0		058	PRTX	
003	STO8		059	SPC	
004	2		060	*LBL9	Generate two values for a problem.
005	0		061	GSB5	
006	STO7		062	STOC	
007	1		063	GSB5	
008	0		064	RCLC	Generate problem.
009	STOD		065	GSBi	
010	STOE		066	RCLA	Set display.
011	1		067	X⇄I	
012	STOA		068	DSPi	
013	.		069	X⇄I	Scale one value.
014	5		070	R↓	
015	2		071	RCLB	
016	8		072	÷	Add values for display of x, y.
017	4		073	+	
018	1		074	0	
019	6		075	+	Place 0 in LST x.
020	3		076	RCL9	
021	*LBLe	Store seed, either default or user.	077	X=Y?	If same problem was just given, gen new problem.
022	STOE		078	GTO9	
023	CLX		079	R↓	
024	RTN		080	STO9	Display problem.
025	*LBLb	Input and store n_{max} + 1. Set flag to eliminate default value.	081	F1?	
026	SF0		082	PRTX	
027	SPC		083	RTN	
028	PRTX		084	*LBL5	Pseudorandom number generation.
029	SPC		085	RCLE	
030	ABS		086	9	
031	1		087	9	
032	+		088	7	
033	STOD		089	×	
034	1	Calculate display setting and store for later access.	090	FRC	
035	0		091	STOE	
036	×		092	√X	Skew numbers high.
037	LOG		093	RCLD	Create integer no larger than n_{max}.
038	INT		094	×	
039	STOA		095	INT	
040	10ˣ	Calculate and store scale for problems.	096	RTN	
041	STOB		097	*LBL1	Addition problem.
042	CLX		098	+	
043	RTN		099	STOC	
044	*LBLA	Select addition.	100	LSTX	
045	1		101	−	
046	GTO1		102	LSTX	
047	*LBLB	Select subtraction.	103	RTN	
048	2		104	*LBL2	Subtraction problem.
049	GTO1		105	STOC	
050	*LBLC	Select multiplication.	106	X⇄Y	
051	3		107	+	
052	GTO1		108	LSTX	
053	*LBLD	Select division.	109	RTN	
054	4		110	*LBL3	Multiplication problem.
055	*LBL1		111	X=0?	
056	STOI	Store +, −, x, ÷ code.	112	X⇄Y	

REGISTERS

0	1	2	3	4	5	6	7	8	9
							20 − n	wrong	problem

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
display	scale	answer	n_{max} + 1	seed	control

```
113   X=0?
114      1
115      x
116   STOC
117   LSTX
118      ÷
119   LSTX
120    RTN    ------------
121  *LBL4
122   STOC    Division problem.
123    X⇄Y
124   X=0?
125   GSB5
126      x
127   LSTX
128    RTN    ------------
129  *LBLE    If keyboard was used to
130   LSTX    solve problem, GTO error
131   X≠0?    routine.
132   GTO7    ------------
133     R↓    If answer is not right,
134   RCLC    display problem again.
135   X≠Y?
136   GTO8    ------------
137      1    Total problems done and
138    F2?    problems wrong.
139   ST+8
140   ST-7    ------------
141   RCL7    If 20 problems have not
142   X≠0?    been done gen. another
143   GTO9    problem.
144    SPC    ------------
145      2    Output results of lesson.
146      6
147   RCL6
148      -
149   PRTX
150      2
151      0
152   PRTX
153      ÷
154    EEX
155      2
156      x
157   PRTX
158    SPC
159    SPC
160    SPC
161    SPC    ------------
162      2
163      0    Start new lesson.
164   STO7
165      0
166   STO8
167   GTO9    ------------
168  *LBL8
169    SF2    Display problem again in
170   RCL9    case of error. Set wrong
171      6    answer flag so that total
172      +    will be incremented.
173    F1?
174    SPC
175    RTN    ------------
176  *LBL7    Display error for cheating.
177      0
178      ÷
179    RTN    ------------
180  *LBL5    Undefined division patch.
181      0
182   STOC
183    CLX
184      1
185    RTN    ------------
186  *LBLc    Print toggle.
187    F1?
188   GTO0
189    SF1
190      1
191    RTN
192  *LBL0
193    CF1
194      0
195    RTN    ------------
196    R/S
```

LABELS					FLAGS	SET STATUS		
A +?	B −?	C x?	D ÷?	E Answer	0	FLAGS	TRIG	DISP
a Start	b (n_{max})	c P?	d	e (seed)	1 Print	ON OFF 0 □ ☒ 1 □ ☒ 2 □ ☒ 3 □ ☒	DEG ☒ GRAD □ RAD □	FIX ☒ SCI □ ENG □ n 2
0 print	1 +	2 −	3 x	4 ÷	2 error			
5 used	6	7 cheat	8 error	9 problem	3			

Moon Rocket Lander

```
001  *LBLA
002      5
003      0
004      0
005   STO6     Store initial conditions.
006      5
007      0
008    CHS
009   STO7
010      6
011      0
012   STO8     — — — — — — — — — — —
013  *LBL9     Divide height by 10000
014   RCL6     for combined display of
015   DSP4     vv.0hhh
016    EEX     — — — — — — — — — — —
017      4
018      ÷
019   RCL7     Build vv.0hhh display taking
020    CF2     negative values into
021   X<0?     account.
022    SF2
023    ABS
024      +
025    F2?
026    CHS     — — — — — — — — — — —
027    PSE     Display velocity and
028    PSE     height.
029   DSP0     — — — — — — — — — — —
030   RCL8     Count down for burn.
031    PSE
032      3
033    PSE
034      2
035    PSE
036      1
037    PSE
038      0     — — — — — — — — — — —
039    PSE     Accept input.
040  *LBL5     — — — — — — — — — — —
041   RCL8     If all fuel has been used,
042    X⇄Y     determine crash velocity.
043   X>Y?
044   GTO2     — — — — — — — — — — —
045   ST-8     Determine velocity and
046      2     height.
047      ×
048      5
049      -
050   STO9
051      2
052      ÷
053   RCL6
054      +
055   RCL7
056      +
```

```
057   RCL9
058   ST+7
059     R↓
060   STO6
061    INT     — — — — — — — — — — —
062   X>0?     If no inpact go for another
063   GTO9     burn.
064  *LBL3     — — — — — — — — — — —
065   DSP0     Flash crash velocity.
066   RCL7
067  *LBL4
068    PSE
069   GTO4     — — — — — — — — — — —
070  *LBL2
071   RCL8     Fuel-exhausted free-fall
072      2     crash velocity.
073      .
074      5
075      -
076   ST+6
077      2
078      ×
079   ST+7
080   RCL6
081      1
082      0
083      ×
084   RCL7
085     X²
086      +
087     √X
088    CHS
089   GTO4
090  *LBLE     — — — — — — — — — — —
091      5     Flame out recovery.
092   ST-8
093      0
094   GTO5     — — — — — — — — — — —
095    R/S
```

REGISTERS

0	1	2	3	4	5	6 x	7 v	8 Fuel	9 Accel.
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

LABELS					FLAGS
A Cntrl	B Restart	C	D	E	0
a	b	c	d	e	1
0 used	1	2 fuel = 0	3 crash	4 flash	2 sign
5 restart	6	7	8	9 burn	3

SET STATUS						
FLAGS			TRIG		DISP	
	ON	OFF				
0	□	☒	DEG	☒	FIX	☒
1	□	☒	GRAD	□	SCI	□
2	□	☒	RAD	□	ENG	□
3	□	☒			n	2

L15-01

Diagnostic Program

Step	Key	Comment
001	*LBL0	Clear registers subroutine.
002	CLRG	
003	P⇄S	
004	CLRG	
005	RTN	
006	*LBLa	Function test subroutine.
007	RND	
008	RCLI	
009	X≠Y?	
010	R/S	
011	*LBL2	
012	DSZI	DSZI & RCLI subroutine.
013	*LBL5	
014	RCLI	
015	RTN	RCLI & STOP if called
016	*LBLc	
017	RCLi	
018	RCLI	Verify registers & sum in R_0 subroutine.
019	X≠Y?	
020	R/S	
021	ST+0	
022	DSZI	
023	GTOc	
024	3	
025	EEX	
026	2	
027	RCL0	
028	X≠Y?	Test R_0
029	R/S	
030	RTN	
031	*LBLe	Decrement x subroutine.
032	1	
033	-	
034	RTN	
035	*LBLA	START & pause after first subroutine execution.
036	5	
037	7	
038	GSB0	
039	PSE	
040	GSBe	Decrement x.
041	ENT↑	
042	R↓	STACK (X,Y,Z,T) TEST
043	X⇄Y	
044	R↑	
045	R↑	
046	X⇄Y	
047	R↑	
048	X≠0?	
049	X≠Y?	
050	RTN	
051	GSBe	Decrement x.
052	X>Y?	X to Y comparisons
053	RTN	
054	GSBe	
055	X=Y?	
056	RTN	

Step	Key	Comment
057	GSBe	
058	X≤Y?	
059	GTO1	
060	RTN	
061	*LBL1	
062	GSBe	Decrement x.
063	STOI	
064	RCLI	I-register test.
065	X⇄Y	
066	X≠Y?	
067	RTN	
068	GSB2	X to 0 comparisons.
069	X≠0?	
070	GTO3	
071	RTN	
072	*LBL3	
073	GSB2	
074	X=0?	
075	RTN	
076	GSB2	
077	X<0?	
078	RTN	
079	GSB2	
080	X>0?	
081	GTO4	
082	RTN	
083	*LBL4	Check set status on flags.
084	DSZI	
085	F2?	
086	GTO5	
087	DSZI	
088	F1?	
089	GTO5	
090	DSZI	
091	F3?	
092	GTO6	
093	GTO5	
094	*LBL6	
095	DSZI	
096	F0?	
097	GTO7	
098	GTO5	
099	*LBL7	Check complement of set status on flags.
100	SF2	
101	SF1	
102	CF0	
103	DSZI	
104	F3?	
105	GTO5	
106	DSZI	
107	F0?	
108	GTO5	
109	DSZI	
110	F2?	
111	GTO8	
112	GTO5	

REGISTERS

0 USED	1 USED	2 USED	3 USED	4 USED	5 USED	6 USED	7 USED	8 USED	9 USED
S0 USED	S1 USED	S2 USED	S3 USED	S4 USED	S5 USED	S6 USED	S7 USED	S8 USED	S9 USED
A USED	B USED	C USED	D USED	E USED	I USED				

```
113  *LBL8
114   DSZI
115    F1?
116   GTO9
117   GTO5     - - - - - - - - - - - -
118  *LBL9     Check F2 for test
119   DSZI     clearing.
120    F2?
121   GTO5     - - - - - - - - - - - -
122   GSB2     Test DEG, SIN, SIN-1
123   DSP7
124    DEG
125    SIN
126  SIN-1
127   GSBa     - - - - - - - - - - - -
128    COS     Test COS, COS -1
129  COS-1
130   GSBa     - - - - - - - - - - - -
131    TAN     Test TAN, TAN -1
132  TAN-1
133   GSBa     - - - - - - - - - - - -
134     →P     Test →P, →R
135     →R
136   GSBa     - - - - - - - - - - - -
137    SIN     Test →HMS, HMS→
138   →HMS
139   HMS→
140  SIN-1
141   GSBa     - - - - - - - - - - - -
142    LOG     Test LOG, 10 x
143    10x
144   GSBa     - - - - - - - - - - - -
145     LN     Test LN, e x
146     ex
147   GSBa     - - - - - - - - - - - -
148     √X     Test √X, X 2
149     X2
150   GSBa     - - - - - - - - - - - -
151   ENT↑     Test y x , LASTx,1/x
152     Yx
153   LSTX
154    1/X
155     Yx
156   GSBa     - - - - - - - - - - - -
157   ENT↑     Test +, −
158      +
159   LSTX
160      -
161   GSBa     - - - - - - - - - - - -
162   ENT↑
163      ×     Test X, ÷
164   LSTX
165      ÷
166   GSBa     - - - - - - - - - - - -
167     √X     Test FRC, INT
168    FRC
```

```
169   LSTX
170    INT
171      +
172     X2     - - - - - - - - - - - -
173   GSBa     Test D→R, R→D
174    D→R
175    R→D
176   GSBa     - - - - - - - - - - - -
177    EEX     Test EEX, %
178      2
179    X⇄Y
180      %
181   GSBa     - - - - - - - - - - - -
182   DSP1     Test registers
183  *LBLb     24→0
184   RCLI
185   STOi     (sensitivity of higher-
186   DSZI      order registers to
187   GTOb      lower-order register
188      2      changes)
189      4
190    X⇄I
191   GSBc     - - - - - - - - - - - -
192   GSB0     Clear registers.
193  *LBLd     - - - - - - - - - - - -
194   DSZI     Test registers
195   RCLI
196    ABS     0→24
197   STOi
198      2     (sensitivity of lower-
199      4      order registers to
200   X≠Y?      higher-order register
201   GTOd      changes)
202   STOI
203   GSBc     - - - - - - - - - - - -
204      9     Generate `PASS"
205    EEX     display.
206      8     -8-888888888-88
207      7
208    1/X
209      8
210    CHS
211      ×
212    SF0     - - - - - - - - - - - -
213    CF1     Reset status
214    SF3     for possible second
215    RAD     pass.
216   DSP3     - - - - - - - - - - - -
217    ENG     Test display
218   PRTX     formatting
219    SCI     and printing.
220   PRTX
221   DSP1
222    FIX
223   PRTX     - - - - - - - - - - - -
224    R/S     END TEST
```

LABELS				
A START	B	C	D	E
a Function test	b Decrementing register store	c Register check & sum	d Incrememting register store	e Decrement X
0 CL all REG	1 X≤Y SKIP	2 DSZI, RCLI	3 X≠0 SKIP	4 X>0 SKIP
5 RCLI & STOP	6 F3 SKIP	7 F0 SKIP	8 F2 SKIP	9 F1 SKIP

FLAGS
0 USED
1 USED
2 USED
3 USED

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☒	□	DEG	□	FIX	☒
1	□	☒	GRAD	□	SCI	□
2	□	☒	RAD	☒	ENG	□
3	☒	□			n 1	

NOTES

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HEWLETT
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00067-90021 Rev. 11/78

A B C ● E