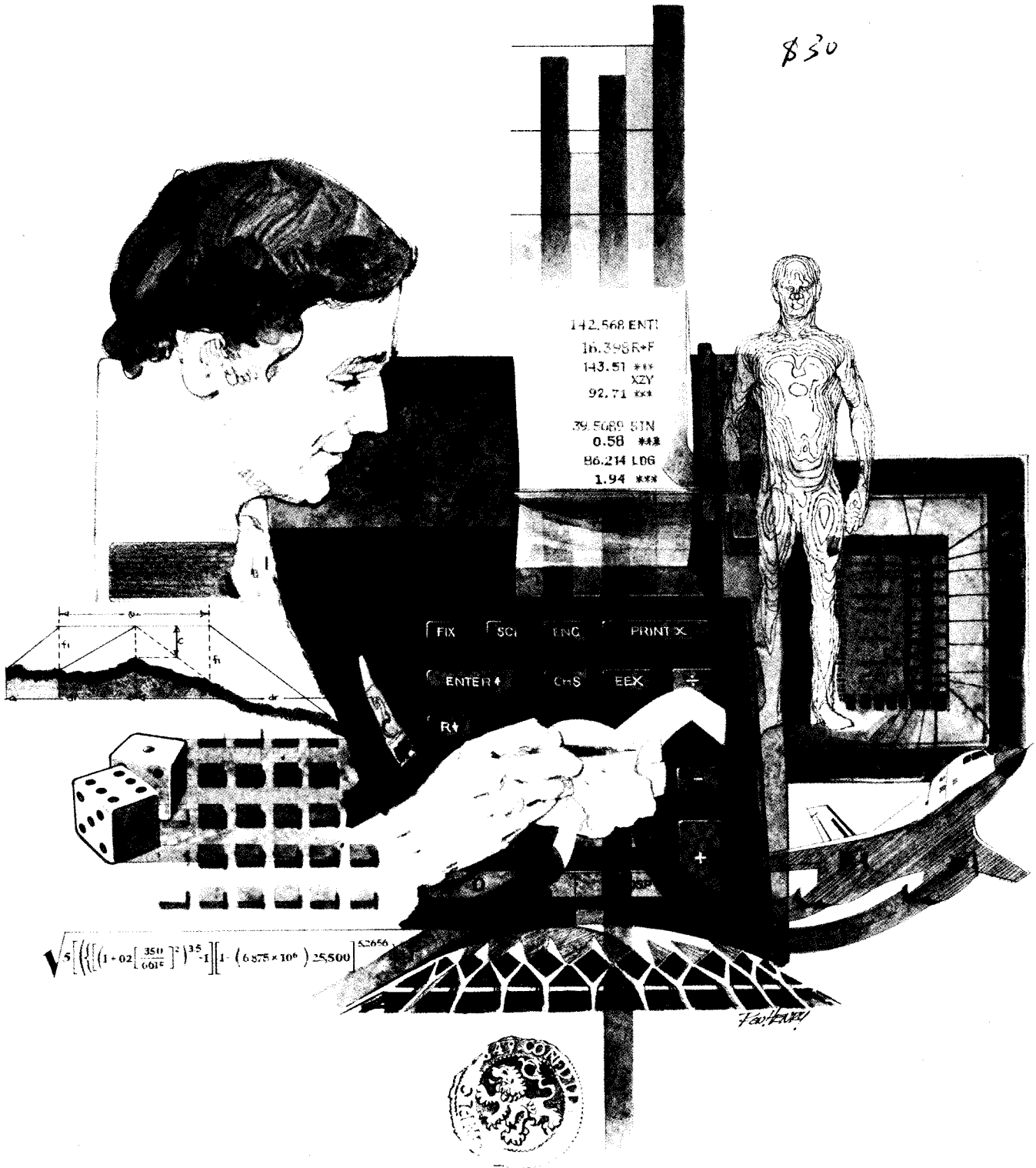


HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions
Industrial Engineering



INTRODUCTION

In an effort to provide continued value to its customers, Hewlett-Packard is introducing a unique service for the HP fully programmable calculator user. This service is designed to save you time and programming effort. As users are aware, Programmable Calculators are capable of delivering tremendous problem solving potential in terms of power and flexibility, but the real genie in the bottle is program solutions. HP's introduction of the first handheld programmable calculator in 1974 immediately led to a request for program **solutions** — hence the beginning of the HP-65 Users' Library. In order to save HP calculator customers time, users wrote their own programs and sent them to the Library for the benefit of other program users. In a short period of time over 5,000 programs were accepted and made available. This overwhelming response indicated the value of the program library and a Users' Library was then established for the HP-67/97 users.

To extend the value of the Users' Library, Hewlett-Packard is introducing a unique service—a service designed to save you time and money. The Users' Library has collected the best programs in the most popular categories from the HP-67/97 and HP-65 Libraries. These programs have been packaged into a series of low-cost books, resulting in substantial savings for our valued HP-67/97 users.

We feel this new software service will extend the capabilities of our programmable calculators and provide a great benefit to our HP-67/97 users.

A WORD ABOUT PROGRAM USAGE

Each program contained herein is reproduced on the standard forms used by the Users' Library. Magnetic cards are not included. The Program Description I page gives a basic description of the program. The Program Description II page provides a sample problem and the keystrokes used to solve it. The User Instructions page contains a description of the keystrokes used to solve problems in general and the options which are available to the user. The Program Listing I and Program Listing II pages list the program steps necessary to operate the calculator. The comments, listed next to the steps, describe the reason for a step or group of steps. Other pertinent information about data register contents, uses of labels and flags and the initial calculator status mode is also found on these pages. Following the directions in your HP-67 or HP-97 **Owners' Handbook and Programming Guide**, "Loading a Program" (page 134, HP-67; page 119, HP-97), key in the program from the Program Listing I and Program Listing II pages. A number at the top of the Program Listing indicates on which calculator the program was written (HP-67 or HP-97). If the calculator indicated differs from the calculator you will be using, consult Appendix E of your **Owner's Handbook** for the corresponding keycodes and keystrokes converting HP-67 to HP-97 keycodes and vice versa. No program conversion is necessary. The HP-67 and HP-97 are totally compatible, but some differences do occur in the keycodes used to represent some of the functions.

A program loaded into the HP-67 or HP-97 is not permanent—once the calculator is turned off, the program will not be retained. You can, however, permanently save any program by recording it on a blank magnetic card, several of which were provided in the Standard Pac that was shipped with your calculator. Consult your **Owner's Handbook** for full instructions. A few points to remember:

The Set Status section indicates the status of flags, angular mode, and display setting. After keying in your program, review the status section and set the conditions as indicated before using or permanently recording the program.

REMEMBER! To save the program permanently, **clip** the corners of the magnetic card once you have recorded the program. This simple step will protect the magnetic card and keep the program from being inadvertently erased.

As a part of HP's continuing effort to provide value to our customers, we hope you will enjoy our newest concept.

TABLE OF CONTENTS

DISCOUNTED CASH FLOW/PRESENT VALUE ANALYSIS.	1
Program finds the net present value or internal rate of return for up to 22 cash flows.	
DEPRECIATION SCHEDULES	8
Program evaluates the depreciation schedules for straight-line, sum-of-the-years'-digits, and declining balance. Also calculates the crossover point between straight-line and declining balance depreciation.	
INVOICING AND INVENTORY CONTROL	20
Program permits automatic price extension, sub and grand totalling of units and dollars, and automatic removal of units from inventory. Unlimited number of line items and associated prices are possible via separate data cards.	
PRODUCTION MONITOR AND RECORD.	25
Computes a production efficiency factor n for each pair of entries (no limit of entries) which consists of a number of units per job and a number of hours to accomplish the job.	
LEARNING CURVE	31
Given the initial value and slope, this program calculates the N th unit value and/or the average value between any two N 's.	
$\bar{X}$ AND R CONTROL CHART	35
$\bar{x}$ (mean) and R (range) are used to decide periodically whether a process is in statistical control.	
SINGLE-AND MULTI-SERVER QUEUES	42
Queueing theory for infinite and finite customers.	
TWO WAY ANALYSIS OF VARIANCE WITH REPLICATIONS FIXED EFFECTS MODEL	51
Program computes a two way ANOVA with replications. Equal cell sizes are necessary. The program requires single data entry and produces a full ANOVA summary table including estimates of strength of association for the three effects. Program is limited to 16 cells. The F ratios computed are for a fixed effect model.	
MULTIPLE LINEAR REGRESSION FOR 3 INDEPENDENT VARIABLES	57
For a set of N data points (3 independent variables), this program fits a linear equation of the form $T=A+BX+CY+DZ$ by the least squares method. Gauss elimination method is applied to solve the system of linear equations.	
SIMULTANEOUS EQUATIONS IN SIX UNKNOWNNS	67
Finds the solution for six simultaneous equations in six unknowns, using Crout's method. This two-card program will also compute the inverse and determinant of the coefficient matrix.	

Program Description I

1

Program Title Discounted Cash-Flow / Present-Value Analysis

Contributor's Name Hernan C. Anzola

Address Stanford University/Escondido Village Apt. 96-H

City Stanford

State California

Zip Code 94305

Program Description, Equations, Variables 1) given a series of up to 22 cash flows (F_j) $j=0$ to n , the program calculates the value of "i" (internal rate of return) that equals to 0 the equation $\sum F_j/(1+i)^j$. The program applies the Newton Formula for successive approximations: $i_k = i_{k-1} - S_{k-1}/S'_{k-1}$ where: $S = \sum F_j/(1+i)^j$ $j=0$ to n

$S' =$ derivative of S respect to $i = \sum -j/(1+i) \times F_j/(1+i)^j$

After each iteration the program displays the value of i_k given by the Newton Formula.

2) Given F_0 , i and n the program calculates the value of $F_1=F_2=\dots=F_n$ that makes the expression for S (see above) equal to 0.

3) Given F_0 , i and $F_1=F_2=\dots=F_n$ the program calculates the value of n that makes $S = 0$.

4) Given up to 22 cash flows ($0,1,2,\dots,n$) the program calculates the present value (PV) of the series for any given discount rate (i).

5) After the unknown in 1), 2), 3) or 4) has been calculated the program can display the following values:

j , $F_j/(1+i)^j$ and $\sum F_k/(1+i)^k$ for $j=1$ to n .

6) $n = -\ln(1 - iF_0/F_1)/\ln(1+i)$ $F_1=F_2=\dots=F_n = iF_0/[1-(1+i)^{-n}]$

Operating Limits and Warnings 1) no more than 22 cash flows ($0,1,\dots,21$) should be used. 2) when calculating "n" the combination of the values for F_0 , i and $F_1=F_2=\dots=F_n$ can make the program unfeasible, in that case ERROR will be displayed. 3) After "n" has been calculated and you press E to get the sequential display of the discounted series, the program will m periods where m is equal to the integer part of the n found.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s) Listed are the cash flow associated with a prosed investment:

End of year	Cash flow (\$)
0	-55,280
1	12,000
2	12,000
3	12,000
4	12,000
5	42,280

What is the internal rate of return of that investment?

keystrokes:

Solution(s)	5 [A]	0.00	
	55280 [CHS] [R/S]	1.00	
	4 [B]	1.00	
	12000 [R/S]	5.00	
	42280 [R/S]	0.00	
	[f] [A]	10.56	(on PAUSE)
		14.58	"
		15.00	"
		15.00	"
		15.00	

internal rate of return with a precision of 0.001 %

Press [E] and the program will display seq. j , $F_j/(1+i)^j$ and $\sum F_j/(1+i)^j$

Reference(s) Mao, James. T.; "Corporate Financial Decisions";
Pavan Publishers, Palo Alto, California, 1976

Program Description II

3

Sketch(es)

Sample Problem(s) Listed are the cash flows associated with a proposed investment:

End of year	cash flow (\$)
0	-1,000
1	500
2	400
3	300
4	100

What is the Present Value when the discount rate is 10% ?

" " " " " " " " " " 20%?

" " " internal rate of return ?

Solution(s) Keystrokes:

4 [A]	0.00
1000 [CHS] [R/S]	1.00
500 [R/S]	2.00
400 [R/S]	3.00
300 [R/S]	4.00
100 [R/S]	0.00
10 [f] [B]	78.82 PV @ 10 %
20 [f] [B]	-83.72 PV @ 20 %

[f] [A] (after 3 iterations) 14.49 int. rate of ret. %

Reference(s) Weston & Brigham, "Managerial Finance", Fifth Edition;
The Dryden Press, Hinsdale, Illinois, 1975

Program Description II

Sketch(es)

Sample Problem(s) A company plans an expansion involving \$300,000 to be raised by selling stock. The equipment will be depreciated in 10 years by the straight line method. The expected net profit per year will be \$45,000. What is the economic payout time when $i = 8\%$?

The cash flow per year is equal to the net profit plus depreciation charges ($\$300,000/10 = 30,000$); this is $\$45,000 + \$30,000 = \$75,000$.

Solution(s) keystrokes:

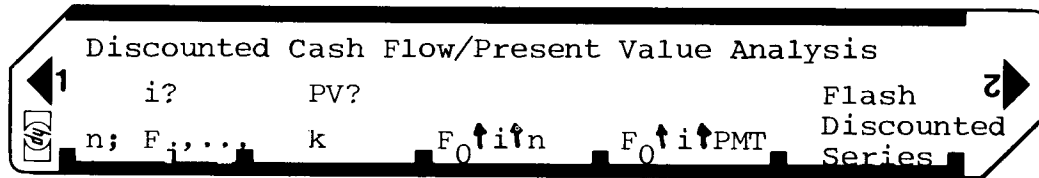
300000 [CHS] [ENTER]	-300000.00
8 [ENTER]	8.00
75000 [D]	5.01 years

* If you want to obtaining for each year the value of $F_j/(1+i)^j$ and its accumulated value, press [E].

Reference(s) Schweyer Herbert, "Process Engineering Economics", McGraw-Hill, New York, 1955

User Instructions

5



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
	If the unknown is the internal rate of return (i) or the present value (PV) do steps 2 and 3:			
2	Input n (number of periods after 0)	n	A	0.00
3	Input the cash flow series $F_0, \dots, F_n$ *Repeat step 3 "n+1" times. Each time the calculator will display the seq. number of the cash flow you should enter: 0,1,2,...,n. After the n-th cash flow has been entered the calculator will display zero	F_j	R/S	j+1
4	Optional: if at any period (j) you want to enter "k" equal cash flows $F_j = F_{j+1} = \dots = F_{j+k}$; input "k" and continue with step 3.	k	B	j
5	If the unknown is "i": After each iteration the value of i obtained at that point from the Newton formula will be displayed for 1 sec. * For a new case go to step 2		f A	i (%)
5	If the unknown is Present Value (PV): * For a new case using a different "i" repeat the step again.	i (%)	f B	PV
2	If the unknown is $F_1 = F_2 = \dots = F_n = PMT$: Input F_0 value Input i value Input n value * For a new case repeat the step again.	F_0 i (%) n	ENT ENT C	F_0 i (%) PMT
2	If the unknown is n: Input F_0 value Input i value Input PMT value ($PMT = F_1 = F_2 = \dots = F_n$) * For a new case repeat the step again.	F_0 i (%) PMT	ENT ENT D	F_0 i (%) n
**	OPTIONAL: If after the calculator has displayed the unknown value (i, PV, n or PMT) you want to see the discounted and accumulated value for each year of the series (in flash mode), beginning with year 1, PRESS [E]		E	j $F_j / (1+i)^j$ $\sum F_j / (1+i)^j$

67 Program Listing I

6

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS		
001	LBL A	31 25 11	To enter n and the series of cash flows.	057	INT	31 83			
002	CF 1	35 61 01		058	CHS	42			
003	CF 2	35 61 02		059	y^x	35 63			
004	CF 0	35 61 00		060	CHS	42			
005	CL REG	31 43		061	1	01			
006	STO C	33 13		062	+	61			
007	1	01		063	$\div$	81			
008	CHS	42		064	STO D	33 14			
009	$X \rightleftharpoons I$	35 24		065	SF 3	35 51 03			
010	LBL 0	31 25 00		066	RTN	35 22			
011	ISZ	31 34	Load the cash flows in R_0 to R_n ($0 < n \leq 21$)	067	LBL 5	31 25 05			
012	LBL 2	31 25 02		068	0	00			
013	RC I	35 34		069	$X \rightleftharpoons I$	35 24			
014	R/S	84		070	SF 1	35 51 01			
015	STO (i)	33 24		071	RCL C	34 13			
016	LBL 8	31 25 08		072	INT	31 83			
017	RC I	35 34		073	STO E	33 15			
018	RCL C	34 13		074	GSB 4	31 22 04			
019	$X \neq Y$	32 61		075	RTN	35 22			
020	GTO 0	22 00		076	LBL D	31 25 14		To calculate n when F_0 , i and $PMT=F_1=F_2=...=F_n$ are given.	
021	0	00	077	CL REG	31 43				
022	RTN	35 22	078	STO D	33 14				
023	LBL B	31 25 12	079	$R \downarrow$	35 53				
024	+	61	080	GSB c	32 22 13				
025	1	01	081	$R \downarrow$	35 53				
026	-	51	082	STO 0	33 00				
027	STO E	33 15	083	CHS	42				
028	RC I	35 34	084	$R \uparrow$	35 54				
029	R/S	84	085	X	71				
030	STO D	33 14	086	RCL D	34 14				
031	STO (i)	33 24	087	+	81				
032	LBL 4	31 25 04	088	1	01				
033	RCL D	34 14	089	-	51				
034	ISZ	31 34	090	CHS	42				
035	STO (i)	33 24	091	LN	31 52				
036	RCL E	34 15	092	CHS	42				
037	INT	31 83	093	GSB 6	31 22 06				
038	RC I	35 34	094	LN	31 52				
039	$X \neq Y$	32 61	095	$\div$	81				
040	GTO 4	22 04	096	ST I	35 33	To calculate the internal rate of return (i) by using the Newton formula. $F = \sum F_j / (1+i)^j$ is store in R_D			
041	F? 1	35 71 01	097	INT	31 83				
042	RTN	35 22	098	RCL C	34 13				
043	GTO 8	22 08	099	+	61				
044	LBL C	31 25 13	100	STO C	33 13				
045	CL REG	31 43	101	RC I	35 34				
046	STO C	33 13	102	SF 3	35 51 03				
047	$R \downarrow$	35 53	103	RTN	35 22				
048	GSB c	32 22 13	104	LBL d	32 25 14				
049	$R \downarrow$	35 53	105	0	00				
050	STO 0	33 00	106	$X \rightleftharpoons I$	35 24				
051	CHS	42	107	STO E	33 15				
052	$R \uparrow$	35 54	108	RCL 0	34 00				
053	FRAC	32 83	109	STO D	33 14				
054	X	71	110	LBL e	32 25 15				
055	GSB 6	31 22 06	111	ISZ	31 34				
056	RCL C	34 13	112	RCL (i)	34 24				
REGISTERS									
0 F_0	1 F_1	2 F_2	3 F_3	4 F_4	5 F_5	6 F_6	7 F_7	8 F_8	9 F_9
S0 F_{10}	S1 F_{11}	S2 F_{12}	S3 F_{13}	S4 F_{14}	S5 F_{15}	S6 F_{16}	S7 F_{17}	S8 F_{18}	S9 F_{19}
A F_{20}	B F_{21}	C n.i		D used		E used		I used	

67 Program Listing II

7

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS		
113	GSB 6	31 22 06	and $F' = \sum -j/(1+i)$ $\times F_j/(1+i)^j$	169	R↓	35 53	After the value of i has been found, this routine store it in R_C (fraction) and displays it as a pertentage.		
114	RC I	35 34		170	R↓	35 53			
115	GSB 9	31 22 09		171	GSB 7	31 22 07			
116	YX	35 63		172	STO C	33 13			
117	÷	81		173	GTO d	22 31 14			
118	GSB 9	31 22 09		174	LBL 3	31 25 03			
119	RCL D	34 14		175	R↓	35 53			
120	X↔Y	35 52		176	R↓	35 53			
121	+	61		177	GSB 7	31 22 07			
122	STO D	33 14		178	STO C	33 13			
123	GSB 9	31 22 09	179	FRAC	32 83	To transform a given i from % to fraction and store it in R_C			
124	F? 0	35 71 00	180	EEX	43				
125	GTO 1	22 01	181	2	02				
126	LST X	35 82	182	X	71				
127	GSB 6	31 22 06	183	RTN	35 22				
128	÷	81	184	LBL c	32 25 13				
129	RC I	35 34	185	EEX	43				
130	X	71	186	2	02				
131	CHS	42	187	÷	81				
132	RCL E	34 15	188	GSB 7	31 22 07		To flash (after the unknown has been calculated) $j, F_j/(1+i)^j, \sum F_j/(1+i)^j$ for $j=1, n$		
133	+	61	189	STO C	33 13				
134	STO E	33 15	190	RTN	35 22				
135	LBL 1	31 25 01	191	LBL E	31 25 15				
136	RC I	35 34	192	F? 3	35 71 03				
137	RCL C	34 13	193	GSB 5	31 22 05				
138	INT	31 83	194	SF 0	35 51 00				
139	X↔Y	32 61	195	GSB d	32 22 14				
140	GTO e	22 31 15	196	RCL D	34 14				
141	F? 0	35 71 00	197	CF 0	35 61 00	To calculate the present value (PV) of n given cash flows (F_j)			
142	RTN	35 22	198	RTN	35 22				
143	F? 2	35 71 02	199	LBL b	32 25 12				
144	RTN	35 22	200	CF 3	35 61 03				
145	RCL C	34 13	201	GSB c	32 22 13				
146	FRAC	32 83	202	SF 2	35 51 02				
147	RCL D	34 14	203	GSB d	32 22 14				
148	RCL E	34 15	204	RCL D	34 14				
149	÷	81	205	RTN	35 22				
150	-	51	206	LBL a	32 25 11		To calculate the internal rate of return (i)		
151	EEX	43	207	CF 3	35 61 03				
152	2	02	208	GTO d	22 31 14				
153	X	71	209	RTN	35 22				
154	PAUSE	35 72	210	LBL 6	31 25 06				
155	EEX	43	211	RCL C	34 13				
156	2	02	212	FRAC	32 83				
157	÷	81	213	1	01				
158	ENTER	41	214	+	61				
159	ENTER	41	215	RTN	35 22	Group of statements used several times			
160	RCL C	34 13	216	LBL 7	31 25 07				
161	FRAC	32 83	217	RCL C	34 13				
162	-	51	218	INT	31 83				
163	ABS	35 64	219	+	61				
164	EEX	43	220	RTN	35 22				
165	CHS	42	221	LBL 9	31 25 09				
166	3	03	222	F? 0	35 71 00				
167	X > Y	32 81	223	- X -	31 84				
168	GTO 3	22 03	224	RTN	35 22		To flash X if flag 0 is ON		
LABELS				FLAGS		SET STATUS			
Aload n and F _i	Bload K equal -F _i	Cto calc. PMT	Dto calc. n	Eflash results	Fflash results	FLAGS		TRIG	DISP
a calc. i	b calc. PV	c used	d used	e used	1 used	ON OFF		DEG ☒	FIX ☒
0 used	1 used	2 used	3 used	4 used	2 used	0 ☐ ☒		GRAD ☐	SCI ☐
5 used	6 used	7 used	8 used	9 used	3 used	1 ☐ ☒		RAD ☐	ENG ☐
						2 ☐ ☒			n 2
						3 ☐ ☒			

Program Description I

Program Title **DEPRECIATION SCHEDULES**

Contributor's Name HEWLETT-PACKARD COMPANY

Address Corvallis Division
1000 N.E. Circle Boulevard

City Corvallis, OR 97330

State

Zip Code

Program Description, Equations, Variables

Three methods of depreciation are commonly used: straight-line, sum-of-the-years'-digits, and declining balance. This program evaluates the depreciation schedules for these three methods, and calculates the crossover point between straight line and declining balance depreciation. For the schedules, the output is the annual depreciation amount (DEP), remaining depreciable amount (RDV), remaining book value (RBV), and the total depreciation to date (TOT DEP), as well as an increment for the next year's schedule.

An option is available to output the depreciation schedule beginning at a specified year. Pressing **F1E** sets and clears the print flag. Successive use of **F1E** will alternately display 1.00 and 0.00, indicating that the print mode is on or off respectively.

Values for the last year of an asset with fractional years life (i.e., the 21st year's values for an asset with 20.5 years life) are calculated correctly. However, all other values represent a full year's depreciation. For this reason only integer values (whole number, 1.0, 2.0, 17.0 etc.) may be entered for YR (the **D** key). The program makes no checks on this value and generates invalid results if other than whole numbers are entered.

Straight Line Depreciation

The annual depreciation allowance using this method is determined by dividing the cost or other basis of valuation (starting book value) less its estimated salvage value by its useful life expectancy. This program develops the starting book value (SBV), salvage value (SAL), life expectancy (LIFE), and first year of the schedule (YR). (The schedule may be started at any point in the useful life.)

Fractional years life must be entered as an integer plus a fraction. Thus a life of 12 years 3 months would be keyed in as 12.25 for LIFE.

Operating Limits:

Sum of the Years' Digits Depreciation

The sum-of-the-years' digits method is an accelerated form of depreciation, allowing more depreciation in the early years of an asset's life than allowed under the straight line method. This program generates the schedule output, given the starting book value (SBV), the salvage value (SAL), expected useful life in years (LIFE), and beginning year (YR) for the schedule. (The schedule may be started at any point in the useful life.)

Fractional years asset life must be entered as an integer plus a fraction. Thus a life of 12 years 3 months would be keyed in as 12.25 for LIFE.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description I

Program Title _____

Contributor's Name _____

Address _____

City _____

State _____

Zip Code _____

Program Description, Equations, Variables

Variable Rate Declining Balance Depreciation

The variable rate declining balance method is another form of accelerated depreciation; as such it provides for more depreciation in earlier years and decreasing depreciation in later years. The program generates the depreciation schedule given the starting book value (SBV), salvage value (SAL), useful life expectancy (LIFE), the declining rate factor (FACT), and the first year of the desired schedule (YR). The schedule may be started at any point in the useful life.

The "variable rate" is indicated as either a factor or percent with equal frequency in the business community. Thus, "1.5 declining balance factor" and "150% declining balance" have the same meaning. The number to be keyed in for FACT (**E**) in this program, should be in factor form, that is 1.25, 1.5, 2, and not 125, 150 or 200.

This method of depreciation is unique in that it may generate depreciation greater than the depreciable value for some assets, while it may not generate sufficient depreciation for others. The crossover calculation (**F D**) is provided to assist in determining the best time to switch to straight line depreciation (tax laws permitting) so that an asset may be fully depreciated.

Fractional years life must be entered as an integer and a decimal. Thus, a life of 12 years 3 months would be keyed in as 12.25.

Crossover Point

As indicated in the description above, the declining balance method of depreciation may not fully depreciate an asset in the asset's lifetime. In these circumstances there is an optimum point in the useful life where a switch from the declining balance method to the straight line method should be made. This is the "crossover point", the first year in which the depreciation by the straight line method is greater than if depreciation were continued using declining balance method. (In accordance with Internal Revenue Service Publication 534, the straight line depreciation is determined by dividing the remaining depreciable value by the remaining useful life.)

Operating Limits :

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description I

Program Title _____

Contributor's Name _____

Address _____

City _____

State _____

Zip Code _____

Program Description, Equations, Variables

Given the starting book value (SBV), salvage value (SAL), useful life expectancy (LIFE), and declining balance factor (FACT), this routine calculates the last year that the declining balance method should be used, and the remaining life and remaining book value after this "last year" so that a switch to straight line depreciation can be made. As in the previous routine, the factor (FACT) should be entered in factor form (1.25, 1.5, 2.0), not as a percent (125, 150, 200).

The crossover routine (**f D**) may be used with the declining balance (**f C**) and straight line (**f A**) depreciation routines as follows:

1. Use **f D** to determine the "crossover point" and associated values.
2. Use **f C** to generate a declining balance depreciation schedule for the early years up to and including the year indicated as being the "last year". Since the same input values are used, only a value for YR (**D**) need be keyed in before pressing **f C**.
3. Now use **f A** to generate a straight line depreciation schedule for the remaining years. The remaining book value at the end of the last "declining balance year" is keyed in for starting book value (**A**), and the remaining life is keyed in for the asset's life (**C**). There is no need to enter the salvage value as it has been retained throughout this process.

For this portion of the depreciation schedule, the value for "total depreciation to date" will be in error by an amount equal to the amount depreciated during the declining balance calculations.

Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s)

Depreciation Schedules

where:

K = value for YR

TOTDEP_K = total depreciation for years 1 through K.

W = integer portion of LIFE

F = decimal portion of LIFE

(i.e., for a LIFE of 12.25 years W = 12 and F = .25)

Straight Line Schedule

$$DEP_K = \frac{SBV - SAL}{LIFE}$$

$$DEP_K (\text{last year}) = \left(\frac{SBV - SAL}{LIFE} \right) \cdot F$$

$$TOTDEP_K = (K) \cdot \left(\frac{SBV - SAL}{LIFE} \right)$$

Solution(s)

$$RDV_K = (LIFE - K) \cdot \left(\frac{SBV - SAL}{LIFE} \right)$$

$$RBV_K = RDV_K + SAL$$

Reference(s)

Program Description II

Sketch(es)

Sample Problem(s)

Sum-of-the-Years'-Digits Schedule

$$SOYD = \frac{(W + 1)(W + 2F)}{2}$$

$$DEP_k = \left(\frac{LIFE + 1 - K}{SOYD} \right) \cdot (SBV - SAL)$$

$$TOTDEP_k = \left[1 - \frac{(W - K + 1) \times (W - K + 2F)}{2 \times (SOYD)} \right] \cdot (SBV - SAL)$$

$$RDV_k = \left[\frac{(W - K + 1) \times (W - K + 2F)}{2 \times (SOYD)} \right] \cdot (SBV - SAL)$$

$$RBV_k = RDV_k + SAL$$

Variable Rate Declining Balance Schedule

Solution(s)

$$DEP_k = SBV \cdot \left(1 - \frac{FACT}{LIFE} \right)^{k-1} \cdot \left(\frac{FACT}{LIFE} \right)$$

$$TOTDEP_k = SBV \cdot \left[1 - \left(1 - \frac{FACT}{LIFE} \right)^k \right]$$

$$RDV_k = (SBV - SAL) - TOTDEP_k$$

$$RBV_k = RDV_k + SAL$$

Crossover Point—Declining Balance to Straight Line

Reference(s)

$$SBV \left(1 - \frac{FACT}{LIFE} \right)^{k-1} \cdot \left(\frac{FACT}{LIFE} \right) > \frac{(SBV - SAL) - TOTDEP_{k-1}}{L + 1 - K}$$

where $TOTDEP_{k-1}$ is determined as shown above.

The largest integer value for K which maintains the above relationship is the "last year" to use the Declining Balance depreciation method.

Program Description II

13

Sketch(es)

Sample Problem(s)

Example 1:

For a starting book value of \$375,000, a salvage value of \$30,000 and an expected life of 40 years, generate the 1st year's depreciation schedule using each of the common methods. Assume a declining balance factor of 1.5. Then jump ahead to the 15th year and generate the data for that year.

Keystrokes:

375000 **STO** **A** 30000 **STO** **B**
40 **STO** **C** 1 **STO** **D**

Outputs:

Straight Line

A →	1.00 (1 st year)
R/S →	8625.00 (1 st year's depreciation)
R/S →	336375.00 (remaining depreciable value)
R/S →	366375.00 (remaining book value)
R/S →	8625.00 (total depreciation to date)

Solution(s)

Now jump ahead to the 15th year.

Keystrokes:

15 **STO** **D** **A** →

Outputs:

R/S →	15.00 (15 th year)
R/S →	8625.00 (15 th year's depreciation)
R/S →	215625.00 (remaining depreciable value)
R/S →	245625.00 (remaining book value)
R/S →	129375.00 (total depreciation after 15 years)

SOYD

1 **STO** **D** **B** →

1.00 (1st year)

R/S →	16829.27 (1 st year's depreciation)
R/S →	328170.73 (remaining depreciable value)
R/S →	358170.73 (remaining book value)

Reference(s)

Program Description II

Sketch(es)

Sample Problem(s)

R/S → 16829.27 (total depreciation to date)

Jump ahead to the 15th year.

15 STO D ■ B → 15.00 (15th year)

R/S → 10939.02 (15th year's depreciation)

R/S → 136737.80 (remaining depreciable value)

R/S → 166737.80 (remaining book value)

R/S → 208262.20 (total depreciation 1st through 15th year)

Declining Balance

1 STO D 1.5 STO E ■ C → 1.00 (1st year)

R/S → 14062.50 (1st year's depreciation)

R/S → 330937.50 (remaining depreciable value)

R/S → 360937.50 (remaining book value)

R/S → 14062.50 (total depreciation to date)

Solution(s)

Keystrokes:

Now jump to the 15th year.

15 STO D ■ C → 15.00 (15th year)

R/S → 8235.18 (15th year's depreciation)

R/S → 181369.51 (remaining depreciable value)

R/S → 211369.51 (remaining book value)

Outputs:

R/S → 163630.49 (total depreciation 1st through 15th year)

Reference(s)

Sketch(es)

Sample Problem(s)

Example 2:

Having just performed the previous calculation, determine the crossover point and the associated remaining life and remaining book value. Generate the depreciation data for the declining balance “last year,” and then switch to the straight line method to generate the depreciation data for the year following the declining balance “last year.”

Keystrokes:

D

R/S

R/S

18 **STO** **D** **C**

R/S 

R/S

R/S

R/S

Solution(s)

188471.01 **STO** **A** 22 **STO** **C**

1 **STO** **D** **A**

R/S

Outputs:

18.00 (last year to use
declining balance)

22.00 (asset's remaining
life after 18
years)

188471.01 (remaining book
value after 18th
year)

18.00 (18th year)

7343.03 (18th year's depreciation)

158471.01 (remaining depreciable value)

188471.01 (remaining book value)

186528.99 (total depreciation
1st through 18th
year)

1.00 (1st year)

7203.23 (19th year's depreciation)

Note:

Although I was keyed in for YR—the first year of straight line depreciation—this is the 19th year of the asset's life.

Reference(s)

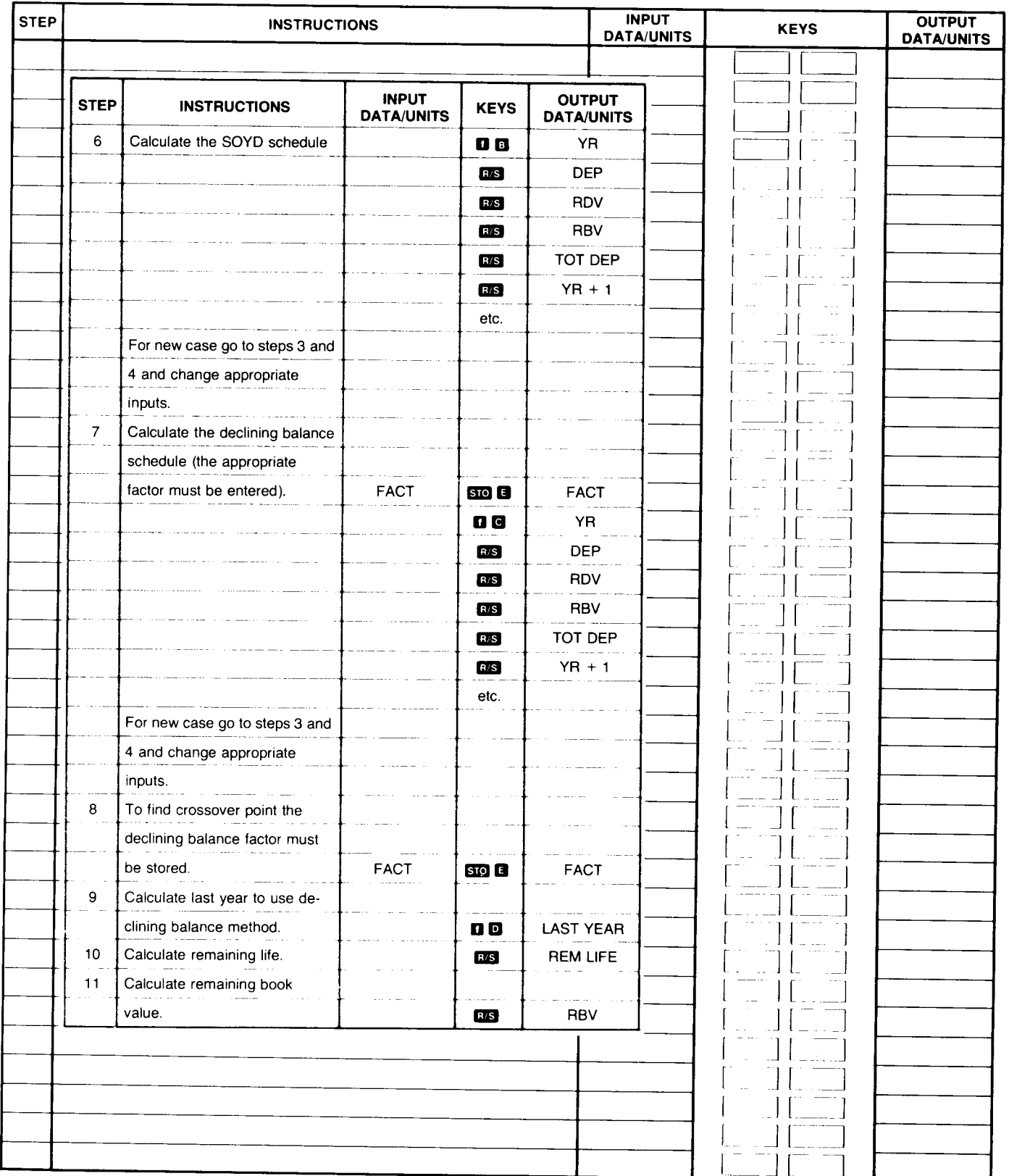
R/S $\longrightarrow$ 151267.78 (remaining depreciable value)

R/S $\longrightarrow$ 181267.78 (remaining book value)

etc.

[illegible]

17



STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBL	21 16 11	Straight Line	057	-	-45	
002	F0?	16 23 00		058	X<0?	16-45	
003	SPC	16-11	k	059	GT03	22 03	
004	RCLD	36 14		060	GSB2	23 02	
005	GSB9	23 09		061	RCL7	36 07	
006	RCLA	36 11	$\frac{SBV-SAL}{LIFE} \rightarrow R_I$	062	÷	-24	
007	RCLB	36 12		063	ST04	35 04	
008	-	-45		064	RCL8	36 08	
009	RCLC	36 13		065	x	-35	
010	÷	-24	DEP	066	*LBL3	21 03	
011	ST01	35 46		067	ST06	35 06	RDV _k
012	GSB9	23 09		068	GSB9	23 09	
013	RCLC	36 13		069	RCLB	36 12	
014	RCLD	36 14	(LIFE-YR)DEP=RDV _k	070	+	-55	
015	-	-45		071	GSB9	23 09	RBV _k =RDV _k +SAL
016	RCLI	36 46		072	1	01	
017	x	-35		073	RCL4	36 04	
018	GSB9	23 09		074	-	-45	
019	RCLB	36 12		075	RCL8	36 08	
020	+	-55		076	x	-35	
021	GSB9	23 09	RBV _k	077	GSB9	23 09	TOT DEP _k
022	RCLI	36 46		078	1	01	
023	RCLD	36 14	$\left(\frac{SBV-SAL}{LIFE}\right)YR=TOT$	079	GSB0	23 14	
024	x	-35	DEP	080	RCLC	36 13	k<LIFE?
025	GSB9	23 09		081	RCLD	36 14	
026	1	01		082	X<Y?	16-35	
027	GSB0	23 14		083	GT06	22 16 12	
028	RCLC	36 13		084	RTN	24	
029	RCLD	36 14	k<LIFE?	085	*LBL2	21 02	
030	X<Y?	16-35		086	ENT↑	-21	
031	GT06	22 16 11		087	FRC	16 44	$\frac{(1+W)(2F+W)}{2}$
032	RTN	24		088	ENT↑	-21	
033	*LBL6	21 16 12	SOYD	089	+	-55	
034	F0?	16 23 00		090	X<Y	-41	= SOYD
035	SPC	16-11		091	INT	16 34	
036	RCLD	36 14		092	+	-55	
037	GSB9	23 09	k	093	LSTX	16-63	
038	RCLA	36 11		094	1	01	
039	RCLB	36 12		095	+	-55	
040	-	-45		096	x	-35	
041	ST08	35 08		097	2	02	
042	RCLC	36 13		098	÷	-24	
043	GSB2	23 02		099	RTN	24	Declining Balance
044	ST07	35 07	$\left(\frac{LIFE+1-k}{SOYD}\right)(SBV-SAL)$	100	*LBL6	21 16 13	
045	RCLC	36 13		101	F0?	16 23 00	
046	1	01		102	SPC	16-11	
047	+	-55		103	RCLD	36 14	
048	RCLD	36 14		104	GSB9	23 09	k
049	-	-45		105	GSB4	23 04	
050	RCL7	36 07		106	RCLD	36 14	
051	÷	-24		107	1	01	
052	RCL8	36 08		108	-	-45	
053	x	-35	DEP _k	109	Y*	31	
054	GSB9	23 09		110	RCLA	36 11	
055	RCLC	36 13		111	x	-35	
056	RCLD	36 14		112	RCL8	36 08	

REGIS.

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

A SBV

B SAL

C LIFE

D Y

97 Program Listing II

19

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	X	-35		169	R/S	51	
114	STOI	35 46		170	RTN	24	
115	GSB9	23 09	DEP _k	171	*LBL1	21 01	
116	1	01		172	PRTX	-14	
117	RCL7	36 07		173	RTN	24	
118	RCLD	36 14		174	*LBLd	21 16 14	
119	Y*	31		175	0	00	Crossover point
120	-	-45		176	STOD	35 14	
121	RCLA	36 11	(SBV-SAL)-TOT DEP _k	177	GSB4	23 04	
122	X	-35		178	*LBL8	21 08	
123	STO9	35 09		179	RCL7	36 07	
124	RCLA	36 11		180	1	01	
125	RCLB	36 12		181	GSBD	23 14	
126	-	-45		182	1	01	
127	RCL9	36 09		183	-	-45	
128	-	-45		184	Y*	31	
129	GSB9	23 09	RDV _k	185	RCLA	36 11	
130	RCLB	36 12		186	X	-35	
131	+	-55		187	RCL8	36 08	
132	GSB9	23 09		188	X	-35	
133	RCL9	36 09	RBV _k	189	RCL7	36 07	
134	GSB9	23 09	TOT DEP _k	190	RCLD	36 14	
135	1	01		191	1	01	
136	GSBD	23 14		192	-	-45	
137	RCLC	36 13		193	Y*	31	
138	RCLD	36 14		194	RCLA	36 11	
139	X<Y?	16-35	K<LIFE?	195	X	-35	
140	GT0c	22 16 13		196	RCLB	36 12	
141	RTN	24		197	-	-45	
142	*LBLD	21 14		198	STO9	35 09	
143	RCLD	36 14	To add to register D	199	RCLC	36 13	
144	+	-55		200	1	01	
145	STOD	35 14		201	+	-55	
146	RTN	24		202	RCLD	36 14	
147	*LBL4	21 04		203	-	-45	
148	1	01		204	÷	-24	
149	RCLC	36 13	FACT/LIFE→R ₈	205	X*Y	-41	
150	RCLC	36 13		206	X>Y?	16-34	
151	÷	-24		207	GT08	22 08	
152	STO8	35 08	1-FACT/LIFE→R ₇	208	RCLD	36 14	
153	-	-45		209	1	01	
154	STO7	35 07		210	-	-45	
155	RTN	24		211	GSB9	23 09	Last year
156	*LBLc	21 16 15		212	RCLC	36 13	
157	F0?	16 23 00	Print/pause	213	X*Y	-41	
158	GT00	22 00		214	-	-45	
159	SF0	16 21 00		215	GSB9	23 09	Remaining life
160	1	01		216	RCL9	36 09	
161	RTN	24		217	RCLB	36 12	
162	*LBL0	21 00		218	+	-55	
163	0	00		219	GT09	22 09	RBV
164	CF0	16 22 00		220	R/S	51	
165	RTN	24					
166	*LBL9	21 09					
167	F0?	16 23 00					
168	GT01	22 01					

LABELS

FLAGS

SET STATUS

A	B	C	D	E	0	Print?	FLAGS	TRIG	DISP
^a St.Line	^b SOYD	^c DEC BAL	^d CROSS	^e SCHED?	1		ON OFF	DEG ☒	FIX ☒
⁰ Used	¹ Used	² SOYD	³ Used	⁴ Used	2		0 ☐ ☒	GRAD ☐	SCI ☐
⁵	⁶	⁷	⁸ Used	⁹ Used	3		1 ☐ ☒	RAD ☐	ENG ☐
							2 ☐ ☒		n <u>2</u>
							3 ☐ ☒		

Program Description I

Program Title Invoicing and Inventory Control

Contributor's Name T.R. Cardoso

Address 258 Taylor Ave.,

City Glen Ellyn

State Illinois

Zip Code 60137

Program Description, Equations, Variables This program permits automatic price extension, sub and grand totalling of units and dollars, and automatic removal of units from inventory. Additionally, inventory review and separate inventory addition and subtraction are available options. Error routines are incorporated to recover from unit input error as well as to prevent accidental tampering of permanent inventory and price data. Unlimited number of line items and associated prices are possible via separate data cards.

Inventory and price are stored together in a single register as: UNITS.DOLLARS. Since only 10 digits are available, units.dollars must be accommodated in this space. The program is set up for six digits of units(up to 999,999) and four digits of dollars(up to \$99.99). Registers used for permanent storage of units.dollars are: R₄-R₉ and R₅₀ - R₅₉, a total of 16. Once unit.dollar information is stored in the appropriate registers and notations made of the access code, a data card is passed through the calculator to record this information for later use. Unlimited amount of data can thus be recorded for use, requiring only that each card's code and associated product be notated for reference.

Operating Limits and Warnings Inventory units are stored without modification, i.e. any positive integer. Dollars(price/unit) must be input as a decimal following associated units, i.e. xxxxxx.nnnn, where last two numbers are cents. If larger dollar/unit are required, program must be modified at steps 30 and 82(such change will result in change to possible number of units stored in "inventory").

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

21

Sketch(es)

Sample Problem(s) Store 10,000 units product A @ 2.31/unit in reg. 4(code 4) 15,000 units product B @ 12.15/unit in reg. 5(code 5) and 25000 units product C @ 6.35/unit in R_{S4} (code 14).

What would customer X's invoice sub total be if he ordered 500 units of A, 1000 units of B and 2000 units of C? What inventory would be remaining after this transaction? Review inventory.

After above, enter 5000 units each of A, B and C into inventory. What is inventory total after this?

Solution(s) Data storage (would normally be available on data cards):

A: 10000.0231 STO 4 (note manner of dollar entry)

B: 15000.1215 STO 5

C: 25000.0635 f P-S ST04 f P-S (stored in R_{S4})

Keystrokes for problem:

reset	(f) (A)	-----	0.00
enter code	4 (A)	-----	4.
enter units	500 (B)	-----	1155.00 (dollars/500 units)
Code "B"	5 (A)	-----	5.
	1000 (B)	-----	12150.00 (dollars/1000 units)
Code "C"	14 (A)	-----	14.
	2000 (B)	-----	12700.00 (dollars/2000 units)

Sub Ttl.	(C)	-----	3500*** (sub total units)
Reference(s)			26005 (sub total dollars)
Rev. Inv.	(4) (A)	-----	4. (code for "A")
	(f) (D)	-----	9500. (remaining inventory of "A")
	(5) (A)	-----	5.
	(f) (D)	-----	14000. (remaining inventory of "B")
	(14) (A)	-----	14.
	(F) (D)	-----	23000. (remaining inventory of "C")

To add inventory:

enter code	4 (A)	-----	4.	access code
enter units	5000 (E)	-----	5000.	number of units entered into "A" invent.
code	5 (A)	-----	5.	
	5000 (E)	-----	5000.	number of units entered into "B" invent.
code	14 (A)	-----	14.	
	5000 (E)	-----	5000.	number of units entered into "C" invent.
rev. invent.	4 (A)	-----	4.	
	(f) (D)	-----	14500.	number of "A" units <u>now</u> in inventory
	5 (A)	-----	5.	
	(f) (D)	-----	19000.	number of "B" units <u>now</u> in inventory
	14 (A)	-----	14.	
	(f) (D)	-----	28000.	number of "C" units <u>now</u> in inventory

NOTE: If units input are in error and code has not been changed, re-input units and press (f) (B) to remove from sub total and return units back to inventory. If code has been changed, re-input code and units.

To readjust inventory for physicals taken, input or subtract via (E) or (f) (E) as required.

For new customer, clear sub total via (f) (C) and input appropriate code. Sub total will start from zero, but Grand Total will continue with running unit and dollar totals, recallable by (D).

23



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
	Prepare data cards per instructions on page 1.				
1	Load side 1 of program				
2	Load side 1 and/or side 2 of data card				
3	Clear non-permanent registers		f	A	0.00
4	Enter product code(corresponding to register number on data card)		n	A	n.
5	Enter units sold	nnnnnnn	B		nnnnnnn.
	Options:				
	Recall sub-total		C		units*** dollars
	Recall grand total		D		units*** dollars
	Add to inventory : input code	n	A	E	units
	Subtract from inventory: input code	n	A	fE	units
	Review inventory remaining: input code	n	A	fD	units
	Clear sub-total		f	C	0.00
	Recover error:				
	input code (if changed)	n	A		n.
	input unit error	nnnnnnn	f	B	0.00
	Note: If non-available code is input "Error" will register. Use Clx and input correct code. If "Error" shows after units are input, this indicates lack of inventory. Review inventory. No operations occur if inventory is lacking, so no recovery is necessary. Prices can be updated by changing appropriate registers and recording on data card.				

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

67 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	F 161 A	31 25 11	CODE ACCESSES INVENTORY. PRICE STORED IN R ₄ -R ₉ + R ₃₀ -R ₃₉ VIA SEPARATE DATA CARD		DSP 0	23 00	INPUT INVENTORY into APPROPRIATE REG. ----- Non-permanent Register RESET
	3	03			h RTN	35 22	
	h X > Y	35 52			g 161 a	32 25 11	
	g X < Y	32 71		060	0 -	00	
	g T0 1	22 01			STD 0	33 00	
	1	01			STD 1	33 01	
	9	09			STD 2	33 02	
	h X < Y	35 52			STD 3	33 03	
	g X > Y	32 81			STD A	33 11	
010	g T0 1	22 01			STD B	33 12	
	h ST I	35 33	SHOWS "ERROR" if INACCESSIBLE REGISTER is INPUT. ----- ERROR ROUTINE		STD C	33 13	----- UNITS ERROR ROUTINE SUBTRACTS extension FROM APPROPRIATE REGISTERS.
	DSP 0	23 00			STD D	33 14	
	h RTN	35 22			STD E	33 15	
	F 161 I	31 25 01		070	4	04	
	0	00			h ST I	35 33	
	÷	81			0	00	
	h RTN	35 22			DSP 2	23 02	
	F 161 B	31 25 12			h RTN	35 22	
	STD A	33 11			g 161 b	32 25 12	
020	RCL i	34 24			RCL i	34 11	
	F INT	31 83	Extend PRICE/unit to APPROPRIATE REG. ----- Show "ERROR" if no STOCK REMAINING in INVENTORY. (no OPERATIONS take PLACE).		STD + i	33 61 24	----- UNITS ERROR ROUTINE SUBTRACTS extension FROM APPROPRIATE REGISTERS.
	RCL A	34 11			STD - 0	33 51 00	
	-	51			STD - 2	33 51 02	
	F X < 0	31 71		080	RCL i	34 24	
	GTD 1	22 01			g FRAC	32 83	
	RCL A	34 11			0	01	
	STD - i	33 51 24			0	00	
	STD + 0	33 61 00			0	00	
	STD + 2	33 61 02			X	71	
030	RCL i	34 24			X	71	
	g FRAC	32 83	Recall sub Total Flash units then DOLLARS.		STD - 1	33 51 01	----- CLEARs Sub Total
	0	01			STD - 3	33 51 03	
	0	00			0	00	
	0	00		090	DSP 2	23 02	
	X	71			h RTN	35 22	
	X	71			g 161 c	32 25 13	
	STD + 1	33 61 01			0	00	
	STD + 3	33 61 03			STD 0	33 00	
	DSP 2	23 02			STD 1	33 01	
040	h RTN	35 22			DSP 2	23 02	
	F 161 C	31 25 13	Recall GRAND Total (sum of Sub Totals) and Flash units then DOLLARS.		h RTN	35 22	Reviews inventory After code is input. Inventory Subtract Routine to adjust PER PHYSICAL INVENTORY AS NEEDED.
	RCL 0	34 00			g 161 d	32 25 14	
	DSP 0	23 00			RCL i	34 24	
	F - X -	31 84		100	F INT	31 83	
	RCL 1	34 01			DSP 0	23 00	
	DSP 2	23 02			h RTN	35 22	
	h RTN	35 22			g 161 e	32 25 15	
	F 161 D	31 25 14			STD - i	33 51 24	
	RCL 2	34 02			DSP 0	23 00	
050	DSP 0	23 00			h RTN	35 22	
	F - X -	31 84	Recall GRAND Total (sum of Sub Totals) and Flash units then DOLLARS.		R/S	84	
	RCL 3	34 03					
	DSP 2	23 02					
	h RTN	35 22		110			
	F 161 E	31 25 15					
	STD + i	33 61 24					

REGISTERS

REGISTERS										
0	1	2	3	4	5	6	7	8	9	
S.T. Units	S.T. #	G.T. Units	G.T. #	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	
INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	INV. PRICE	
A Units STORE		B		C		D		E		I CODE

Program Description I

25

Program Title PRODUCTION MONITOR & RECORD PROG #1

Contributor's Name ROBERT K. McDONALD

Address 3587 PINE RIDGE WAY

City SAN JOSE State CAL Zip Code 95127

Program Description, Equations, Variables TAKES 2 ENT., "N" OF UNITS PER JOB (ORDER LOT, & OR ETC.) & HOURS TO COMPLETE & COMPUTES AN EFFICIENCY "N" (SUCH AS UNITS PER SECOND, MINUTE, OR HOUR AS DESIRED) FOR EACH PAIR OF DATA ENTRIES, THEN STORING THE RAW DATA FOR FUTURE RECALL.

THE RAW DATA PLUS THE "N" OF JOBS & WKS IS STORED SIMULTANEDUSLY IN 3 SEPERATE SETS OF REGISTERS WHICH REPRESENTS WK Σ+, MTH. Σ+, & YR Σ+ THAT MAY BE SEPERATELY RCL. AT WILL. THE PROGRAM AUTOMATICLY ADDS 1 FOR EACH PAIR DATA POINTS TO A COUNTER REG & 1 OR DECIMAL TO WKLY COUNTER EACH TIME THE WK REG. IS CLEARED TO PROVIDE (X WK CAL.) OF THE MTH. & YR. RECALL (SEE PROG DESCRIPTION PAGE #2) THE WK. COUNTER IS CALLED UP BY [R/S] AFTER WK AUTO DSP. TO BE MODIFIED IF WK IS SHORT X DAYS, THE 1 or DECIMAL IS THEN ENT. BY [R/S] WHICH ALSO CLEARS WK REG & DSP. CRD TO REMIND USER TO W/DATA IF DESIRED. MTH. REGISTERS MAY ALSO CLEARED FOR SUBSEQUENT MTH. Σ+ WHILE CONTINUING YR Σ+ FOR YR TO DATE X & TOTALS. YR Σ+ REG. MAY NOT BE SEPERATELY CLEARED BY PROG.

SEE PAGE #2 FOR DISCRPTION OF AUTO-DSP MEANING. NOTE: THERE ARE ERROR BLOCKS IN PROG. TO PREVENT STD. ERRORS

Operating Limits and Warnings WK'S REGISTER MUST BE CLEARED BEFORE RESULTS ARE CORRECT FROM MTH & YR'S RCL. DELETE ONLY GOOD FOR LAST ENTRY!

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description I

Program Title **PRODUCTION MONITOR & RECORD**
PROG #1 REVISION A
 Contributor's Name **Robert K. McDonald**
 Address **3587 PINE RIDGE WAY**
 City **SAN JOSE** State **CAL** Zip Code **95127**

Program Description, Equations, Variables **THIS REVISION PROVIDES FOR DIRECT CONVERSION OF HR:MIN:SEC ENTRIES TO HRS IF DESIRED (DELETE STEP 005 IF NOT) IT ALSO SPEEDS UP DATA INPUT TIME BY USING F?0 AS AN INLINE OPERATION RATHER THAN "GSB" OPERATION.**

IT WAS ALSO NECESSARY TO REPOSITION SUB "LBL8" TO GAIN THE ONE STEP FOR HR:MIN:SEC CONVERSION & STILL MAINTAIN ERROR BLOCK PROTECTION THAT PREVENTS AN UNWANTED R/S FROM DESTROYING DATA ALREADY STORED. THE "GTO-UNUSED LBL" SERVES AS AN ABSOLUTE STOP OR BLOCK, (GTO 3).

DELETE IF HR:MIN:SEC CONVERSION NOT DESIRED.

THE REG. "0" TEST STEP'S PREVIOUSLY LOCATED @ 212 213 & 217 WERE ALSO FOUND NOT NECESSARY & DELETED.

Operating Limits and Warnings **BE SURE TO CONVERT HRS IN THE TEST PROBLEMS PAGE 2 & 3 TO HRS:MIN:SEC**
[9] →H.MS IF STEP "005" IS USED.

NOTE: STEP'S "060" & "209" (GTO 3) MAY BE OMITTED FOR MORE PROG STEPS IF SUB-ROUTINES ARE FURTHER RE-ARRANGED SO THAT RECALL ONLY SUB'S FOLLOWS THE RUN COMPLETIONS.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Sample Problem(s) LISTED IS A PROBLEM INVOLVING DATA FROM AN ELECTRO-MASK PATTERN GENERATOR W/THE EFFICIENCY η BASED ON FLASHES PER SECOND:

JOB#	1. (KEY)	2. (KEY)	3. (KEY)	4. KEY	
FLASHES:	500 [A]	1000 [A]	2500 [A]	10000 [A]	1ST WK'S
HOURS:	.02 [R/S]	.14 R/S	.18 [R/S]	.56 [R/S]	INPUTS
EFF. %	(6.94)	(1.98)	(3.86)	(4.96)	← EFF. %

(1ST WK MUST BE CLEARED BEFORE 2ND WK ENT.)

F C → (SEE SOLUTION FOR AUTO DSP). **R/S** 1 (WK COUNTER). **R/S** CLREG

4 REQ. CRD (CLX) MAY ALSO BE USED IF DATA IS NOT TO BE KEPT

FLASHES:	9567 A	10260 A	675 A	15001 A	2ND WK'S
HOURS:	.48 R/S	.98 R/S	.08 R/S	1.32 R/S	INPUTS
FPS.	(5.54)	(2.91)	(2.34)	(3.16)	EFF. N

$\boxed{F} \boxed{C} \rightarrow \text{AUTO DSP.} \cdot \boxed{R/S} \text{ (WK } ^*\text{COUNTER). } \boxed{R/S} \text{ CL REG \& CRD REQ}$

Solution(s)	FL:	14000.00	35503.00	FL:	49503.00
KEY	HR:	0.90	2.86	KEY	24751.50
IN	$\bar{X}$ FPS	4.32	3.45	IN	3.76
[FC]	X JOB HRS:	0.23	0.72	[FD]	1.88
1st & 2nd	X JOB FL	3500.00	8875.75	FOR	3.66
WK'S	HIGH FPS	6.94	5.54	$\bar{X}$ F.P.S.	47
DATA	LOW FPS	1.98	2.34	$\bar{X}$ Job HRS:	6187.88
RCL	n JOBS	1.00	0.00	$\bar{X}$ Job FL:	1
AUTO	TOTAL	4.00	4.00	n OF JOBS:	0.50
DSP.				n < 2 FPS:	

AUTO DSP STOPS →	4.00	4.00		NO OF WK'S:	2.00	MTH FOR
[R/S] →	1.00	1.00		TOTAL Jobs:	8.00	THIS RUN)
WK COUNTER MODIFY FOR SHORT WK			PROGRAM STOPS	X WK TOTJobs:	4.00	
[R/S]	CRD **	CRD **	[R/S]	CLEARS MTH REG & SHOWS CARD DISP TO REMIND OF DATA RETENTION		
** ENTER CARD FOR DATA HOLD & CLEARS WK'S REG.						

User Instructions

PRODUCTION MONITOR # 1

RCL WKST JWKNI CLR	RCL MTHST CLR	RCL YRST
-----------------------	------------------	----------

UNITS HRS

DUP	DEL
-----	-----

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1.	LOAD BOTH SIDES OF PROG CARD		☐ ☐	
2.	LOAD BOTH SIDES OF DATA CARD (UNLESS BEGINNING OF YR)		☐ ☐	
3.	INPUT UNITS VALUE n	500	A ☐	500.00
4.	INPUT HOUR VALUE n ☐ R/S ☐ B	.02	R/S ☐	6.94
5.	PROGRAM PAUSES 1 SEC TO COPY EFF. "N" WHILE STORING DATA TO SAVE TIME (OMIT 021 IF DESIRED) & HALTS ON SAME n		☐ ☐	
6.	(OPTION) IF UNITS "N" IS REPEATED BUT HRS CHANGED KEY IN NEW HR. n &	.07	B ☐	1.98
7.	DELETE — PAUSES 1 SEC. ON DELETED F.P.S. & THEN W/DRAWS UNDESIRE DATA FROM REGS HALTING ON THE CONTENTS OF LOW REG PRESS ☐ h ☐ X ☐ Z ☐ Y TO SEE HIGH REG		D ☐	1.98
8.	DUP-LAST ENTRY		☐ ☐	6.94
9.	RCL WK DATA, AT COMPLETION/ TOTAL n OF JOBS AUTO DSP.		☐ ☐	6.94
10.	AFTER WK'S DATA IS COPIED OFF ON PAPER PRESS R/S TO BRING UP WK-COUNTER n WHICH MAY BE ALTERED TO DECIMAL FOR SHORT WK		C ☐	1.98
11.	W/ 1.00 or ALTERED DECIMAL IN "X" PRESS R/S AGAIN TO CLEAR WK & DSP W/DATA REMINDER		F C ☐	AUTO DSP
12.	MTH RCL USE ONLY AFTER CLR WK PROG HALTS ON $\bar{x}$ WK TOTAL OF JOBS		☐ ☐	2.00
13.	CLEAR MTH FOR NEW MTH'S DATA WHICH RESULTS IN w/data REMINDER (AS W/WK ONLY ACCESSABLE AT END OF AUTO DSP.)		R/S ☐	1.00
14.	RCL YR DATA, COMPLETES ON $\bar{x}$ WK TOTAL JOBS (NO CLR AVAIL)		☐ ☐	
	(SEE PAGE 2 FOR COMPLETE AUTO DSP. DATA.)		R/S ☐	CRD
			F D ☐	AUTO DSP
			☐ ☐	2.00
			R/S ☐	CRD
			F E ☐	AUTO DSP
			☐ ☐	2.00

29

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS												
001 *	LBL A	312511	TEMP. STO OF RAW DATA (*)		GSB 5	312205	* STO												
002	STO A	3311			RCL I	3534	COMPLETE RUN												
003	R/S	84			RTN	3522	* RCL F.P.S.												
004 *	LBL B	312512		060	GTO 3	2203	ERROR BLOCK												
005	H←	3174	USE OR OMIT	*	LBL 8	312508	DEL LAST												
006	STO B	3112	(*)		P↔S	3142	ENTRY OF												
*	LBL C	312513	DUP. ACCESS		RCL 9	3409	HIGH & LOW												
	RCL C	3413	TEMP. STO		RCL 7	3407	F.P.S. AND												
	RCL 9	3409	LAST HIGH &		P↔S	3142	CFO FOR												
010	P↔S	3142	LOW F.P.S.		STO C	3313	COMPLETION												
	STO 9	3309			X↔Y	3552	OF RUN												
	X↔Y	3552			STO 9	3309													
	STO 7	3307			CFO	356100													
	P↔S	3142		070	RTN	3522													
*	LBL 1	31251	DEL. ACCESS	*	LBL 0	312500	LOW REG.												
	RCL A	3411	COMPUTE		9	09	PREP. SUB.												
	RCL B	3412	F.P.S. RATE		STO 9	3309													
	GSB 2	312202	* TEMP. STO		RTN	3522													
	ST I	3533		*	LBL 2	312502	THIS SUB.												
020	PAUSE	3572	DSP F.P.S.		÷	81	COMPUTES F.P.S.												
	RCL 8	3408	TEST FOR		3	03	FROM FLASHES												
	X=0?	3151	CORRECT P↔S		6	06	PER HOUR												
	GSB 6	312206	ORIENTATION		0	00													
	RCL 9	3409	SET LOW STO-R	080	0	00													
	X=0?	3151	TO ACCEPT FUTURE		÷	81													
	GSB 0	312200	TESTS		RTN	3522													
	1	01	JOB COUNTER	*	LBL 4	312504	N < 2 COUNTER												
	F?0	357100	ADDS 1 TO		1	01	ADDS 1 TO WK,												
	CHS	42	WK, MTH, & YR		F?0	357100	MTH, & YR REG.												
030	STO + 0	336100	STO-REG.		CHS	42	FOR JOB'S W/F.P.S.												
	STO + 1	336101			P↔S	3142	UNDER 2												
	STO + 2	336102			STO + 0	336100	(ALSO HAS DELETE												
	RCL A	3411	STO N UNITS	090	STO + 1	336101	FLAG TEST)												
	F?0	357100	IN WK, MTH, & YR		STO + 2	336102													
	CHS	42	STO. REG.		P↔S	3142													
	STO + 3	336103	(STO +)		RTN	3522													
	STO + 4	336104		*	LBL 5	312505	STO LOW F.P.S.												
	STO + 5	336105			RCL I	3534	SUB.												
	RCL B	3412	STO HRS. IN		STO 9	3309													
040	F?0	357100	WK, MTH, & YR		RTN	3522													
	CHS	42	STO - REG	*	LBL 6	322513	WK DATA												
	STO + 6	336106	(STO +)		RCL 3	3403	RECALL W/												
	STO + 7	336107			-X-	3184	5 SEC AUTO												
	STO + 8	336108		100	RCL 6	3406	DSP.												
	RCL I	3534	TEST FOR		-X-	3184													
	2	02	F.P.S. N < 2		GSB 2	312202													
	X > Y?	3281			-X-	3184													
	GSB 4	312204			RCL 6	3406													
	F?0	357100	DEL. FLAG		RCL 0	3400													
050	GTO 8	2208	TEST		÷	81													
	RCL C	3413	TEST FOR HIGH		-X-	3184													
	RCL I	3534	F.P.S. & STO		RCL 3	3403													
	X > Y?	3281			RCL 0	3400													
	STO C	3313		110	÷	81													
	RCL 9	3409	TEST FOR LOW		-X-	3184													
	X > Y?	3281	F.P.S.		RCL C	3413													
REGISTERS																			
0	n WK	1	n MTH	2	n YR	3	UNITS WK	4	UNITS MTH	5	UNITS YR	6	HRS WK	7	HRS MTH	8	HRS YR	9	LOW F.P.S. WK
S0	n < 2 WK	S1	n < 2 MTH	S2	n < 2 YR	S3		S4		S5		S6		S7	TEMP. HIGH F.P.S.	S8	USED	S9	TEMP. LOW F.P.S.
A	LST UNITS	B	LST HRS	C	HIGH F.P.S. WK	D	n OF WKS PER MTH	E	n OF WKS PER YR	I	USED								

67Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS	
	-X-	31 84			R/S	84	CLEAR MTH STO-REG.	
	RCL 9	34 09		170	0	00		
	-X-	31 84			STO 1	33 01		
	P $\Rightarrow$ S	31 42			STO 4	33 04		
	RCL 0	34 00			STO 7	33 07		
	P $\Rightarrow$ S	31 42			STO D	33 14		
	-X-	31 84			P $\Rightarrow$ S	31 42		
	RCL 0	34 00			STO 1	33 01		
	R/S	84			P $\Rightarrow$ S	31 42		
	2	02			W/DATA	31 41		
	3	03	PREP FOR n OF WKS COUNTER		R/S	84	W/DATA REMINDER DSP	
	STO I	35 33	ACCESS TO MODIFY WK COUNTER "n"	180	* LBL 0	32 25 15	YR RECALL DATA	
	1	01			2	02		
	R/S	84			4	04		
	STO+(i)	33 61 24			STO I	35 33		
	ISZ	31 34			RCL 5	34 05		
	STO+(i)	33 61 24		ADD WK "n" COUNTER TO MTH +YR STO-REG.		GSB 7		31 22 07
	0	00		CLEAR WK'S STO-REG'S		RCL 8		34 08
	STO 0	33 00				GSB 7		31 22 07
	STO 3	33 03				RCL 5		34 05
	STO 6	33 06				RCL 8		34 08
	STO 9	33 09			190	GSB 2	31 22 02	
	STO C	33 13			-X-	31 84		
	P $\Rightarrow$ S	31 42			RCL 8	34 08		
	STO 0	33 00			RCL 2	34 02		
	P $\Rightarrow$ S	31 42			$\div$	81		
	W/DATA	31 41	W/DATA REMINDER DSP.			-X-	31 84	
	R/S	84	MTH DATA RECALL		RCL 5	34 05		
140	* LBL d	32 25 14			RCL 2	34 02		
	2	02			$\div$	81		
	3	03			-X-	31 84		
	STO I	35 33			P $\Rightarrow$ S	31 42		
	RCL 4	34 04			RCL 2	34 02		
	GSB 7	31 22 07			GSB 7	31 22 07		
	RCL 7	34 07			P $\Rightarrow$ S	31 42		
	GSB 7	31 22 07			RCL E	34 15		
	RCL 4	34 04			-X-	31 84		
	RCL 7	34 07		RCL 2	34 02			
150	GSB 2	31 22 02		GSB 7	31 22 07			
	-X-	31 84		R/S	84			
	RCL 7	34 07		GTO 3	22 03			
	RCL 1	34 01		210	* LBL 7	31 25 07		
	$\div$	81		-X-	31 84			
	-X-	31 84		RCL (i)	34 24			
	RCL 4	34 04		$\div$	81			
	RCL 1	34 01		-X-	31 84			
	$\div$	81		RTN	35 22			
160	-X-	31 84		* LBL D	31 25 14			
	P $\Rightarrow$ S	31 42		SFO	35 51 00			
	RCL 1	34 01		GTO 1	22 01			
	GSB 7	31 22 07		* LBL 6	31 25 06			
	RCL D	34 14		P $\Rightarrow$ S	31 42			
	-X-	31 84		RTN	35 22			
	P $\Rightarrow$ S	31 42						
	RCL 1	34 01						
	GSB 7	31 22 07						
LABELS				FLAGS		SET STATUS		
A UNITS	B HRS	C $\rightarrow$ DUP	D DEL	E	0 USED	FLAGS	TRIG	DISP
a	b	c RCL WK DATA	d RCL MTH DATA	e RCL YR DATA	1	ON OFF		
0 9 STO 9	1 DEL-ACC	2 $\div$ 3600 $\div$	3 ERROR B	4 LOW STO	2	0 ☐ ☒	DEG ☒	FIX ☒
5 STO LOW	6 P $\Rightarrow$ S CORRECT	7 X WK LOOP	8 DEL HIGH LOW	9 USED	3	1 ☐ ☐	GRAD ☐	SCI ☐
						2 ☐ ☐	RAD ☐	ENG ☐
						3 ☐ ☐		n <u>2</u>

Program Description I

Program Title *67 - Learning Curve*

Contributor's Name *George J. Sellers*

Address *1033 Bishop Walsh Rd.*

City *Cumberland*

State *Md.*

Zip Code *21502*

Program Description, Equations, Variables

$$Y_n = A n^b$$

$$\alpha = 2^b$$

$$b = (\log_{10} \alpha) / (\log_{10} 2)$$

$$\bar{Y}_{i-f} = \frac{A}{(\Delta n + 1)(b + 1)} \left[(n_f + 0.5)^{(b+1)} - (n_i - 0.5)^{(b+1)} \right]$$

Y_n = value at unit n

A = value for initial unit

b = slope of learning curve equation ($\approx .1520$ usually)

α = learning curve factor ($\approx .90$ usually)

$\bar{Y}_{i-f}$ = average unit value between n_i and n_f

n_i = initial unit number for average

n_f = final unit number for average

$\Delta n = n_f - n_i$

Operating Limits and Warnings

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s) Manufacturing of a product yields data which exhibits a learning curve factor of .90 (α) and an initial unit cost of \$500. What is the projected unit cost at unit 1000? An order is anticipated for 600 units when 1000 units have been produced. What is the average unit cost from unit 1001 thru 1600? If a unit price of \$150 must be reached by unit 2000 to be competitive what learning curve factor must be achieved?

Solution(s) Enter program.

500 $\uparrow$, .90 $\boxed{A}$, 1000 $\boxed{B}$

$$Y_{1000} = \$174.97$$

1001 $\uparrow$, 1600 $\boxed{C}$

$$\bar{Y}_{1001 \rightarrow 1600} = \$168.38$$

2000 $\uparrow$, 150 $\uparrow$, 500 $\boxed{D}$

$$\alpha = .8960$$

Reference(s)

User Instructions

Learning Curve

1 $A, b \rightarrow \alpha$ 2

A, α $n \rightarrow y_n$ $n_i, p, n_f \rightarrow \bar{y}_i - y_f$ Clear

[illegible]

67 Program Listing I

34

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	LBL E	31 25 15			STO 1	33 01	
	CL Reg	31 43			$\div$	81	
	CLX	44			log	31 53	
	RTN	35 22		060	$x \rightleftharpoons y$	35 52	
	LBL A	31 25 11			log	31 53	
	log	31 53			$\div$	81	
	2	02			RCL 1	34 01	
	log	31 53			$x \rightleftharpoons y$	35 52	
	$\div$	81			GTO a	22 31 11	
010	LBL a	32 25 11					
	STO 2	33 02					
	R↓	35 53					
	STO 1	33 01					
	RCL 2	34 02		070			
	2	02					
	log	31 53					
	X	71					
	10 ^x	32 53					
	RTN	35 22					
020	LBL B	31 25 12					
	STO 8	33 08					
	RCL 2	34 02					
	y ^x	35 63					
	RCL 1	34 01		080			
	X	71					
	STO 3	33 03					
	RTN	35 22					
	LBL C	31 25 13					
	.	83					
030	5	05					
	+	61					
	STO 5	33 05					
	R↓	35 53					
	log x	35 82		090			
	-	51					
	STO 4	33 04					
	RCL 5	34 05					
	RCL 2	34 02					
	1	01					
040	+	61					
	STO 9	33 09					
	y ^x	35 63					
	RCL 4	34 04					
	RCL 9	34 09					
	y ^x	35 63					
	-	51					
	RCL 1	34 01					
	X	71					
	RCL 9	34 09					
050	$\div$	81					
	RCL 5	34 05					
	RCL 4	34 04					
	-	51					
	$\div$	81					
	RTN	35 22					
	LBL D	31 25 14					

FLAGS		SET STATUS		
		FLAGS	TRIG	DISP
0		ON OFF		
1		0 ☐ ☒	DEG ☒	FIX ☒
2		1 ☐ ☒	GRAD ☐	SCI ☐
3		2 ☐ ☒	RAD ☐	ENG ☐
		3 ☐ ☒		n <u>2</u>

LABELS				
A Enter A, A	B Enter n	C Enter n ₁ , n ₂	D Enter n, y ₀ , A	E Clear
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

REGISTERS

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

Program Description I

Program Title **$\bar{x}$ AND R CONTROL CHARTS**

Contributor's Name

Address

City

State

Zip Code

Program Description

In quality control, a chart is used to decide periodically whether a process is in statistical control. The use of such a chart facilitates the detection and elimination of assignable causes of process variation, thereby reducing rejects and rework, improving product quality, and lowering inspection cost. The $\bar{x}$ chart and R chart are two of the most frequently encountered, they deal with measurement data.

Suppose x_{ij} represents the j^{th} data point from the i^{th} sample, $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$. This program computes (1) the sample mean $\bar{x}$ and the sample range R_i , (2) the over-all mean $\bar{\bar{x}}$ and the average range $\bar{R}$, (3) the upper control limit $U_{\bar{x}}$ and the lower control limit $L_{\bar{x}}$ for $\bar{x}$, and (4) the upper control limit U_R and the lower control limit L_R for R.

Equations:

1.

$$\bar{x}_i = \sum_{j=1}^n x_{ij}/n$$

$$R_i = x_{\max} - x_{\min}$$

where $x_{\max}$ is the maximum of the x values and $x_{\min}$ is the minimum of the x values in the i^{th} sample.

2.

$$\bar{\bar{x}} = \sum_{i=1}^m \bar{x}_i/m$$

$$\bar{R} = \sum_{i=1}^m R_i/m$$

Operating Limits

3.

$$L_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R}$$

$$U_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$$

where A_2 is the factor for the $\bar{x}$ chart, which can be found in the following table.

4.

$$L_R = D_3\bar{R}$$

$$U_R = D_4\bar{R}$$

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description I

Program Title

Contributor's Name

Address

City

State

Zip Code

Program Description, Equations, Variables

D_3 and D_4 are factors for the R chart, which can be found in the table.

Factors for determining from R the 3-sigma control limits for $\bar{x}$ and R charts.

Number of observations in subgroup n	Factor for $\bar{x}$ chart A_2	Factors for R chart	
		Lower limit D_3	Upper limit D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59

Operating Limits a

All factors are based on the normal distribution.

The table is reproduced from *Statistical Quality Control*, by Grant and Leavenworth, 1972, with permission of McGraw-Hill Book Company.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s)

Example:

For the following set of data, find the lower and upper control limits for $\bar{x}$ and R.

	i \ j	1	2	3	4	5
Sample	1	10.04	10.00	10.02	10.01	10.02
	2	10.00	10.01	10.03	10.02	10.01
	3	10.02	10.02	10.02	10.04	10.01

(Note: $n = 5, A_2 = 0.58, D_3 = 0, D_4 = 2.11$)

Keystrokes:

Outputs:

A	→	0.00	
B	→	1.00	
10.04 C	→	10.04 ***	
		1.00 ***	
10 C	→	10.00 ***	
		2.00 ***	
10.02 C	→	10.02 ***	
		3.00 ***	
11.11 C	→	11.11 ***	(error)
		4.00 ***	
11.11 D	→	11.11 ***	(correction)
		3.00 ***	
10.01 C	→	10.01 ***	
		4.00 ***	
10.02 C	→	10.02 ***	
		5.00 ***	
E	→	10.04 ***	($x_{1 \max}$)
E	→	10.00 ***	($x_{1 \min}$)
f A	→	10.02 ***	($\bar{x}_1$)
f A	→	0.04 ***	(R_1)
10 C	→	10.00 ***	
		1.00 ***	
10.01 C	→	10.01 ***	
		2.00 ***	
10.03 C	→	10.03 ***	
		3.00 ***	
10.02 C	→	10.02 ***	
		4.00 ***	

Reference(s)

Program Description II

Sketch(es)

Sample Problem(s)

10.01 **C** → 10.01 ***
5.00 ***

E → 10.03 *** (x_2 max)

E → 10.00 *** (x_2 min)

f A → 10.01 *** ($\bar{x}_2$)

f A → 0.03 *** (R_2)

10.02 **C** → 10.02 ***

1.00 ***

10.02 **C** → 10.02 ***

2.00 ***

10.04 **C** → 10.04 *** (error)

3.00 ***

10.04 **D** → 10.04 *** (correction)

2.00 ***

10.02 **C** → 10.02 ***

3.00 ***

10.04 **C** → 10.04 ***

4.00 ***

Solution(s)

10.01 **C** → 10.01 ***
5.00 ***

E → 10.04 *** (x_3 max)

E → 10.01 *** (x_3 min)

f A → 10.02 *** ($\bar{x}_3$)

f A → 0.03 *** (R_3)

f B → 10.02 *** ($\bar{x}$)

f B → 0.03 *** ($\bar{R}$)

0.58 **f C** → 10.00 *** ($L_{\bar{x}}$)

f C → 10.04 *** ($U_{\bar{x}}$)

Reference(s)

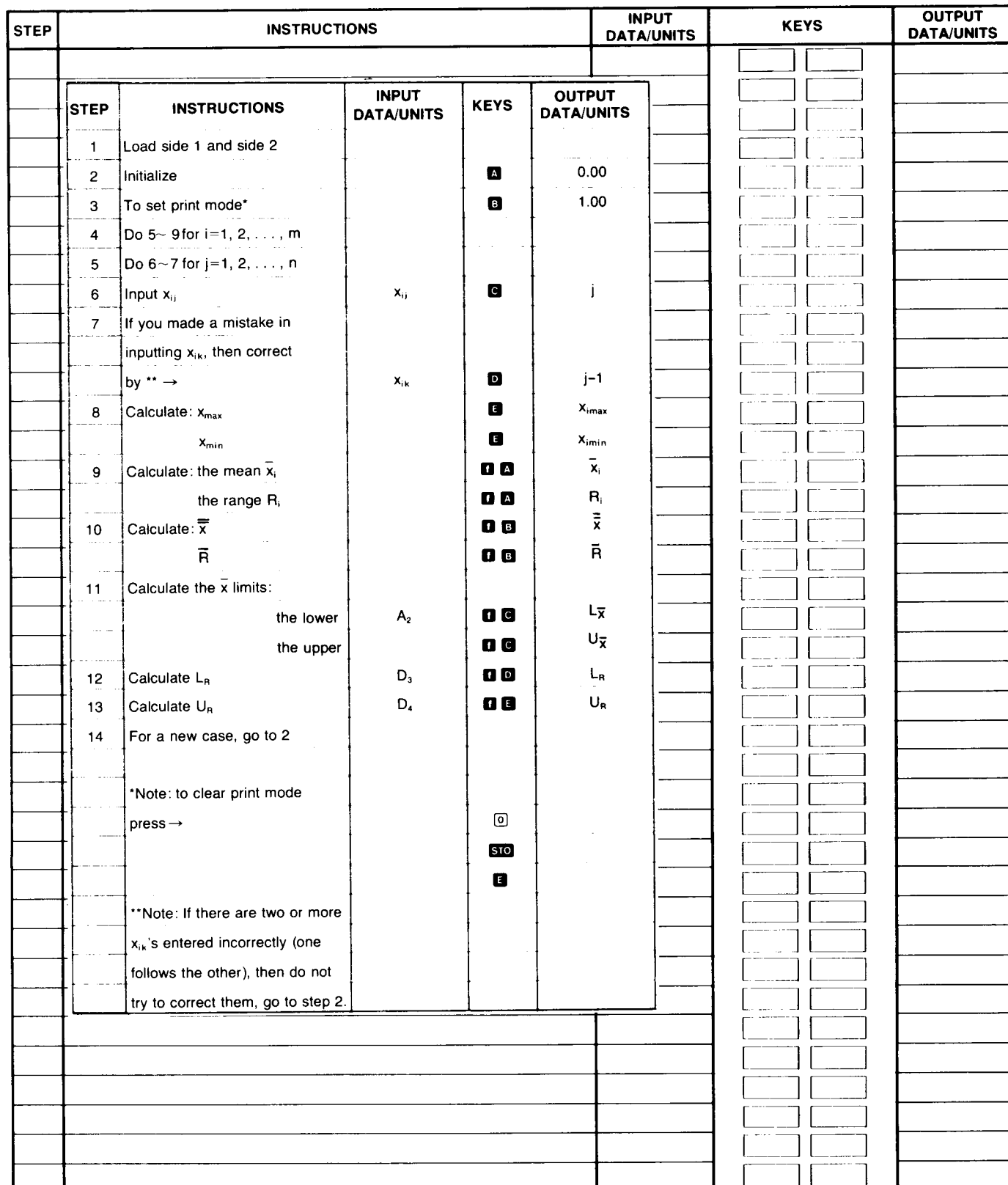
0 **f D** → 0.00 *** (L_R)

2.11 **f E** → 0.07 *** (U_R)

Reference:

Grant and Leavenworth, *Statistical Quality Control*, McGraw-Hill, 1972

39



97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	Initialize	057	R/S	51	
002	CLRG	16-53		058	*LBLB	21 15	
003	CF0	16 22 00		059	RCL5	36 05	
004	CF1	16 22 01		060	GSB9	23 09	
005	0	00		061	RTN	24	
006	RTN	24		062	*LBLC	21 16 11	
007	*LBLB	21 12		063	CF1	16 22 01	
008	1	01		064	RCL6	36 06	
009	STOE	35 15		065	1	01	
010	RTN	24		066	+	-55	
011	*LBLC	21 13	Store 1 in R _E for print.	067	STOE	35 06	$\bar{x}_i$
012	STOE	35 00		068	RCL2	36 02	
013	RCL4	36 04		069	RCL1	36 01	
014	STOA	35 11		070	=	-24	
015	RCL5	36 05		071	GSB9	23 09	
016	STOB	35 12		072	ST+7	35-55 07	
017	RCL0	36 00		073	R/S	51	
018	GSB9	23 09		074	*LBLA	21 16 11	
019	F1?	16 23 01		075	RCL4	36 04	
020	GT01	22 01		076	RCL5	36 05	
021	0	00	Input x _{ij}	077	-	-45	R_i
022	ST01	35 01		078	ST+8	35-55 08	
023	ST02	35 02		079	GSB9	23 09	
024	ST03	35 03		080	GSB7	23 07	
025	XZY	-41		081	R/S	51	
026	ST04	35 04		082	*LBLB	21 16 12	
027	ST05	35 05		083	RCL7	36 07	
028	SF1	16 21 01		084	RCL6	36 06	
029	*LBL1	21 01		085	=	-24	
030	RCL4	36 04		086	GSB9	23 09	
031	XZY	-41		087	RTN	24	$\bar{x}$
032	X>Y?	16-34		088	*LBLB	21 16 12	
033	ST04	35 04		089	RCL8	36 08	
034	RCL5	36 05		090	RCL6	36 06	
035	XZY	-41		091	=	-24	
036	X≤Y?	16-35		092	ST03	35 03	
037	ST05	35 05		093	GSB9	23 09	
038	F0?	16 23 00		094	GSB7	23 07	
039	CHS	-22		095	R/S	51	
040	ST+2	35-55 02		096	*LBLC	21 16 13	
041	X²	53		097	RCL3	36 03	$L\bar{x}$
042	F0?	16 23 00		098	x	-35	
043	CHS	-22		099	RCL7	36 07	
044	ST+3	35-55 03		100	RCL6	36 06	
045	RCL1	36 01		101	=	-24	
046	1	01		102	XZY	-41	
047	F0?	16 23 00		103	-	-45	
048	CHS	-22		104	GSB9	23 09	
049	+	-55		105	R/S	51	
050	ST01	35 01		106	*LBLC	21 16 13	
051	GSB9	23 09	x_{max}, x_{min}	107	LSTX	16-63	$U\bar{x}$
052	RTN	24		108	2	02	
053	*LBLB	21 15		109	x	-35	
054	GSB7	23 07		110	+	-55	
055	RCL4	36 04		111	GSB9	23 09	
056	GSB9	23 09		112	GSB7	23 07	

REGIS.

0	1	2	3	4	5	6	7	8	9
x_{ij}	n	$\sum x_{ij}$	$\sum x_{ij}^2, \bar{R}$	x_{max}	x_{min}	m	$\sum \bar{x}_i$	$\sum R_i$	Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A Last x_{max}		B Last x_{min}		C		D		E 1 for print	

41

[illegible]

Program Description I

Program Title	SINGLE- AND MULTI-SERVER QUEUES		
Contributor's Name			
Address			
City	State	Zip Code	

Program Description

I. Infinite Customers

Suppose there are n ($n \geq 1$) identical stations available to service calls from an infinite number of customers. Let λ be the arrival rate of customers (Poisson input), μ be the service rate of each server (exponential service), and let the service discipline be first-come, first-served. Assume all customers wait in a single line and are directed to whichever station is available. Assume further that, no customers are lost from the queue.

This program computes the following values for given n , λ and μ .

Equations:

1. The intensity factor

$$\rho = \frac{\lambda}{\mu}$$

(ρ must be less than n)

2. The probability that all servers are idle

$$P_0 = \left[\sum_{k=0}^{n-1} \frac{\rho^k}{k!} + \frac{\rho^n}{n! \left(1 - \frac{\rho}{n} \right)} \right]^{-1}$$

3. The probability that all servers are busy

Operating Limits a

$$P_b = \frac{\rho^n P_0}{n! \left(1 - \frac{\rho}{n} \right)}$$

4. The average number of customers in the queue

$$L_q = \frac{\rho P_b}{n - \rho}$$

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description I

Program Title _____

Contributor's Name _____

Address _____

City _____

State _____

Zip Code _____

Program Description, Equations, Variables

5. The average number of customers in the system (waiting or being served)

$$L = L_q + \rho$$

6. The average waiting time in the queue

$$T_q = \frac{L_q}{\lambda}$$

7. The average flow time through the system

$$T = \frac{L}{\lambda}$$

8. The probability of waiting longer than time t

$$P(t) = P_b e^{-(n\mu - \lambda)t}$$

Remarks:

1. n must be an integer greater than or equal to 1.
2. $\rho < n$, otherwise the queue increases without bound.
3. λ and μ are rates, that is, numbers per unit time.

II. Finite Customers

Operating Limits:

Suppose there are n ($n \geq 1$) identical stations available to service calls. This program handles the case in which demand arises from a finite rather than an infinite population of customers.

Let the number of customers m be fixed; let a be the mean time between service calls; and s be the mean time to serve one customer. Given m , n , s and a , this program computes the following values.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description I

Program Title

Contributor's Name

Address

City

State

Zip Code

Program Description

Equations:

1. The average number of customers in the system (waiting or being served)

$$L = \frac{\sum_{k=0}^m k Q_k}{\sum_{k=0}^m Q_k}$$

where

$$Q_0 = 1$$

$$(m - k + 1) \rho Q_{k-1} = \begin{cases} k Q_k & \text{if } 1 \leq k \leq n \\ n Q_k & \text{if } n < k \leq m \end{cases}$$

and

$$\rho = \frac{s}{a}$$

2. The average flow time through the system

$$T = aL$$

3. The average number of customers in the queue

$$L_q = m \left[(\rho + 1) \left(\frac{L}{m} - 1 \right) + 1 \right]$$

Operating Limits:

4. The average waiting time in the queue
5. The over-all efficiency factor of the system

$$F = - (\rho + 1) \left(\frac{L}{m} - 1 \right)$$

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description I

Program Title _____

Contributor's Name _____

Address _____

City _____

State _____

Zip Code _____

Program Description, Equations, Variables

Remarks:

1. For large values of m and/or small values of ρ , the calculation of Q_k in the routine under **(f) (c)** may underflow. To avoid this, the program tests to see if $Q_k < 10^{-90}$. If it does, the program will halt its recursive solution for Q_k and go directly to the calculation of L . This should not affect the calculated value of L .
2. For certain combinations of m , n , s and a , an overflow condition will occur. In that case, the program halts and the display shows all 9's.
3. The execution time for L depends on m ; the larger m is, the longer it takes. A rough estimate of the time for this routine (**(f) (c)**) is given by $m/30$ minutes.
4. Suppose instead of knowing s and a , the service rate μ of each server and the arrival rate λ are given. Then the following formulas can be used to compute s and a in order to run this program.

$$s = \frac{1}{\mu}$$

$$a = \frac{1}{\lambda}$$

Note that

$$\rho = \frac{\lambda}{\mu}$$

References:

Operating Limits :

1. H. M. Wagner, *Principles of Operations Research with Applications to Managerial Decisions*, Prentice-Hall, 1969.
2. James Martin, *Systems Analysis for Data Transmission*, Prentice-Hall, 1972.
3. Hillier and Lieberman, *Introduction to Operations Research*, Holden-Day, 1970.
4. Peck and Hazelwood, *Finite Queuing Tables*, John Wiley and Sons, 1958.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s)

Example 1:

Bank customers arrive at a bank on the average of 1.2 customers per minute. They join a common queue for 3 tellers, each teller serves at a rate of 30 customers per hour. Find ρ , P_0 , P_b , L_q , L , T_q , T and the probability $P(2)$ that a customer will have to wait for more than 2 minutes.

$$\left(\begin{array}{l} \text{Note: Service rate } \mu = \frac{30}{60} = 0.5 \text{ customers per minute} \\ \text{Arrival rate } \lambda = 1.2 \text{ customers per minute} \end{array} \right)$$

Keystrokes:

.5 **ENTER** 1.2 **ENTER** 3 **A**

Outputs:

0.5 *** (μ)
1.20 *** (λ)
3.00 *** (n)
2.40 *** (ρ)

B → 0.06 *** (P_0)

B → 0.65 *** (P_b)

C → 2.59 *** (L_q)

C → 4.99 *** (L)

D → 2.16 *** (T_q)

D → 4.16 *** (T)

2 **E** → 2.00 *** (t)

0.36 *** ($P(t)$)

Solution(s)

Reference(s)

Program Description II

Sketch(es)

Sample Problem(s)

Example 2:

A laundromat has 12 washers which require an average of 4 hours of service after every 60 hours of operation. If there is only one service person in the laundromat, find ρ , L , T , L_q , T_q and F .

Keystrokes:

12 **ENTER** 1 **f** **A**

Outputs:

12.00 *** (m)
1.00 *** (n)

4 **ENTER** 60 **f** **B**

4.00 *** (s)
60.00 *** (a)
0.07 *** (ρ)

f **C**

1.64 *** (L)

f **C**

98.66 *** (T)

f **D**

0.95 *** (L_q)

f **D**

57.24 *** (T_q)

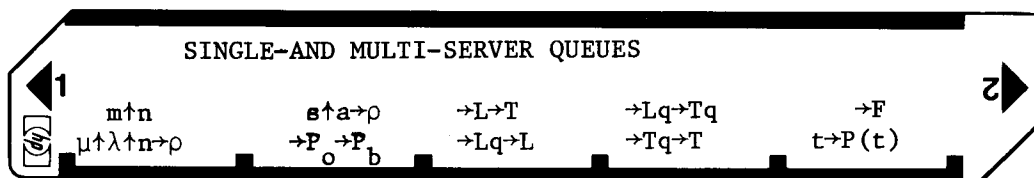
f **E**

0.92 *** (F)

Solution(s)

Reference(s)

User Instructions

[illegible]

97 Program Listing I

49

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	ρ	057	RCL1	36 01	L_q, L
002	GSB9	23 09		058	RCL3	36 03	
003	ST01	35 01		059	-	-45	
004	ST01	35 46		060	$\div$	-24	
005	R↓	-31		061	ST04	35 04	
006	ST02	35 02		062	SPC	16-11	
007	X*Y	-41		063	PRTX	-14	
008	ST05	35 05		064	R/S	51	
009	$\div$	-24		065	*LBLC	21 13	
010	ST03	35 03		066	RCL3	36 03	
011	PRTX	-14		067	+	-55	
012	R/S	51		068	ST06	35 06	
013	*LBLB	21 12		069	PRTX	-14	
014	1	01		070	R/S	51	
015	ST04	35 04		071	*LBLD	21 14	T_q, T
016	0	00		072	RCL4	36 04	
017	*LBL1	21 01		073	RCL2	36 02	
018	RCL4	36 04		074	$\div$	-24	
019	+	-55		075	SPC	16-11	
020	LSTX	16-63		076	PRTX	-14	
021	RCL3	36 03		077	R/S	51	
022	x	-35		078	*LBLD	21 14	
023	RCL1	36 01		079	RCL6	36 06	
024	RCL1	36 46		080	RCL2	36 02	
025	-	-45	P_o, P_b	081	$\div$	-24	$P(t)$
026	1	01		082	PRTX	-14	
027	+	-55		083	R/S	51	
028	$\div$	-24		084	*LBLE	21 15	
029	ST04	35 04		085	SPC	16-11	
030	R↓	-31		086	PRTX	-14	
031	DSZI 16	25 46		087	RCL1	36 01	
032	GT01	22 01		088	RCL5	36 05	
033	1	01		089	x	-35	
034	RCL3	36 03		090	RCL2	36 02	Print u, λ, n .
035	RCL1	36 01		091	-	-45	
036	$\div$	-24		092	x	-35	
037	-	-45		093	CHS	-22	
038	RCL4	36 04		094	e^x	33	
039	X*Y	-41		095	RCL1	36 46	
040	$\div$	-24		096	x	-35	
041	ST01	35 46		097	PRTX	-14	
042	+	-55		098	SPC	16-11	
043	1/X	52		099	R/S	51	
044	SPC	16-11		100	*LBL9	21 09	m, n
045	PRTX	-14		101	R↓	-31	
046	R/S	51		102	R↓	-31	
047	*LBLB	21 12		103	SPC	16-11	
048	RCL1	36 46		104	PRTX	-14	
049	x	-35		105	R↑	16-31	
050	ST01	35 46		106	PRTX	-14	
051	PRTX	-14		107	R↑	16-31	
052	R/S	51		108	PRTX	-14	
053	*LBLC	21 13		109	RTN	24	
054	RCL1	36 46		110	*LBLa 21	16 11	
055	RCL3	36 03		111	GSB8	23 08	
056	x	-35		112	ST02	35 02	

REGISTER

0	1	2	3	4	5	6	7	8	9
	n, m	λ, n	ρ	L_q, k	μ, Q_k, L	L, ZQ_k	$\sum_k Q_k, -F$	a	Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	Used, P_b				

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	R↓	-31		169	ST05	35 05	
114	ST01	35 01		170	SPC	16-11	
115	R/S	51		171	PRTX	-14	
116	*LBL6 21 16 12		<i>p</i>	172	R/S	51	<i>T</i>
117	GSB8	23 08		173	*LBL6 21 16 13		
118	ST08	35 08		174	RCL8	36 08	
119	÷	-24		175	x	-35	
120	ST03	35 03		176	PRTX	-14	
121	PRTX	-14		177	R/S	51	
122	R/S	51		178	*LBLd 21 16 14		<i>Lg</i>
123	*LBL6 21 16 13			179	RCL5	36 05	
124	CLX	-51		180	RCL1	36 01	
125	ST07	35 07		181	÷	-24	
126	1	01		182	1	01	
127	ST04	35 04		183	-	-45	
128	ST05	35 05		184	RCL3	36 03	
129	ST06	35 06		185	1	01	
130	*LBL3	21 03		186	+	-55	
131	RCL2	36 02		187	x	-35	
132	RCL4	36 04		188	ST07	35 07	
133	X>Y?	16-34		189	1	01	
134	X≠Y	-41		190	+	-55	
135	RCL3	36 03		191	RCL1	36 01	
136	X≠Y	-41		192	x	-35	
137	÷	-24		193	SPC	16-11	
138	RCL1	36 01		194	PRTX	-14	
139	RCL4	36 04		195	R/S	51	
140	-	-45		196	*LBLd 21 16 14		<i>Tg</i>
141	1	01	<i>L</i>	197	RCL8	36 08	
142	+	-55		198	x	-35	
143	x	-35		199	PRTX	-14	
144	RCL5	36 05		200	R/S	51	
145	x	-35		201	*LBL6 21 16 15		
146	ST05	35 05		202	RCL7	36 07	
147	EEX	-23		203	CHS	-22	<i>F</i>
148	CHS	-22		204	SPC	16-11	
149	9	09		205	PRTX	-14	
150	0	00		206	SPC	16-11	
151	X>Y?	16-34		207	R/S	51	
152	GT02	22 02		208	*LBL8 21 08		<i>Print m,n,s,a.</i>
153	R↓	-31		209	R↓	-31	
154	ST+6 35-55 06			210	SPC	16-11	
155	RCL4	36 04		211	PRTX	-14	
156	x	-35		212	R↑	16-31	
157	ST+7 35-55 07			213	PRTX	-14	
158	RCL1	36 01		214	RTN	24	
159	RCL4	36 04					
160	1	01					
161	+	-55					
162	ST04	35 04					
163	X≠Y?	16-35					
164	GT03	22 03		220			
165	*LBL2	21 02					
166	RCL7	36 07					
167	RCL6	36 06					
168	÷	-24					

LABELS					FLAGS	SET STATUS		
A	B	C	D	E	0	FLAGS	TRIG	DISP
...	P ₀ →P ₆	L _g →L	T _g →T	t→P(t)		ON OFF		
m↑n→	STa→P	L→T	L _g →T _g	→F	1	0 ☐ ☒	DEG ☒	FIX ☒
	P ₀ ,P ₆	L	K		2	1 ☐ ☒	GRAD ☐	SCI ☐
					3	2 ☐ ☒	RAD ☐	ENG ☐
5	6	7	8 Print	9 Print		3 ☐ ☒		n <u>2</u>

Program Description I

Program Title TWO WAY ANALYSIS OF VARIANCE (WITH REPLICATIONS) FIXED EFFECTS MODEL

Contributor's Name PAUL RAFFELD

Address 7878 LASALLE #239

City BATON ROUGE

State LA.

Zip Code 70806

Program Description, Equations, Variables A TRADITIONAL EQUAL CELL N, 2 WAY ANOVA IS COMPUTED USING THE FOLLOWING FORMULAS:

$$SS_{TOTAL} = \sum_i \sum_j \sum_k x_{ijk}^2 - \left(\sum_i \sum_j \sum_k x_{ijk} \right)^2 / nrc \quad \text{SUM OF SQUARES = SS}$$

$$SS_{ROW} = \sum_i \left(\sum_j \sum_k x_{ijk} \right)^2 / nc - \left(\sum_i \sum_j \sum_k x_{ijk} \right)^2 / nrc$$

$$SS_{COLS} = \sum_j \left(\sum_i \sum_k x_{ijk} \right)^2 / nr - \left(\sum_i \sum_j \sum_k x_{ijk} \right)^2 / nrc$$

$$SS_{INTERACTION} = \sum_i \sum_j \left(\sum_k x_{ijk} \right)^2 / n - SS_{ROW} - SS_{COL} + \left(\sum_i \sum_j \sum_k x_{ijk} \right)^2 / nrc$$

$$SS_{ERROR} = \sum_i \sum_j \sum_k x_{ijk}^2 - \sum_i \sum_j \left(\sum_k x_{ijk} \right)^2 / n$$

DEGREES OF FREEDOM: — $df_{ROW} = r-1$, $df_{COL} = c-1$, $df_{INT.} = (r-1)(c-1)$
 $df_{ERROR} = rc(n-1)$

MEAN SQUARES: — $MS_{ROW} = SS_{ROW} / df_{ROW}$, $MS_{COL} = SS_{COL} / df_{COL}$, $MS_{INT.} = SS_{INT.} / df_{INT.}$
 $MS_{ERROR} = SS_{ERROR} / df_{ERROR}$ [$F = MS_{EFFECT} / MS_{ERROR}$] $r, COL, INT.$

ω^2 ASSOCIATION: $\omega^2_{ROW} = \frac{SS_{ROW} - (r-1)MS_{ERROR}}{MS_{ERROR} + SS_{TOTAL}}$, $\omega^2_{COL} = \frac{SS_{COL} - (c-1)MS_{ERROR}}{MS_{ERROR} + SS_{TOTAL}}$

$\omega^2_{INT.} = \frac{SS_{INT.} - (r-1)(c-1)MS_{ERROR}}{MS_{ERROR} + SS_{TOTAL}}$

Operating Limits and Warnings A MAXIMUM OF 16 CELLS ARE ALLOWED (ie; ROW X COLS ≤ 16) IF THIS LIMIT IS EXCEEDED, AN "ERROR" CONDITION WILL SHOW IN THE DISPLAY. ONLY ERRORS MADE WHILE ENTERING DATA IN A CELL CAN BE CORRECTED, EXCEPT FOR THE LAST CELL ENTRY! ω^2 VALUES THAT ARE NEGATIVE SHOULD BE TREATED AS 0.

This program has been verified only with respect to the numerical example given in Program Description II. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s) A 2×4 FIXED EFFECTS ANOVA — TWO LEVELS OF SOCIAL REINFORCEMENT A_1 & A_2 AND FOUR LEVELS OF DEPRIVATION $B_1 \dots B_4$

	B_1	B_2	B_3	B_4
A_1	3	4	7	7
	6	5	8	8
	3	4	7	9
	3	3	6	8
A_2	1	2	5	10
	2	3	6	10
	2	4	5	9
	2	3	6	11

Solution(s) $2 \uparrow 4 \uparrow 4 [A] \rightarrow 0.00$

$3[B] 6[B] 3[B] 3[B] \rightarrow 4.00/1.00 \quad 4[B] 5[B] 4[B] 3[B] \dots 10[B] 10[B] 9[B] 11[B] \rightarrow 4.00/8.00$

[C]

$$\begin{aligned}
 SS_{TOT} &= 235.50 & MS_{INT} &= 6.46 \\
 SS_{ROW} &= 3.13 & MS_{ERROR} &= 0.77 \\
 SS_{COL} &= 194.50 & F_{ROW} &= 4.05 \\
 SS_{INT} &= 19.38 & F_{COL} &= 84.11 \\
 SS_{ERROR} &= 18.50 & F_{INT} &= 8.38 \\
 df_{ROW} &= 1.00 & W_{ROW}^2 &= .0100
 \end{aligned}$$

Reference(s) KIRK, R.E. EXPERIMENTAL DESIGN :
PROCEDURES FOR THE BEHAVIORAL
SCIENCES. BROOKS/COLE PUBLISHING &
COMP., CALIF., 1968.

$$\begin{aligned}
 df_{COL} &= 3.00 & W_{COL}^2 &= .8134 \\
 df_{INT} &= 3.00 & W_{INT}^2 &= .0722 \\
 df_{ERROR} &= 24.00 \\
 MS_{ROW} &= 3.13 \\
 MS_{COL} &= 64.83
 \end{aligned}$$

User Instructions

53

1

TWO WAY ANALYSIS OF VARIANCE WITH REPLICATIONS (CARD 1)

2

(4)
 Y↑COL↑CELL $X_{ijk} \rightarrow n_i$
 COMPUTE
 PRT CELL ?
REMOVE CELL ERROR

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	LOAD SIDE 1 AND SIDE 2			
2	OPTIONAL PRT. CELL & SUM MODE		D	
3	INPUT # OF ROWS *	# OF ROWS	↑	
4	INPUT # OF COLS *	# OF COLS	↑	
5	INPUT # IN CELL ** (ALL REGS. ARE CLEARED)	# IN CELL	A	0.00
	* Rows x COLS ≤ 16			
	** CELL SIZES MUST BE EQUAL			
6	PERFORM (6) FOR $i=1,2,\dots,r, j=1,2,\dots,c, k=1,2,\dots,n$	X_{ijk}	B	$n_k / \text{CELL \#}$
7	OPTIONAL - CORRECT ERRONEOUS X_{ijk} ***	UNWANTED X_{ijk}	E	
	*** CORRECT ONLY WITHIN A CELL AND CANNOT CORRECT LAST CELL ENTRY.			
8	BEGIN COMPUTATIONS		C	SS TOTAL
9	INSERT CARD 2 IN READER AFTER PRESSING (C) IN (8)			SS ROW
				SS COL
				SS INT
				SS ERROR
				df ROW
				df COL
				df INT
				df ERROR
				MS ROW
				MS COL
				MS INT
				F ROW
				F COL
				F INT
				W^2 ROW
				W^2 COL
				W^2 INT
STEP	INSTRUCTIONS			
1	INSERT CARD 2 IN READER AFTER PRESSING (C) ON CARD 1			

1

TWO WAY ANALYSIS OF VARIANCE WITH REPLICATIONS (CARD 2)

2

(4)
 AUTO - READ

97 Program Listing I

54

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	INITIALIZE \$ STORE Rows Cols # IN CELL	057	R↓	-31	
002	CLRG	16-53		058	R↓	-31	
003	P2S	16-51		059	ST+1	35-55 45	
004	CLRG	16-53		060	ISZI	16 26 46	
005	STOA	35 11		061	X²	53	
006	R↓	-31		062	ST+1	35-55 45	
007	STOP	35 12		063	R↑	16-31	
008	R↓	-31		064	X²I	16-41	
009	STOC	35 13		065	0	00	
010	R↑	16-31		066	STOD	35 14	
011	X	-35	ERROR CHECK FOR Row X Col > 16 ENTRY OF Xijk	067	RCLB	36 12	SET FLAG FOR PRINTING OF CELL DATA & SUM REMOVE CELL ERROR
012	1	01		068	RCLC	36 15	
013	E	06		069	X=Y?	16-33	
014	X²Y	-41		070	GSB2	23 02	
015	X²Y?	16-34		071	ISZI	16 26 46	
016	GT09	22 09		072	RCLI	36 46	
017	1	01		073	1	01	
018	STOI	35 46		074	-	-45	
019	0	00		075	RTN	24	
020	RTN	24		076	*LBLD	21 14	
021	*LBL9	21 09	COMPUTE \$ STORE CELL & Row Sums \$ Sums of Squares	077	SF1	16 21 01	CLEAR \$ RESET FOR NEXT Row
022	0	00		078	RTN	24	
023	÷	-24		079	*LBLE	21 15	
024	RTN	24		080	ST-1	35-45 45	
025	*LBLB	21 12		081	X²	53	
026	F1?	16 23 01		082	ST-0	35-45 00	
027	PRTX	-14		083	RCLD	36 14	
028	ST+1	35-55 45		084	1	01	
029	X²	53		085	-	-45	
030	ST+0	35-55 00		086	STOD	35 14	
031	RCLD	36 14		087	RTN	24	BEGIN GENERATION OF Sums of Squares & ANOVA TABLE
032	1	01		088	*LBL2	21 02	
033	+	-55		089	1	01	
034	STOD	35 14		090	7	07	
035	RCLA	36 11		091	X²I	16-41	
036	RCLD	36 14		092	STOE	35 15	
037	X=Y?	16-33		093	RCL1	36 45	
038	GSB1	23 01		094	X²	53	
039	RTN	24		095	ISZI	16 26 46	
040	*LBL1	21 01		096	ISZI	16 26 46	
041	PSE	16 51		097	ST+1	35-55 45	
042	RCLC	36 15		098	DSZI	16 25 46	
043	1	01		099	DSZI	16 25 46	
044	+	-55		100	0	00	
045	STOE	35 15		101	STOI	35 45	
046	RCL1	36 45		102	RCLC	36 15	
047	F1?	16 23 01		103	X²I	16-41	
048	SPC	16-11		104	0	00	
049	F1?	16 23 01		105	STOE	35 15	
050	PRTX	-14		106	RTN	24	
051	F1?	16 23 01		107	*LBLC	21 13	
052	SPC	16-11		108	RCL0	36 00	
053	RCLI	36 46		109	STOE	35 15	
054	1	01		110	0	00	
055	7	07		111	STO0	35 00	
056	X²I	16-41		112	1	01	

REGISTERS

0 USED	1 CELL 1	2 CELL 2	3 CELL 3	4 CELL 4	5 CELL 5	6 CELL 6	7 CELL 7	8 CELL 8	9 CELL 9
S0 CELL 10	S1 CELL 11	S2 CELL 12	S3 CELL 13	S4 CELL 14	S5 CELL 15	S6 CELL 16	S7 USED	S8 USED	S9 USED
A # IN CELL	B # COLS.	C # Rows	D USED	E USED	I USED				

97 Program Listing II

55

STPD	KEY ENTRY	KEY CODE	COMMENTS	STPD	KEY ENTRY	KEY CODE	COMMENTS
113	STOI	35 46		169	DSZI	16 25 46	
114	STOD	35 14		170	RCLA	36 11	
115	*LBL _e	21 16 15		171	ST÷i	35-24 45	
116	RCLB	36 12		172	DSZI	16 25 46	
117	RCLC	36 13		173	RCLC	36 13	
118	*	-35		174	RCLA	36 11	
119	RCLD	36 14		175	*	-35	
120	+	-55		176	ST÷i	35-24 45	
121	X=Y?	16-33		177	RCL0	36 00	
122	GT03	22 03		178	X²	53	
123	RCLi	36 45		179	RCLA	36 11	
124	ST+0	35-55 00		180	RCLB	36 12	
125	RCLB	36 12		181	*	-35	
126	RCLi	36 46		182	RCLC	36 13	
127	+	-55		183	*	-35	
128	STOI	35 46		184	STOA	35 11	
129	GT0 _e	22 16 15		185	÷	-24	
130	*LBL3	21 03		186	ST00	35 00	
131	RCLD	36 14		187	*LBL5	21 05	
132	RCLB	36 12		188	RCL0	36 00	
133	1	01		189	ST-i	35-45 45	
134	+	-55		190	ISZI	16 26 46	
135	X=Y?	16-33		191	RCLi	36 46	
136	GT04	22 04		192	2	02	
137	RCLD	36 14		193	0	00	
138	1	01		194	X#Y?	16-32	
139	+	-55		195	GT05	22 05	
140	STOI	35 46		196	RCL _E	36 15	
141	STOD	35 14		197	RCL0	36 00	
142	RCL0	36 00		198	-	-45	
143	X²	53		199	ST0E	35 15	
144	P÷S	16-51		200	P÷S	16-51	
145	ST+7	35-55 07		201	RCL7	36 07	
146	P÷S	16-51		202	RCL8	36 08	
147	0	00		203	X#Y	-41	
148	ST00	35 00		204	ST08	35 08	
149	RCLi	36 46		205	R↓	-31	
150	GT0 _e	22 16 15		206	ST07	35 07	
151	*LBL4	21 04		207	RCL _E	36 15	
152	0	00		208	RCL7	36 07	
153	ST00	35 00		209	-	-45	
154	1	01		210	STOD	35 14	
155	6	06		211	RCL7	36 07	
156	STOI	35 46		212	RCL8	36 08	
157	*LBL ₆	21 16 12		213	-	-45	
158	RCLi	36 45		214	RCL9	36 09	
159	ST+0	35-55 00		215	-	-45	
160	DSZI	16 25 46		216	ST07	35 07	
161	GT0 ₆	22 16 12		217	RCL _E	36 15	
162	1	01		218	SPC	16-11	
163	9	09		219	PRTX	-14	
164	STOI	35 46		220	RCL9	36 09	
165	RCLA	36 11		221	PRTX	-14	
166	RCLB	36 12		222	RCL8	36 08	
167	*	-35		223	PRTX	-14	
168	ST÷i	35-24 45		224	PSE	16 51	

BEGIN
PRINT
ROUTINE

LABELS					FLAGS	SET STATUS		
A Yow CELL COL INIT.	B X _{ijk} → n	C COMPUTE	D STF1	E Z -	0 -	FLAGS	TRIG	DISP
a	b USED	c	d	e USED	1 USED	ON OFF		
0	1 USED	2 USED	3 USED	4 USED	2 -	0 ☐ ☒	DEG ☒	FIX ☒
5 USED	6	7	8	9 ERROR	3 -	1 ☐ ☒	GRAD ☐	SCI ☐
						2 ☐ ☒	RAD ☐	ENG ☐
						3 ☐ ☒		n <u>2</u>

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	RCL7	36 07		057	6	06	
002	PRTX	-14		058	X#Y?	16-32	
003	RCLD	36 14		059	GT07	22 07	
004	PRTX	-14		060	SPC	16-11	
005	SPC	16-11		061	DSP4	-63 04	
006	RCLC	36 13		062	RCLC	36 13	
007	1	01		063	RCL9	36 09	
008	-	-45		064	X	-35	
009	STOC	35 13		065	RCLC	36 13	
010	PRTX	-14		066	RCLD	36 14	
011	ST=9	35-24 09		067	X	-35	
012	RCLB	36 12		068	-	-45	
013	1	01		069	RCLD	36 14	
014	-	-45		070	RCLE	36 15	
015	STOB	35 12		071	+	-55	
016	PRTX	-14		072	=	-24	
017	ST=8	35-24 08		073	PRTX	-14	
018	RCLB	36 12		074	RCLB	36 12	
019	RCLC	36 13		075	RCL8	36 08	
020	X	-35		076	X	-35	
021	STOI	35 46		077	RCLB	36 12	
022	PRTX	-14		078	RCLD	36 14	
023	ST=7	35-24 07		079	X	-35	
024	RCLA	36 11		080	-	-45	
025	RCLB	36 12		081	RCLD	36 14	
026	-	-45		082	RCLE	36 15	
027	RCLC	36 13		083	+	-55	
028	-	-45		084	=	-24	
029	RCLI	36 46		085	PRTX	-14	
030	-	-45		086	RCLB	36 12	
031	1	01		087	RCLC	36 13	
032	-	-45		088	X	-35	
033	PRTX	-14		089	RCL7	36 07	
034	RCLD	36 14		090	X	-35	
035	X#Y	-41		091	RCLB	36 12	
036	=	-24		092	RCLC	36 13	
037	STOD	35 14		093	X	-35	
038	SPC	16-11		094	RCLD	36 14	
039	RCL9	36 09		095	X	-35	
040	PRTX	-14		096	-	-45	
041	RCL8	36 08		097	RCLD	36 14	
042	PRTX	-14		098	RCLE	36 15	
043	RCL7	36 07		099	+	-55	
044	PRTX	-14		100	=	-24	
045	RCLD	36 14		101	PRTX	-14	
046	PRTX	-14		102	RTN	24	
047	SPC	16-11		103	R/S	51	
048	9	09					
049	STOI	35 46					
050	*LBL7	21 07					
051	RCL7	36 45					
052	RCLD	36 14					
053	=	-24					
054	PRTX	-14					
055	DSZI	16 25 46					
056	RCLI	36 46					

REGISTERS

0	1	2	3	4	5	6	7	8	9
—	—	—	—	—	—	—	MS _{INT}	MS _{COL}	MS _{ROW}
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
USED	USED	USED	USED	USED	USED	USED	USED	USED	—
A	B	C	D	E	F	G	H	I	J
N	df _{COL}	df _{ROW}	MS _{ERROR}	SS _{TOTAL}	USED				

Program Description I

57

Program Title Multiple Linear Regression for 3 Independent Variables

Contributor's Name

Address

City

State

Zip Code

Program Description, Equations, Variables Regression coefficients a, b, c, and d can be found by solving the following system of equations. Gauss' elimination method is applied.

$$\sum t_i = na + b \sum x_i + c \sum y_i + d \sum z_i$$

$$\sum x_i t_i = a \sum x_i + b \sum (x_i)^2 + c \sum (x_i y_i) + d \sum (x_i z_i)$$

$$\sum y_i t_i = a \sum y_i + b \sum (x_i y_i) + c \sum (y_i)^2 + d \sum (y_i z_i)$$

$$\sum z_i t_i = a \sum z_i + b \sum (z_i x_i) + c \sum (y_i z_i) + d \sum (z_i)^2$$

Also the multiple correlation coefficient is

$$R^2 = \frac{a \sum t_i + b \sum x_i t_i + c \sum y_i t_i + d \sum z_i t_i - \frac{1}{n} (\sum t_i)^2}{\sum t_i^2 - \frac{1}{n} (\sum t_i)^2}$$

This program also allows the user to choose a regression with zero intercept (i.e., $a = 0$).

Multiple linear regression with two independent variables can also be calculated by using this program; refer to the examples for details.

Operating Limits and Warnings

The set of data points must not be collinear nor coplanar.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s) A set of data points are given as the following:

i	1	2	3	4	5
x_i	7	1	11	11	7
y_i	25	29	56	31	52
z_i	6	15	8	8	6
t_i	60	52	20	47	33

Find the regression coefficients a, b, c, d, R^2 , sums of squares, and sums of cross products.

Solution(s) Load side one and two of card 1.

[A] 7 [↑] 25 [↑] 6 [↑] 60 [C]----> 1, 1 [↑] 29 [↑] 15 [↑] 52 [C]----> 2,.....

7 [↑] 52 [↑] 6 [↑] 33 [C]----> 5

($\Sigma x_i = 37, \Sigma y_i = 193, \Sigma z_i = 43, \Sigma t_i = 212,$

$\Sigma xy = 1525, \Sigma xz = 275, \Sigma xt = 1440, \Sigma yz = 1593, \Sigma yt = 7301, \Sigma zt = 1874,$

$\Sigma x^2 = 341, \Sigma y^2 = 8267, \Sigma z^2 = 425, \Sigma t^2 = 10002)$

Load side one and two of card 2. Switch to **NORM**.

[C]----> $a = 103.447, b = -1.284, c = -1.037, d = -1.339; [D]----> R^2 = 0.999$

7 [↑] 25 [↑] 6 [E]----> $\hat{t} = 60.50$

Reference(s) Draper & Smith "Applied Regression Analysis" John Wiley & Sons, Inc. 1966

Program Description II

Sketch(es)

	i	1	2	3	4	5
x		1	2	3	4	5
y		2	3	9	11	7
z		3	7	7	9	3
t		14	29	42	53	28

Sample Problem(s) Example 2: Decide the regression line for the above set of data points.

Solution:

Load side 1 and side 2 of card 1. **A** **B**

1 **↑** 2 **↑** 3 **↑** 14 **C** → $1(x_1), 2(y_1), 3(z_1), 14(t_1), 1.(i)$

2 **↑** 3 **↑** 7 **↑** 29 **C** →

3 **↑** 9 **↑** 7 **↑** 42 **C** →

4 **↑** 11 **↑** 9 **↑** 53 **C** →

5 **↑** 7 **↑** 3 **↑** 28 **C** →

E → $15(\Sigma x), 32(\Sigma y), 29(\Sigma z), 166(\Sigma t).$

f **D** → $114(\Sigma xy), 89(\Sigma xz), 550(\Sigma xt), 210(\Sigma yz), 1272(\Sigma yt), 1100(\Sigma zt).$

f **E** → $55(\Sigma x^2), 264(\Sigma y^2), 197(\Sigma z^2), 6394(\Sigma t^2).$

To store data on a card, **f** **WRITE DATA**.

Load side 1 and side 2 of card 2. Switch to **NORM**

C → $1.000....-8(a), 1.000(b), 2.000(c), 3.000(d).$

D → $1.000(R^2)$

The tiny value of "a" suggests zero intercept. Therefore load data card and

f **C** → $1.000(b), 2.000(c), 3.000(d)$

D → $1.000(R^2), 4 \uparrow 11 \uparrow 9 \text{ **E** } \rightarrow 53(\hat{t}), 5 \uparrow 7 \uparrow 3 \text{ **E** } \rightarrow 28(\hat{t}).$

Therefore the set of data points is an exact zero intercept regression line.

Reference(s)

Program Description II

Sketch(es)

i	1	2	3	4
x	1.5	0.45	1.8	2.8
y	0.7	2.3	1.6	4.5
t	2.1	4.0	4.1	9.4

Sample Problem(s) Example 3: For the above set of data points, find the regression line with two independent variables.

i.e., $t = a + bx + cy$

Solution: Simply consider all the z_i 's as zero, and treat this problem as an 3 independent variable linear regression.

Keystrokes:

Load side 1 and side 2 of card 1. [A] [B]

1.5[↑].7[↑]0[↑]2.1[C] → 1.5(x_1), 0.7(y_1), 0(z_1), 2.1(t_1), 1(i).

.45[↑]2.3[↑]0[↑]4[C] →,

1.8[↑]1.6[↑]0[↑]4.1[C] →,

2.8[↑]4.5[↑]0[↑]9.4[C] →,

[E] → 6.55, 9.10, 0, 19.6 (Σx , Σy , Σz , Σt)

[f][D] → 17.57, 0, 38.65, 0, 59.53, 0. (Σxy , Σxz , Σxt , Σyz ...)

[f][E] → 13.53, 28.59, 0, 125.58 (Σx^2 , Σy^2 , Σz^2 , Σt^2)

Load side 1 and side 2 of card 2. Switch to [NORM].

[C] → -0.097(a), 0.791(b), 1.627(c), 0(d).

[D] → 0.998 (R^2)

2[↑]3[↑]0[E] → 6.366($\hat{t}$)

Reference(s)

User Instructions

Multiple Linear Regression Card 1

1



Start

Print?

$x_i \uparrow \dots \rightarrow (\Sigma+)$

$\rightarrow \Sigma xy, \dots \rightarrow \Sigma x^2, \dots$

$x_j \uparrow \dots \rightarrow (\Sigma-)$

$\rightarrow \Sigma x_j, \dots$

2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and 2 of card 1		C D	
2	Initialize		A D	0.00
3	To set print mode*		B D	1.00
4	Do step 5 6 for $i = 1, 2, \dots, n$		C D	
5	Input data: x_i	x_i	↑ D	
	y_i	y_i	↑ D	
	z_i	z_i	↑ D	
	t_i	t_i	C D	i
6	If you made a mistake in inputting x_j, y_j, z_j, t_j , then correct by ---->	x_j	↑ D	
		y_j	↑ D	
		z_j	↑ D	
		t_j	D D	j - 1
7	(optional) Recall the sums		E D	$\Sigma x_i, \Sigma y_i, \Sigma z_i$
			C D	Σt_i
8	(optional) Recall the sums of products		f D	$\Sigma xy, \Sigma xz, \Sigma xt$
			C D	$\Sigma yz, \Sigma yt, \Sigma zt$
9	(optional) Recall the sums of squares		f E	$\Sigma x_i^2, \Sigma y_i^2,$
			C D	$\Sigma z_i^2, \Sigma t_i^2$
10	(Optional) To record data, press f WRITE DATA and record.		C D	
11	Load side 1 and side 2 of card 2.		C D	
12	For zero intercept, go to step 14.		C D	
13	Calculate normal regression coefficients then go to step 15		C D	a,b,c,d
14	Calculate zero intercept regression coefficients		f C	b,c,d
15	Calculate the correlation coefficient		D D	R^2
16	Calculate estimated $\hat{t}$ from regression input x	x	↑ D	
	y	y	↑ D	
	z	z	E D	$\hat{t}$
17	Repeat step 16 for different (x, y, z)'s		C D	
18	For a different regression, load data card and go to step 12.		C D	
			C D	
			C D	
	USER INSTRUCTIONS Continued next page		C D	
			C D	
			C D	

User Instructions

Multiple Linear Regression Card 2

1 ←

→b,c,d

→a,b,c,d

→R²

x↑y↑z →ŷ

→ 2

[illegible]

97 Program Listing I Card 1

63

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	Initialize	057	x	-35	
002	CF0	16 22 00		058	GSB0	23 00	
003	CF1	16 22 01		059	ST+7	35-55 07	
004	CLRG	16-53		060	P+S	16-51	
005	P+S	16-51		061	ST+1	35-55 01	
006	CLRG	16-53		062	P+S	16-51	
007	P+S	16-51		063	RCLA	36 11	
008	0	00		064	RCLD	36 14	
009	RTN	24		065	x	-35	
010	*LBLB	21 12		066	GSB0	23 00	
011	SF0	16 21 00	Set flag for print	067	ST+9	35-55 09	
012	1	01		068	RCLB	36 12	
013	RTN	24		069	RCLC	36 13	
014	*LBLC	21 13		070	x	-35	
015	X+I	16-41		071	GSB0	23 00	
016	ST+1	35-55 01		072	P+S	16-51	
017	ST+2	35-55 02		073	ST+3	35-55 03	
018	ST+3	35-55 03		074	ST+7	35-55 07	
019	ST+4	35-55 04		075	RCLB	36 12	
020	X+I	16-41		076	RCLD	36 14	
021	STOD	35 14	Input x_i, y_i, z_i, t_i , and calculate	077	x	-35	
022	GSB0	23 00		078	GSB0	23 00	
023	ST+4	35-55 04		079	ST+4	35-55 04	
024	X ²	53		080	RCLC	36 13	
025	GSB0	23 00		081	RCLD	36 14	
026	ST+0	35-55 00		082	x	-35	
027	R+	-31		083	GSB0	23 00	
028	STOC	35 13		084	ST+9	35-55 09	
029	GSB0	23 00		085	RCLA	36 11	
030	ST+3	35-55 03		086	RCLC	36 13	
031	P+S	16-51		087	x	-35	
032	ST+5	35-55 05		088	GSB0	23 00	
033	X ²	53		089	ST+6	35-55 06	
034	GSB0	23 00		090	P+S	16-51	
035	ST+0	35-55 00		091	ST+8	35-55 08	
036	P+S	16-51		092	F0?	16 23 00	
037	R+	-31		093	GSB9	23 09	
038	STOB	35 12		094	RCLI	36 46	
039	GSB0	23 00		095	1	01	
040	ST+2	35-55 02		096	GSB0	23 00	
041	P+S	16-51		097	+	-55	
042	ST+0	35-55 00		098	STOI	35 46	
043	X ²	53		099	RCL4	36 04	
044	GSB0	23 00		100	STOA	35 11	
045	ST+2	35-55 02		101	RCLI	36 46	
046	P+S	16-51		102	STOB	35 12	
047	R+	-31		103	ST=1	35-24 01	
048	STOA	35 11		104	ST=2	35-24 02	
049	GSB0	23 00		105	ST=3	35-24 03	
050	ST+1	35-55 01		106	ST=4	35-24 04	
051	ST+5	35-55 05		107	F0?	16 23 00	
052	X ²	53		108	GSB8	23 08	
053	GSB0	23 00		109	RTN	24	
054	ST+6	35-55 06		110	*LBL9	21 09	
055	RCLA	36 11		111	RCLA	36 11	
056	RCLB	36 12		112	PRTX	-14	

REGISTERS

⁰ $\Sigma(t^2)$	¹ $\Sigma x/n$	² $\Sigma y/n$	³ $\Sigma z/n$	⁴ $\Sigma t/n$	⁵ $\Sigma x, \Sigma xt$	⁶ Σx^2	⁷ $\Sigma(xy)$	⁸ $\Sigma(xz)$	⁹ $\Sigma(xt)$
^{S0} $\Sigma y, \Sigma(yt)$	^{S1} $\Sigma(xy), \Sigma t$	^{S2} $\Sigma(y)^2$	^{S3} $\Sigma(yz)$	^{S4} $\Sigma(yt)$	^{S5} $\Sigma z, \Sigma(zt)$	^{S6} $\Sigma xz, \Sigma z^2/n$	^{S7} $\Sigma(yz)$	^{S8} $\Sigma(z)^2$	^{S9} $\Sigma(zt)$
^A temp x, $\Sigma t, a$		^B temp y, b		^C temp z, c		^D temp t, d		^E Used	^I Index

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	RCLB	36 12		169	SPC	16-11	
114	PRTX	-14		170	RTN	24	
115	RCLC	36 13		171	*LBL e 21	16 15	
116	PRTX	-14		172	RCL6	36 06	
117	RCLD	36 14		173	PRTX	-14	Recall $\Sigma x^2, \Sigma y^2,$
118	PRTX	-14		174	P Σ S	16-51	$\Sigma z^2, \Sigma t^2$
119	RTN	24		175	RCL2	36 02	
120	*LBL8	21 08		176	PRTX	-14	
121	DSP0	-63 00	Print i	177	RCL8	36 08	
122	PRTX	-14		178	PRTX	-14	
123	DSP2	-63 02		179	P Σ S	16-51	
124	SPC	16-11		180	RCL0	36 00	
125	RTN	24		181	PRTX	-14	
126	*LBL0	21 00		182	SPC	16-11	
127	F1? 16	23 01	Change sign	183	RTN	24	
128	CHS	-22	for correction				
129	RTN	24					
130	*LBLD	21 14	Correction				
131	SF1 16	21 01					
132	GSBC	23 13					
133	CF1 16	22 01					
134	RTN	24		190			
135	*LBL E	21 15					
136	RCL1	36 01					
137	RCL1	36 46					
138	x	-35					
139	PRTX	-14					
140	RCL2	36 02	Recall $\Sigma x, \Sigma y,$				
141	RCL1	36 46	$\Sigma z, \Sigma t$				
142	x	-35					
143	PRTX	-14					
144	RCL3	36 03		200			
145	RCL1	36 46					
146	x	-35					
147	PRTX	-14					
148	RCL4	36 04					
149	RCL1	36 46					
150	x	-35					
151	PRTX	-14					
152	SPC	16-11					
153	RTN	24					
154	*LBL d 21	16 14		210			
155	RCL7	36 07					
156	PRTX	-14					
157	RCL8	36 08	Recall $\Sigma xy, \Sigma xz,$				
158	PRTX	-14	$\Sigma xt, \Sigma yz, \Sigma yt,$				
159	RCL9	36 09	Σzt				
160	PRTX	-14					
161	P Σ S	16-51					
162	RCL3	36 03					
163	PRTX	-14					
164	RCL4	36 04		220			
165	PRTX	-14					
166	RCL9	36 09					
167	PRTX	-14					
168	P Σ S	16-51					

LABELS					FLAGS	SET STATUS		
A Start	B Print	C Input	D Correction	E $\Sigma x, \Sigma y, \dots$	0 Print	FLAGS	TRIG	DISP
a	b	c	d	e	1 Correction	ON OFF	DEG ☒	FIX ☒
0 CHS	1	2	3	4	2	0 ☐ ☒	GRAD ☐	SCI ☐
5	6	7	8 Print i	9 Print	3	1 ☐ ☒	RAD ☐	ENG ☐
						2 ☐ ☒		n <u>2</u>
						3 ☐ ☒		

65

REGISTERS

$\sum (t^2)$	$\sum x/n$	$\sum y/n$	$\sum z/n$	$\sum t/n$	$\sum x, \sum xt$	$\sum x^2$	$\sum (xy)$	$\sum (xz)$	$\sum (xt)$	
$\sum y, \sum (yt)$	$\sum (xy), \sum t$	$\sum (y)^2$	$\sum (yz)$	$\sum (yt)$	$\sum z, \sum (zt)$	$\sum xz, \sum t^2/n$	$\sum (yz)$	$\sum (z^2)$	$\sum (zt)$	
A temp x, $\sum t, a$		B temp y, b		C temp z, c		D temp t, d		E Used		I Index

97 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
113	STOB	35 12		169	STOI	35 46	
114	RCL1	36 01		170	X $\div$ Y	-41	
115	X	-35		171	ST-i	35-45 45	
116	CHS	-22		172	RTN	24	
117	RCLC	36 13		173	*LBL E	21 15	
118	RCL2	36 02		174	RCLD	36 14	
119	X	-35		175	X	-35	
120	-	-45		176	X $\div$ Y	-41	
121	RCLD	36 14		177	RCLC	36 13	
122	RCL3	36 03		178	X	-35	
123	X	-35		179	+	-55	
124	-	-45		180	X $\div$ Y	-41	
125	RCL4	36 04		181	RCLB	36 12	
126	+	-55		182	X	-35	
127	F1? 16 23 01			183	+	-55	
128	0	00		184	RCLA	36 11	
129	STOA	35 11		185	+	-55	
130	F1? 16 23 01			186	*LBL 8	21 08	
131	GT07	22 07		187	PRTX	-14	
132	PRTX	-14		188	SPC	16-11	
133	*LBL 7	21 07		189	CF1 16 22 01		
134	RCLB	36 12		190	RTN	24	
135	RCLC	36 13		191	*LBL D	21 14	
136	RCLD	36 14		192	RCL5	36 05	
137	GT09	22 09		193	RCLB	36 12	
138	*LBL 6	21 16 12		194	X	-35	
139	RCL E	36 15		195	P $\div$ S	16-51	
140	1	01		196	RCL1	36 01	
141	+	-55		197	RCLA	36 11	
142	STOE	35 15		198	X	-35	
143	STOI	35 46		199	+	-55	
144	RCLC	36 13		200	RCL0	36 00	
145	GSB a	23 16 11		201	RCLC	36 13	
146	RCL E	36 15		202	X	-35	
147	4	04		203	+	-55	
148	X=Y?	16-33		204	RCL5	36 05	
149	RTN	24		205	RCLD	36 14	
150	5	05		206	X	-35	
151	+	-55		207	+	-55	
152	X=Y?	16-33		208	RCL6	36 06	
153	RTN	24		209	-	-45	
154	5	05		210	P $\div$ S	16-51	
155	+	-55		211	LSTX	16-63	
156	X=Y?	16-33		212	RCL0	36 00	
157	RTN	24		213	-	-45	
158	5	05		214	CHS	-22	
159	+	-55		215	$\div$	-24	
160	X=Y?	16-33		216	GT08	22 08	
161	RTN	24		217	*LBL 9	21 09	
162	GT06	22 16 12		218	R $\downarrow$	-31	
163	*LBL a	21 16 11		219	R $\downarrow$	-31	
164	RCL i	36 45		220	PRTX	-14	
165	X	-35		221	R $\uparrow$	16-31	
166	RCL I	36 46		222	PRTX	-14	
167	RCLD	36 14		223	R $\uparrow$	16-31	
168	+	-55		224	GT08	22 08	

LABELS			FLAGS			SET STATUS		
A	B	C	D	E	F	ON	TRIG	DISP
a	b	c	d	e	f	OFF		
a	Subroutine	x and -			1	☒	DEG ☒	FIX ☒
0	1	2	3 rd elim.	4	2	☒	GRAD ☐	SCI ☐
5	6	7	Print	8	3	☒	RAD ☐	ENG ☐
			Print x,y,z			☒		n <u>3</u>

Subroutine for
elimination

Multiply and
subtract

Input x,y,z,
and calculate
t

Calculate R^2

Print x,y,z

Program Description I

67

Program Title **SIMULTANEOUS EQUATIONS IN SIX UNKNOWNNS**

Contributor's Name **Robert E. DeBolt**

Address **9667 Tayler Court**

City **Pickerington**

State **Ohio**

Zip Code **43147**

Program Description, Equations, Variables

Coefficient
Matrix:

$$\begin{Bmatrix} r1 & s1 & t1 & u1 & v1 & w1 & k1 \\ r2 & s2 & t2 & u2 & v2 & w2 & k2 \\ r3 & s3 & t3 & u3 & v3 & w3 & k3 \\ r4 & s4 & t4 & u4 & v4 & w4 & k4 \\ r5 & s5 & t5 & u5 & v5 & w5 & k5 \\ r6 & s6 & t6 & u6 & v6 & w6 & k6 \end{Bmatrix}$$

By Crout's method, let (a_{ij}) be the elements of the given matrix and (A_{ij}) be the elements of the derived matrix. Then

$$A_{ii} = a_{ii} - \sum_{k=1}^{i-1} A_{ik} A_{ki} \quad (\text{diagonal terms})$$

$$A_{ij} = a_{ij} - \sum_{k=1}^{j-1} A_{ik} A_{kj} \quad (i > j, \text{ gives the lower half})$$

$$A_{ij} = \left\{ a_{ij} - \sum_{k=1}^{i-1} A_{ik} A_{kj} \right\} / A_{ii} \quad (i < j, \text{ gives the upper half})$$

The solution vector is

$$X_i = A_{i,n+1} - \sum_{k=i+1}^n A_{ik} X_k \quad (i = 1, \dots, n)$$

Operating Limits and Warnings

1. Re-order the equations, such that $r1$ is not zero.
2. "Error" implies inconsistency.

This program has been verified only with respect to the numerical example given in *Program Description II*. User accepts and uses this program material AT HIS OWN RISK, in reliance solely upon his own inspection of the program material and without reliance upon any representation or description concerning the program material.

NEITHER HP NOR THE CONTRIBUTOR MAKES ANY EXPRESS OR IMPLIED WARRANTY OF ANY KIND WITH REGARD TO THIS PROGRAM MATERIAL, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NEITHER HP NOR THE CONTRIBUTOR SHALL BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH OR ARISING OUT OF THE FURNISHING, USE OR PERFORMANCE OF THIS PROGRAM MATERIAL.

Program Description II

Sketch(es)

Sample Problem(s) **Compute the solution for the following set of equations:**

Variables and coefficient matrix:

r	s	t	u	v	w	k
17	34	170	748	3816.5	19669	1781.6
34	170	748	3816.5	19669	105325.625	4864.65
170	748	3816.5	19669	105325.625	573286.75	22810.975
748	3816.5	19669	105325.625	573286.75	3172438.532	90845.9625
3816.5	19669	105325.625	573286.75	3172438.532	17757325.57	412295.4438
19669	105325.625	573286.75	3172438.532	17757325.57	100361561.9	1856770.791

Solution(s)

r = -11.52568830
s = -28.86312210
t = 45.32824695
u = 1.755025950
v = -2.615475715
w = .1994145369

Reference(s)

Nielsen, Kaj L., Methods in Numerical Analysis,
page 185, The Macmillan Company, 1956.

Program Description II

69

Sketch(es)

Sample Problem(s) **Compute the determinant and the inverse of the coefficient matrix in the preceding problem.**

1. In order to compute the determinant of the coefficient matrix, less the k vector, do the following:

1.1 Record the values obtained after calculation for the following:

s2 $\Rightarrow$ record c1 t3 $\Rightarrow$ record c2

u4 $\Rightarrow$ record c3 v5 $\Rightarrow$ record c4

w6 $\Rightarrow$ record c5

1.2 The determinant = r1 x c1 x c2 x c3 x c4 x c5

2. The inverse may be computed by substituting each column of the identity matrix of order 5 for the k vector. The solutions obtained by solving the system with this program represent the respective column vectors of the inverse matrix.

Solution(s) **determinant =**

$$17 \times 102 \times 484.5 \times 2180.25 \times 9447.7507 \times 39365.555 = 6.812303266 \times 10^{17}$$

$$A^{-1} = \begin{bmatrix} .23704060 & -.00407230 & -.07938403 & .00976420 & -.00381044 & -.00057157 \\ -.00407230 & .30094782 & -.06239595 & -.06620895 & .02375172 & -.00206822 \\ -.07938403 & -.06239595 & .06240250 & .00928796 & -.00859995 & .00095261 \\ .00976420 & -.06620895 & .00928796 & .01782172 & -.00603319 & .00051864 \\ .00381044 & .02375172 & -.00859995 & -.00603319 & .00264614 & -.00025403 \\ -.00057157 & -.00206822 & .00095261 & .00051864 & -.00025403 & .00002540 \end{bmatrix}$$

Reference(s)

RCL (for card 2/2)

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1.	Load side 1 and side 2 of card 1/2.			
2.	Place side 1 of card 2/2 into reader slot but do not engage.			
3.	Enter r1:	r1	A	r1
4.	Enter s1, t1, u1, v1, w1, k1, r2, s2, t2, u2, ... thru v5 followed by R/S each entry:			
5.	Immediately upon entry of v5:R/S, engage card 2/2 in the card reader. The card will be read automatically. The calculator will stop with value A ₅₅ after side 2 of the card has been entered.		R/S	
6.	Enter w5, k5, r6, s6, t6, ... thru k6 followed by R/S each entry:			A ₅₅
7.	After entry of k6, the calculator will run for approximately 20 seconds and will stop with solution r.		R/S	
8.	To display all solutions:			r
			A	r
			R/S	s
			R/S	t
			R/S	u
			R/S	v
			R/S	w
	Note: If, during step 5, you fail to engage card 2/2 in the card reader, then do the following steps:			
9.	Prepare for Merge:			
10.	Enter card 2/2, side 1 and side 2.		g MERGE	
11.	Start program:			
12.	Go to Step 6.		R/S	A ₅₅

71

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	f LBL B	31 25 12			f LBL A	31 25 11	START:
	x	71			STO 0	33 00	with rl.
	-	51			R/S	84	Enter: sl.
	f LBL C	31 25 13		060	h X:I	35 24	
	RCL 0	34 00			2	02	
	÷	81			4	04	
	STO(i)	33 24			h X:I	35 24	
	f DSZ	31 33			f GSB C	31 22 13	
	h RTN	35 22			R/S	84	t1
010	f LBL 0	31 25 00	RCL 10		f GSB C	31 22 13	u1
	0	00			R/S	84	
	GTO D	22 14			f GSB C	31 22 13	v1
	f LBL 1	31 25 01	RCL 11		R/S	84	
	1	01		070	f GSB C	31 22 13	v1
	GTO D	22 14			R/S	84	k1
	f LBL 2	31 25 02	RCL 12		f GSB C	31 22 13	r2
	2	02			R/S	84	a2
	GTO D	22 14			RCL 1	34 01	
	f LBL 3	31 25 03	RCL 13		RCL E	34 15	
020	3	03		080	f GSB E	31 22 15	
	GTO D	22 14			STO 0	33 00	t2
	f LBL 4	31 25 04	RCL 14		R/S	84	
	4	04			RCL 1	34 01	
	GTO D	22 14			RCL D	34 14	
	f LBL 5	31 25 05	RCL 15		f GSB B	31 22 12	u2
	5	05			R/S	84	
	GTO D	22 14			RCL 1	34 01	
	f LBL 6	31 25 06	RCL 16		RCL C	34 13	
030	6	06			f GSB B	31 22 12	v2
	GTO D	22 14		090	R/S	84	
	f LBL 7	31 25 07	RCL 17		RCL 1	34 01	w2
	7	07			RCL B	34 12	
	GTO D	22 14			f GSB B	31 22 12	
	f LBL 8	31 25 08	RCL 18		R/S	84	k2
	8	08			RCL 1	34 01	
	GTO D	22 14			RCL 2	34 02	
	f LBL 9	31 25 09	RCL 19		RCL E	34 15	
040	9	09		100	f GSB 9	31 22 09	
	f LBL D	31 25 14			f GSB C	31 22 13	r3
	1	01			R/S	84	a3
	0	00			STO 2	33 02	
	+	61			R/S	84	
	h X:I	35 24			RCL 2	34 02	
	RCL(i)	34 24			RCL E	34 15	
	h X:Y	35 52			f GSB E	31 22 15	t3
	h X:I	35 24			STO 1	33 01	
	h R↓	35 53			R/S	84	
	f LBL E	31 25 15		110	RCL 2	34 02	
	x	71			RCL D	34 14	
050	-	51			f GSB E	31 22 15	
	h RTN	35 22					
	g LBLfa	32 25 11	Overlay control.				
	g MERGE	32 41					
	h PAUSE	35 72					
	R/S	84					
	h SPACE	35 84					

REGISTERS

0	s	1	t	2	u	3	v	4	w	5	r	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								

67 Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS							
	RCL 1	34 01	u3		f GSB E	31 22 15	w4							
	f GSB 8	31 22 08			170	RCL 2		34 02						
	STO 0	33 00				f GSB 6		31 22 06						
	R/S	84				RCL 1		34 01						
	RCL 2	34 02				f GSB 2		31 22 02						
	RCL C	34 13				f GSB C		31 22 13						
	f GSB E	31 22 15				R/S		84						
120	RCL 1	34 01				RCL 3		34 03						
	f GSB 7	31 22 07				RCL A		34 11						
	f GSB C	31 22 13				f GSB E		31 22 15						
	R/S	84	v3		RCL 2	34 02								
	RCL 2	34 02			180	f GSB 5	31 22 05							
	RCL B	34 12				RCL 1	34 01							
	f GSB E	31 22 15				f GSB 1	31 22 01							
	RCL 1	34 01				f GSB C	31 22 13							
	f GSB 6	31 22 06				R/S	84							
	f GSB C	31 22 13				RCL 3	34 03							
	R/S	84				f GSB 9	31 22 09							
	RCL 2	34 02				RCL 2	34 02							
	RCL A	34 11				f GSB 4	31 22 04							
	f GSB E	31 22 15	v3		RCL 1	34 01								
	RCL 1	34 01			190	f GSB 0	31 22 00							
	f GSB 5	31 22 05				f GSB C	31 22 13							
	f GSB C	31 22 13				R/S	84							
	R/S	84				STO 4	33 04							
	RCL 2	34 02				R/S	84							
	f GSB 9	31 22 09				RCL 4	34 04							
140	RCL 1	34 01				RCL E	34 15							
	f GSB 4	31 22 04				f GSB E	31 22 15							
	f GSB C	31 22 13				STO 3	33 03							
	R/S	84	r4		R/S	84								
	STO 3	33 03			200	RCL 4	34 04							
	R/S	84				RCL D	34 14							
	RCL 3	34 03				f GSB E	31 22 15							
	RCL E	34 15				RCL 3	34 03							
	f GSB E	31 22 15				f GSB 8	31 22 08							
	STO 2	33 02				STO 2	33 02							
	R/S	84				R/S	84							
150	RCL 3	34 03				RCL 4	34 04							
	RCL D	34 14				RCL C	34 13							
	f GSB E	31 22 15	u4		f GSB E	31 22 15								
	RCL 2	34 02			210	RCL 3	34 03							
	f GSB 8	31 22 08				f GSB 7	31 22 07							
	STO 1	33 01				RCL 2	34 02							
	R/S	84				f GSB 3	31 22 03							
	RCL 3	34 03				STO 1	33 01							
	RCL C	34 13				R/S	84							
160	f GSB E	31 22 15				RCL 4	34 04							
	RCL 2	34 02				RCL B	34 12							
	f GSB 7	31 22 07				f GSB E	31 22 15							
	RCL 1	34 01	v4		RCL 3	34 03								
	f GSB 3	31 22 03			220	f GSB 6	31 22 06							
	STO 0	33 00				RCL 2	34 02							
	R/S	84				f GSB 2	31 22 02							
	RCL 3	34 03				RCL 1	34 01							
	RCL B	34 12				GTO fa	22 31 11							
LABELS				FLAGS		SET STATUS								
A	START	B		used	C	used	D	used	E	used	0	FLAGS	TRIG	DISP
a	used	b			c		d		e		1	ON OFF	DEG ☒	FIX ☒
0	used	1		used	2	used	3	used	4	used	2	0 ☐ ☒	GRAD ☐	SCI ☐
5	used	6	used	7	used	8	used	9	used	3	1 ☐ ☒	RAD ☐	ENG ☐	
											2 ☐ ☒		n <u>2</u>	
											3 ☐ ☒			

67 Program Listing I

73

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	RCL 9	34 09			RCL 2	34 02	
	f GSB E	31 22 15			RCL 9	34 09	
	STO 0	33 00			f GSB E	31 22 15	
	R/S	84	w5	060	STO 1	33 01	
	RCL 4	34 04			R/S	84	w6
	RCL A	34 11			RCL 5	34 05	
	f GSB E	31 22 15			RCL A	34 11	
	RCL 3	34 03			f GSB E	31 22 15	
	f GSB 5	31 22 05			RCL 4	34 04	
010	RCL 2	34 02			f GSB 5	31 22 05	
	f GSB 1	31 22 01			RCL 3	34 03	
	RCL 1	34 01			f GSB 1	31 22 01	
	RCL 8	34 08			RCL 2	34 02	
	f GSB B	31 22 12		070	RCL 8	34 08	
	R/S	84	k5		f GSB E	31 22 15	
	RCL 4	34 04			RCL 1	34 01	
	f GSB 9	31 22 09			RCL 6	34 06	
	RCL 3	34 03			f GSB E	31 22 15	
	f GSB 4	31 22 04			RCL 0	34 00	
020	RCL 2	34 02			h X:Y	35 52	
	f GSB 0	31 22 00			STO 0	33 00	
	RCL 1	34 01			R/S	84	k6
	RCL 7	34 07			h X:Y	35 52	
	f GSB B	31 22 12		080	h R↓	35 53	
	STO 0	33 00	r6		h X:Y	35 52	
	R/S	84	s6		RCL 5	34 05	
	STO 5	33 05			h X:Y	35 52	
	R/S	84			STO 5	33 05	
	RCL 5	34 05			h R↓	35 53	
030	RCL E	34 15			f GSB 9	31 22 09	
	f GSB E	31 22 15			RCL 4	34 04	
	STO 4	33 04			f GSB 4	31 22 04	
	R/S	84	t6		RCL 3	34 03	
	RCL 5	34 05		090	f GSB 0	31 22 00	
	RCL D	34 14			RCL 2	34 02	
	f GSB E	31 22 15			RCL 7	34 07	
	RCL 4	34 04			f GSB E	31 22 15	
	f GSB 8	31 22 08			RCL 1	34 01	
	STO 3	33 03			RCL 5	34 05	
040	R/S	84	u6		f GSB B	31 22 12	soln: w
	RCL 5	34 05			RCL 5	34 05	
	RCL C	34 13			RCL 4	34 04	
	f GSB E	31 22 15			RCL 6	34 06	
	RCL 4	34 04		100	f GSB E	31 22 15	
	f GSB 7	31 22 07			STO 3	33 03	v
	RCL 3	34 03			RCL 7	34 07	
	f GSB 3	31 22 03			RCL 4	34 04	
	STO 2	33 02			RCL 8	34 08	
	R/S	84	v6		f GSB E	31 22 15	
050	RCL 5	34 05			RCL 3	34 03	
	RCL B	34 12			RCL 9	34 09	
	f GSB E	31 22 15			f GSB E	31 22 15	
	RCL 4	34 04			STO 2	33 02	u
	f GSB 6	31 22 06		110	0	00	
	RCL 3	34 03			g GSBfe	32 22 15	
	f GSB 2	31 22 02			f GSB 1	31 22 01	

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				

LABELS					FLAGS	SET STATUS			
A	B	C	D	E		FLAGS		TRIG	DISP
a	b	c	d	e	1	0	ON ☐ OFF ☒	DEG ☒	FIX ☒
0	1	2	3	4	2	1	☐	GRAD ☐	SCI ☐
						2	☐	RAD ☐	ENG ☐
5	6	7	8	9	3	3	☒		n <u>2</u>

Hewlett-Packard Software

In terms of power and flexibility, the problem-solving potential of the Hewlett-Packard line of fully programmable calculators is nearly limitless. And in order to see the practical side of this potential, we have several different types of software to help save you time and programming effort. Every one of our software solutions has been carefully selected to effectively increase your problem-solving potential. Chances are, we already have the solutions you're looking for.

Application Pacs

To increase the versatility of your fully programmable Hewlett-Packard calculator, HP has an extensive library of "Application Pacs". These programs transform your HP-67 and HP-97 into specialized calculators in seconds. Each program in a pac is fully documented with commented program listing, allowing the adoption of programming techniques useful to each application area. The pacs contain 20 or more programs in the form of prerecorded cards, a detailed manual, and a program card holder. Every Application Pac has been designed to extend the capabilities of our fully programmable models to increase your problem-solving potential.

You can choose from:

Statistics
Mathematics
Electrical Engineering
Business Decisions
Clinical Lab and Nuclear Medicine

Mechanical Engineering
Surveying
Civil Engineering
Navigation
Games

Users' Library

The main objective of our Users' Library is dedicated to making selected program solutions contributed by our HP-67 and HP-97 users available to you. By subscribing to our Users' Library, you'll have at your fingertips, literally hundreds of different programs. No longer will you have to: research the application; program the solution; debug the program; or complete the documentation. Simply key your program to obtain your solution. In addition, programs from the library may be used as a source of programming techniques in your application area.

A one-year subscription to the Library costs \$9.00. You receive: a catalog of contributed programs; catalog updates; and coupons for three programs of your choice (a \$9.00 value).

Users' Library Solutions Books

Hewlett-Packard recently added a unique problem-solving contribution to its existing software line. The new series of software solutions are a collection of programs provided by our programmable calculator users. Hewlett-Packard has currently accepted over 6,000 programs for our Users' Libraries. The best of these programs have been compiled into 40 Library Solutions Books covering 39 application areas (including two game books).

Each of the Books, containing up to 15 programs without cards, is priced at \$10.00, a savings of up to \$35.00 over single copy cost.

The Users' Library Solutions Books will compliment our other applications of software and provide you with a valuable new tool for program solutions.

Options/Technical Stock Analysis
Portfolio Management/Bonds & Notes
Real Estate Investment
Taxes
Home Construction Estimating
Marketing/Sales
Home Management
Small Business
Antennas
Butterworth and Chebyshev Filters
Thermal and Transport Sciences
EE (Lab)
Industrial Engineering
Aeronautical Engineering
Control Systems
Beams and Columns
High-Level Math
Test Statistics
Geometry
Reliability/QA

Medical Practitioner
Anesthesia
Cardiac
Pulmonary
Chemistry
Optics
Physics
Earth Sciences
Energy Conservation
Space Science
Biology
Games
Games of Chance
Aircraft Operation
Aviation
Calendars
Photo Dark Room
COGO-Surveying
Astrology
Forestry

INDUSTRIAL ENGINEERING

Programs selected from the areas of business, math, and statistics including Depreciation Schedules, Invoicing-Inventory Control, Simultaneous Equations, Multiple Linear Regression, and Single- and Multi-Server Queues.

DISCOUNTED CASH FLOW/PRESENT VALUE ANALYSIS

DEPRECIATION SCHEDULES

INVOICING AND INVENTORY CONTROL

PRODUCTION MONITOR AND RECORD

LEARNING CURVE

$\bar{x}$ and R CONTROL CHART

SINGLE- AND MULTI-SERVER QUEUES

TWO WAY ANALYSIS OF VARIANCE WITH REPLICATIONS
FIXED EFFECTS MODEL

MULTIPLE LINEAR REGRESSION FOR 3 INDEPENDENT
VARIABLES

SIMULTANEOUS EQUATIONS IN SIX UNKNOWNNS



1000 N.E. Circle Blvd., Corvallis, OR 97330

Reorder No. 00097-14035 Printed in U.S.A. 00097-90210
Revision D 11-78

Scan Copyright ©
The Museum of HP Calculators
www.hpmuseum.org

Original content used with permission.

Thank you for supporting the Museum of HP
Calculators by purchasing this Scan!

Please to not make copies of this scan or
make it available on file sharing services.