

HEWLETT-PACKARD

HP-67/HP-97

Stat Pac I



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Introduction

The 21 programs of Stat Pac I have been drawn from the fields of general statistics and related areas.

Each program in this pac is represented by one or more magnetic cards and a section in this manual. The manual provides a description of the program with relevant equations, a set of instructions for using the program, and one or more example problems, each of which includes a list of the actual keystrokes required for its solution. Program listings for all the programs in the pac appear at the back of this manual. Explanatory comments have been incorporated in the listings to facilitate your understanding of the actual working of each program. Thorough study of a commented listing can help you to expand your programming repertoire, since interesting techniques can often be found in this way.

On the face of each magnetic card are various mnemonic symbols which provide shorthand instructions to the use of the program. You should first familiarize yourself with a program by running it once or twice while following the complete User Instructions in the manual. Thereafter, the mnemonics on the cards themselves should provide the necessary instructions, including what variables are to be input, which user-definable keys are to be pressed, and what values will be output. A full explanation of the mnemonic symbols for magnetic cards may be found in appendix A.

If you have already worked through a few programs in the Standard Pac, you will understand how to load a program and how to interpret the User Instructions form. If these procedures are not clear to you, take a few minutes to review the sections, "Loading a Program" and "Format of User Instructions," in your Standard Pac.

We hope that Stat Pac I will assist you in the solution of numerous problems in your discipline. We would very much appreciate knowing your reactions to the programs in this pac, and to this end we have provided a questionnaire inside the front cover of this manual. Would you please take a few minutes to give us your comments on these programs? It is in the comments we receive from you that we learn how best to increase the usefulness of programs like these.

Program	CONTENTS	Page
GENERAL STATISTICS		
1.	Basic Statistics for Two Variables . . . . .	.01-01
	Basic statistics for two variables, grouped or ungrouped.	
2.	Factorial, Permutation and Combination . . . . .	.02-01
	Calculate factorial (extended range), permutation, and combination.	
3.	Moments, Skewness and Kurtosis (For Grouped or Ungrouped Data) . . . . .	.03-01
	Moments, Skewness and Kurtosis are calculated for general (geometrical) description of a distribution, symmetry, relative peakness or flatness, etc.	
4.	Random Number Generator . . . . .	.04-01
	Generate up to 500000 different numbers.	
5.	Histogram . . . . .	.05-01
	A histogram program for 24 intervals of equal width between specified upper and lower limits.	
ANALYSIS OF VARIANCE		
6.	Analysis of Variance (One Way) . . . . .	.06-01
	This program is used to test the observed differences among k sample means.	
7.	Two Way Analysis of Variance . . . . .	.07-01
	The row effects and the column effects are tested independently in the analysis of the total variability of a set of data.	
8.	Analysis of Covariance (One Way) . . . . .	.08-01
	This program tests the effect of one variable separately from the effect of the second variable.	
DISTRIBUTION FUNCTIONS		
9.	Normal and Inverse Normal Distribution . . . . .	.09-01
	Polynomial approximation is used to calculate normal and inverse normal distribution.	
10.	Chi-Square Distribution . . . . .	.10-01
	This program evaluates the chi-square density. A series approximation is used to evaluate the cumulative distribution.	
11.	t Distribution . . . . .	.11-01
	This program evaluates the t density function and the cumulative distribution for a given x and degrees of freedom ν .	
12.	F Distribution . . . . .	.12-01
	This program evaluates the integral of the F distribution for given values of x(>0), degrees of freedom ν_1 , ν_2 , provided either ν_1 or ν_2 is even.	
CURVE FITTING		
13.	Multiple Linear Regression . . . . .	.13-01
	Linear regression for two independent variables, using least squares method.	

14. Polynomial Approximation	14-01
This program approximates in the least square sense the function $f(x)$ by a polynomial of degree m , where $2 \leq m \leq 4$. Data from equally spaced points are required.	
TEST STATISTICS	
15. t Statistics	15-01
Paired t statistic tests the null hypothesis $H_0: \mu_1 = \mu_2$ for two observations.	
t statistic for two means tests the null hypothesis $H_0: \mu_1 - \mu_2 = d$ for two independent random samples.	
16. Chi-Square Evaluation	16-01
This program calculates the value of χ^2 statistic for the goodness of fit test.	
17. Contingency Table	17-01
2 \times k and 3 \times k contingency tables test the null hypothesis that two variables are independent.	
18. Spearman's Rank Correlation Coefficient	18-01
This program tests whether 2 rankings are substantially in agreement with one another.	
QUALITY CONTROL	
19. \bar{x} and R Control Chart	19-01
\bar{x} (mean) and R (range) are used to decide periodically whether a process is in statistical control.	
20. Operating Characteristic Curves	20-01
This program evaluates the probability P_a of acceptance for a single sampling plan with finite or infinite lot size.	
QUEUEING THEORY	
21. Single- and Multi-Server Queues	21-01
Queueing theory for infinite customers and finite customers.	
PROGRAM LISTINGS L00-01	
APPENDIX A A-1	

A WORD ABOUT PROGRAM USAGE

This application pac has been designed for both the HP-97 Programmable Printing Calculator and the HP-67 Programmable Pocket Calculator. The most significant difference between the HP-67 and the HP-97 calculators is the printing capability of the HP-97. The two calculators also differ in a few minor ways. The purpose of this section is to discuss the ways that the programs in this pac are affected by the differences in the two machines, and to suggest how you can make optimal use of your machine, be it an HP-67 or an HP-97.

Some of the computed results in this pac are output by PRINTx statements. On the HP-97, these results will be output on the printer. On the HP-67, each PRINT command will be interpreted as a PAUSE: the program will halt, display the result for about five seconds, then continue execution. The term "PRINT/PAUSE" is used to describe this output condition.

If you own an HP-67, you may want more time to copy down the number displayed by a PRINT/PAUSE. All you need to do is press down any key on the keyboard. If the command being executed is PRINTx (eight rapid blinks of the decimal point), pressing down a key will cause the program to halt. If the command being executed is PRINT STACK (two slow blinks of the decimal point), the number in the display will remain there until the depressed key is released; then the next register in the stack will be displayed, and so on. After display of all four registers, the program will halt execution if a key was pressed at any time during the display of the stack contents. In both cases, execution of the halted program may be re-initiated by pressing **R/S**.

HP-97 users may also want to keep a permanent record of the values input to a certain program. A convenient way to do this is to set the Print Mode switch to NORMAL before running the program. In this mode, all input values and their corresponding user-definable keys will be listed on the printer, thus providing a record of the entire operation of the program.

Another area that could reflect differences between the HP-67 and the HP-97 is in the keystroke solutions to example problems. It is sometimes necessary in these solutions to include operations that involve prefix keys, namely, **f** on the HP-97 and **f**, **g**, and **h** on the HP-67. For example, the operation **[10^x]** is performed on the HP-97 as **f [10^x]** and on the HP-67 as **g [10^x]**. In such cases, the keystroke solution omits the prefix key and indicates only the operation (as

here, $\boxed{10^x}$). As you work through the example problems, take care to press the appropriate prefix keys (if any) for your calculator.

Also in keystroke solutions, those values which are output by the command PRINT_x will be followed by three asterisks (***)�.

BASIC STATISTICS FOR TWO VARIABLES

BASIC STATISTICS FOR TWO VARIABLES				ST1-01A
 P?	$\rightarrow \bar{x}, \bar{y} \rightarrow V_x, V_y$	$\rightarrow S_x, S_y \dots$	$\rightarrow S_{xy}, \dots \rightarrow Y_{xy}$	$\rightarrow \sum x_i \dots$
START	$x_i, y_i, (\Sigma +)$	$x_k, y_k, (\Sigma -)$	$x_i, \dots (\Sigma +)$	$x_k, \dots (\Sigma -)$

This program calculates means, standard deviations, covariance, correlation coefficient, coefficients of variation, sums of data points, sum of multiplication of data points, and sums of squares of data points derived from a set of ungrouped data points $\{(x_i, y_i), i = 1, 2, \dots, n\}$, or grouped data points $\{(x_i, y_i, f_i), i = 1, 2, \dots, n\}$. f_i denotes the frequency of repetition of (x_i, y_i) .

$$\text{means } \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i$$

$$\begin{aligned} \text{standard deviations } s_x &= \sqrt{\frac{\sum x_i^2 - n\bar{x}^2}{n-1}} \\ \left(\text{or } s_x' \right) &= \sqrt{\frac{\sum x_i^2 - n\bar{x}^2}{n}} \\ s_y &= \sqrt{\frac{\sum y_i^2 - n\bar{y}^2}{n-1}} \\ \left(\text{or } s_y' \right) &= \sqrt{\frac{\sum y_i^2 - n\bar{y}^2}{n}} \end{aligned}$$

$$\begin{aligned} \text{covariance } s_{xy} &= \frac{1}{n-1} \left(\sum x_i y_i - \frac{1}{n} \sum x_i \sum y_i \right) \\ \left(\text{or } s_{xy}' \right) &= \frac{1}{n} \left[\sum x_i y_i - \frac{1}{n} \sum x_i \sum y_i \right] \end{aligned}$$

$$\text{correlation coefficient } \gamma_{xy} = \frac{s_{xy}}{s_x s_y}$$

$$\text{Coefficients of variation } V_x = \frac{s_x}{\bar{x}} \cdot 100 \quad , \quad V_y = \frac{s_y}{\bar{y}} \cdot 100$$

Note: n is a positive integer and $n > 1$.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		f A	1.00
4	For grouped data points, go to 8			
5	For ungrouped data points, do 6~7 for $i=1, 2, \dots, n$			
6	Input x_i	x_i	ENTER ↴	
	y_i	y_i	B	i
7	If you made a mistake in inputting x_k and y_k , then correct by →			
		x_k	ENTER ↴	
		y_k	C	$i-1$
8	For grouped data points do 9~10 for $i=1, 2, \dots, n$			
9	Input x_i	x_i	ENTER ↴	
	y_i	y_i	ENTER ↴	
	f_i	f_i	D	Σf_i
10	If you made a mistake in inputting x_k , y_k and f_k , then correct by →			
		x_k	ENTER ↴	
		y_k	ENTER ↴	
		f_k	E	$\Sigma f_i - f_k$
11	Calculate means: \bar{x}		f B	\bar{x}
	\bar{y}		R/S	\bar{y}
12	Calculate coefficients of variation: V_x		f B	V_x
	V_y		R/S	V_y

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
13	Calculate standard deviations:			
	s_x		f C	s_x
	s_y		R/S	s_y
	s'_x		f C	s'_x
	s'_y		R/S	s'_y
14	Calculate: covariance			
	s_{xy}		f D	s_{xy}
	s_{xy}'		R/S	s_{xy}'
15	Calculate correlation			
	coefficient γ_{xy}		f D	γ_{xy}
16	Calculate sums: Σx_i		f E	Σx_i
	Σy_i		R/S	Σy_i
	$\Sigma x_i y_i$		R/S	$\Sigma x_i y_i$
17	Calculate sums of squares			
	Σx_i^2		f E	Σx_i^2
	Σy_i^2		R/S	Σy_i^2
	For a new case, go to 2			
	*Note: to clear print mode			
	press →		CLF	
			Q	

Example 1:

For the following set of data, find the means, standard deviations, covariance, correlation coefficient, coefficients of variation, and the sums.

x _i	26	30	44	50	62	68	74
y _i	92	85	78	81	54	51	40

Keystrokes:

A → 0.00

f A → 1.00

26 ENTER 92 B → 26.00 *** (x₁)
 92.00 *** (y₁)
 1.00 ***

Outputs:

100 [ENTER] 100 [B] → 100.00 *** (x_2)
 100.00 *** (y_2) (error)
 2.00 ***

100 [ENTER] 100 [C] → 100.00 *** (x_2)
 100.00 *** (y_2) (correction)
 1.00 ***

30 [ENTER] 85 [B] → 30.00 *** (x_2)
 85.00 *** (y_2)
 2.00 ***

44 [ENTER] 78 [B] → 44.00 *** (x_3)
 78.00 *** (y_3)
 3.00 ***

50 [ENTER] 81 [B] → 50.00 *** (x_4)
 81.00 *** (y_4)
 4.00 ***

62 [ENTER] 54 [B] → 62.00 *** (x_5)
 54.00 *** (y_5)
 5.00 ***

68 [ENTER] 51 [B] → 68.00 *** (x_6)
 51.00 *** (y_6)
 6.00 ***

74 [ENTER] 40 [B] → 74.00 *** (x_7)
 40.00 *** (y_7)
 7.00 ***

[f] [B] → 50.57 *** (\bar{x})
 R/S → 68.71 *** (\bar{y})

[f] [B] → 36.58 *** (V_x)
 R/S → 29.10 *** (V_y)

[f] [C] → 18.50 *** (s_x)
 R/S → 20.00 *** (s_y)

[f] [C] → 17.13 *** (s_x')
 R/S → 18.51 *** (s_y')

01-05

f [D] → -354.14 *** (s_{xy})
 R/S → -303.55 *** (s_{xy}')
 f [D] → -0.96 *** (γ_{xy})
 f [E] → 354.00 *** ($\sum x_i$)
 R/S → 481.00 *** ($\sum y_i$)
 R/S → 22200.00*** ($\sum x_i y_i$)
 f [E] → 19956.00*** ($\sum x_i^2$)
 R/S → 35451.00*** ($\sum y_i^2$)

Example 2:

Apply the program to the following set of grouped data.

x_i	4.8	5.2	3.8	4.4	4.1
y_i	15.1	11.5	14.3	13.6	12.8
f_i	1	3	1	6	2

Keystrokes:

A → 0.00
 f [A] → 1.00
 4.8 [ENTER] 15.1 [ENTER] 1 [D] → 4.80 *** (x_1)
 15.10 *** (y_1)
 1.00 *** (f_1)
 1.00 ***

 5.2 [ENTER] 11.5 [ENTER] 3 [D] → 5.20 *** (x_2)
 11.50 *** (y_2)
 3.00 *** (f_2)
 4.00 *** ($\sum f_i$)

 10 [ENTER] 10 [ENTER] 4 [D] → 10.00 ***
 10.00 *** (error)
 4.00 ***
 8.00 ***

 10 [ENTER] 10 [ENTER] 4 [E] → 10.00 ***
 10.00 *** (correction)
 4.00 ***
 4.00 ***

 3.8 [ENTER] 14.3 [ENTER] 1 [D] → 3.80 *** (x_3)
 14.30 *** (y_3)
 1.00 *** (f_3)
 5.00 *** ($\sum f_i$)

Outputs:

4.4 [ENTER] 13.6 [ENTER] 6 [D] → 4.40 *** (x_4)
 13.60 *** (y_4)
 6.00 *** (f_4)
 11.00 *** (Σf_i)

4.1 [ENTER] 12.8 [ENTER] 2 [D] → 4.10 *** (x_5)
 12.80 *** (y_5)
 2.00 *** (f_5)
 13.00 *** (Σf_i)

[f] [B] → 4.52 *** (\bar{x})
 R/S → 13.16 *** (\bar{y})

[f] [B] → 9.93 *** (V_x)
 R/S → 8.42 *** (V_y)

[f] [C] → 0.45 *** (s_x)
 R/S → 1.11 *** (s_y)

[f] [C] → 0.43 *** (s'_x)
 R/S → 1.07 *** (s'_y)

[f] [D] → -0.31 *** (s_{xy})
 R/S → -0.28 *** (s'_{xy})
 [f] [D] → -0.62 *** (γ_{xy})

[f] [E] → 58.80 *** (Σx_i)
 R/S → 171.10 *** (Σy_i)
 R/S → 770.22 *** ($\Sigma x_i y_i$)

[f] [E] → 268.38 *** (Σx_i^2)
 R/S → 2266.69 *** (Σy_i^2)

FACTORIAL, PERMUTATION AND COMBINATION



This program finds the extended range factorial (n can be greater than 69), permutation and combination. Permutation and combination are functions of the factorial, but this program will not use the factorial key, so that better accuracy and larger range can be obtained.

The equations are:

$$\text{Factorial} \quad n! = n(n-1)(n-2) \cdots 2 \cdot 1$$

$$\text{Permutation} \quad {}_mP_n = \frac{m!}{(m-n)!} = m(m-1)\dots(m-n+1)$$

$$\text{Combination} \quad {}_mC_n = \frac{m!}{(m-n)!n!} = \frac{m(m-1)\dots(m-n+1)}{1 \cdot 2 \cdot \dots \cdot n}$$

where m, n are integers and $0 \leq n \leq m$.

Notes: 1. ${}_mP_0 = 1$, ${}_mP_1 = m$, ${}_mP_m = m!$
therefore $n!$ should be used for large m .

$$2. \quad {}_mC_0 = {}_mC_m = 1$$

$$3. \quad {}_mC_1 = {}_mC_{m-1} = m$$

$$4. \quad {}_mC_n = {}_mC_{m-n}$$

5. In calculating $n!$, the accuracy will be reduced for $n > 69$, since it is calculated by taking Log., ie

$$n! = \log^{-1} [\log(n) + \log [(n-1)!]]$$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Go to 5 or 6 or 7			
5	Calculate $n!$			
	(i) $n \leq 69$	n	C	$n!$
	(ii) $n > 69^{**}$	n	C	n
			R/S	exp. of 10
			R/S	decimal No.
6	Calculate ${}_mP_n$	m	ENTER	
		n	D	${}_mP_n$
7	Calculate ${}_mC_n$	m	ENTER	
		n	E	${}_mC_n$
	For a new case, go to 2			
	*Note: to clear print mode			
	press →		CLF	
			0	
	**In Print Mode, the 3-number			
	result will be printed out			
	automatically.			

02-03

Examples:

1. $5! = 120$
2. $69! = 1.711224524 \times 10^{98}$
3. $70! = 1.197857069 \times 10^{100}$
4. $100! = 9.332622518 \times 10^{157}$
5. ${}_{27}P_5 = 9687600.00$
6. ${}_{73}C_4 = 1088430.00$

Keystrokes:	Output:	
A	0.00	
B	1.00	
5 C	5.00 *** 120.00 ***	(5!)
69 C	69.00 *** 1.711224524+98 ***	(69!)
70 C	70.00*** 100.00 *** 1.197857069 ***	(10^{100}) (decimal no.)
100 C	100.00 *** 157.00 *** 9.332622518 ***	(10^{157}) (decimal no.)
27 ENTER↑ 5 D	27.00 *** 5.00 *** 9687600.00 ***	$({}_{27}P_5)$
73 ENTER↑ 4 E	73.00 *** 4.00 *** 1088430.00 ***	$({}_{73}C_4)$

Notes

MOMENTS, SKEWNESS AND KURTOSIS (FOR GROUPED OR UNGROUPED DATA)

MOMENTS, SKEWNESS AND KURTOSIS				ST1-03A
P?	$\rightarrow \bar{x}$	$\rightarrow m_2; m_3; m_4$	$\rightarrow \gamma_1; \gamma_2$	
START	$x_i(\Sigma+)$	$x_k(\Sigma-)$	$y_i + f_i(\Sigma+)$	$y_h + f_h(\Sigma-)$

For grouped or ungrouped data, moments are used to describe sets of data, skewness is used to measure the lack of symmetry in a distribution, and kurtosis is the relative peakness or flatness of a distribution. For a given set of data

$$\{x_1, x_2, \dots, x_n\}:$$

$$1^{\text{st}} \text{ moment} \quad \bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

$$2^{\text{nd}} \text{ moment} \quad m_2 = \frac{1}{n} \sum x_i^2 - \bar{x}^2$$

$$3^{\text{rd}} \text{ moment} \quad m_3 = \frac{1}{n} \sum x_i^3 - \frac{3}{n} \bar{x} \sum x_i^2 + 2\bar{x}^3$$

$$4^{\text{th}} \text{ moment} \quad m_4 = \frac{1}{n} \sum x_i^4 - \frac{4}{n} \bar{x} \sum x_i^3 + \frac{6}{n} \bar{x}^2 \sum x_i^2 - 3\bar{x}^4$$

Moment coefficient of skewness

$$\gamma_1 = \frac{m_3}{m_2^{3/2}}$$

Moment coefficient of kurtosis

$$\gamma_2 = \frac{m_4}{m_2^2}$$

This program also provides the option for calculating those statistics for grouped data (using similar formulas as for ungrouped data):

data	y_1	y_2	...	y_m
frequency	f_1	f_2	...	f_m

Note that for this case, 1st moment

$$\bar{x} = \frac{\sum_{i=1}^m f_i x_i}{\sum_{i=1}^m f_i}$$

Reference: Theory and Problems of Statistics, M. R. Spiegel, Schaum's Outline, McGraw-Hill, 1961

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		f A	1.00
4	For grouped data, go to 12,			
5	Do 6~7 for $i = 1, 2, \dots, n$ for ungrouped data			
6	Input x_i	x_i	B	i
7	If you made a mistake in inputting x_k , then correct by →	x_k	C	$i-1$
8	Calculate: \bar{x}		f B	\bar{x}
9	Calculate: m_2		f C	m_2
	m_3		R/S	m_3
	m_4		R/S	m_4
10	Calculate: γ_1		f D	γ_1
	γ_2		R/S	γ_2
11	For a new case, go to 2			
12	Do 13~14 for $j = 1, 2, \dots, m$ for grouped data			
13	Input	y_j	ENTER+	
	and	f_j	D	j
14	If you made a mistake in inputting y_h and f_h , then correct by	y_h	ENTER+	
		f_h	E	$j-1$
15	Go to 8			
	*Note: to clear print mode press →		CLF	
			Q	

Examples:

1. Ungrouped data

i	1	2	3	4	5	6	7	8	9
x_i	2.1	3.5	4.2	6.5	4.1	3.6	5.3	3.7	4.9

$$\bar{x} = 4.21, m_2 = 1.39, m_3 = 0.39, m_4 = 5.49$$

$$\gamma_1 = 0.24, \gamma_2 = 2.84$$

Keystrokes:

		Outputs:
A	→	0.00
f A	→	1.00
2.1 B	→	2.10 *** (x_1) 1.00 ***
4 B	→	4.00 *** (x_2) (error) 2.00 ***
4 C	→	4.00 *** (x_2) (correction) 1.00 ***
3.5 B	→	3.50 *** (x_2) 2.00 ***
4.2 B	→	4.20 *** (x_3) 3.00 ***
6.5 B	→	6.50 *** (x_4) 4.00 ***
4.1 B	→	4.10 *** (x_5) 5.00 ***
3.6 B	→	3.60 *** (x_6) 6.00 ***
5.3 B	→	5.30 *** (x_7) 7.00 ***

3.7 **B** → 3.70 *** (x₈)
 8.00 ***

4.9 **B** → 4.90 *** (x₉)
 9.00 ***

f B → 4.21 *** (\bar{x})

f C → 1.39 *** (m₂)

R/S → .39 *** (m₃)

R/S → 5.49 *** (m₄)

f D → 0.24 *** (γ_1)

R/S → 2.84 *** (γ_2)

2. Grouped data

j	1	2	3	4	5
y _j	3	2	4	6	1
f _j	4	5	3	2	1

$$\bar{x} = 3.13, m_2 = 1.98, m_3 = 2.14, m_4 = 11.05 \\ \gamma_1 = 0.77, \gamma_2 = 2.81$$

Keystrokes:

A → 0.00

f A → 1.00

3 **ENTER** 4 **D** → 3.00*** (y₁)

4.00 *** (f₁)

1.00 ***

Outputs:

03-05

2 **ENTER** 5 **D** → 2.00 *** (y₂)
5.00 *** (f₂)
2.00 ***

5 **ENTER** 5 **D** → 5.00 *** (y₃)
5.00 *** (f₃)
3.00 *** (error)

5 **ENTER** 5 **E** → 5.00 *** (y₃)
5.00 *** (f₃) (correction)
2.00 ***

4 **ENTER** 3 **D** → 4.00 *** (y₃)
3.00 *** (f₃)
3.00 ***

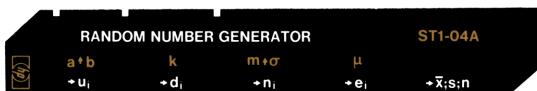
6 **ENTER** 2 **D** → 6.00 *** (y₄)
2.00 *** (f₄)
4.00 ***

1 **ENTER** 1 **D** → 1.00 *** (y₅)
1.00 *** (f₅)
5.00 ***

f B → 3.13 *** (\bar{x})
f C → 1.98 *** (m₂)
R/S → 2.14 *** (m₃)
R/S → 11.05 *** (m₄)
f D → 0.77 *** (γ_1)
R/S → 2.81 *** (γ_2)

Notes

RANDOM NUMBER GENERATOR



Random numbers are useful in a wide variety of applications, e.g., simulation, sampling, computer programming, numerical analysis and games. This program calculates (1) uniformly distributed numbers, (2) random integers, (3) normally distributed numbers, (4) exponentially distributed numbers, (5) mean, standard deviation and counter of the numbers generated.

This program calculates:

1. Uniformly distributed pseudo random numbers u_i in the range $a < u_i < b$:
The multiplicative linear congruential method is used.

$$u_{i+1} = f_{i+1} (b - a) + a$$

where $i = 0, 1, 2, \dots$ and

$$f_{i+1} = \text{fractional part of } (997 f_i)$$

$$f_0 = 0.5284163.$$

The period has length 500000, i.e., 500000 different numbers can be generated before repeating. The least significant digits (the righthand digits) of u_i are not as random as the most significant digits (the left-hand digits). Thus random digits, if needed, should be taken from the most significant end of the numbers. This generator passes the chi-square frequency test for uniformity, serial test and run tests for randomness.

If a different sequence of numbers is desired, a different starting value f_0 ($0 < f_0 < 1$) can be used. Some program steps (the starting value stored under **LBL** [0]) must be changed accordingly. Note that if $10^7 \times f_0$ is not divisible by 2 or 5, then the period of the generator has length 500000. All the tests mentioned above should be applied to the new generator before using it.

2. Pseudo random integers d_i such that $1 \leq d_i \leq k$:

Suppose u_i ($i = 1, 2, \dots$) is a sequence of uniformly distributed pseudo random numbers between 0 and 1.

$$d_i = 1 + \text{integer part of } (ku_i)$$

3. Normally distributed pseudo random numbers n_i if the mean m and the standard deviation σ are given:

Suppose u_i ($i = 1, 2, \dots$) is a sequence of uniformly distributed pseudo random numbers between 0 and 1.

Let

$$v_1 = (2u_i - 1), \quad v_2 = (2u_{i+1} - 1) \\ S = v_1^2 + v_2^2 \quad (i = 1, 2, \dots)$$

If $S \geq 1$, discard the two uniform numbers u_i, u_{i+1} and generate the next two numbers in the sequence until $S < 1$. Then compute the normally distributed numbers according to the following equations

$$n_i = \sigma v_1 \quad \sqrt{\frac{-2 \ln S}{S}} + m$$

$$n_{i+1} = \sigma v_2 \quad \sqrt{\frac{-2 \ln S}{S}} + m$$

4. Exponentially distributed pseudo random numbers e_i with mean μ :

Suppose u_i ($i = 1, 2, \dots$) is a sequence of uniformly distributed pseudo random numbers between 0 and 1.

$$e_i = -\mu \ln u_i$$

5. The mean \bar{x} , standard deviation s and counter n of the random numbers computed:

$$\bar{x} = \sum_{i=1}^n x_i/n \\ s = \sqrt{\frac{\sum x_i^2 - n\bar{x}^2}{n-1}}$$

where x_i can be u_i, d_i, n_i or e_i .

Reference:

Donald E. Knuth, *The Art of Computer Programming*, Vol. 2, Addison-Wesley, 1971.

04-03

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	For random integers, go to 6			
	For normal numbers, go to 9			
	For exponential numbers, go to 12			
3	Input interval range for uniform numbers	a	ENTER	
		b	f A	b
4	Perform 4 for $i=1, 2, \dots$		A	u_i
5	For \bar{x} and s, go to 14			
6	Input maximum integer desired	k	f B	k
7	Perform 7 for $i=1, 2, \dots$		B	d_i
8	For \bar{x} and s, go to 14			
9	For normal numbers, input mean and standard deviation	m σ	ENTER f C	
10	Perform 10 for $i=1, 2, \dots$		C	n_i
11	For \bar{x} and s, go to 14			
12	Input mean for exponential numbers	μ	f D	μ
13	Perform 13 for $i=1, 2, \dots$		D	e_i
14	Optional: Calculate the mean the standard deviation the counter		E R/S R/S	\bar{x} s n
15	To continue the calculation, go back to 4, 7, 10, or 13			
16	For a new case, go to 2			

Example 1:

Generate a sequence of uniform pseudo random numbers between 0 and 1.

Keystrokes:

0 **ENTER** 1 **f A**

Outputs:

0.00 *** (a)
1.00 *** (b)

A → 0.83 ***

A → 0.56 ***

A → 0.27 ***

A → 0.04 ***

A → 0.20 ***

A → 0.75 ***

A → 0.83 ***

A → 0.95 ***

E → 0.55 *** (mean)

R/S → 0.34 *** (s)

R/S → 8.00 *** (counter)

A → 0.68 ***

A → 0.63 ***

A → 0.22 ***

etc.

Example 2:

Use the random number generator to simulate the successive tosses of a die.

Keystrokes:

6 **f B**

Outputs:

6.00 *** (k)

B → 5.00 ***

B → 4.00 ***

B → 2.00 ***

B → 1.00 ***

B → 2.00 ***

B → 5.00 ***

etc.

Example 3:

A professor decides to assign grades randomly and without bias to the students. The grades should have a normal distribution with average grade being 75 and standard deviation being 10. How can the random number generator be used for this purpose?

Keystrokes:

75 **ENTER** 10 **f** **C** → 75.00 *** (m)
10.00 *** (σ)

Outputs:

C	→ 87.42 ***
C	→ 77.17 ***
C	→ 67.44 ***
C	→ 81.23 ***
C	→ 89.91 ***
C	→ 85.32 ***

etc.

Example 4:

Suppose a radioactive substance emits alpha particles at a rate such that on the average, one particle is emitted every 5 seconds. Note that the amount of time between two successive emissions has the exponential distribution with mean 5. Generate a sequence of random numbers so that each of them can be used as the amount of time between two emissions.

Keystrokes:

5 **f** **D** → 5.00 *** (μ)

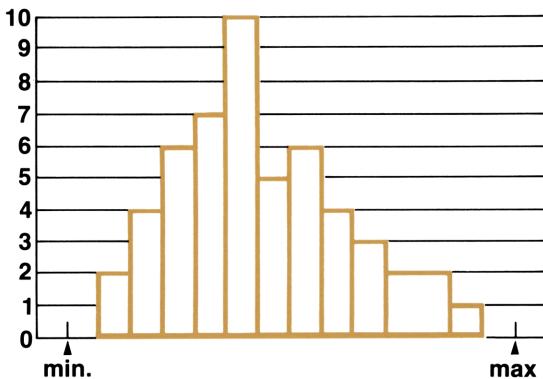
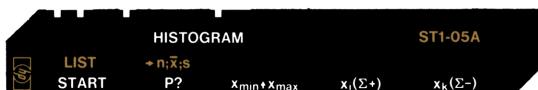
Outputs:

D	→ 0.93 ***
D	→ 2.92 ***
D	→ 6.49 ***
D	→ 15.93 ***
D	→ 8.14 ***
D	→ 1.44 ***

etc.

Notes

HISTOGRAM



A histogram or bar chart can provide a meaningful way of representing tabular data or the output of an algorithm. By viewing a histogram, trends and biases can be spotted easily.

This program sorts input data into 24 intervals or bins of equal width between specified upper and lower limits.

One is added to the bin whose number is calculated. This procedure is repeated for all x values in the data set. After all data has been input, pressing **f B**, **R/S**, **R/S** will cause the printout of the total number of inputs, the mean of the inputs, and the standard deviation of the inputs. Pressing **f A** gives the number of inputs in each bin and a representation of the histogram. The bins are arranged in maximum x value to minimum x value order.

The 24 intervals are stored three at a time in registers $R_1 \sim R_8$.

Incorrect values may be deleted at any time by keying them in and pressing **E**. However, if the value is out of bounds, then "Error" will be displayed. Press **CLX** and continue.

To start the program you must specify the minimum expected value x_{\min} and the maximum expected value x_{\max} .

Equations:

For the histogram:

$$\text{mean} = \frac{\sum x}{n}$$

$$\text{standard deviation} = \sqrt{\frac{\sum x^2 - n \bar{x}^2}{n-1}}$$

$$y_i = 1 + \text{INT} \left[24 \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \right]$$

where

y_i = interval number

x_i = input data

x_{\min} = lower limit of histogram

x_{\max} = upper limit of histogram

INT = integer part of

Remark:

Because each interval is represented by only three digits, overflow from one interval to the next lower interval will occur for most of the intervals if there are more than 999 counts in the interval.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Input minimum value	x_{\min}	ENTER ↴	
	maximum value	x_{\max}	C	x_{\min}, x_{\max}
5	Do 6~7 for $i=1, 2, \dots, n$			
6	Input x_i	x_i	D	i
7	If you made a mistake in inputting x_k , then correct by →	x_k	E	$i-1$
8	List histogram		f A	LIST

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
9	Print n, \bar{x} , s		f B	n
			R/S	\bar{x}
			R/S	s
10	For a new case, go to 2			
	*Note: to clear print mode			
	press→		CLF	
			0	

Example 1:

Compute a histogram of the following data with $x_{\min}=0$, $x_{\max}=24$. (18.1, 14.3, 8.4, 0.7, 20.2, 14, 17.2, 24, 8.8, 5.7, 13.2, 22.1, 15.7, 18.9, 23).

Keystrokes:

	Outputs:
A	0.00
B	1.00
0 ENTER 24 C	0.00 *** (x_{\min}) 24.00 *** (x_{\max})
18.1 D	18.10 *** 1. ***
14.3 D	14.30 *** 2. ***
8.4 D	8.40 *** 3. ***
0.7 D	0.70 *** 4. ***
9.9 D	9.90 *** (error) 5. ***
9.9 E	9.90 *** (correction) 4. ***
20.2 D	20.20 *** 5. ***
14.0 D	14.00 *** 6. ***
17.2 D	17.20 *** 7. ***

24	D	→	24.00 ***
			8. ***
8.8	D	→	8.80 ***
			9. ***
5.7	D	→	5.70 ***
			10. ***
13.2	D	→	13.20 ***
			11. ***
22.1	D	→	22.10 ***
			12. ***
15.7	D	→	15.70 ***
			13. ***
18.9	D	→	18.90 ***
			14. ***
23	D	→	23.00 ***
			15. ***

f	B	→	15.00 ***	(n)
R/S		→	14.95 ***	(\bar{x})
R/S		→	6.71 ***	(s)

f	A	→	0.00 ***
			1.00 ***
			1. ***

1.00 ***
2.00 ***
0. ***

2.00 ***
3.00 ***
0. ***

3.00 ***
4.00 ***
0. ***

4.00 ***
5.00 ***
0. ***

05-05

5.00 ***

6.00 ***

1. ***

6.00 ***

7.00 ***

0. ***

7.00 ***

8.00 ***

0. ***

8.00 ***

9.00 ***

2. ***

9.00 ***

10.00 ***

0. ***

10.00 ***

11.00 ***

0. ***

11.00 ***

12.00 ***

0. ***

12.00 ***

13.00 ***

0. ***

13.00 ***

14.00 ***

1. ***

14.00 ***

15.00 ***

2. ***

15.00 ***

16.00 ***

1. ***

16.00 ***

17.00 ***

0. ***

17.00 ***
18.00 ***
1. ***

18.00 ***
19.00 ***
2. ***

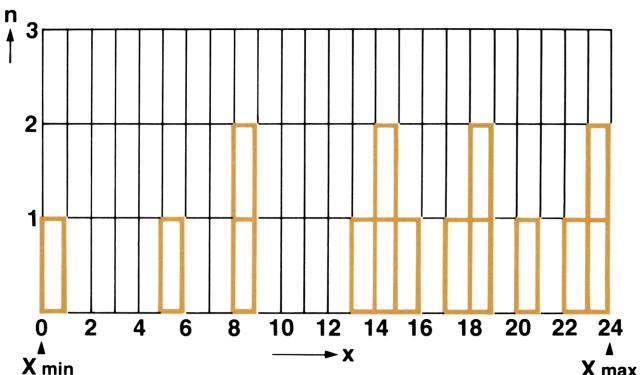
19.00 ***
20.00 ***
0. ***

20.00 ***
21.00 ***
1. ***

21.00 ***
22.00 ***
0. ***

22.00 ***
23.00 ***
1. ***

23.00 ***
24.00 ***
2. ***



ANALYSIS OF VARIANCE (ONE WAY)



The one-way analysis of variance is used to test if observed differences among k sample means can be attributed to chance or whether they are indicative of actual differences among the corresponding population means. Suppose the i^{th} sample has n_i observations (samples may have equal or unequal number of observations). The null hypothesis we want to test is that the k population means are all equal. This program generates the complete ANOVA table.

1. Mean of observations in the i^{th} sample ($i=1, 2, \dots, k$)

$$\bar{x}_i = \frac{1}{n_i} \sum_{j=1}^{n_i} x_{ij}$$

2. Standard deviation of observations in the i^{th} sample

$$s_i = \left[\left(\sum_{j=1}^{n_i} x_{ij}^2 - n_i \bar{x}_i^2 \right) / (n_i - 1) \right]^{1/2}$$

3. Sum of observations in the i^{th} sample

$$\text{Sum}_i = \sum_{j=1}^{n_i} x_{ij}$$

4. Total sum of squares

$$\text{TSS} = \sum_{i=1}^k \sum_{j=1}^{n_i} x_{ij}^2 - \frac{\left(\sum_{i=1}^k \sum_{j=1}^{n_i} x_{ij} \right)^2}{\sum_{i=1}^k n_i}$$

5. Treatment sum of squares

$$\text{TrSS} = \sum_{i=1}^k \left(\frac{\sum_{j=1}^{n_i} x_{ij}^2}{n_i} \right) - \left(\frac{\sum_{i=1}^k \sum_{j=1}^{n_i} x_{ij}^2}{\sum_{i=1}^k n_i} \right)$$

6. Error sum of squares

$$\text{ESS} = \text{TSS} - \text{TrSS}$$

7. Treatment degrees of freedom

$$df_1 = k - 1$$

8. Error degrees of freedom

$$df_2 = \sum_{i=1}^k n_i - k$$

9. Total degrees of freedom

$$df_3 = df_1 + df_2 = \sum_{i=1}^k n_i - 1$$

10. Treatment mean square

$$\text{TrMS} = \frac{\text{TrSS}}{df_1}$$

11. Error mean square

$$\text{EMS} = \frac{\text{ESS}}{df_2}$$

12. The F ratio

$$F = \frac{\text{TrMS}}{\text{EMS}} \quad (\text{with degrees of freedom } df_1, df_2)$$

Reference:

J. E. Freund, *Mathematical Statistics*, Prentice Hall, 1962.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		[A]	0.00
3	To set print mode*		[B]	1.00
4	Do 4 ~ 8 for $i=1, 2, \dots, k$			
5	Do 6 for $j=1, 2, \dots, n_i$			
6	Input x_{ij}	x_{ij}	[C]	j
7	If you made a mistake in inputting x_{im} , then correct by	x_{im}	[D]	$j-1$
8	Calculate: mean \bar{x}_i		[E]	\bar{x}_i
	standard deviation s_i		[R/S]	s_i
	sum Sum_i		[R/S]	Sum_i
9	Calculate: total sum of squares		[I] [A]	TSS
	treatment sum of squares		[R/S]	TrSS
	error sum of squares		[R/S]	ESS
10	Calculate degrees of freedom			
	df_1		[I] [B]	df_1
	df_2		[R/S]	df_2
	df_3		[R/S]	df_3
11	Calculate:			
	treatment mean square		[I] [C]	TrMS
	error mean square		[R/S]	EMS
	F ratio		[R/S]	F
12	For a new case, go to 2			
	*Note: to clear print mode			
	press →		[CLF]	
			[O]	

Example:

The following are the scores obtained in an achievement test by random samples of students from four different schools:

	i j	1	2	3	4	5	6	7
School 1		88	99	96	68	85		
School 2		78	62	98	83	61	88	
School 3		80	61	74	92	78	54	77
School 4		71	65	90	46			

Calculate the ANOVA table and test the null hypothesis that the differences among the sample means can be attributed to chance. Use significance level $\alpha = 0.01$.

Keystrokes:

- A → 0.00
- B → 1.00
- 88 C → 88.00 ***
1.00 ***
- 99 C → 99.00 ***
2.00 ***
- 96 C → 96.00 ***
3.00 ***
- 68 C → 68.00 ***
4.00 ***
- 85 C → 85.00 ***
5.00 ***
- E → 87.20 *** (\bar{x}_1)
- R/S → 12.15 *** (s_1)
- R/S → 436.00 *** (Sum_1)
- 78 C → 78.00 ***
1.00 ***

Outputs:

06-05

62 C → 62.00 ***
2.00 ***

98 C → 98.00 ***
3.00 ***

83 C → 83.00 ***
4.00 ***

61 C → 61.00 ***
5.00 ***

88 C → 88.00 ***
6.00 ***

E → 78.33 *** (\bar{x}_2)
R/S → 14.62 *** (s_2)
R/S → 470.00 *** (Sum_2)

80 C → 80.00 ***
1.00 ***

61 C → 61.00 ***
2.00 ***

74 C → 74.00 ***
3.00 ***

92 C → 92.00 ***
4.00 ***

78 C → 78.00 ***
5.00 ***

54 C → 54.00 ***
6.00 ***

77 C → 77.00 ***
7.00 ***

E → 73.71 *** (\bar{x}_3)
R/S → 12.61 *** (s_3)
R/S → 516.00 *** (Sum_3)

- 71 C → 71.00 ***
1.00 ***
- 66 C → 66.00 *** (error)
2.00 ***
- 66 D → 66.00 *** (correction)
1.00 ***
- 65 C → 65.00 ***
2.00 ***
- 90 C → 90.00 ***
3.00 ***
- 46 C → 46.00 ***
4.00 ***
- E → 68.00 *** (\bar{x}_4)
R/S → 18.13 *** (s_4)
R/S → 272.00 *** (Sum_4)
- f A → 4530.00 *** (TSS)
R/S → 930.44 *** (TrSS)
R/S → 3599.56 *** (ESS)
- f B → 3.00 *** (df_1)
R/S → 18.00 *** (df_2)
R/S → 21.00 *** (df_3)
- f C → 310.15 *** (TrMS)
R/S → 199.98 *** (EMS)
R/S → 1.55 *** (F)

ANOVA Table

	SS	df	MS	F
Treatments	930.44	3	310.15	1.55
Error	3599.56	18	199.98	
Total	4530.00	21		

Since $F = 1.55$ does not exceed $F_{.01,3,18} = 5.09$, the null hypothesis can not be rejected. We conclude that the means of the scores for the four schools are not significantly different.

TWO WAY ANALYSIS OF VARIANCE (NO REPLICATIONS)



The analysis of variance is the analysis of the total variability of a set of data (measured by their total sum of squares) into components which can be attributed to different sources of variation.

The two way analysis of variance tests the row effects and the column effects independently. This program will generate the ANOVA table for the case such that (1) each cell only has one observation and (2) the row and column effects do not interact.

Equations:

1. Sums

$$\text{Row } RS_i = \sum_j x_{ij} \quad i = 1, 2, \dots, r$$

$$\text{Column } CS_j = \sum_i x_{ij} \quad j = 1, 2, \dots, c$$

2. Sums of squares

$$\text{Total TSS} = \Sigma \Sigma x_{ij}^2 - (\Sigma \Sigma x_{ij})^2 / rc$$

$$\text{Row RSS} = \sum_i \left(\sum_j x_{ij} \right)^2 / c - (\Sigma \Sigma x_{ij})^2 / rc$$

$$\text{Column CSS} = \sum_j \left(\sum_i x_{ij} \right)^2 / r - (\Sigma \Sigma x_{ij})^2 / rc$$

$$\text{Error ESS} = \text{TSS} - \text{RSS} - \text{CSS}$$

3. Degrees of freedom

$$\text{Row } df_1 = r - 1$$

$$\text{Column } df_2 = c - 1$$

$$\text{Error } df_3 = (r - 1)(c - 1)$$

4. F ratios

$$\text{Row } F_1 = \frac{\text{RSS}}{\text{df}_1} \quad / \quad \frac{\text{ESS}}{\text{df}_3}$$

$$\text{Column } F_2 = \frac{\text{CSS}}{\text{df}_2} \quad / \quad \frac{\text{ESS}}{\text{df}_3}$$

Reference:

Dixon and Massey, *Introduction to Statistical Analysis*, McGraw-Hill, 1969.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Input: number of rows r	r	ENTER ↴	
	number of columns c	c	C	c
5	Do 5~9 for i=1, 2, ..., r			
	Do 6 for j=1, 2, ..., c			
6	Input x_{ij}	x_{ij}	D	j
7	If you made a mistake in			
	inputting x_{im} , then correct by	x_{im}	E	j-1
8	Calculate row sums RS _i		f A	RS _i
9	Re-initialize for columns		f B	0.00
10	Do 11~14 for j=1, 2, ..., c			
11	Do 12 for i=1, 2, ..., r			
12	Input x_{ij}	x_{ij}	D	i
13	If you made a mistake in			
	inputting x_{hj} , then correct by	x_{hj}	E	i-1
14	Calculate column sums CS _i		f C	CS _i
15	Calculate F ratios: Row F ₁		f D	F ₁
	Column F ₂		R/S	F ₂

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
16	Calculate degrees of freedom:			
	row df_1		[I] [D]	df_1
	column df_2		[R/S]	df_2
	error df_3		[R/S]	df_3
17	Calculate sums of squares:			
	row RSS		[I] [E]	RSS
	column CSS		[R/S]	CSS
	error ESS		[R/S]	ESS
	total TSS		[R/S]	TSS
18	For a new case, go to 2			
	*Note: to clear print mode			
	press →		[CLF]	
			[Q]	

Example:

Apply this program to analyze the following set of data.

		Column				
		j	1	2	3	4
Row	i					
	1	7	6	8	7	
	2	2	4	4	4	
	3	4	6	5	3	

Keystrokes:

- A → 0.00
- B → 1.00
- 3 [ENTER] 4 C → 3.00 *** (r)
4.00 *** (c)
- 7 D → 7.00 ***
1.00 ***
- 6 D → 6.00 ***
2.00 ***
- 8 D → 8.00 ***
3.00 ***

Outputs:

7	D		7.00 ***
			4.00 ***
f	A		28.00 *** (RS ₁)
2	D		2.00 ***
			1.00 ***
4	D		4.00 ***
			2.00 ***
4	D		4.00 ***
			3.00 ***
4	D		4.00 ***
			4.00 ***
f	A		14.00 *** (RS ₂)
4	D		4.00 ***
			1.00 ***
7	D		7.00 *** (error)
			2.00 ***
7	E		7.00 *** (correction)
			1.00 ***
6	D		6.00 ***
			2.00 ***
5	D		5.00 ***
			3.00 ***
3	D		3.00 ***
			4.00 ***
f	A		18.00 *** (RS ₃)
f	B		0.00 ***
7	D		7.00 ***
			1.00 ***
2	D		2.00 ***
			2.00 ***
4	D		4.00 ***
			3.00 ***
f	C		13.00 *** (CS ₁)
6	D		6.00 ***
			1.00 ***
4	D		4.00 ***
			2.00 ***

07-05

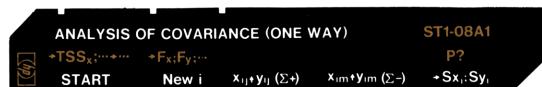
- 6 D → 6.00 ***
3.00 ***
- f C → 16.00 *** (CS₂)
- 8 D → 8.00 ***
1.00 ***
- 4 D → 4.00 ***
2.00 ***
- 5 D → 5.00 ***
3.00 ***
- f C → 17.00 *** (CS₃)
- 7 D → 7.00 ***
1.00 ***
- 4 D → 4.00 ***
2.00 ***
- 3 D → 3.00 ***
3.00 ***
- f C → 14.00 *** (CS₄)
- f D → 11.70 *** (F₁)
R/S → 1.00 *** (F₂)
- f D → 2.00 *** (df₁)
R/S → 3.00 *** (df₂)
R/S → 6.00 *** (df₃)
- f E → 26.00 *** (RSS)
R/S → 3.33 *** (CSS)
R/S → 6.67 *** (ESS)
R/S → 36.00 *** (TSS)

ANOVA

	SS	df	F ratio
Row	26.00	2	11.70
Column	3.33	3	1.00
Error	6.67	6	
Total	36.00		

Notes

ANALYSIS OF COVARIANCE (ONE WAY)



The one way analysis of covariance program tests the effect of one variable separately from the effect of a second variable, if the second variable represents an actual measurement for each individual (rather than a category).

Suppose (x_{ij}, y_{ij}) represents the j^{th} observation from the i^{th} population ($i = 1, 2, \dots, k$, $j = 1, 2, \dots, n_i$). Note that samples may have equal or unequal number of observations. The analysis of covariance tests for a difference in means of residuals. The residuals are the differences of the observations and a regression quantity based on the associated second variable. The analysis of covariance procedure is based on the separations of the sums of squares and the sums of products into several portions. This program will generate the complete ANOCOV table.

Equations:

1. Sums and sums of squares

$$Sx_i = \sum_j x_{ij} \quad (i = 1, 2, \dots, k)$$

$$TSSx = \sum \sum x_{ij}^2 - \frac{(\sum \sum x_{ij})^2}{\sum_i n_i}$$

$$ASSx = \sum_i \frac{\left(\sum_j x_{ij} \right)^2}{n_i} - \frac{(\sum \sum x_{ij})^2}{\sum_i n_i}$$

$$WSSx = TSSx - ASSx$$

2. Degrees of freedom

$$df_1 = k - 1$$

$$df_2 = \sum_i n_i - k$$

3. Mean squares and F statistic

$$AMSx = \frac{ASSx}{df_1}$$

$$WMSx = \frac{WSSx}{df_2}$$

$$F_x = \frac{AMSx}{WMSx} \text{ with degrees of freedom } df_1, df_2$$

By changing x_{ij} to y_{ij} , similar formulas for y_{ij} can be obtained.

4. Sums of products

$$TSP = \sum \sum x_{ij} y_{ij} - \frac{(\sum \sum x_{ij})(\sum \sum y_{ij})}{\sum_i n_i}$$

$$ASP = \sum_i \frac{\left(\sum_j x_{ij} \right) \left(\sum_j y_{ij} \right)}{n_i} - \frac{(\sum \sum x_{ij})(\sum \sum y_{ij})}{\sum_i n_i}$$

$$WSP = TSP - ASP$$

5. Residual sums of squares

$$TSS\hat{y} = TSSy - \frac{(TSP)^2}{TSSx}$$

$$WSS\hat{y} = WSSy - \frac{(WSP)^2}{WSSx}$$

$$ASS\hat{y} = TSS\hat{y} - WSS\hat{y}$$

6. Residual degrees of freedom

$$df_3 = k - 1$$

$$df_4 = \sum_i n_i - k - 1$$

7. Residual mean squares and F statistic

$$AMS\hat{y} = \frac{ASS\hat{y}}{df_3}$$

$$WMS\hat{y} = \frac{WSS\hat{y}}{df_4}$$

$$F = \frac{AMS\hat{y}}{WMS\hat{y}} \text{ with degrees of freedom } df_3, df_4$$

ANOCOV Table

	degrees of freedom	SSx	SP	SSy	degrees of freedom	Residuals		
Among means	df ₁	ASSx	ASP	ASSy	df ₃	ASS\hat{y}	AMS\hat{y}	F
Within groups	df ₂	WSSx	WSP	WSSy	df ₄	WSS\hat{y}	WMS\hat{y}	
Total				TSS\hat{y}			TSS\hat{y}	

Remarks:

1. F_x can be used to test if the X means are equal (ANOVA for X).
2. F_y can be used to test if the Y means (not making use of the X values) are equal (ANOVA for unadjusted Y).

Reference:

Dixon and Massey, *Introduction to Statistical Analysis*, McGraw-Hill, 1969.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2 of card 1			
2	Initialize		A	0.00
3	To set print mode*		f E	1.00
4	Do 5~9 for $i=1, 2, \dots, k$			
5	Initialize for new i		B	i
6	Do 6 for $j=1, 2, \dots, n_j$			
7	Input x_{ij} and y_{ij}	x_{ij}	ENTER	
		y_{ij}	C	j
8	If you made a mistake in inputting x_{im} and y_{im} , then correct by	x_{im}	ENTER	
		y_{im}	D	$j-1$
9	Calculate the i^{th} sums S_x , S_y ,		E	Sx_i
			R/S	Sy_i
10	Calculate: the total sum of squares for x		f A	TSS x
	Among means sum of squares for x		R/S	ASS x
	Within groups sum of squares for x		R/S	WSS x
11	Calculate: the total sum of squares for y		f A	TSS y
	Among means sum of squares for y		R/S	ASS y
	Within groups sum of squares for y		R/S	WSS y
12	Calculate: F_x		f B	F_x
	F_y		R/S	F_y
	degrees of freedom df_1 ,		R/S	df_1
	df_2		R/S	df_2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
13	Load side 1 of card 2			
14	Calculate: the total sum of			
	products (SP)		[f] [C]	TSP
	among means SP		[R/S]	ASP
	within group SP		[R/S]	WSP
15	Calculate: TSS̄		[f] [D]	TSS̄
	WSS̄		[R/S]	WSS̄
	ASS̄		[R/S]	ASS̄
16	Calculate: residual mean			
	squares		[f] [E]	AMS̄
	WMS̄		[R/S]	WMS̄
	the F statistic		[R/S]	F
	the degrees of freedom df ₃		[R/S]	df ₃
	df ₄		[R/S]	df ₄
17	For a new case, go to 1			
	*Note: to clear print mode			
	press →		[CLF]	
			[O]	

Example:

		j				
		1	2	3	4	
i		x	3	2	1	2
1		y	10	8	8	11
2		x	4	3	3	5
i		y	12	12	10	13
3		x	1	2	3	1
y		6	5	8	7	

(k = 3, n₁ = n₂ = n₃ = 4)

Keystrokes:

Load side 1 and side 2 of card 1

Keystrokes:

Keystrokes:	Outputs:
A	→ 0.00
f E	→ 1.00
B	→ 1.00 ***
3 ENTER↑ 10 C	→ 3.00 *** 10.00 *** 1.00 ***
2 ENTER↑ 8 C	→ 2.00 *** 8.00 *** 2.00 ***
5 ENTER↑ 5 C	→ 5.00 *** 5.00 *** 3.00 *** (error)
5 ENTER↑ 5 D	→ 5.00 *** 5.00 *** 2.00 *** (correction)
1 ENTER↑ 8 C	→ 1.00 *** 8.00 *** 3.00 ***
2 ENTER↑ 11 C	→ 2.00 *** 11.00 *** 4.00 ***
E	→ 8.00 *** (Sx ₁)
R/S	→ 37.00 *** (Sy ₁)
B	→ 2.00 ***
4 ENTER↑ 12 C	→ 4.00 *** 12.00 *** 1.00 ***
3 ENTER↑ 12 C	→ 3.00 *** 12.00 *** 2.00 ***
3 ENTER↑ 10 C	→ 3.00 *** 10.00 *** 3.00 ***

08-07

5 **ENTER** 13 **C** → 5.00 ***
13.00 ***
4.00 ***

E → 15.00 *** (Sx₂)
R/S → 47.00 *** (Sy₂)

B → 3.00 ***

1 **ENTER** 6 **C** → 1.00 ***
6.00 ***
1.00 ***

2 **ENTER** 5 **C** → 2.00 ***
5.00 ***
2.00 ***

3 **ENTER** 8 **C** → 3.00 ***
8.00 ***
3.00 ***

1 **ENTER** 7 **C** → 1.00 ***
7.00 ***
4.00 ***

E → 7.00 *** (Sx₃)
R/S → 26.00 *** (Sy₃)

f A → 17.00 *** (TSSx)
R/S → 9.50 *** (ASSx)
R/S → 7.50 *** (WSSx)

f A → 71.67 *** (TSSy)
R/S → 55.17 *** (ASSy)
R/S → 16.50 *** (WSSy)

f B → 5.70 *** (Fx)
R/S → 15.05 *** (Fy)
R/S → 2.00 *** (df₁)
R/S → 9.00 *** (df₂)

Load side 1 of card 2

f C → 27.00 *** (TSP)
R/S → 20.75 *** (ASP)
R/S → 6.25 *** (WSP)

f D → 28.78 *** (TSS \hat{y})
R/S → 11.29 *** (WSS \hat{y})
R/S → 17.49 *** (ASS \hat{y})

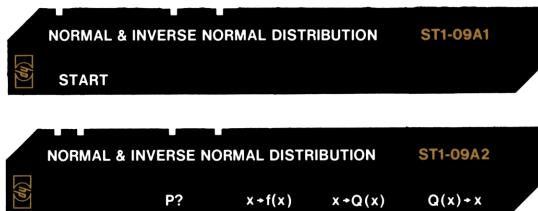
f E → 8.75 *** (AMS \hat{y})
R/S → 1.41 *** (WMS \hat{y})
R/S → 6.20 *** (F)
R/S → 2.00 *** (df₃)
R/S → 8.00 *** (df₄)

ANOCOV Table

Residuals

	df	SSx	SP	SSy	df	SS \hat{y}	MS \hat{y}	F
Among means	2	9.50	20.75	55.17	2	17.49	8.75	6.20
Within groups	9	7.50	6.25	16.50	8	11.29	1.41	
Total		17.00	27.00	71.67		28.78		

NORMAL AND INVERSE NORMAL DISTRIBUTION



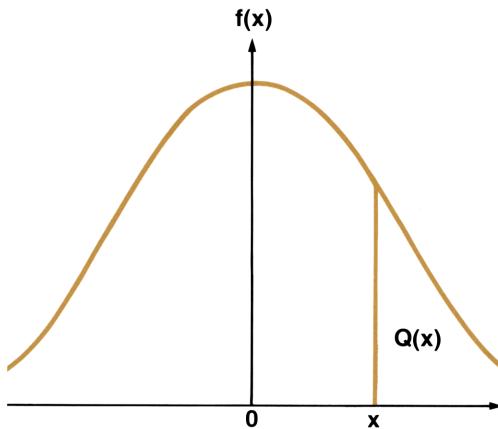
This program evaluates the standard normal density function $f(x)$ and the normal integral $Q(x)$ for given x . If Q is given, x can also be found.

The standard normal distribution has mean 0 and standard deviation 1.

Equations:

1. Standard normal density

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$$



2. Normal integral

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-\frac{t^2}{2}} dt$$

Polynomial approximation is used to compute $Q(x)$ for given x .

Define $R = f(x) (b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5) + \epsilon(x)$

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

$$t = \frac{1}{1+r|x|}, \quad r = 0.2316419$$

$$b_1 = .319381530, \quad b_2 = -.356563782$$

$$b_3 = 1.781477937, \quad b_4 = -1.821255978$$

$$b_5 = 1.330274429$$

$$\text{Then } Q(x) = \begin{cases} R & \text{if } x \geq 0 \\ 1-R & \text{if } x < 0 \end{cases}$$

3. Inverse normal

For a given $Q > 0$, x can be found such that

$$Q = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-\frac{t^2}{2}} dt.$$

The following rational approximation is used:

$$\text{Define } y = t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} + \epsilon(Q)$$

where $|\epsilon(Q)| < 4.5 \times 10^{-4}$

$$t = \begin{cases} \sqrt{\ln \frac{1}{Q^2}} & \text{if } 0 < Q \leq 0.5 \\ \sqrt{\ln \frac{1}{(1-Q)^2}} & \text{if } 0.5 < Q < 1 \end{cases}$$

09-03

$$\begin{aligned}c_0 &= 2.515517 \\c_1 &= 0.802853 \\c_2 &= 0.010328\end{aligned}$$

$$\begin{aligned}d_1 &= 1.432788 \\d_2 &= 0.189269 \\d_3 &= 0.001308\end{aligned}$$

Then $x = \begin{cases} y & \text{if } 0 < Q \leq 0.5 \\ -y & \text{if } 0.5 < Q < 1 \end{cases}$

Reference:

Abramowitz and Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, 1970.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2 of card 1			
2	Initialize		A	0.00
3	Load side 1 and side 2 of card 2			
4	To set print mode*		B	1.00
	Optional: Step 5			
5	Input x to compute f(x)	x	C	f(x)
6	Input x to compute Q(x)	x	D	Q(x)
	For a new case of x, go to 5 or 6			
7	Input Q(x) to compute x	Q(x)	E	x
	For a new case of Q(x), go to 7			
	*Note: to clear print mode press →		0 STO A STO B	

Example 1:

Find $f(x)$ and $Q(x)$ for $x = 1.18$ and $x = -2.28$.

Keystrokes:

Outputs:

Load side 1 and side 2 of card 1

A → 0.00

Load side 1 and side 2 of card 2

B	→	1.00	
1.18 C	→	1.18 ***	
		0.20 ***	(f(1.18))
1.18 D	→	1.18 ***	
		0.12 ***	(Q(1.18))
2.28 CHS D	→	-2.28 ***	
		0.99 ***	(Q(-2.28))
2.28 CHS C	→	-2.28 ***	
		0.03 ***	(f(-2.28))

Example 2:

Given $Q = 0.12$ and $Q = 0.95$, find x .

(If you have run through Example 1, then you can proceed; otherwise you have to load programs as described in Example 1).

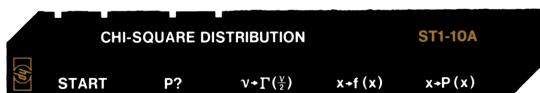
Keystrokes:

Outputs:

0.12 E → 0.12 ***
1.18 *** (x)

0.95 E → 0.95 ***
-1.65 *** (x)

CHI-SQUARE DISTRIBUTION

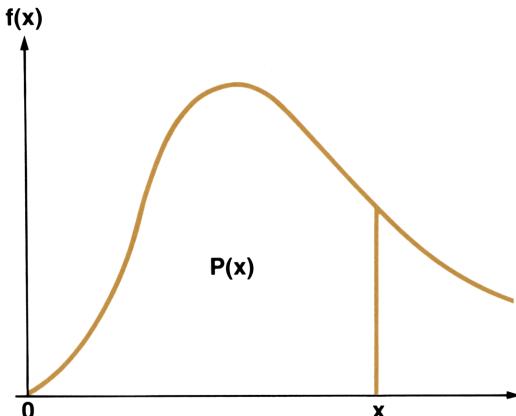


This program evaluates the chi-square density

$$f(x) = \frac{1}{2^{\frac{\nu}{2}} \Gamma\left(\frac{\nu}{2}\right)} x^{\frac{\nu}{2}-1} e^{-\frac{x}{2}}$$

where $x \geq 0$

ν is the degrees of freedom.



Series approximation is used to evaluate the cumulative distribution

$$P(x) = \int_0^x f(t) dt$$

$$= \left(\frac{x}{2}\right)^{\frac{\nu}{2}} \frac{e^{-\frac{x}{2}}}{\Gamma\left(\frac{\nu+2}{2}\right)} \left[1 + \sum_{k=1}^{\infty} \frac{x^k}{(\nu+2)(\nu+4)\dots(\nu+2k)} \right]$$

The program computes successive partial sums of the above series. When two consecutive partial sums are equal, the value is used as the sum of the series.

Notes: 1. Program requires $\nu < 141$. If $\nu > 141$, erroneous overflow will result.

2. If both x and ν are large, $f(x)$ may overflow the machine.
3. If ν is even,

$$\Gamma\left(\frac{\nu}{2}\right) = \left(\frac{\nu}{2} - 1\right)!$$

If ν is odd,

$$\Gamma\left(\frac{\nu}{2}\right) = \left(\frac{\nu}{2} - 1\right)\left(\frac{\nu}{2} - 2\right) \dots \left(\frac{1}{2}\right) \Gamma\left(\frac{1}{2}\right)$$

$$4. \Gamma\left(\frac{1}{2}\right) = \sqrt{\pi}$$

Reference:

Abramowitz and Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, 1970.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Input degrees of freedom ν	ν	C	$\Gamma(\nu/2)$
	Optional: Step 5			
5	Input x to compute $f(x)$	x	D	$f(x)$
6	Input x to compute $P(x)$	x	E	$P(x)$
	(i) For a new case with the same ν go to 5 or 6			
	(ii) For a new case with different ν , go to 2			
	*Note: to clear print mode			
	press →		[CLF]	
			[O]	

10-03

Example 1:

If degrees of freedom $\nu = 20$, find $f(x)$, $P(x)$ for $x = 9.6$ and $x = 15$.

Keystrokes:	Outputs:
A	0.00
B	1.00
20 C	20.00 *** 362880.00 *** ($\Gamma(20/2)$)
9.6 D	9.60 *** 0.02 *** ($f(9.6)$)
9.6 E	9.60 *** 0.03 *** ($P(9.6)$)
15 E	15.00 *** 0.22 *** ($P(15)$)
15 D	15.00 *** 0.06 *** ($f(15)$)

Example 2:

If $\nu = 3$, find $f(x)$ and $P(x)$ for $x = 7.82$.

Keystrokes:	Outputs:
A	0.00
B	1.00
3 C	3.00 *** 0.89 *** ($\Gamma(3/2)$)
7.82 D	7.82 *** 0.02 *** ($f(7.82)$)
7.82 E	7.82 *** 0.95 *** ($P(7.82)$)

Notes

t DISTRIBUTION

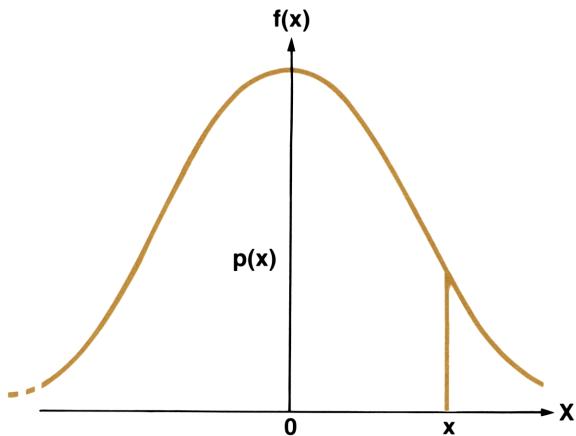


This program evaluates the t density function $f(x)$ and the cumulative distribution $P(x)$ for a given x and degrees of freedom v .

Equations:

1. Density function

$$f(x) = \frac{\Gamma\left(\frac{v+1}{2}\right)}{\sqrt{\pi v} \Gamma\left(\frac{v}{2}\right)} \left(1 + \frac{x^2}{v}\right)^{-\frac{v+1}{2}}$$



2. Cumulative distribution function

$$P(x) = \int_{-\infty}^x f(y) dy$$

$$\text{Let } \theta = \tan^{-1} \left(\frac{|x|}{\sqrt{v}} \right)$$

(a) ν even

$$\text{Let } R = \sin\theta \left\{ 1 + \frac{1}{2} \cos^2 \theta + \frac{1 \cdot 3}{2 \cdot 4} \cos^4 \theta + \dots + \frac{1 \cdot 3 \cdot 5 \dots (\nu-3)}{2 \cdot 4 \cdot 6 \dots (\nu-2)} \cos^{\nu-2} \theta \right\}$$

(b) ν odd

$$\text{Let } R = \begin{cases} \frac{2\theta}{\pi} & \text{if } \nu = 1 \\ \frac{2\theta}{\pi} + \frac{2}{\pi} \cos\theta & \left\{ \sin\theta \left[1 + \frac{2}{3} \cos^2 \theta + \dots + \frac{2 \cdot 4 \dots (\nu-3)}{1 \cdot 3 \dots (\nu-2)} \cos^{\nu-3} \theta \right] \right\} & \text{if } \nu > 1 \end{cases}$$

$$\text{Then } P(x) = \begin{cases} \frac{1+R}{2} & \text{if } x > 0 \\ \frac{1-R}{2} & \text{if } x \leq 0 \end{cases}$$

Remark:The program requires $\nu < 141$ for $f(x)$, otherwise erroneous overflow will result.**Reference:**Abramowitz and Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, 1970.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Input degrees of freedom ν	ν	C	ν
	Optional: Step 5			
5	Input x to compute $f(x)$	x	D	$f(x)$
6	Input x to compute $P(x)$	x	E	$P(x)$
7	(i) For a new case with the same ν go to 5 or 6			
	(ii) For a new case with a different ν , go to 2			
	*Note: to clear print mode			
	press →		CLF	
			O	

Example 1:Find $f(x)$ and $P(x)$ for $x = 2.2$, $\nu = 11$.**Keystrokes:**

- A** → 0.00
B → 1.00
11 **C** → 11.00 *** (ν)
- 2.2 **E** → 2.20 *** (x)
0.97*** ($P(2.2)$)
- 2.2 **D** → 2.20 *** (x)
0.04 *** ($f(2.2)$)

Outputs:

Example 2:

Find $f(x)$ and $P(x)$ for $x = -1.75$, $\nu = 30$.

Keystrokes:

	Outputs:
A	0.00
B	1.00
30 C	30.00 *** (ν)
1.75 CHS D	-1.75 *** (x) 0.09 *** ($f(-1.75)$)
1.75 CHS E	-1.75 *** (x) 0.05 *** ($P(-1.75)$)

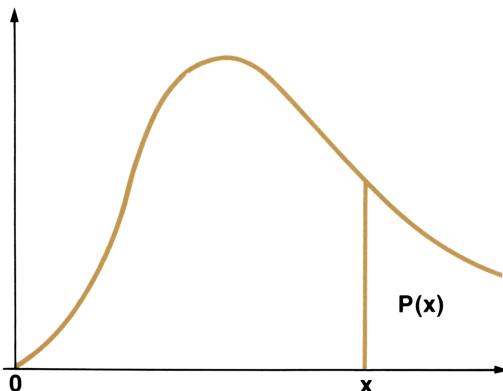
F DISTRIBUTION

	F DISTRIBUTION		ST1-12A
	START	P?	v ₁
			v ₂
			x+P(x)

This program evaluates the integral of the F distribution

$$P(x) = \int_x^{\infty} \frac{\Gamma\left(\frac{\nu_1 + \nu_2}{2}\right) y^{\frac{\nu_1}{2}-1} \left(\frac{\nu_1}{\nu_2}\right)^{\frac{\nu_1}{2}}}{\Gamma\left(\frac{\nu_1}{2}\right) \Gamma\left(\frac{\nu_2}{2}\right) \left(1 + \frac{\nu_1}{\nu_2} y\right)^{\frac{\nu_1 + \nu_2}{2}}} dy$$

for given values of x (>0), degrees of freedom ν_1 , ν_2 , provided either ν_1 or ν_2 is even.



The integral is evaluated by means of the following series:

(1) ν_1 even

$$P(x) = t^{\frac{\nu_2}{2}} \left[1 + \frac{\nu_2}{2}(1-t) + \dots + \frac{\nu_2(\nu_2+2)\dots(\nu_2+\nu_1-4)}{2\cdot4\dots(\nu_1-2)} (1-t)^{\frac{\nu_1-2}{2}} \right]$$

(2) ν_2 even

$$P(x) = 1 - (1-t)^{\frac{\nu_1}{2}} \left[1 + \frac{\nu_1}{2}t + \dots + \frac{\nu_1(\nu_1+2)\dots(\nu_2+\nu_1-4)}{2\cdot4\dots(\nu_2-2)} t^{\frac{\nu_2-2}{2}} \right]$$

$$\text{where } t = \frac{\nu_2}{\nu_2 + \nu_1 x}$$

Note: Usually ν_1 is identified as the degree of freedom for numerator, and ν_2 is identified as the degree of freedom for denominator.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Input ν_1	ν_1	C	ν_1
5	Input ν_2	ν_2	D	ν_2
6	Input x to calculate P(x)	x	E	P(x)
7	For a new case go to 2			
	*Note: to clear print mode			
	press →		[CLF]	
			[Q]	

Examples:

$$1. \nu_1 = 7, \nu_2 = 6$$

$$P(4.21) = 0.05$$

$$2. \nu_1 = 4, \nu_2 = 20$$

$$P(2.25) = 0.10$$

Keystrokes:

- A** → 0.00
- B** → 1.00
- 7 **C** → 7.00 *** (ν_1)
- 6 **D** → 6.00 *** (ν_2)
- 4.21 **E** → 4.21 *** (x)
0.05 *** $(P(x))$

Outputs:

- 4 **C** → 4.00 *** (ν_1)
- 20 **D** → 20.00 *** (ν_2)
- 2.25 **E** → 2.25 *** (x)
0.10 *** $(P(x))$

MULTIPLE LINEAR REGRESSION



For a set of data points $\{(x_i, y_i, z_i), i = 1, 2, \dots, n\}$ this program fits a linear equation of the form

$$z = a + bx + cy$$

by the least squares method.

Regression coefficients a, b, c can be found by solving the normal equations:

$$\left. \begin{array}{l} \sum z_i = an + b \sum x_i + c \sum y_i \\ \sum x_i z_i = a \sum x_i + b \sum x_i^2 + c \sum x_i y_i \\ \sum y_i z_i = a \sum y_i + b \sum x_i y_i + c \sum y_i^2 \end{array} \right\} \quad i = 1, 2, \dots, n$$

$$c = \frac{A - B}{[n \sum x_i^2 - (\sum x_i)^2] [n \sum y_i^2 - (\sum y_i)^2] - [n \sum x_i y_i - (\sum x_i)(\sum y_i)]^2}$$

$$\text{where } A = [n \sum x_i^2 - (\sum x_i)^2] [n \sum y_i z_i - (\sum y_i)(\sum z_i)]$$

$$B = [n \sum x_i y_i - (\sum x_i)(\sum y_i)] [n \sum x_i z_i - (\sum x_i)(\sum z_i)]$$

$$b = \frac{[n \sum x_i z_i - (\sum x_i)(\sum z_i)] - c [n \sum x_i y_i - (\sum x_i)(\sum y_i)]}{n \sum x_i^2 - (\sum x_i)^2}$$

$$a = \frac{1}{n} (\sum z_i - c \sum y_i - b \sum x_i)$$

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

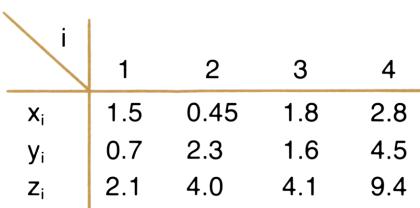
Reference: Introduction to the Theory of Statistics, Mood and Graybill, McGraw-Hill, 1963

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Do 5~6 for $i = 1, 2, \dots, n$			
5	Input x_i	x_i	ENTER ↴	
	y_i	y_i	ENTER ↴	
	z_i	z_i	C	i
6	If you made a mistake in inputting x_k , y_k , and z_k , then correct by →	x_k	ENTER ↴	
		y_k	ENTER ↴	
		z_k	D	i-1
7	Calculate coefficients: a		E	a
	b		R/S	b
	c		R/S	c
8	Calculate the square of multiple correlation coefficient R^2		f A	R^2
9	Calculate estimated z from regression, input: x	x	ENTER ↴	
	y	y	f B	\hat{z}
10	Repeat step 9 for different (x, y)'s			
11	Recall sums: Σx_i		f C	Σx_i
	Σy_i		R/S	Σy_i
	Σz_i		R/S	Σz_i
12	Recall sums of squares: Σx_i^2		f D	Σx_i^2
	Σy_i^2		R/S	Σy_i^2
	Σz_i^2		R/S	Σz_i^2

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
13	Recall sums of cross products: $\sum x_i y_i$			
	$\sum x_i z_i$		R/S	$\sum x_i z_i$
	$\sum y_i z_i$		R/S	$\sum y_i z_i$
14	For a new case, go to 2			
	*Note: to clear print mode			
	press →		CLF	
			②	

Example:

A set of data points are given as the following



Find the regression line, coefficients a, b, c, R^2 , \hat{z} , sums, sums of squares, and sums of products.

Keystrokes:

A → 0.00
B → 1.00
 1.5 **ENTER** 0.7 **ENTER** 2.1 **C** → 1.50 ***
 0.70 ***
 2.10 ***
 1.00 ***

Outputs:

9 **ENTER** 9 **ENTER** 9 **C** → 9.00 ***
 9.00 *** (error)
 9.00 ***
 2.00 ***

9 [ENTER] 9 [ENTER] 9 [D] → 9.00 ***
 (correction)
 9.00 ***
 9.00 ***
 1.00 ***

0.45 [ENTER] 2.3 [ENTER] 4 [C] → 0.45 ***
 2.30 ***
 4.00 ***
 2.00 ***

1.8 [ENTER] 1.6 [ENTER] 4.1 [C] → 1.80 ***
 1.60 ***
 4.10 ***
 3.00 ***

2.8 [ENTER] 4.5 [ENTER] 9.4 [C] → 2.80 ***
 4.50 ***
 9.40 ***
 4.00 ***

[E] → -0.10 *** (a)
 [R/S] → 0.79 *** (b)
 [R/S] → 1.63 *** (c)

[f] [A] → 1.00 *** (R²)
 [DSP] [9] [PRINT X] → 0.998411259 ***
 [DSP] [2]
 2 [ENTER] 3 [f] [B] → 2.00 ***
 3.00 ***
 6.37 *** (ẑ)

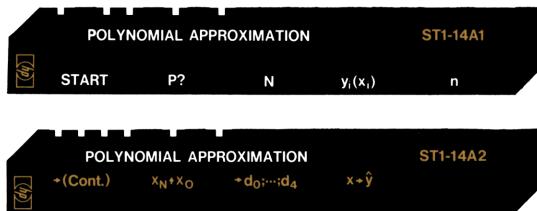
[f] [C] → 6.55 *** (Σx_i)
 [R/S] → 9.10 *** (Σy_i)
 [R/S] → 19.60 *** (Σz_i)
 [f] [D] → 13.53 *** (Σx_i^2)
 [R/S] → 28.59 *** (Σy_i^2)
 [R/S] → 125.58 *** (Σz_i^2)
 [f] [E] → 17.57 *** ($\Sigma x_i y_i$)
 [R/S] → 38.65 *** ($\Sigma x_i z_i$)
 [R/S] → 59.53 *** ($\Sigma y_i z_i$)

Regression line is

$$z = -0.10 + 0.79x + 1.63y$$

For x = 2 and y = 3, ẑ = 6.37

POLYNOMIAL APPROXIMATION



Suppose x_0, x_1, \dots, x_N are equally spaced points ($x_0 < x_N$) at which the corresponding values $f(x_0), f(x_1), \dots, f(x_N)$ of a function $f(x)$ are known.

This program approximates in the least squares sense the function $f(x)$ by a polynomial of degree m , where $2 \leq m \leq 4$. The special Chebyshev polynomials for discrete intervals are used.

Equations:

Let $f_n(x)$ be the orthogonal polynomials ($x = 0, 1, 2, \dots, N$) such that

$$f_0(x) = 1$$

$$f_1(x) = 1 - \frac{2x}{N} \text{ and}$$

$$(n+1)(N-n) f_{n+1}(x) = (2n+1)(N-2x) f_n(x) - n(N+n+1) f_{n-1}(x)$$

where

$$n = 1, 2, \dots, m-1.$$

Then let

$$(f_n, f_n) = \frac{(N+n+1)! (N-n)!}{(2n+1) (N!)^2}$$

$$(f, f_n) = \sum_{j=0}^n f_n(j) f(x_j)$$

and

$$a_n = \frac{(f, f_n)}{(f_n, f_n)}.$$

This program computes all values of (f, f_n) for $n = 0, 1, 2, 3, 4$. If the degree $m = 4$, all terms are used; if $m = 3$, (f, f_4) is replaced by zero in later calculations; and if $m = 2$, (f, f_4) and (f, f_3) are both replaced by zero.

Let $g_n(u)$ be the symmetrical form of the orthogonal polynomial in the domain $-1 < u < 1$ such that

$$g_0(u) = 1 \quad g_1(u) = u$$

and

$$g_{n+1}(u) = \frac{(2 + 1) N}{(n + 1)(N - n)} u g_n(u) - \frac{n(N + n + 1)}{(n + 1)(N - n)} g_{n-1}(u)$$

where

$$n = 1, 2, \dots, m - 1.$$

The program computes the coefficients of the polynomial

$$\sum_{n=0}^N a_n g_n(u) = b_0 + b_1 u + b_2 u^2 + b_3 u^3 + b_4 u^4. \quad (1)$$

Then $g_n(u)$ is shifted to a proper interval between x_0 and x_N by letting

$$u = \beta + \alpha x$$

where

$$\alpha = \frac{-2}{x_N - x_0}$$

$$\beta = \frac{x_N + x_0}{x_N - x_0}$$

The transformation is done in two steps. First, let $z = u - \beta$, thus (1) becomes

$$c_0 + c_1 z + c_2 z^2 + c_3 z^3 + c_4 z^4 \quad (2)$$

14-03

where

$$c_0 = b_0 + b_1 \beta + b_2 \beta^2 + b_3 \beta^3 + b_4 \beta^4$$

$$c_1 = b_1 + 2b_2 \beta + 3b_3 \beta^2 + 4b_4 \beta^3$$

$$c_2 = b_2 + 3b_3 \beta + 6b_4 \beta^2$$

$$c_3 = b_3 + 4 b_4 \beta$$

$$c_4 = b_4.$$

Then set $z = \alpha x$ and (2) becomes

$$d_0 + d_1 x + d_2 x^2 + d_3 x^3 + d_4 x^4 \quad (3)$$

where

$$d_i = \alpha^i c_i \quad (i = 0, 1, 2, 3, 4).$$

(3) is the polynomial approximation for the function $f(x)$.

Note: $N \geq 4$ has to be satisfied in order to make the program work.

Reference:

Abramowitz and Stegun, *Handbook of Mathematical Functions*, National Bureau of Standards, 1970.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2 of card 1			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Input N**	N	C	N
5	Do 6 for $i = 0, 1, 2, \dots, N$			
6	Input $y_i (x_i)$	$y_i (x_i)$	D	i
7	Input n for nth order fit	n	E	0.00
8	Load side 1 and side 2 of card 2			
9	To continue execution of			
	program		f A	1.00

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
10	Input x_N	x_N	ENTER	
	and x_0	x_0	f B	
11	To obtain the coefficients: d_i		f C	d_0
			R/S	d_1
			R/S	d_2
			R/S	d_3
			R/S	d_4
12	To evaluate y from the polynomial	x	f D	\hat{y}
13	For a new case, go to 1			
	$**N = \text{No. of data} - 1$			
	*Note: to clear print mode			
	press →		CLF	
			⑤	

Example:

Find a third order polynomial approximation for the following data.

x	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
f(x)	2.72	3.49	4.48	5.75	7.39	9.49	12.18	15.64	20.09

(Note: $f(x) = e^x$)

Keystrokes:

Load side 1 and side 2 of Card 1

A → 0.00
B → 1.00
8 **C** → 8.00 *** (N)

Outputs:

2.72 **D** → 2.72 ***
1.00 ***

3.49 **D** → 3.49 ***
2.00 ***

14-05

4.48 **D** → 4.48***
3.00 ***

5.75 **D** → 5.75 ***
4.00 ***

7.39 **D** → 7.39 ***
5.00 ***

9.49 **D** → 9.49 ***
6.00 ***

12.18 **D** → 12.18 ***
7.00 ***

15.64 **D** → 15.64 ***
8.00 ***

20.09 **D** → 20.09 ***
9.00 ***

3 **E** → 3.00 *** (n)

Load side 1 and side 2 of Card 2

f A → 1.00
3 **ENTER** 1 **f B** → 3.00 *** (x_N)
1.00 *** (x_o)

f C → -1.79 *** (d_0)

R/S → 7.03 *** (d_1)

R/S → -3.85 *** (d_2)

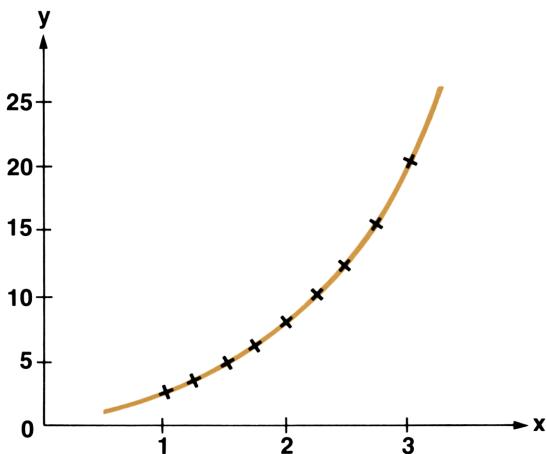
R/S → 1.31 *** (d_3)

R/S → 0.00 *** (d_4)

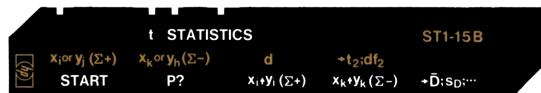
2 **f D** → 2.00 ***
7.35 *** (\hat{y})

3	f	D	→	3.00 ***	
				20.06 ***	(ŷ)
1	f	D	→	1.00 ***	
				2.69 ***	(ŷ)

The polynomial is $-1.79 + 7.03 x - 3.85 x^2 + 1.31 x^3$.



t STATISTICS



I. Paired t Statistic

Given a set of paired observations from two normal populations with means μ_1, μ_2 (unknown)

x_i	x_1	x_2	\dots	x_n
y_i	y_1	y_2	\dots	y_n

let

$$D_i = x_i - y_i$$

$$\bar{D} = \frac{1}{n} \sum_{i=1}^n D_i$$

$$s_D = \sqrt{\frac{\sum D_i^2 - \frac{1}{n} (\sum D_i)^2}{n-1}}$$

$$s_{\bar{D}} = \frac{s_D}{\sqrt{n}}$$

The test statistic

$$t = \frac{\bar{D}}{s_{\bar{D}}}$$

which has $n - 1$ degrees of freedom (df) can be used to test the null hypothesis

$$H_0: \mu_1 = \mu_2$$

Reference:

Statistics in Research, B. Ostle, Iowa State University Press, 1963.

II. t Statistic For Two Means

Suppose $\{x_1, x_2, \dots, x_{n_1}\}$ and $\{y_1, y_2, \dots, y_{n_2}\}$ are independent random samples from two normal populations having means μ_1, μ_2 (unknown) and the same unknown variance σ^2 .

We want to test the null hypothesis

$$H_0: \mu_1 - \mu_2 = d$$

Define

$$\bar{x} = \frac{1}{n_1} \sum_{i=1}^{n_1} x_i$$

$$\bar{y} = \frac{1}{n_2} \sum_{i=1}^{n_2} y_i$$

$$t = \frac{\bar{x} - \bar{y} - d}{\sqrt{\frac{\frac{1}{n_1} + \frac{1}{n_2}}{\frac{\sum x_i^2 - n_1 \bar{x}^2 + \sum y_i^2 - n_2 \bar{y}^2}{n_1 + n_2 - 2}}}}$$

We can use this t statistic which has the t distribution with $n_1 + n_2 - 2$ degrees of freedom (df) to test the null hypothesis H_0 .

Note: $n_2, \sum y_i, \sum y_i^2, n_1, \sum x_i, \sum x_i^2$ are in registers R₁ through R₆.

Reference:

Statistical Theory and Methodology in Science and Engineering, K. A. Brownlee, John Wiley & Sons, 1965.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	For paired t statistic, go to 6			
5	For t statistic for two means,			
	go to 11			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	Paired t statistic:			
6	Do $7 \sim 8$ for $i = 1, 2, \dots, n$			
7	Input: x_i	x_i	ENTER	
	y_i	y_i	C	i
8	If you made a mistake in inputting x_k, y_k then correct by	x_k	ENTER	
		y_k	D	$i-1$
9	Calculate: \bar{D}		E	\bar{D}
	s_D		R/S	s_D
	test statistic:		R/S	t
	degrees of freedom		R/S	df
10	For a new case, go to 2			
	t statistic for two means:			
11	Do $12 \sim 13$ for $i = 1, 2, \dots, n_1$			
12	Input x_i	x_i	f A	i
13	If you made a mistake in inputting x_k , then correct by →	x_k	f B	$i-1$
14	Null hypothesis test	d	f C	d
15	Do $16 \sim 17$ for $j = 1, 2, \dots, n_2$	y_j	f A	j
16	If you made a mistake in inputting y_k , then correct by →	y_k	f B	$j-1$
17	Calculate: t		f D	t
	df		R/S	df
18	For a different value of d	d	f C	d
	Calculate: t		f D	t
	df		R/S	df
19	For a new case, go to 2			
	*Note: to clear print mode			
	press →		CLF	
			O	

Example 1:

x_1	14	17.5	17	17.5	15.4
y_1	17	20.7	21.6	20.9	17.2

$$\bar{D} = -3.20$$

$$s_D = 1.00$$

$$t = -7.16$$

$$df = 4.00$$

Keystrokes:**Outputs:**

A → 0.00

B → 1.00

14 [ENTER] 17 C → 14.00 ***
17.00 ***
1.00 ***

17 [ENTER] 15 C → 17.00 ***
15.00 *** (error)
2.00 ***

17 [ENTER] 15 D → 17.00 ***
15.00 *** (correction)
1.00 ***

17.5 [ENTER] 20.7 C → 17.50 ***
20.70 ***
2.00 ***

17 [ENTER] 21.6 C → 17.00 ***
21.60 ***
3.00 ***

17.5 [ENTER] 20.9 C → 17.50 ***
20.90 ***
4.00 ***

15.4 [ENTER] 17.2 C → 15.40 ***
17.20 ***
5.00 ***

15-05

E → -3.20 *** (D)
R/S → 1.00 *** (s_D)
R/S → -7.16 *** (t)
R/S → 4.00 *** (df)

Example 2:

x: 79, 84, 108, 114, 120, 103, 122, 120

y: 91, 103, 90, 113, 108, 87, 100, 80, 99, 54

n₁ = 8

n₂ = 10

If d = 0 (i.e., H₀: $\mu_1 = \mu_2$)

then t = 1.73, df = 16.00

Keystrokes:

Outputs:

A → 0.00
B → 1.00
79 f A → 79.00 ***
1.00 ***

84 f A → 84.00 ***
2.00 ***

99 f A → 99.00 ***
3.00 *** (error)

99 f B → 99.00 ***
2.00 *** (correction)

108 f A → 108.00 ***
3.00 ***

114 f A → 114.00 ***
4.00 ***

120 f A → 120.00 ***
5.00 ***

103 f A → 103.00 ***
6.00 ***

122 f A → 122.00 ***
7.00 ***

120 **f A** → 120.00 ***
8.00 ***

0 **f C** → 0.00 *** (d)

91 **f A** → 91.00 ***
1.00 ***

103 **f A** → 103.00 ***
2.00 ***

90 **f A** → 90.00 ***
3.00 ***

113 **f A** → 113.00 ***
4.00 ***

108 **f A** → 108.00 ***
5.00 ***

87 **f A** → 87.00 ***
6.00 ***

100 **f A** → 100.00 ***
7.00 ***

80 **f A** → 80.00 ***
8.00 ***

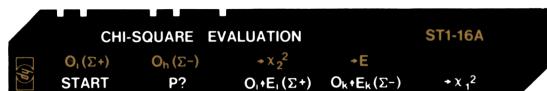
99 **f A** → 99.00 ***
9.00 ***

54 **f A** → 54.00 ***
10.00 ***

f D → 1.73 *** (t)

R/S → 16.00 *** (df)

CHI-SQUARE EVALUATION



This program calculates the value of the χ^2 statistic for the goodness of fit test by the equation

$$\chi_1^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i}$$

where O_i = observed frequency
 E_i = expected frequency

If the expected values are equal

$$\left(E = E_i = \frac{\Sigma O_i}{n} \text{ for all } i \right)$$

then

$$\chi_2^2 = \frac{n \Sigma O_i^2}{\Sigma O_i} - n$$

Note: In order to apply the goodness of fit test to a set of given data, combining some classes may be necessary to make sure that each expected frequency is not too small (say, not less than 5).

Reference: Mathematical Statistics, J. E. Freund, Prentice Hall, 1962

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	For equal expected values, go to 10			
5	Do 6~7 for $i = 1, 2, \dots, n$			
6	Input: O_i	O_i	ENTER +	
	E_i	E_i	C	i

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
7	If you made a mistake in inputting O_k and E_k , then correct by →	O_k	ENTER	
		E_k	D	i-1
8	Calculate χ_1^2		E	χ_1^2
9	For a new case, go to 2			
10	Do 11~12 for $i = 1, 2, \dots, n$ for equal expected values			
11	Input: O_i	O_i	f A	i
12	If you made a mistake in inputting O_h , then correct by →	O_h	f B	i-1
13	Calculate: χ_2^2		f C	χ_2^2
	E		f D	E
14	For a new case, go to 2			
	*Note: to clear print mode press →		CLF	
			Q	

Examples 1:

Find the value of χ^2 statistic for the goodness of fit for the following data set:

O_i	8	50	47	56	5	14
E_i	9.6	46.75	51.85	54.4	8.25	9.15

$\chi_1^2 = 4.84$

Keystrokes:

- A** → 0.00
B → 1.00
8 **ENTER** 9.6 **C** → 8.00 ***
9.60 ***
1.00 ***

Outputs:

16-03

50 **ENTER** 46.75 **C** → 50.00 ***
46.75 ***
2.00 ***

47 **ENTER** 51.85 **C** → 47.00 ***
51.85 ***
3.00 ***

56 **ENTER** 54.4 **C** → 56.00 ***
54.40 ***
4.00 ***

5 **ENTER** 8.25 **C** → 5.00 ***
8.25 ***
5.00 ***

100 **ENTER** 100 **C** → 100.00 *** (error)
100.00 ***
6.00 ***

100 **ENTER** 100 **D** → 100.00 *** (correction)
100.00 ***
5.00 ***

14 **ENTER** 9.15 **C** → 14.00 ***
9.15 ***
6.00 ***

E → 4.84 *** (χ_1^2)

Example 2:

The following table shows the observed frequencies in tossing a die 120 times.
 χ^2 can be used to test if the die is fair.

Note: Assume that the expected frequencies are equal.

number	1	2	3	4	5	6
frequency O_i	25	17	15	23	24	16

$$\chi_2^2 = 5.00$$

$$E = 20.00$$

Keystrokes:	Outputs:
A	→ 0.00
B	→ 1.00
25 f A	→ 25.00 *** 1.00 ***
17 f A	→ 17.00 *** 2.00 ***
19 f A	→ 19.00 *** (error) 3.00 ***
19 f B	→ 19.00 *** (correction) 2.00 ***
15 f A	→ 15.00 *** 3.00 ***
23 f A	→ 23.00 *** 4.00 ***
24 f A	→ 24.00 *** 5.00 ***
16 f A	→ 16.00 *** 6.00 ***
f C	→ 5.00 *** (χ^2)
f D	→ 20.00 *** (E)

CONTINGENCY TABLE

CONTINGENCY TABLE				ST1-17A
	$P?$ 3xk: $X_{1j} \rightarrow (C_j)$ START $2 \times k: X_{ij} \rightarrow (C_i)$	$X_{ih} \rightarrow (\Sigma -)$ $X_{1h} \rightarrow (\Sigma -)$	$\rightarrow \chi^2, C_c$ $\rightarrow \chi^2, C_c$	$\rightarrow R_1; R_2; \dots$ $\rightarrow R_1; R_2; T$

Contingency tables can be used to test the null hypothesis that two variables are independent.

I. $2 \times k$ CONTINGENCY TABLE

j	1	2	...	k	Totals
i	1	2	...	k	Totals
1	x_{11}	x_{12}	...	x_{1k}	R_1
2	x_{21}	x_{22}	...	x_{2k}	R_2
Totals	C_1	C_2	...	C_k	T

Test statistic

$$\chi^2 = \frac{T}{R_1} \sum_{i=1}^k \frac{x_{1i}^2}{C_i} + \frac{T}{R_2} \sum_{i=1}^k \frac{x_{2i}^2}{C_i} - T$$

Degrees of freedom $df = k - 1$

Pearson's coefficient of contingency C_c measures the degree of association between the two variables

$$C_c = \sqrt{\frac{\chi^2}{T + \chi^2}}$$

II. $3 \times k$ CONTINGENCY TABLE

j	1	2	...	k	Totals
i	1	2	...	k	Totals
1	x_{11}	x_{12}	...	x_{1k}	R_1
2	x_{21}	x_{22}	...	x_{2k}	R_2
3	x_{31}	x_{32}	...	x_{3k}	R_3
Totals	C_1	C_2	...	C_k	T

This program computes the χ^2 statistic (with $2(k - 1)$ degrees of freedom) for testing the independence of the two variables. Also Pearson's coefficient of contingency C_c , which measures the degree of association between the two variables, is calculated.

Equations:

$$\text{Row sum } R_i = \sum_{j=1}^k x_{ij} \quad i = 1, 2, 3$$

$$\text{Column sum } C_j = \sum_{i=1}^3 x_{ij} \quad j = 1, 2, \dots, k$$

$$\text{Total } T = \sum_{i=1}^3 \sum_{j=1}^k x_{ij}$$

Chi-square statistic

$$\begin{aligned} \chi^2 &= \sum_{i=1}^3 \sum_{j=1}^k \frac{(x_{ij} - E_{ij})^2}{E_{ij}} \\ &= T \left(\sum_{i=1}^3 \sum_{j=1}^k \frac{x_{ij}^2}{R_i C_j} \right) - T \end{aligned}$$

Where the expected frequency

$$E_{ij} = \frac{R_i C_j}{T}$$

Contingency coefficient

$$C_c = \sqrt{\frac{\chi^2}{T + \chi^2}}$$

Reference:

B. Ostle, *Statistics in Research*, Iowa State University Press, 1972.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		I A	1.00
4	For $2 \times k$ go to 5			
	For $3 \times k$ go to 11			
5	Do 6~7 for $j = 1, 2, \dots, k$			
	for $2 \times k$			
6	Input: x_{1j}	x_{1j}	ENTER+	
	x_{2j}	x_{2j}	B	j
	(Optional) Calculate column sum C_j		R/S	C_j
7	If you made a mistake in inputting x_{1h} and x_{2h} , then correct by →	x_{1h}	ENTER+	
		x_{2h}	C	j-1
	(Optional) Calculate column sum C_h (correction)		R/S	$-C_h$
8	Calculate: χ^2		D	χ^2
	C_c		R/S	C_c
9	Calculate: row sums R_1		E	R_1
	R_2		R/S	R_2
	total T		R/S	T
10	For a new case go to 2			
11	Do 12~13 for $j = 1, 2, \dots, k$			
	for $3 \times k$			
12	Input x_{1j}	x_{1j}	ENTER+	
	x_{2j}	x_{2j}	ENTER+	
	x_{3j}	x_{3j}	I B	j
	(Optional) Calculate column sum C_j		R/S	C_j

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
13	If you made a mistake in inputting X_{1h} , X_{2h} and X_{3h} , then correct by →	X_{1h}	[ENTER]	
		X_{2h}	[ENTER]	
		X_{3h}	[F] [C]	j-1
	(Optional) Calculate column sum C_h (correction)		[R/S]	$-C_h$
14	Calculate: χ^2		[F] [D]	χ^2
	C_c		[R/S]	C_c
15	Calculate: row sums R_1		[F] [E]	R_1
	R_2		[R/S]	R_2
	R_3		[R/S]	R_3
	total T		[R/S]	T
16	For a new case go to 2			
	*Note: to clear print mode			
	press →		[CLF]	
			[O]	

Example 1:

A random sample of 250 men and 250 women were polled as to their desires concerning the ownership of television sets. The data in the following table resulted. Apply the program to analyze the result of the poll, i.e., can the hypothesis that the desire to own a television set is independent of sex be rejected?

Results of Sample Poll on Television Ownership

Classification	Men	Women	Total
Want television	80	120	200
Don't want television	170	130	300
Total	250	250	500

Keystrokes:

A → 0.00
f A → 1.00
 $80 \text{ [ENTER} \downarrow 170 \text{ [B]} \rightarrow 80.00 \text{ ***}$
 170.00 ***
 1.00 ***

$120 \text{ [ENTER} \downarrow 130 \text{ [B]} \rightarrow 120.00 \text{ ***}$
 130.00 ***
 2.00 ***

D → 13.33 *** (χ^2)

$$\chi^2 = 13.33 > \chi^2_{.99(1)} = 6.63$$

Thus, the hypothesis that desire to own a television set is independent of sex is rejected.

Example 2:

Find test statistic χ^2 and coefficient of contingency C_c for the following set of data.

	1	2	3
A	2	5	4
B	3	8	7

Keystrokes:

A → 0.00
f A → 1.00
 $2 \text{ [ENTER} \downarrow 3 \text{ [B]} \rightarrow 2.00 \text{ ***}$
 3.00 ***
 1.00 ***

R/S → 5.00 *** (C_1)

$5 \text{ [ENTER} \downarrow 8 \text{ [B]} \rightarrow 5.00 \text{ ***}$
 8.00 ***
 2.00 ***

R/S → 13.00 *** (C₂)

6 **ENTER** 9 **B** → 6.00 *** (error)
 9.00 ***
 3.00 ***

R/S → 15.00 *** (C₃)

6 **ENTER** 9 **C** → 6.00 *** (correction)
 9.00 ***
 2.00 ***

R/S → -15.00 *** (-C₃)

4 **ENTER** 7 **B** → 4.00 ***
 7.00 ***
 3.00 ***

R/S → 11.00 *** (C₃)

D → 0.02 *** (χ^2)
R/S → 0.03 *** (C_c)

E → 11.00 *** (R₁)
R/S → 18.00 *** (R₂)
R/S → 29.00 *** (T)

Example 3:

Find test statistic χ^2 and coefficient of contingency C_c for the following set of data.

i \ j	1	2	3	4
1	36	67	49	58
2	31	60	49	54
3	58	87	80	68

17-07

Keystrokes:

A → 0.00
f A → 1.00
36 **ENTER** 31 **ENTER** 58 **f B** → 36.00 ***
31.00 ***
58.00 ***
1.00 ***

R/S → 125.00 *** (C₁)

67 **ENTER** 60 **ENTER** 87 **f B** → 67.00 ***
60.00 ***
87.00 ***
2.00 ***

R/S → 214.00 *** (C₂)

4 **ENTER** 49 **ENTER** 80 **f B** → 4.00 *** (error)
49.00 ***
80.00 ***
3.00 ***

R/S → 133.00 *** (C₃)

49 **ENTER** 49 **ENTER** 80 **f B** → 49.00 ***
49.00 ***
80.00 ***
4.00 ***

R/S → 178.00 *** (C₄)

4 **ENTER** 49 **ENTER** 80 **f C** → 4.00 *** (correction)
49.00 ***
80.00 ***
3.00 ***

R/S → -133.00 *** (-C₃)

58 **ENTER** 54 **ENTER** 68 **f B** → 58.00 ***
54.00 ***
68.00 ***
4.00 ***

R/S → 180.00 *** (C₄)

f D → 3.36 *** (χ^2)
R/S → 0.07 *** (C_c)

f E → 210.00 *** (R₁)
R/S → 194.00 *** (R₂)
R/S → 293.00 *** (R₃)
R/S → 697.00 *** (T)

SPEARMAN'S RANK CORRELATION COEFFICIENT



Spearman's rank correlation coefficient is a measure of rank correlation under the following circumstance: n individuals are ranked from 1 to n according to some specified characteristic by 2 observers, and we wish to know if the 2 rankings are substantially in agreement with one another.

Spearman's rank correlation coefficient is defined by

$$r_s = 1 - \frac{6 \sum_{i=1}^n D_i^2}{n(n^2 - 1)}$$

where n = number of paired observations (x_i, y_i)
 D_i = rank (x_i) - rank (y_i) = $R_i - S_i$

If the X and Y random variables from which these n pairs of observations are derived are independent, then r_s has zero mean and a variance equals to

$$\frac{1}{n - 1}$$

A test for the null hypothesis

$$H_0: X, Y \text{ are independent}$$

is using

$$z = r_s \sqrt{n - 1}$$

which is approximately a standardized normal variable (for large n, say $n \geq 10$).

If the null hypothesis of independence is not rejected, we can infer that the population correlation coefficient $\rho(x, y) = 0$, but dependence between the variables does not necessarily imply that $\rho(x, y) \neq 0$.

Note: $-1 \leq r_s \leq 1$

$r_s = 1$ indicates complete agreement in order of the ranks and $r_s = -1$ indicates complete agreement in the opposite order of the ranks.

Reference: Nonparametric Statistical Inference, J. D. Gibbons, McGraw Hill, 1971

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Do 5~6 for $i=1, 2, \dots, n$			
5	Input R_i	R_i	ENTER ↴	
	S_i	S_i	C	i
6	If you made a mistake in inputting R_k and S_k , then correct by →	R_k	ENTER ↴	
		S_k	D	$i-1$
7	Calculate: r_s		E	r_s
	z		R/S	z
8	For a new case, go to 2			
	*Note: to clear print mode press →		CLF	
			Q	

Example:

The following data set is the result of two tests in a class; find r_s and z .

Student	x_i Math Grade	y_i Stat Grade	R_i Rank of x_i	S_i Rank of y_i
1	82	81	6	7
2	67	75	14	11
3	91	85	3	4
4	98	90	1	2
5	74	80	11	8
6	52	60	15	15
7	86	94	4	1
8	95	78	2	9
9	79	83	9	6
10	78	76	10	10
11	84	84	5	5
12	80	69	8	13
13	69	72	13	12
14	81	88	7	3
15	73	61	12	14

Keystrokes:

A → 0.00

B → 1.00

6 ENTER ↴ 7 C → 6.00 ***
7.00 ***
1.00 ***14 ENTER ↴ 11 C → 14.00 ***
11.00 ***
2.00 ***3 ENTER ↴ 4 C → 3.00 ***
4.00 ***
3.00 ***1 ENTER ↴ 2 C → 1.00 ***
2.00 ***
4.00 *****Outputs:**

11 **ENTER** 8 **C** → 11.00 ***
8.00 ***
5.00 ***

5 **ENTER** 5 **C** → 5.00 *** (errors)
5.00 ***
6.00 ***

5 **ENTER** 5 **D** → 5.00 *** (correction)
5.00 ***
5.00 ***

15 **ENTER** 15 **C** → 15.00 ***
15.00 ***
6.00 ***

4 **ENTER** 1 **C** → 4.00 ***
1.00 ***
7.00 ***

2 **ENTER** 9 **C** → 2.00 ***
9.00 ***
8.00 ***

9 **ENTER** 6 **C** → 9.00 ***
6.00 ***
9.00 ***

10 **ENTER** 10 **C** → 10.00 ***
10.00 ***
10.00 ***

5 **ENTER** 5 **C** → 5.00 ***
5.00 ***
11.00 ***

8 **ENTER** 13 **C** → 8.00 ***
13.00 ***
12.00 ***

18-05

13 **ENTER** 12 **C** → 13.00 ***
12.00 ***
13.00 ***

7 **ENTER** 3 **C** → 7.00 ***
3.00 ***
14.00 ***

12 **ENTER** 14 **C** → 12.00 ***
14.00 ***
15.00 ***

E → 0.76 *** (r_s)
R/S → 2.85 *** (z)

Notes

\bar{x} AND R CONTROL CHARTS



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 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.

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

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

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.

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

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

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 x and R charts.

Number of observations in subgroup n	Factor for 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

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.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	Do 5~9 for $i=1, 2, \dots, m$			
5	Do 6~7 for $j=1, 2, \dots, n$			
6	Input x_{ij}	x_{ij}	C	j
7	If you made a mistake in inputting x_{ik} , then correct by ** →	x_{ik}	D	j-1
8	Calculate: x_{\max}		E	$x_{i\max}$
	x_{\min}		E	$x_{i\min}$
9	Calculate: the mean \bar{x}_i the range R_i		I A	\bar{x}_i
10	Calculate: $\bar{\bar{x}}$ \bar{R}		I B	$\bar{\bar{x}}$
11	Calculate the \bar{x} limits: the lower	A_2	I C	$L_{\bar{x}}$
	the upper		I C	$U_{\bar{x}}$
12	Calculate L_R	D_3	I D	L_R
13	Calculate U_R	D_4	I E	U_R
14	For a new case, go to 2			
	*Note: to clear print mode press →		O	
			STO	
			E	
	**Note: If there are two or more x_{ik} 's entered incorrectly (one follows the other), then do not try to correct them, go to step 2.			

Example:

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

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

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

Keystrokes:

- | A | → | 0.00 | Outputs: |
|-------------------|---|-----------|------------------|
| 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 *** | |

19-05

10.01 C → 10.01 ***
5.00 ***

E → 10.03 *** (x_2 max)
E → 10.00 *** (x_2 min)
A → 10.01 *** (\bar{x}_2)
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 ***

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 *** ($\bar{\bar{x}}$)
f B → 0.03 *** (\bar{R})

0.58 f C → 10.00 *** ($L_{\bar{x}}$)
f C → 10.04 *** ($U_{\bar{x}}$)

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

Notes

OPERATING CHARACTERISTIC CURVES



This program evaluates the probability P_a of acceptance for a single sampling plan with finite or infinite lot size.

Equations:

1. Finite lot size

The hypergeometric distribution is used to evaluate the probability P_a . The lot size N , sample size n and the acceptance number c (maximum allowable number of defectives in the sample) should be given. The probability P_a , which is the ordinate of the type A operating characteristic curve, can be computed for the different values of the fraction defective p in the lot.

$$P_a = \sum_{x=0}^c f(x)$$

$$f(x) = \frac{\binom{M}{x} \binom{N-M}{n-x}}{\binom{N}{n}}$$

where $f(x)$ is the hypergeometric density function, M is the number of defectives in a lot which is calculated as the integer part of Np .

The recursive relation

$$f(x+1) = \frac{(x-M)(x-n)}{(x+1)(N-M-n+x+1)} f(x)$$

$$(x = 0, 1, 2, \dots, n-1)$$

is used to find the probability

$$P_a = \sum_{x=0}^c f(x)$$

with starting value

$$f(0) = \frac{\binom{N-M}{n}}{\binom{N}{n}}$$

The binomial coefficient $\binom{N}{n}$ is computed by the formula

$$\binom{N}{n} = \frac{N(N - 1) \dots (N-n+1)}{1 \cdot 2 \cdot \dots \cdot n}$$

2. Infinite lot size

The binomial distribution is used to evaluate the probability P_a . The sample size n and the acceptance number c should be given. The probability P_a , which is the ordinate of the type B operating characteristic curve, can be computed for different values of the fraction defective p .

$$P_a = \sum_{x=0}^c f(x)$$

$$f(x) = \binom{n}{x} p^x (1-p)^{n-x}$$

where $0 \leq p < 1$.

The recursive relation

$$f(x + 1) = \frac{p(n - x)}{(x + 1)(1 - p)} f(x)$$

$$(x = 0, 1, 2, \dots, n - 1)$$

is used to find the probability

$$P_a = \sum_{x=0}^c f(x)$$

with starting value

$$f(0) = (1 - p)^n$$

Remarks:

1. The program requires that $0 \leq p < 1$.
2. For the type A curve (finite lot size), if $c = 0$, $P_a = f(0)$.

20-03

3. For certain combinations of N , n , and c (usually when they are large), an overflow condition will occur. In that case, the program halts and the display shows all 9's.
4. If the lot size is finite (type A), the execution time mainly depends on the sample size n and the acceptance number c ; the larger they are, the longer it takes.
5. The type A OC curve for finite lot sizes is really a set of discrete points, since defectives can occur only as whole numbers. For very large lot sizes, these points come very close together, giving a practically continuous curve.

Type B OC curves can be considered as suitable approximations to type A OC curves, provided the sample size n is small compared with the lot size N (in general, if $n/N \leq 0.1$).

6. The lot size N has a relatively small effect on the type A OC curve as long as n/N is not large. The absolute sample size n is a much more controlling factor in determining the type A OC curve.
7. The acceptance number c affects drastically the probability of acceptance for the type B OC curve for any given fraction defective p .

References:

1. Dodge and Romig, *Sampling Inspection Tables*, John Wiley and Sons, 1959.
2. Grant and Leavenworth, *Statistical Quality Control*, McGraw-Hill, 1972.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	Initialize		A	0.00
3	To set print mode*		B	1.00
4	For infinite lot size (type B), go to 11			
5	For finite lot size (type A), do 6~9			
6	Input lot size	N	C	N
7	Input: sample size acceptance number	n c	ENTER+ D	n c
8	Calculate probability P_a	p	E	P_a

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
9	For a different p, go to 8			
10	For a new case, go to 2			
11	Input: sample size acceptance number	n c	ENTER ↴ f D	n c
12	Calculate probability P_a	p	f E	P_a
13	For a different p, go to 12			
14	For a new case, go to 2			
	*Note: to clear print mode			
	press →		CLF	
			①	

Example 1:

Find the type A OC curve for the sampling plan with $N = 200$, $n = 20$ and $c = 0$ (compute P_a for $p = 0, 0.02, 0.04, 0.06, 0.08, 0.1, 0.12, 0.14$).

Keystrokes:

	Outputs:
A	0.00
B	1.00
200 C	200.00 *** (N)
20 ENTER ↴ 0 D	20.00 *** (n) 0.00 *** (c)
0 E	0.00 *** 1.00 ***
0.02 E	0.02 *** 0.65 ***
0.04 E	0.04 *** 0.42 ***
0.06 E	0.06 *** 0.27 ***

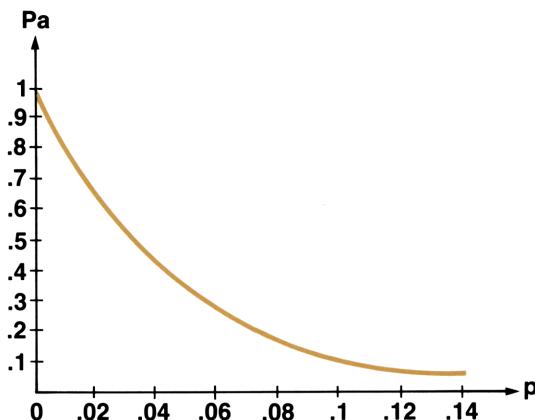
20-05

0.08 **E** → 0.08 ***
0.17 ***

0.1 **E** → 0.10 ***
0.11 ***

0.12 **E** → 0.12 ***
0.07 ***

0.14 **E** → 0.14 ***
0.04 ***



Example 2:

Find the type B OC curve for the sampling plan with $n = 200$, $c = 1$ (compute P_a for $p = 0, 0.01, 0.02, 0.03$ and 0.04).

Keystrokes:

A → 0.00

B → 1.00

200 **ENTER** **f** **D** → 200.00 ***
1.00 ***

Outputs:

(n)
(c)

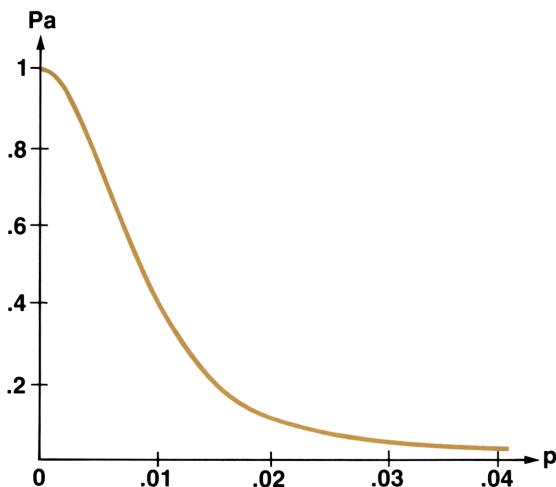
0 **f** **E** → 0.00 ***
1.00 ***

0.01   → 0.01 ***
0.40 ***

0.02   → 0.02 ***
0.09 ***

0.03   → 0.03 ***
0.02 ***

0.04   → 0.04 ***
2.656338303-03 ***



SINGLE- AND MULTI-SERVER QUEUES

SINGLE - AND MULTI-SERVER QUEUES					ST1-21A
	$m+n$ $\mu+\lambda+n+\rho$	$s+a+p$ $P_o \rightarrow P_b$	$+L+T$ $\rightarrow L_q+L$	$+Lq+Tq$ $\rightarrow Tq+T$	$+F$ $t \rightarrow P(t)$

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

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

4. The average number of customers in the queue

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

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

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.

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

$$Q_0 = 1$$

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

and

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

2. The average flow time through the system

$$T = aL$$

3. The average number of customers in the queue

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

4. The average waiting time in the queue

$$T_q = aL_q$$

5. The over-all efficiency factor of the system

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

Remarks:

- 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 .
- 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.
- 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:

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.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load side 1 and side 2			
2	For finite customers go to 11			
3	Do 4 ~ 9 for infinite customers			
4	Input μ	μ	ENTER+	
	λ	λ	ENTER+	
	n	n	A	ρ
5	Calculate P_o		B	P_o
	P_b		B	P_b
6	Calculate: L_q		C	L_q
	L		C	L

21-05

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
7	Calculate: T_q		D	T_q
	T		D	T
8	Input t to calculate $P(t)$	t	E	$P(t)$
9	For a different t, go to 8			
10	For a new case, go to 2			
11	Do 12 ~ 16 for finite customers			
12	Input: number of customers	m	ENTER♦	
	number of servers	n	f A	m
13	Input: service time	s	ENTER♦	
	arrival time	a	f B	ρ
14	Calculate: customers in system		f C	L
	time through system		f C	T
15	Calculate: queue length		f D	L_q
	waiting time in queue		f D	T_q
16	Calculate efficiency factor F		f E	F
17	For a new case, go to 2			

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

Outputs:

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))

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** → 12.00 *** (m)
1.00 *** (n)

Outputs:

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)

Notes

PROGRAM LISTINGS

The following listings are included for your reference. A table of keycodes and keystrokes corresponding to the symbols used in the listings can be found in Appendix E of your Owners Handbook.

Program	Page
1. Basic Statistics for Two Variables .....	. L01-01
2. Factorial, Permutation and Combination .....	. L02-01
3. Moments, Skewness and Kurtosis (For Grouped or Ungrouped Data) .....	. L03-01
4. Random Number Generator .....	. L04-01
5. Histogram .....	. L05-01
6. Analysis of Variance (One Way) .....	. L06-01
7. Two Way Analysis of Variance .....	. L07-01
8. Analysis of Covariance (One Way) .....	. L08-01
Card 1	
Card 2	
9. Normal and Inverse Normal Distribution .....	. L09-01
Card 1	
Card 2	
10. Chi-Square Distribution .....	. L10-01
11. t Distribution .....	. L11-01
12. F Distribution .....	. L12-01
13. Multiple Linear Regression .....	. L13-01
14. Polynomial Approximation .....	. L14-01
Card 1	
Card 2	
15. t Statistics .....	. L15-01
16. Chi-Square Evaluation .....	. L16-01
17. Contingency Table .....	. L17-01
18. Spearman's Rank Correlation Coefficient .....	. L18-01
19. \bar{x} and R Control Chart .....	. L19-01
20. Operating Characteristic Curves .....	. L20-01
21. Single- and Multi-Server Queues .....	. L21-01

Basic Statistics for Two Variables

001 *LBLA			057 ST09					
002 CLR6			058 PZS					
003 CF0		Initialize	059 GSB9					
004 CF1			060 GSB8					
005 CF2			061 RTN					
006 PZS			062 *LBL6					
007 CLR6			063 SF1					Correction for x_k, y_k, f_k .
008 PZS			064 GSB0					
009 0			065 CF1					
010 RTN			066 RTN					
011 *LBLa		Set flag 0 for print.	067 *LBL3					
012 SF0			068 F1?					
013 1			069 GT04					
014 RTN			070 Σ+					
015 *LBLC		Correction for x_k, y_k .	071 RTN					
016 F0?			072 *LBL4					
017 GSB0			073 Σ-					
018 SF1			074 RTN					
019 X?Y			075 *LBL6					
020 Σ-			076 X̄					X̄, Ȳ
021 GSB9			077 GSB9					
022 GSB8			078 R/S					
023 CF1			079 X?Y					
024 RTN			080 GSB9					
025 *LBLB			081 GSB8					
026 F0?		Input x_i, y_i .	082 RTN					
027 GSB0			083 *LBL6					
028 X?Y			084 X̄					
029 Σ+			085 ST08					
030 GSB9			086 X?Y					
031 GSB8			087 PZS					
032 RTN			088 ST08					
033 *LBLD		Input x_i, y_i, f_i .	089 PZS					
034 ST0C			090 S					Vx, Vy
035 F1?			091 EEX					
036 CHS			092 2					
037 ST+9			093 X					
038 R↓			094 X?Y					
039 ST08			095 LSTX					
040 R↓			096 X					
041 ST0A			097 X?Y					
042 RT			098 RCL0					
043 F0?			099 ÷					
044 GSB0			100 GSB9					
045 RT			101 R/S					
046 ABS			102 X?Y					
047 GSB9			103 PZS					
048 ST01			104 RCL0					
049 *LBL2			105 PZS					
050 RCLB			106 ÷					
051 RCLA			107 GSB9					
052 GSB3			108 GSB8					
053 DSZI			109 RTN					
054 GT02			110 *LBL6					
055 RCL9			111 S					
056 PZS			112 GSB9					

REGISTERS

0 - x	1	2	3	4	5	6	7	B	9 - Σf_i
S0 - y	S1	S2	S3	S4 Σx_i	S5 Σx_i^2	S6 Σy_i	S7 Σy_i^2	S8 $\Sigma x_i y_i$	S9 n
A x_i	B y_i	C f_i	D	E	F	G	H	I	J

LABELS						FLAGS			SET STATUS		
A Start	B $x_i \uparrow y_i (\Sigma+)$	C $x_k \uparrow y_k (\Sigma-)$	D x_i, y_i, f_i	E x_k, y_k, f_k	F Print	FLAGS	TRIG	DISP	ON OFF	DEG \ddot{x}	FIX \ddot{x}
^a Print	^b Used	^c Used	^d Used	^e $\Sigma x_i \dots$	^f $\Sigma -(\text{Correct.})$	0			0	<input type="checkbox"/>	<input checked="" type="checkbox"/>
0 Print x_i, y_i	1 Used	2 Used	3 Used	4 Used	5 S_y'	1	<input type="checkbox"/>		1	<input type="checkbox"/>	<input type="checkbox"/>
5	6	7	8 Space	9 Print	3	2	<input type="checkbox"/>		2	<input type="checkbox"/>	<input type="checkbox"/>
						3	<input type="checkbox"/>		3	<input type="checkbox"/>	<input type="checkbox"/>
									n	<u>2</u>	
113 R/S 114 X#Y 115 GSB9 116 GSB8 117 RTN 118 #LBLc 119 S 120 #LBL1 121 P#S 122 RCL9 123 P#S 124 ENT↑ 125 X#Y 126 1 127 - 128 ÷ 129 JX 130 ÷ 131 GSB9 132 F2↑ 133 GSB8 134 CF2 135 R/S 136 LSTX 137 S 138 X#Y 139 SF2 140 ST01 141 RTN 142 #LBLd 143 X̄ 144 X#Y 145 P#S 146 ST00 147 RCL8 148 RCL4 149 RCL0 150 X 151 - 152 RCL9 153 1 154 - 155 ÷ 156 P#S 157 ST0E 158 GSB9 159 R/S 160 P#S 161 RCL9 162 P#S 163 ENT↑ 164 X#Y 165 1 166 - 167 ÷ 168 ÷						169 GSB9 170 RTN 171 #LBLd 172 S 173 RCLC 174 ÷ 175 X 176 1/X 177 GSB9 178 GSB8 179 RTN 180 #LBLe 181 RCLΣ 182 GSB9 183 R/S 184 X#Y 185 GSB9 186 R/S 187 P#S 188 RCL8 189 P#S 190 GSB9 191 GSB8 192 RTN 193 #LBLe 194 P#S 195 RCL7 196 RCL5 197 P#S 198 GSB9 199 R/S 200 X#Y 201 GSB9 202 GSB8 203 RTN 204 #LBLθ 205 X#Y 206 PR TX 207 X#Y 208 PR TX 209 RTN 210 #LBL9 211 F0↑ 212 PR TX 213 RTN 214 #LBL8 215 F0↑ 216 SPC 217 RTN	Yxy $\Sigma x_i, \Sigma y_i$ $\Sigma x_i^2, \Sigma y_i^2$ Print x_i, y_i .				
						Subroutine for print.					
						Subroutine for space.					

Factorial, Permutation and Combination

001 *LBLA		Initialize		057 LSTX					
002 CLRG				058 X \leq Y?					
003 SF0				059 GSB6					
004 0				060 ST07					
005 RTN				061 1					
006 *LBLB		Set flag 0 for print.		062 ST01					
007 SF0				063 +					
008 1				064 ST06					
009 RTN				065 CLX					
010 *LBLD				066 X=Y?					
011 X \geq Y				067 GT03					
012 GSB6		Input m, n for mP_n .		068 *LBLB					
013 X \geq Y				069 R \downarrow					
014 GSB6				070 1					
015 X \geq Y?				071 RCLI					
016 GT02				072 +					
017 ENT \uparrow				073 ST01					
018 0				074 X \geq Y?					
019 X=Y?				075 GT05					
020 GT03				076 RCL7					
021 CLX				077 X \geq Y					
022 1				078 +					
023 X=Y?				079 LSTX					
024 GT04				080 \div					
025 -				081 RCL6					
026 ST01				082 x					
027 R \downarrow				083 ST06					
028 ST07				084 GT08					
029 *LBL1				085 *LBL4					
030 RCL7				086 R \downarrow					
031 1				087 R \downarrow					
032 -				088 GSB _a		$mP_1 = m$			
033 ST07				089 GSB _b					
034 x				090 RTN					
035 DSZ1				091 *LBL6					
036 ST01				092 ST06					
037 GSB _a				093 X \geq Y					
038 GSB _b				094 RTN					
039 RTN				095 *LBL5					
040 *LBL2				096 RCL6					
041 0				097 GSB _a					
042 \div				098 GSB _b					
043 *LBL3		Error		099 RTN					
044 ENT \uparrow				100 *LBLC					
045 1				101 GSB _a					
046 GSB _a				102 ST01					
047 GSB _b				103 ST03					
048 RTN				104 6		Input n for n!			
049 *LBLE				105 9					
050 X \geq Y				106 X \geq Y					
051 GSB _a				107 X \geq Y?					
052 X \geq Y				108 GT09					
053 GSB _a				109 X \geq Y					
054 XY?				110 -					
055 GT02				111 ST01					
056 -				112 LSTX					

REGISTERS

0	1 m, n	2 Log(69!) + ...	3 (n - i)	4	5	6 Used	7 m	8 n - 1	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J m - 69

113	N!							
114	LOG							
115	STO2							
116	RCL1							
117	ENT†							
118	LOG							
119	ST+2							
120	*LBL7							
121	DSZ1							
122	GTO8							
123	GTO7							
124	*LBL7							
125	RCL2							
126	INT							
127	GSB _a							
128	RCL2							
129	FRC							
130	10 ^x							
131	DSP9							
132	GSB _a							
133	DSP2							
134	RCL1							
135	GSB _b							
136	R/S							
137	R↓							
138	R↑							
139	R/S							
140	R↑							
141	RTN							
142	*LBL8							
143	RCL3			Take log (n - 1).				
144	1							
145	-							
146	STO3							
147	LOG							
148	ST+2							
149	GTO7							
150	*LBL9			For n ≤ 69.				
151	N!							
152	GSB _a							
153	GSB _b							
154	RTN							
155	*LBL _a							
156	F09			Subroutine for print.				
157	PRTX							
158	RTN							
159	*LBL _b							
160	F09			Subroutine for space.				
161	SPC							
162	RTN							
LABELS					FLAGS		SET STATUS	
A Start	B Print?	C n→n!	D mtn→mP _n	E mtn→mC _n	0 Print	FLAGS	TRIG	DISP
^a Print	^b Space	c	d	e	1	0 ON OFF	DEG X	FIX K
0 mC _n	1 m!	2 Error	3 mP ₀ , mC ₀	4 mP ₁ , mC ₁	2	1	GRAD	SCI
5 Output	6 x←y	7 n > 69	8 n > 69	9 n ≤ 69	3	2	RAD	ENG
						3	X	n-2

Moments, Skewness and Kurtosis (For Grouped or Ungrouped Data)

001 *LBLA			057 F1?			
002 CLRG			058 CHS			
003 PZS			059 ST+1			
004 CLRG			060 X ^Y			
005 PZS			061 X			
006 CF1			062 ST+2			
007 CF0			063 LSTX			
008 0			064 X			
009 RTN			065 ST+3			
010 *LBL0			066 LSTX			
011 SF0			067 X			
012 1			068 ST+4			
013 RTN			069 LSTX			
014 *LBLB			070 X			
015 ST0A			071 ST+5			
016 GSB9			072 RCLC			
017 Z+			073 1			
018 *LBL1			074 F1?			
019 PZS			075 CHS			
020 RCL4			076 +			
021 RCL5			077 STOC			
022 RCL9			078 GSB9			
023 PZS			079 GSB8			
024 ST01			080 RTN			
025 R4			081 *LBL0E			
026 ST03			082 SF1			
027 R4			083 GSB0			Correction for y_h, f_h .
028 ST02			084 CF1			
029 RCLA			085 RTN			
030 3			086 *LBL0b			
031 Y*			087 RCL2			
032 F1?			088 RCL1			
033 CHS			089 ÷			
034 ST+4			090 ST06			
035 RCLA			091 GSB9			
036 4			092 GSB8			
037 Y			093 RTN			
038 F1?			094 *LBL0c			
039 CHS			095 RCL3			
040 ST+5			096 RCL1			
041 RCL1			097 ÷			
042 GSB9			098 RCL6			
043 GSB8			099 X ²			
044 RTN			100 ST08			
045 *LBL0C			101 -			
046 GSB9			102 ST07			
047 SF1			103 GSB9			
048 Z-			104 R-S			
049 GSB1			105 RCL4			
050 CF1			106 RCL3			
051 RTN			107 RCL6			
052 *LBL0D			108 X			
053 X ^Z Y			109 3			
054 GSB9			110 X			
055 X ^Z Y			111 -			
056 GSB9			112 RCL1			
REGISTERS						
0	1 n or $\sum f_i$	2 $\sum x_i$ or $\sum f_i y_i$	3 $\sum x_i^2$ or $\sum f_i y_i^2$	4 $\sum x_i^3$ or $\sum f_i y_i^3$	5 $\sum x_i^4$ or $\sum f_i y_i^4$	6 \bar{x}, m_4
S0	S1	S2	S3	S4 $\sum x_i$	S5 $\sum x_i^2$	S6 $\sum y_i$
A	X _i	B	C n	D	E	F

113	\div				169	F09			
114	RCL6				170	SPC			
115	RCL8				171	RTN			
116	x								
117	2								
118	x								
119	+								
120	ST09								
121	GSB9								
122	R/S								
123	RCL5								
124	RCL6								
125	RCL4								
126	x	m4							
127	4								
128	x								
129	-								
130	RCL8								
131	RCL3								
132	x								
133	6								
134	x								
135	+								
136	RCL1								
137	\div								
138	RCL8								
139	X ²								
140	3								
141	x								
142	-								
143	ST06								
144	GSB9								
145	GSB8								
146	RTN								
147	*LBL4								
148	RCL9	γ_1							
149	RCL7								
150	1								
151	.								
152	5								
153	Y*								
154	\div								
155	GSB9								
156	R/S								
157	RCL6								
158	RCL7								
159	X ²								
160	\div	γ_2							
161	GSB9								
162	GSB8								
163	RTN								
164	*LBL9								
165	F09								
166	PRTX								
167	RTN								
168	*LBL8								
			LABELS		FLAGS		SET STATUS		
A	Start	B $x_1 (\Sigma+)$	C $x_k (\Sigma-)$	D $y_{v_1} f_1 (\Sigma+)$	E $y_k f_k (\Sigma-)$	0 Print	FLAGS	TRIG	DISP
a	Print?	b \bar{x}	c $\rightarrow m_2, m_3, m_4$	d $\rightarrow \gamma_1, \gamma_2$	e	1 Correction	ON OFF	DEG X	FIX K
0	1 Used	2	3	4	5	6	1	GRAD	SCI
5	6	7	8 Space	9 Print	3	2	2	RAD	ENG
						3	3	3	n-2

Random Number Generator

001 *LBLa	Input a, b, clear secondary registers.	057 *LBL5							
002 P _S S		058 *LBLC							
003 CLRG		059 GSB7							
004 FIS		060 ST07							
005 GT0c		061 GSB7							
006 *LBLA		062 2							
007 GSB7		063 x							
008 RCLC		064 1							
009 RCLD		065 -							
010 -		066 ST02							
011 x	u _i	067 RCL7							
012 RCLD		068 2							
013 +		069 x							
014 *LBL2		070 1							
015 PRTX		071 -							
016 ST09		072 ST01							
017 Σ+		073 +P							
018 RCLA		074 X ²							
019 +		075 1							
020 ST0A		076 X≤Y?							
021 RCL9		077 GT05							
022 X ²		078 R ₄							
023 RCLB		079 ENT↑							
024 +		080 LN							
025 STOB		081 2							
026 1		082 x							
027 RCLI		083 CHS							
028 +		084 X ^Z Y							
029 ST01		085 ÷							
030 RCL9		086 IX							
031 RTN		087 ST08							
032 *LBLb		088 RCL1							
033 ST0D		089 GSB6							
034 GSB0		090 RTN							
035 RCLD		091 *LBLC							
036 *LBL3		092 RCL8							
037 PRTX		093 RCL ₃							
038 SPC		094 *LBL6							
039 RTN		095 x							
040 *LBLB		096 RCLC							
041 GSB7		097 x							
042 RCLD		098 RCLD							
043 x		099 +							
044 INT		100 GT02							
045 1		101 *LBLd							
046 +		102 GT0b							
047 GT02		103 *LBLD							
048 *LBLc		104 GSB7							
049 ST0C		105 LN							
050 XZY		106 CHS							
051 ST00		107 RCLD							
052 GSB0		108 x							
053 RCLD		109 GT02							
054 GSB4		110 *LBLE							
055 RCLC		111 SPC							
056 GT03		112 x̄							
REGISTERS									
0	¹ V ₁	² V ₂	³	⁴	⁵	⁶	⁷ u _i	⁸ √-2 ln S/S	⁹
S0	S1	S2	S3	S4 Σx_i	S5 Σx_i^2	S6	S7	S8	S9 n
A Used	B Used	C b or σ	D a or k or m or μ	E f _{i+1}	I index n				

113	GSB4							
114	R/S							
115	S	s						
116	GSB4							
117	R/S							
118	P/S							
119	RCL9							
120	P/S							
121	GSB4							
122	SPC	n						
123	RTN							
124	*LBL4	Subroutine to print.						
125	PRTX							
126	RTN							
127	*LBL0							
128	.							
129	5							
130	2							
131	8							
132	4							
133	1	u ₀						
134	6							
135	3							
136	STOE							
137	θ							
138	STOA							
139	STOB							
140	STOI							
141	SPC							
142	RTN							
143	*LBL7	Random number generator.						
144	RCL6							
145	9							
146	9							
147	7							
148	x							
149	FRC							
150	STOE							
151	RTN							

LABELS					FLAGS	SET STATUS		
A → u _i	B → d _i	C → n _i	D → e _i	E → x, s; n	0	FLAGS	TRIG	DISP
^a a†b→	^b k→	^c m†a→	^d μ→	e	1	ON OFF	DEG x	FIX x
0 u ₀ to RE	1 Used	2	3 Print, space	4 Print	2	0 □ x	GRAD □	SCI □
5 Used	6 n _i , n _{i+1}	7 997 × u _i	8	9	3	1 □ x	RAD □	ENG □
						2 □ x		n 2
						3 □ x		

Histogram

001 *LBLA		Initialize	057 RCLD						
002 CLRG			058 X#Y						
003 P#S			059 X=Y?						
004 CLRG			060 GSB2						
005 P#S			061 RCLC						
006 CF0			062 -						
007 CF1			063 RCLA						
008 0			064 1/X						
009 RTN			065 x						
010 *LBLC			066 INT						
011 R4			067 1						
012 GSB8		Input x _{min} , x _{max} .	068 X#Y						
013 STOC			069 +						
014 RT			070 LSTX						
015 STOD			071 3						
016 GSB8			072 -						
017 GSB7			073 INT						
018 GSB7			074 1						
019 X#Y			075 +						
020 -			076 STOI						
021 2			077 1						
022 4			078 -						
023 STOE			079 3						
024 ÷			080 x						
025 STOA			081 -						
026 RTN			082 GT01						
027 *LBLE			083 *LBL9						
028 0			084 RCL9						
029 STOI			085 DSP8						
030 X#Y			086 GSB8						
031 GSB8		Correction	087 GSB7						
032 Σ-			088 DSP2						
033 SF1			089 CF1						
034 GSBc			090 R/S						
035 CF1			091 RTN						
036 RTN			092 *LBL1						
037 *LBLD			093 GSBd						
038 STOB			094 F1?						
039 0			095 CHS						
040 STOI		Input x _i .	096 ST+i						
041 RT			097 GT09						
042 GSB8			098 *LBLd						
043 RCLC			099 3						
044 XYY?			100 CHS						
045 GT08			101 x						
046 RT			102 10^						
047 RCLD			103 RTN						
048 X#Y			104 *LBLo						
049 XYY?			105 SPC						
050 GT06			106 0						
051 0			107 STOI						
052 X#Y			108 RCLC						
053 X+			109 STOB						
054 *LBLc			110 *LBL5						
055 ST09			111 ISZI						
056 RCL0			112 2						
REGISTERS									
0 x _i	1, 2, 3	2, 4, 5, 6	3, 7, 8, 9	4, 10, 11, 12	5, 13, 14, 15	6, 16, 17, 18	7, 19, 20, 21	8, 22, 23, 24	9 n
S0	S1	S2	S3	S4 Σx_i	S5 Σx_i^2	S6 Σy_i	S7 Σy_i^2	S8 $\Sigma x_i y_i$	S9 n
A $(x_{\max} - x_{\min})/24$	B x _{min} , last range	C x _{min}	D x _{max}	E 24	F	Counter 1-8			

113	ST09			169	RCL9			
114	GSBe			170	-			
115	RCLI			171	x			
116	EEX			172	+			
117	3			173	PRTX			
118	x			174	STOB			
119	INT			175	RTN			
120	DSPθ			176	*LBLB			
121	PRTX			177	SF0			
122	SPC			178	1			
123	DSP2			179	RTN			
124	1			180	*LBLb			
125	ST09			181	GSB7			
126	GSBe			182	GSB7			
127	RCLI			183	F2S			
128	EEX			184	RCL9			
129	3			185	F2S			
130	x			186	GSB8			
131	FRC			187	R/S			
132	EEX			188	χ			
133	3			189	GSB8			
134	x			190	R/S			
135	INT			191	S			
136	DSPθ			192	GSB8			
137	PRTX			193	GSB7			
138	SPC			194	RTN			
139	DSP2			195	*LBL8			
140	θ			196	F0?			
141	ST09			197	PRTX			
142	GSBe			198	RTN			
143	RCLI			199	*LBL7			
144	EEX			200	F0?			
145	6			201	SPC			
146	x			202	RTN			
147	FRC			203	*LBL2			
148	EEX			204	RCLA			
149	3			205	2			
150	x			206	÷			
151	INT			207	-			
152	DSPθ			208	RTN			
153	PRTX							
154	SFC							
155	DSP2							
156	RCLI							
157	8							
158	X>Y?							
159	GT05							
160	RTN							
161	*LBL8							
162	RLCB							
163	PRTX							
164	RCLC							
165	RCLA							
166	RCLI							
167	3							
168	x							
		LABELS			FLAGS		SET STATUS	
A Start	B Print	C x_{max}, x_{min}	D Input	E Correct	F Print			
^a List	b n, \bar{x}, s	c y	d 10^x	e Used	f Correction	FLAGS	TRIG	DISP
^b Error	¹ Sorting	² Cor. for x_{max}	³	⁴	⁵	ON OFF	DEG x	FIX x
^c Listing	⁶	⁷ Space	⁸ Print	⁹ Print index	³	1 <input checked="" type="checkbox"/> x	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>
						2 <input type="checkbox"/> x	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>
						3 <input type="checkbox"/> x		n <u> </u> 2

Analysis of Variance (One Way)

001 *LBLA			057 RTN		
002 CLRG			058 *LBL9		
003 P _i S			059 P _i S		Clear registers for new i.
004 CLRG	Initialize		060 CLRG		
005 F _i S			061 P _i S		
006 CF0			062 RTN		
007 CF1			063 *LBLD		
008 CF2			064 GSB3		Correction
009 0			065 Σ-		
010 RTN			066 GSB8		
011 *LBLC	Input x _{ij}		067 RTN		
012 F?2			068 *LBLB		Set flag 0 for print.
013 GSB9			069 SF0		
014 GSB3			070 J		
015 Σ+			071 RTN		
016 *LBL8			072 *LBLa		
017 F?S			073 RCL4		
018 RCL4			074 RCL7		
019 RCL5			075 X ²		
020 F?S			076 RCL6		
021 STOB			077 ÷	TSS	
022 R↓			078 STOB		
023 STOA			079 -		
024 R↓			080 STOB		
025 GSB3			081 GSB3	TrSS	
026 GSB0			082 R/S		
027 RTN			083 RCL5		
028 *LBLE			084 RCL8		
029 J			085 -		
030 ST+9			086 STO1		
031 SF2			087 GSB3		
032 RCLA			088 R/S		
033 ST+7			089 RCL0	ESS	
034 RCLB			090 RCL1		
035 ST+4			091 -		
036 F?S			092 STO2		
037 RCL9	̄x _i		093 GSB3		
038 F?S			094 GSB0		
039 ST+6			095 RTN		
040 RCLA			096 *LBL0	Subroutine for space.	
041 X ²			097 F?2		
042 F?S			098 SPC		
043 RCL9			099 RTN		
044 F?S			100 *LBL3	Subroutine to print.	
045 ÷			101 F?2		
046 ST+5			102 PRTX		
047 ̄x			103 RTN		
048 GSB3			104 *LBL6		
049 R/S			105 RCL9		
050 S	s _i		106 1	df ₁	
051 GSB3			107 -		
052 R/S			108 STOB		
053 RCLA			109 GSB3		
054 GSB3			110 R/S		
055 GSB0	Sum _i		111 RCL6	df ₂	
056 GSB0			112 RCL9		
REGISTERS					
0 TSS	1 T,SS	2 ESS	3 df ₁	4 ΣΣx _{ij} ²	5 Σ(Σx _{ij}) ² /n _i
S0	S1	S2	S3	S4 Σx _i	S5 Σx _i ²
A Σx _{ij} , df ₂	B Σx _{ij} ² , F	C	D	E	I
S6 Σy _i	S7 Σy _i ²	S8 Σx _i y _i	S9 n		

113 - 114 STO A 115 GSB3 116 R/S 117 RCL A 118 RCL3 119 + 120 GSB3 121 GSB0 122 RTN 123 #LBL c 124 RCL1 125 RCL3 126 ÷ 127 GSB3 128 R/S 129 RCL2 130 RCL A 131 ÷ 132 GSB3 133 R/S 134 ÷ 135 GSB3 136 GSB0 137 STOB 138 RTN		df ₃	T _r M _s	EMS	F	
LABELS						
^A Start	^B Print?	^C x _{ij} (Σ +) \rightarrow	^D x _{im} (Σ -) \rightarrow	^E x, s _i , sum _i	⁰ Print	FLAGS
^a TSS, ...	^b df ₁ , ...	^c T _r M _s , ...	^d	^e	¹ Correction	SET STATUS
⁰ Space	1	2	³ Print	4	² New data	FLAGS
⁵	6	7	⁸ Σx_i , Σx_i^2	⁹ CLREG	3	ON OFF
						DEG <input checked="" type="checkbox"/> SCI <input type="checkbox"/>
						GRAD <input type="checkbox"/> RAD <input type="checkbox"/> ENG <input type="checkbox"/>
						n <u>2</u>

Two Way Analysis of Variance

001 *LBLA			057 RCL6					
002 CLR6		Initialize	058 x					
003 CF0			059 ÷					
004 0			060 ST07					
005 RTN			061 CHS					
006 *LBLC			062 RCL2					
007 X ² Y		Input r, c.	063 +					
008 ST05			064 ST01					
009 GSB9			065 RCL3					
010 R4			066 RCL6					
011 ST06			067 ÷					
012 GSB9			068 RCL7					
013 GSB8			069 -					
014 RTN			070 ST02					
015 *LBLD			071 RCL4					
016 ST+7		Input x _{ij} :	072 RCL5					
017 GSB9			073 ÷					
018 X ²			074 RCL7			F ₁ , F ₂		
019 ST+2			075 -					
020 RCLA			076 ST03					
021 1			077 RCL2					
022 +			078 *					
023 ST0A			079 CHS					
024 GSB9			080 RCL1					
025 RTN			081 +					
026 *LBL0			082 ST04					
027 RCL7			083 RCL5					
028 ST+1			084 1					
029 X ²		Calculate RS _i :	085 -					
030 ST+3			086 ST05					
031 *LBL0			087 RCL6					
032 RCL7			088 1					
033 0			089 -					
034 ST0A			090 ST06					
035 ST07			091 x					
036 X ² Y			092 ST07					
037 GSB9			093 ÷					
038 GSB8			094 ST08					
039 RTN			095 RCL2					
040 *LBLB			096 RCL5					
041 RCLA		Re-initialize for column.	097 ÷					
042 ST08			098 RCL8					
043 0			099 ÷					
044 ST02			100 GSB8					
045 ST04			101 GSB9					
046 GSB8			102 R/S					
047 RTN			103 RCL3					
048 *LBLC			104 RCL6					
049 RCL7		CS _i	105 ÷					
050 X ²			106 RCL8					
051 ST+4			107 ÷					
052 GT00			108 GSB9					
053 *LBLD			109 GSB8					
054 RCL1		F ₁ , F ₂	110 RTN					
055 X ²			111 *LBLd					
056 RCL5			112 RCL5					

REGISTERS

0	1 $\sum \sum x_{ij}$, TSS	2 $\sum \sum x_{ij}^2$, RSS	3 Used	4 Used	5 r, r - 1	6 c, c - 1	7 Used	8 Used	9 0
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A i, j	B r	C	D	E	F	G	H	I	J

LABELS						FLAGS	SET STATUS		
A	B	C	D	E	F	0	FLAGS	TRIG	DISP
^a → RS _i	^b Print?	^c r↑c →	^d x _{ij} (Σ+) →	^e x _m (Σ-) →	^f Print		ON OFF	x	x
						1	0 <input type="checkbox"/> <input checked="" type="checkbox"/>	DEG <input type="checkbox"/>	FIX <input type="checkbox"/>
^g 0 to R _A , R _T	1	2	3	4	2		1 <input type="checkbox"/> <input checked="" type="checkbox"/>	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>
5	6	7	^h Space	ⁱ Print	3		2 <input type="checkbox"/> <input checked="" type="checkbox"/>	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>
							3 <input type="checkbox"/> <input checked="" type="checkbox"/>	n <input type="checkbox"/>	2

Analysis of Covariance (One Way) (Card 1)

001 *LBLA			057 RCLA					
002 CLR6			058 +					
003 F2S			059 STOA					
004 CLRG			060 RCL5					
005 P2S			061 RCLB					
006 CF0			062 +					
007 0			063 STOB					
008 ST08			064 RCL6					
009 RTN			065 RCLC					
010 *LBLB			066 +					
011 P2S			067 STOC					
012 0		For new i.	068 RCL7					
013 ST04			069 RCLD					
014 ST05			070 +					
015 ST06			071 STOD					
016 ST07			072 RCL8					
017 ST08			073 RCLE					
018 ST09			074 +					
019 P2S			075 STOE					
020 ISZI			076 P2S					
021 RCLI			077 RCL9					
022 GSB0			078 ST+0		Σn_i			
023 GSB1			079 P2S					
024 RTN			080 ST+0					
025 *LBL9		Subroutine to print x_{ij} , y_{ij} .	081 RCL4		$\Sigma \frac{(\Sigma x_{ij})^2}{n_i}$			
026 R4			082 P2S					
027 PRTX			083 GSB8					
028 R↑			084 P2S					
029 PRTX			085 RCL6		$\Sigma \frac{(\Sigma y_{ij})^2}{n_i}$			
030 RTN			086 GSB8					
031 *LBL6e		Set flag 0 for print.	087 RCL4					
032 SF0			088 RCL6					
033 1			089 X					
034 ST08			090 RCL9					
035 RTN			091 ÷					
036 *LBLD		Correction for x_{im} , y_{im} .	092 P2S					
037 F0?			093 ST+5					
038 GSB9			094 P2S					
039 XZY			095 RCL6					
040 Σ-			096 RCL4					
041 ST09			097 P2S					
042 GSB0			098 GSB8		s_{xi}			
043 GSB1			099 R/S					
044 RTN			100 R↑					
045 *LBLC		Input for x_{ij} , y_{ij} .	101 GSB8					
046 F0?			102 GSB1					
047 GSB9			103 R/S		s_{yi}			
048 XZY			104 *LBL8					
049 Σ+			105 X ²					
050 ST09			106 RCL9					
051 GSB0			107 ÷					
052 GSB1			108 ST+2					
053 RTN			109 RTN					
054 *LBL6			110 *LBLa					
055 P2S			111 RCLB					
056 RCL4			112 RCLA		TSS _x			
REGISTERS								
0 Σn_i	1 TSS _x	2 Used	3 WSS _x	4 TSP _i	5 Used	6 WSP	7 WSS _y	8 1 or 0
S0 Σn_i	S1 TSS _y	S2 Used	S3 WSS _y	S4 Σx_{ij}	S5 Σx_{ij}^2	S6 Σy_{ij}	S7 Σy_{ij}^2	S8 $\Sigma x_{ij}y_{ij}$
A $\Sigma \Sigma x_{ij}$	B $\Sigma \Sigma x_{ij}^2$	C $\Sigma \Sigma y_{ij}$	D $\Sigma \Sigma y_{ij}^2$	E $\Sigma \Sigma x_{ij}y_{ij}$	I $i = 1, 2, \dots k$			

113	GSB7			169	-				
114	R/S			170	\div				
115	RCL2			171	\div				
116	RCL ^A			172	GSB0				
117	GSB6			173	R/S				
118	R/S			174	F ^Z S				
119	-			175	RCL2				
120	ST03			176	RCLI				
121	GSB0			177	1				
122	GSB1			178	-				
123	R/S			179	\div				
124	*LBL ^a	TSS _y		180	RCL3				
125	RCL0			181	F ^Z S				
126	RCLC			182	RCL0				
127	F ^Z S			183	RCLI				
128	GSB7			184	-				
129	F ^Z S			185	\div				
130	R/S	ASS _y		186	\div		F _y		
131	F ^Z S			187	GSB0				
132	RCL2			188	R/S				
133	RCLC			189	RCLI				
134	GSB6			190	1				
135	F ^Z S			191	-		df ₁		
136	R/S			192	GSB0				
137	-			193	R/S				
138	F ^Z S	WSS _y		194	RCL0				
139	ST03			195	RCLI				
140	F ^Z S			196	-		df ₂		
141	GSB0			197	GSB0				
142	GSB1			198	GSB1				
143	R/S			199	RTN				
144	*LBL ^b	For (TSS _x or y)		200	*LBL0		Subroutine for print.		
145	X ²			201	F0?				
146	RCL0			202	PTX				
147	\div			203	RTN				
148	-			204	*LBL1		Subroutine for space.		
149	ST01			205	F0?				
150	GSB0			206	SPC				
151	RTN			207	RTN				
152	*LBL ^c	For (ASS _x or y)							
153	X ²								
154	RCL0								
155	\div								
156	-								
157	ST02								
158	GSB0								
159	RTN								
160	*LBL ^b								
161	RCL2								
162	RCLI								
163	1								
164	-								
165	\div								
166	RCL3								
167	RCL0								
168	RCLI	F _x							
LABELS									
FLAGS									
SET STATUS									
^a Start	^b New i	^c x _{ij} ↑y _{ij} (Σ +)	^d x _{im} ↑y _{im} (Σ -)	^e s _{xi} , s _{yi}	^f Print	^g 1	^h FLAGS	ⁱ TRIG	^j DISP
^a TSS _x ; ...	^b F _x ; ...	^c	^d	^e	^f Print	^g 1	^h ON OFF	ⁱ DEG x	^j FIX x
⁰ Print	¹ Space	²	³	⁴	⁵ 2	⁶ 0	⁷ 0	⁸ GRAD	⁹ SCI
⁵	⁶ ASS _x	⁷ TSS _x	⁸ $\Sigma \Sigma x_{ij}/n_i$	⁹ Print x _{ij} , y _{ij}	³	¹ 0	² 0	³ RAD	⁴ ENG
						³ 0	⁴ 0	⁵ n	⁶ 2

(Card 2)

001 *LBLc			057 \div			
002 GSB2			058 GSB0			AMSp
003 RCLc			059 R/S			
004 RCLa			060 RCL7			
005 RCLc			061 RCL0			
006 x			062 RCLI			
007 RCL0			063 -			
008 \div			064 1			
009 -	TSP		065 -			
010 ST04			066 \div			
011 GSB0			067 GSB0			
012 R/S			068 R/S		F	
013 RCL5			069 \div			
014 RCLa			070 GSB0			
015 RCLc			071 R/S			
016 x			072 RCLI			
017 RCL0			073 1			
018 \div	ASP		074 -		df ₃	
019 -			075 GSB0			
020 GSB0			076 R/S			
021 R/S			077 RCL0			
022 -	WSP		078 RCLI			
023 ST06			079 -		df ₄	
024 GSB0			080 1			
025 GSB1			081 -			
026 RTN			082 GSB0			
027 *LBLd			083 GSB1			
028 F2S			084 RTN			
029 RCLI			085 *LBL0		Subroutine for print.	
030 F2S			086 F0"			
031 RCL4			087 FRTX			
032 X ²			088 RTN			
033 RCLI			089 *LBL1		Subroutine for space.	
034 \div	TSS _y		090 F0"			
035 -			091 SPC			
036 GSB0			092 RTN			
037 F/S			093 *LBL2			
038 F2S			094 CF0		Subroutine for setting	
039 RCL3			095 RCL8		flag 0 for print.	
040 F2S			096 1			
041 RCL6			097 X=Y?			
042 X ²			098 SF0			
043 RCL3			099 RTN			
044 \div						
045 -	WSS _y					
046 ST07						
047 GSB0						
048 R/S						
049 -	ASS _y					
050 GSB0						
051 GSB1						
052 R/S						
053 *LBLe						
054 RCLI						
055 1						
056 -						

REGISTERS

⁰ Σn_i	¹ TSS _x	² Used	³ WSS _x	⁴ TSP _i	⁵ Used	⁶ WSP	⁷ WSS _y	⁸ 1 or 0	⁹ j
S ₀ Σn_i	S ₁ TSS _y	S ₂ Used	S ₃ WSS _y	S ₄ Σx_{ij}	S ₅ Σx_{ij}^2	S ₆ Σy_{ij}	S ₇ Σy_{ij}^2	S ₈ $\Sigma x_{ij}y_{ij}$	S ₉ $n_{i \neq j}$
A $\Sigma \Sigma x_{ij}$	B $\Sigma \Sigma x_{ij}^2$			C $\Sigma \Sigma y_{ij}$	D $\Sigma \Sigma y_{ij}^2$	E $\Sigma \Sigma x_{ij}y_{ij}$	F i = 1, 2, ... k		

LABELS					FLAGS		SET STATUS		
A	B	C	D	E	0 Print		FLAGS	TRIG	DISP
a	b	c TSP; ...	d TSS \hat{y} ; ...	e AMS \hat{y} ; ...	1	ON OFF	DEG <input checked="" type="checkbox"/>	FIX <input checked="" type="checkbox"/>	
0 Print	1 Space	2 Used	3	4	2	0 <input type="checkbox"/> <input checked="" type="checkbox"/>	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>	
5	6	7	8	9	3	1 <input type="checkbox"/> <input checked="" type="checkbox"/>	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>	n <u>2</u>

Normal and Inverse Normal Distribution (Card 1)

001 *LBLA		057 2			
002 .		058 CHS			
003 2		059 ST07			
004 3		060 .			
005 1		061 3			
006 6		062 1			
007 4		063 9			
008 1		064 3			
009 9		065 8			
010 ST03		066 1			
011 1		067 5			
012 .		068 3			
013 3		069 ST08			
014 3		070 PZS			
015 0		071 2			
016 2		072 .			
017 7		073 5			
018 4		074 1			
019 4		075 5			
020 2		076 5			
021 9		077 1			
022 ST04		078 7			
023 1		079 ST01			
024 .		080 .			
025 8		081 8			
026 2		082 0			
027 1		083 2			
028 2		084 8			
029 5		085 5			
030 5		086 3			
031 9		087 ST02			
032 7		088 .			
033 8		089 0			
034 CHS		090 1			
035 ST05		091 0			
036 1		092 3			
037 .		093 2			
038 7		094 8			
039 8		095 ST03			
040 1		096 1			
041 4		097 .			
042 7		098 4			
043 7		099 3			
044 9		100 2			
045 3		101 7			
046 7		102 8			
047 ST06		103 8			
048 .		104 ST04			
049 3		105 .			
050 5		106 1			
051 6		107 8			
052 5		108 9			
053 6		109 2			
054 3		110 6			
055 7		111 9			
056 8		112 ST05			
REGISTERS					
0	1	2	3 r		
S0	S1 C ₀	S2 C ₁	S3 C ₂		
A	B	C	D	E	I
S5 d ₂	S6 d ₃	S7	S8	S9	

```

113   .
114   0
115   0
116   1
117   3
118   0
119   8
120   ST06
121   PSS
122   0
123   ST0A
124   ST0B
125   RTN

```

LABELS					FLAGS	SET STATUS		
A	B	C	D	E	0	FLAGS	TRIG	DISP
a	b	c	d	e	1	0 <input type="checkbox"/> X <input checked="" type="checkbox"/>	DEG <input checked="" type="checkbox"/>	FIX <input type="checkbox"/>
0	1	2	3	4	2	1 <input type="checkbox"/> X <input checked="" type="checkbox"/>	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>
5	6	7	8	9	3	2 <input type="checkbox"/> X <input checked="" type="checkbox"/>	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>
						3 <input type="checkbox"/> X <input checked="" type="checkbox"/>		h <u>2</u>

(Card 2)

001 *LBLB			057 x		
002 1			058 RCL2		
003 STO4		Store 1 in R _A for print.	059 x		
004 RTN			060 F0?		
005 *LBLC			061 GSB9		
006 GSB9			062 F0?		
007 STO1			063 GSB6		
008 ENT↑			064 RTN		
009 x		Input x and compute f(x).	065 *LBL1		
010 2			066 CF0		
011 ÷			067 RCL1		
012 CHS			068 CHS		
013 e^			069 STO1		
014 Pi			070 GSBc		
015 2			071 1		
016 x			072 X ² Y		
017 JX			073 -		
018 ÷			074 STO9		
019 STO2			075 GSB9		
020 GSB9			076 GSB6		
021 GSB6			077 RCL9		
022 GSB3			078 RTN		
023 RCL2			079 *LBLE		
024 RTN			080 GSB9		
025 *LBLD			081 X ² ?		
026 GSB9			082 GT00		
027 STO1			083 1		
028 GSB5			084 X ² Y?		
029 GSBc			085 GT00		
030 RCL1			086 R↓		
031 X ² 0?			087 .		
032 GT01		Input x and calculate Q(x).	088 5		
033 SF0			089 X ² Y		
034 *LBLc			090 X ² Y?		
035 1			091 GSB8		
036 RCL1			092 ENT↑		
037 RCL3			093 x		
038 +			094 1/X		
039 +			095 LN		
040 1/X			096 JX		
041 ENT↑			097 FIS		
042 ENT↑			098 STO7		
043 ENT↑			099 RCL3		
044 RCL4			100 x		
045 x			101 RCL2		
046 RCL5			102 +		
047 +			103 RCL7		
048 x			104 x		
049 RCL6			105 RCL1		
050 +			106 +		
051 x			107 RCL7		
052 RCL7			108 RCL6		
053 +			109 x		
054 x			110 RCL5		
055 RCL8			111 +		
056 +			112 RCL7		
REGISTERS					
0	1 x	2 f(x)	3 r	4 b ₅	5 b ₄
S0	S ¹ C ₀	S ² C ₁	S ³ C ₂	S ⁴ d ₁	S ⁵ d ₂
A 1 or 0	B 1 or 0	C	D	E	F

113	x				169	RTN		
114	RCL4				170	*LBL2		
115	+				171	1		
116	RCL7				172	STO A		
117	x				173	RTN		
118	1							Restore 1 to RA.
119	+							
120	÷							
121	RCL7							
122	X#Y							
123	-							
124	PIS							
125	F1?							
126	CMS							
127	GSB9							
128	GSB6							
129	CF1							
130	RTN							
131	*LBL8			For (1 - Q)				
132	SF1							
133	1							
134	-							
135	CMS							
136	RTN							
137	*LBL9			Subroutine to print.				
138	RCLA							
139	X>0?							
140	GSB7							
141	R↓							
142	RTN							
143	*LBL7							
144	R↓							
145	PRTX							
146	R↑							
147	RTN							
148	*LBL6			Subroutine for space.				
149	RCLA							
150	X>0?							
151	SPC							
152	R↓							
153	RTN							
154	*LBL5			Clear RA for calculating O(x).				
155	RCLA							
156	X>0?							
157	GSB4							
158	R↓							
159	RTN							
160	*LBL4							
161	STOB							
162	CLX							
163	STOA							
164	RTN							
165	*LBL3							
166	RCLB							
167	X>0?							
168	GSB2							
		LABELS			FLAGS		SET STATUS	
A	B Print?	C x→f(x)	D x→Q(x)	E Q(x)→x	F x positive	G FLAGS	H TRIG	I DISP
a	b	c Q(x)	d	e	f Q(x) > .5	ON OFF	DEG x	FIX x
0 Error	1 x < 0	2 1→RA	3 R_B > 0?	4 0→RA	5	0 <input type="checkbox"/> x	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>
5 RA→RB	6 Space	7 Print	8	9 Print	3	1 <input type="checkbox"/> x	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>
						2 <input type="checkbox"/> x		n <u>2</u>
						3 <input type="checkbox"/> x		

Chi-Square Distribution

<pre> 001 *LBLA 002 CLRG 003 CF0 004 CF1 005 0 006 RTN 007 *LBLB 008 SF0 009 1 010 RTN 011 *LBLC 012 GSB9 013 1 014 ST03 015 X=Y 016 2 017 ÷ 018 ST01 019 INT 020 LSTX 021 X?Y? 022 GT01 023 1 024 - 025 N! 026 GSB9 027 GSB8 028 ST03 029 R/S 030 *LBL1 031 . 032 5 033 X=Y? 034 GT02 035 X?Y 036 1 037 - 038 ST×3 039 GT01 040 *LBL2 041 Pi 042 IX 043 RCL3 044 x 045 ST03 046 GSB9 047 GSB8 048 R/S 049 *LBLD 050 SF1 051 *LBLe 052 GSB9 053 ST02 054 RCL1 055 1 056 - </pre>		<p>Initialize</p> <p>Set flag for print.</p> <p>Input ν.</p> <p>Calculate $\Gamma\left(\frac{\nu}{2}\right)$</p> <p>Input x, calculate f(x).</p> <p>Input x, calculate f(x).</p>	<pre> 057 Y* 058 RCL2 059 2 060 ÷ 061 CHS 062 e* 063 x 064 2 065 RCL1 066 Y* 067 ÷ 068 RCL3 069 ÷ 070 ST05 071 F1? 072 GSB9 073 F1? 074 GSB8 075 LF1 076 RTN 077 *LBLE 078 GSB8e 079 RCL2 080 RCL1 081 ÷ 082 ST×5 083 2 084 RCL1 085 x 086 ST06 087 1 088 ST04 089 *LEL3 090 RCL2 091 RCL6 092 2 093 + 094 ST06 095 ÷ 096 RCL4 097 x 098 ST04 099 + 100 X?Y? 101 GT03 102 RCLS 103 x 104 GSB9 105 GSB8 106 RTN 107 *LBL9 108 F0? 109 PRTX 110 RTN 111 *LBL8 112 F0? </pre> <p>Subroutine for print.</p>					
REGISTERS								
0	1 $\nu/2$	2 x	3 $1, \Gamma(\nu/2)$	4 Used	5 f(x)	6 Used	7	8
S0	S1	S2	S3	S4	S5	S6	S7	S8
A	B	C	D	E	F	G	H	I

113	SPC								
114	RTN								
Subroutine for space.									
LABELS						FLAGS		SET STATUS	
A Start	B Print?	C $\nu \rightarrow \Gamma(\nu/2)$	D $x \rightarrow f(x)$	E $x \rightarrow P(x)$	F Print	FLAGS	TRIG	DISP	
a	b	c	d	e $f(x)$	f $P(x)$	0 ON OFF	DEG x	FIX x	
0	1 $\nu = ? \frac{1}{2}$	2 $\Gamma(\frac{1}{2})$	3 $P(x)$	4	5	1 OFF	GRAD	SCI	
5	6	7	8 Space	9 Print	3	2 RAD	ENG	n 2	

t Distribution

001 *LBLA 002 CLRG 003 CFE 004 CF1 005 E 006 RTN 007 *LBLB 008 SFE 009 I 010 RTN 011 *LBLC 012 STO0 013 GSB7 014 GSBS 015 RTN 016 *LBLD 017 GSE7 018 STO4 019 RCL0 020 GSE4 021 STO5 022 RCL0 023 I 024 + 025 GSE4 026 STO4 027 RCL4 028 RCL4 029 RCL5 030 I 031 F1 032 RCL0 033 X 034 JX 035 + 036 I 037 RCL4 038 XE 039 RCL0 040 = 041 + 042 RCL0 043 I 044 + 045 2 046 = 047 CHS 048 Y* 049 X 050 STO5 051 GSE7 052 GSBS 053 RTN 054 *LBL4 055 I 056 STO5		Initialize Set flag 0 for print. Input ν . Input x, compute f(x).	057 X#Y 058 2 059 = 060 STO1 061 INT 062 LSTX 063 X#Y? 064 GT01 065 1 066 - 067 N! 068 STO3 069 RTN 070 *LBL1 071 . 072 5 073 X=1? 074 GT02 075 X#Y 076 1 077 - 078 STX2 079 STO1 080 *LBL2 081 F1 082 JX 083 RCL3 084 X 085 STO3 086 RTN 087 *LBLB 088 STO4 089 GSE7 090 ABS 091 RCL6 092 RAD 093 JX 094 = 095 TAN ⁻¹ 096 STO2 097 RCL0 098 2 099 = 100 INT 101 LSTX 102 X#Y? 103 GT04 104 E 105 STO5 106 *LBL6 107 RCL2 108 COS 109 X ² 110 STO3 111 RCL2 112 SIN	Compute $\Gamma(\nu/2)$. Compute $R(x)$. For even ν .				
REGISTERS								
0	ν	1	2 θ	3 Used	4 $\sin \theta$	5 Used	6 Used	7 $2\theta/\pi, R$
S0	S1	S2	S3	S4	S5	S6	S7	S8
A x	B $\Gamma(\nu/2)$	C $\Gamma(\nu + 1/2)$	D	E				

		LABELS		FLAGS		SET STATUS		
A	B	C	D	E	F	FLAGS	TRIG	DISP
^a Start	^b Print	^c $P \rightarrow$	^d $x \rightarrow f(x)$	^e $x \rightarrow P(x)$	^f Print			
^a $\nu/2$ integer	^b even ν	^c	^d	^e Used	^f odd ν	ON OFF	DEG X	FIX X
⁰ $P(x), x > 0$	¹ $\nu/2$ no integer	² $\sqrt{\pi} \cdot x$	³ even ν	⁴ odd ν	⁵	0 [] x	GRAD []	SCI []
^b Space	^c $P(x), x \leq 0$	^d Print	^e For even ν	^f For odd ν	^g	1 [] x	RAD []	ENG []
					³	2 [] x		n [] 2
						3 [] x		

For odd ν .

Compute $P(x)$ from $R(x)$ for $x \leq 0$.

Compute $P(x)$ for $x > 0$.

Subroutine to print.

Subroutine to space.

F Distribution

081 *LBL4			057 RCL4					
082 CLRG			058 GSB9					
083 CFB		Initialize	059 RTN					
084 CF1			060 *LBL5					
085 0			061 1					
086 RTN			062 ST05					
087 *LBLB		Set flag 0 for print.	063 RCL3					
088 SF0			064 -					
089 1			065 ST03					
010 RTN			066 RCL2					
011 *LBLC		Input ν_1 .	067 2					
012 STO1			068 ÷					
013 GSB9			069 X					
014 RTN			070 ST+5					
015 *LBLD			071 DSZ1					
016 STO2		Input ν_2 .	072 GT03					
017 GSB9			073 GT02					
018 RTN			074 *LBL3					
019 *LBLE		Input x.	075 RCL2					
020 GSB9			076 2					
021 STO6			077 +					
022 ENT†			078 ST02					
023 RCL1			079 RCL7					
024 X			080 2					
025 RCL2			081 +					
026 +			082 ST07					
027 RCL2			083 ÷					
028 X \neq Y			084 RCL3					
029 ÷			085 X					
030 STO3			086 X					
031 RCL1			087 ST+5					
032 2			088 DSZ1					
033 ÷		If ν_1 even then go to LBL d else go to LBL e.	089 GT03					
034 FRC			090 *LBL2					
035 0			091 RCL5					
036 X \neq Y?			092 RCL4					
037 GT0d			093 X					
038 GT0e			094 F1?					
039 RTN			095 GSB9					
040 *LBLd			096 F1?					
041 RCL3			097 GSB8					
042 RCL2			098 RTN					
043 2			099 *LBLe					
044 STO7			100 CF1					
045 ÷			101 RCL1					
046 Y x		For even ν_1 .	102 RCL2					
047 STO4			103 STO1					
048 RCL1			104 X \neq Y					
049 2			105 ST02					
050 -			106 1					
051 2			107 RCL3					
052 ÷			108 -					
053 STO1			109 ST03					
054 0			110 GSBd					
055 X \neq Y?			111 SF1					
056 GT05			112 1					
REGISTERS								
0	1 ν_1 or ν_2	2 ν_2 or ν_1	3 t, 1 - t	4 $t^{\nu_1}/2$ or $t^{\nu_1}/2$	5 Used	6 x	7 Used	8 Used
S0	S1	S2	S3	S4	S5	S6	S7	S8
A	B	C	D	E			I	Used

<pre> 113 X#Y 114 - 115 GSB9 116 GSB8 117 R/S 118 #LBL9 119 F0? 120 FRTX 121 RTN 122 #LBL8 123 F0? 124 SPC 125 RTN </pre>					Subroutine for print.					
<pre> 113 X#Y 114 - 115 GSB9 116 GSB8 117 R/S 118 #LBL9 119 F0? 120 FRTX 121 RTN 122 #LBL8 123 F0? 124 SPC 125 RTN </pre>					Subroutine for space.					
LABELS										
A Start	B Print?	C $\nu_1 \rightarrow$	D $\nu_2 \rightarrow$	E $x \rightarrow P(x)$	F Print	FLAGS	SET STATUS			
a	b	c	d even ν_1	e odd ν_1	f ν_1 even	ON OFF	DEG	FIX		
0	1	2 output	3 for $P(x)$	4	2		1	SCI		
5 for $P(x)$	6	7 Space	8 Print	9	3	2	2	RAD		
						3	3	ENG		
							n	2		

Multiple Linear Regression

001 *LBLA			057 X ²		
002 CLR6		Initialize	058 GSB2		
003 CF8			059 ST+I		
004 CF1			060 RTN		
005 0			061 *LBLB		
006 RTN			062 RCL0		
007 *LBLC			063 RCL4		
008 STOC			064 X		
009 R↓			065 RCL7		
010 STOB			066 X ²		
011 R↓			067 -		
012 STOA			068 STOD		
013 GSB7			069 RCL0		
014 7			070 RCL3		
015 STOI			071 X		
016 R↓	Input x _i , y _i , z _i .		072 RCL8		
017 GSB1			073 RCL9		
018 8			074 X		
019 STOI			075 -		
020 RCLB	Compute Σx _i , Σy _i , Σz _i ;		076 X		
021 GSB9	Σx _i ² , Σy _i ² , Σz _i ² ; Σx _i y _i ,		077 STOC		
022 GSB1	Σy _i z _i , Σz _i x _i .		078 RCL0		
023 9			079 RCL1		
024 STOI			080 X		
025 RCLC			081 RCL7		
026 GSB9			082 RCL8		
027 GSB1			083 X		
028 RCLA			084 -		
029 RCLB			085 STOA		
030 X			086 RCL0		
031 GSB2			087 RCL2		
032 ST+I			088 X		
033 RCLA			089 RCL7		
034 RCLC			090 RCL9		
035 X			091 X		
036 GSB2			092 -		
037 ST+2			093 STOB		
038 RCLB			094 X		
039 RCLC			095 RCLC		
040 X			096 XY		
041 GSB2			097 -		
042 ST+3			098 RCLD		
043 1			099 RCL0		
044 GSB2			100 RCL5		
045 ST+0			101 X		
046 RCL0			102 RCL8		
047 GSB9			103 X ²		
048 RTN			104 -		
049 *LBL1			105 X		
050 GSB2	Subroutine for Σx _i , Σx _i ² ...		106 RCLA		
051 ST+I			107 X ²		
052 RCLI			108 -		
053 3			109 ÷		
054 -			110 STOC		
055 STOI			111 RCLB		
056 R↓			112 RCLA		
REGISTERS					
0 n	1 Σx _i y _i	2 Σx _i z _i	3 Σy _i z _i	4 Σx _i ²	5 Σy _i ²
S0 S1	S2	S3	S4	S5	S6
A Used, a	B Used, b	C z _i , B in b, c	D [nΣx _i ² - (Σx _j) ²]	E nΣx _i ² - (Σx _{ij}) ²	I

113	RCLC			169	GSB9			
114	x			170	ENT↑			
115	-			171	RCLC			
116	RCLD			172	x			
117	÷			173	X ^Y			
118	STOB			174	RCLB			
119	RCL9			175	x			
120	RCLC			176	+			
121	RCL8			177	RCLA			
122	x			178	+			
123	-			179	GSB9			
124	RCLB			180	RTN			
125	RCL7			181	*LBLc			
126	x			182	F0?			
127	-			183	SPC			
128	RCL0			184	6			
129	÷	a		185	STO1			
130	STOA			186	GT08			
131	GSB7			187	RTN			
132	R/S	b		188	*LBLd			
133	RCLB			189	3			
134	GSB9			190	STO1			
135	R/S	c		191	GSB8			
136	RCLC			192	RTN			
137	GSB9			193	*LBLe			
138	R/S			194	0			
139	*LBLa			195	STO1			
140	RCLA			196	GSB8			
141	RCL9			197	RTN			
142	x			198	*LBL8			
143	RCLB			199	ISZI			
144	RCL2			200	RCLI			
145	x			201	GSB9			
146	+			202	R/S			
147	RCLC			203	GT08			
148	RCL3		Calculating R ²	204	RTN			
149	x			205	*LBL0			
150	+			206	SF1			
151	RCL9			207	GSBC			
152	X ²			208	CF1			
153	RCL0			209	RTN			
154	÷			210	*LBLB			
155	-			211	SF0			
156	RCL6			212	1			
157	RCL9			213	RTN			
158	X ²			214	*LBL7			
159	RCL0			215	F0?			
160	÷			216	SPC			
161	-			217	*LBL9			
162	÷			218	F0?			
163	GSB7			219	PRTX			
164	RTN			220	RTN			
165	*LBLb			221	*LBL2			
166	X ^Y			222	F1?			
167	GSB7			223	CHS			
168	X ^Y			224	RTN			
LABELS					FLAGS		SET STATUS	
A Start	B Print?	C Input	D Correction	E → a; b; c	0 Print	FLAGS	TRIG	DISP
a → R ²	b x ^y → z	c → Σx _i , ...	d → Σx _i ² , ...	e → Σx _i y _i , ...	1 Correction	ON OFF	DEG X	FIX X
0	1 Σx _i , Σx _i ²	2 CHS	3	4	2	1 □ x	GRAD □	SCI □
5	6	7 Space	8 Print	9 Print	3	2 □ x	RAD □	ENG □
						3 □ x	n — 2	

Polynomial Approximation (Card 1)

001	*LBLH		Initialize	057	ST+6						
002	CLRG			058	GTO0						
003	CF0			059	*LBL0						
004	CF1			060	RCL8						
005	0			061	ENT†						
006	RTN			062	+						
007	*LBL0C			063	1						
008	F0?			064	+						
009	PRTX			065	x						
010	ST07			066	RCL7						
011	F0?			067	RCL6						
012	SPC			068	-						
013	RTN			069	x						
014	*LBL0D			070	X?Y						
015	F1?			071	RCL7						
016	GT07			072	RCL8						
017	SF1			073	+						
018	F0?			074	1						
019	FRTX			075	+						
020	ST01			076	x						
021	ST02			077	RCL8						
022	ST03			078	x						
023	ST04			079	-						
024	ST05			080	RCL7						
025	2			081	RCL8						
026	ST0E			082	-						
027	*LBL0E			083	÷						
028	1			084	RCL8						
029	ST08			085	1						
030	RCL6			086	+						
031	2			087	ST08						
032	÷			088	÷						
033	F0?			089	RCL9						
034	FRTX			090	X?Y						
035	F0?			091	ST09						
036	SPC			092	RTN						
037	F'S			093	*LBL0E						
038	*LBL7			094	F0?						
039	F0?			095	FRTX						
040	FRTX			096	ENT†						
041	ST+1			097	2						
042	1			098	X=Y?						
043	RCL6			099	GT02						
044	RCL7			100	CLX						
045	÷			101	3						
046	-			102	X=Y?						
047	x			103	GT03						
048	ST+2			104	CLX						
049	ST09			105	4						
050	EESE			106	X=Y?						
051	ST+3			107	GT04						
052	EESE			108	CLX						
053	ST+4			109	0						
054	EESE			110	÷						
055	ST+5			111	*LBL2						
056	2			112	CLX						

REGISTERS

0	1 (f, f ₀), a ₀	2 (f, f ₁), a ₁	3 (f, f ₂), a ₂	4 (f, f ₃), a ₃	5 (f, f ₄), a ₄	6 2j	7 N	8 n	9 f _n (i) f(x _i)		
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9		
A 1 for print	B	C	D	E				I			

113	ST04				169	X ² Y			
114	*LBL3				170	X			
115	CLK				171	ST09			
116	ST05				172	LSTX			
117	*LBL4				173	RCL6			
118	RCL1				174	X			
119	RCL7				175	ST07			
120	1				176	CLX			
121	ST08				177	R/S			
122	+				178	*LBLd			
123	÷				179	RCL7			(f, fi)
124	ST01				180	RCL8			
125	GSBd				181	1			
126	ST÷2				182	+			
127	GSBd				183	+			
128	ST÷3				184	N!			
129	GSBd				185	RCL7			
130	ST÷4				186	RCL8			
131	GSBd				187	-			
132	ST÷5				188	N!			
133	RCL7				189	x			
134	RCL7				190	RCL8			
135	RCL7				191	RCL8			
136	1				192	1			
137	-				193	+			
138	2				194	ST08			
139	x				195	+			
140	ST06				196	÷			
141	÷				197	RCL7			
142	3				198	N!			
143	x				199	ENT↑			
144	ST08				200	x			
145	R4				201	÷			
146	2				202	RTN			
147	+				203	*LBLB			
148	RCL6				204	SF0			Set flag 0 for print.
149	÷				205	1			
150	ST06				206	ST0A			
151	RCL3				207	RTN			
152	x								
153	ST-1								
154	RCL8								
155	RCL3								
156	x								
157	ST03								
158	RCL7								
159	RCL7								
160	RCL7								
161	2								
162	-								
163	÷								
164	5								
165	x								
166	3								
167	÷								
168	RCL8								
LABELS					FLAGS		SET STATUS		
^A Start	^B Print?	^C N→	^D Y _i →	^E n→	^F Print		^G FLAGS	^H TRIG	^I DISP
a	b	c	d	e (f _n , f _n)	f Y _i , i > 1		ON OFF	DEG x̄	FIX .ix
0 Print i	1	2 Used	3 Used	4 Used	2		0 <input type="checkbox"/> <input checked="" type="checkbox"/>	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>
5	6	7 i > 1	8	9 f _n (i) f(x _i)	3		1 <input type="checkbox"/> <input checked="" type="checkbox"/>	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>
							2 <input type="checkbox"/> <input checked="" type="checkbox"/>		n <u>2</u>

(Card 2)

001 *LBL0			057 RCL7				
002 RT			058 X#Y				
003 RT			059 X				
004 3			060 ST+8				
005 +			061 LSTX				
006 ENT†			062 RCL9				
007 ENT†			063 X				
008 5			064 RCL5				
009 -			065 X				
010 ÷			066 ST05				
011 2			067 LSTX				
012 X			068 STX8				
013 3			069 RCL6				
014 ÷			070 X				
015 RCL7	Continue		071 ST+1				
016 +			072 RCL8				
017 ST07			073 ST-3				
018 RCL4			074 *LBLB				
019 X			075 RCLA				
020 ST-2			076 X>0?				
021 LSTX			077 SF0				
022 RCL9			078 1				
023 X			079 R/S				
024 ST04			080 *LBLB				
025 RT			081 X#Y				
026 RT			082 GS89				
027 4			083 X#Y				
028 +			084 GS88				
029 ENT†			085 -				
030 ENT†			086 ST08				
031 7			087 LSTX				
032 -			088 2				
033 ÷			089 X				
034 3			090 +				
035 X			091 RCL8				
036 4			092 ÷				
037 ÷			093 ST06				
038 RCL6			094 2				
039 X#Y			095 RCL8				
040 X			096 ÷				
041 ST06			097 ST08				
042 LSTX			098 RCL1				
043 RCL8			099 RCL6				
044 X			100 RCL2				
045 ST08			101 X				
046 RT			102 +				
047 ENT†			103 RCL6				
048 ENT†			104 ENT†				
049 ENT†			105 X				
050 3			106 RCL3				
051 -			107 X				
052 ÷			108 +				
053 7			109 ST01				
054 X			110 RCL2				
055 4			111 RCL6				
056 ÷			112 RCL3				
REGISTERS							
0	1, b ₀ , c ₀ , d ₀	2, b ₁ , c ₁ , d ₁	3 b ₂ , c ₂ , d ₂	4 b ₃ , c ₃ , d ₃	5 b ₄ , c ₄ , d ₄	6 Used	7 Used
S0	S1	S2	S3	S4	S5	S6	S7
A 1 for print	B	C	D	E	F	G	H

Input X_N, X₀.

113	x				169	RCL1				
114	2				170	GSB9				
115	x				171	R/S				
116	+				172	RCL2				
117	ST02				173	GSB9				
118	RCL4				174	R/S				
119	RCL6				175	RCL3				
120	x				176	GSB9				
121	3				177	R/S				
122	x				178	RCL4				
123	ST+3				179	GSB9				
124	RCL6				180	R/S				
125	x				181	RCL5				
126	ST+2				182	GSB9				
127	3				183	R/S				
128	÷				184	RTN				
129	RCL6				185	*LBLd				
130	x				186	GSB9				
131	ST+1				187	ST07				
132	RCL5				188	RCL2				
133	RCL6				189	x				
134	x				190	RCL7				
135	4				191	X ²				
136	x				192	RCL3				
137	ST+4				193	x				
138	RCL6				194	+				
139	x				195	RCL7				
140	1				196	3				
141	.				197	Y ^x				
142	5				198	RCL4				
143	x				199	x				
144	ST+3				200	+				
145	LSTX				201	RCL7				
146	÷				202	X ²				
147	RCL6				203	X ²				
148	x				204	RCL5				
149	ST+2				205	x				
150	4				206	+				
151	÷				207	RCL1				
152	RCL6				208	+				
153	x				209	GSB8				
154	ST+1				210	RTN				
155	RCL8				211	*LBL9				
156	CMS				212	F0?				
157	ENT↑				213	SPC				
158	EHT↑				214	*LBL8				
159	EHT↑				215	F0?				
160	STx2				216	PRTX				
161	x				217	RTN				
162	STx3									
163	x									
164	STx4									
165	x									
166	STx5									
167	R/S									
168	*LBLc									
LABELS										
A	B Set flag 0	C	D	E	0	Print	FLAGS	SET STATUS		
a (continue)	b $x_N \mapsto x_0$	c $\rightarrow d_0, d_1,$	d $x \mapsto \hat{y}$	e	1		FLAGS	TRIG	DISP	
0	1	2	3	4	2		0 <input type="checkbox"/> X	DEG <input type="checkbox"/> X	FIX <input type="checkbox"/> X	
5	6	7	8 Print	9 Used	3		1 <input type="checkbox"/> X	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>	
							2 <input type="checkbox"/> X	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>	
							3 <input type="checkbox"/> X	n <u>—</u> 2		

t Statistics

001 *LBLA			057 -		
002 CF0			058 ST-2		
003 CF1		Initialize	059 X ²		
004 θ			060 ST-3		
005 ST01			061 RCL1		
006 ST02			062 1		
007 ST03			063 -		
008 RTN			064 ST01		
009 *LBLC		Input x _i , y _i for paired t statistics.	065 GSB0		
010 F0?			066 RTN		Set flag 0 for print.
011 GSB9			067 *LBLE		
012 -			068 SF0		
013 ST+2			069 1		
014 X ²			070 RTN		
015 ST+3			071 *LBL9		Print x _i , y _i .
016 RCL1			072 X ²		
017 1			073 SPC		
018 +			074 PRTX		
019 ST01			075 X ²		
020 GSB0			076 PRTX		
021 RTN			077 RTN		
022 *LBLE		D, S _D , t ₁ , df ₁	078 *LBL6		Input x _i or y _i for t statistics for two means.
023 RCL2			079 GSB0		
024 RCL1			080 ST+2		
025 ÷			081 X ²		
026 GSB1			082 ST+3		
027 GSB0			083 RCL1		
028 R/S			084 1		
029 RCL3			085 +		
030 RCL2			086 ST01		
031 X ²			087 GSB0		
032 RCL1			088 GSB1		
033 ÷			089 RTN		
034 -			090 *LBLC		
035 RCL1			091 ST07		
036 1			092 GSB0		
037 -			093 GSB1		
038 ÷			094 F1		
039 JX			095 R/S		
040 GSB0			096 RCL1		
041 R/S			097 ST04		d
042 RCL1			098 RCL2		
043 JX			099 ST05		
044 ÷			100 RCL3		
045 ÷			101 ST06		
046 GSB0			102 θ		
047 R/S			103 ST01		
048 RCL1			104 ST02		
049 1			105 ST03		
050 -			106 RCL7		
051 GSB0			107 SF1		
052 GSB1			108 RTN		
053 RTN			109 *LBLD		
054 *LBLD		For correction of x _k , y _k .	110 RCL6		
055 F0?			111 RCL5		
056 GSB9			112 X ²		

REGISTERS

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

113 RCL4 114 ÷ 115 - 116 RCL3 117 + 118 RCL2 119 × 120 RCL1 121 ÷ 122 - 123 RCL1 124 RCL4 125 + 126 2 127 - 128 ST08 129 ÷ 130 JX 131 1 132 RCL1 133 ÷ 134 1 135 RCL4 136 ÷ 137 + 138 JX 139 - 140 RCL5 141 RCL4 142 ÷ 143 RCL3 144 RCL1 145 ÷ 146 - 147 RCL7 148 - 149 X#Y 150 ÷ 151 GSB8 152 R/S 153 RCL8 154 GSB8 155 GSB1 156 RTN 157 #LBLk 158 GSB8 159 ST-Z 160 × 161 ST-Z 162 RCL1 163 1 164 - 165 ST01 166 GSB8 167 GSB1 168 RTN					169 *LBL0 170 F0C 171 PRX 172 RTN 173 *LBL1 174 F0C 175 SPC 176 RTN			Subroutine for space.		
					t ₂ , df ₂					
					For correction of x _k or y _k .					
					LABELS			FLAGS		
A Start	B Print	C x _i ↑y _i	D x _k ↑y _k →	E →D, S _D ...	F Print	G	H	I	J	K
^a x _i or y _i	^b x _k or y _k	^c d→	^d t ₂ , df ₂	^e	^f New d	ON	OFF	DEG	X!	FIX
0 Print	1 Space	2	3	4	5	1	0	GRAD	□	SCI
5	6	7	8	9 Print x _i , y _i	3	2	0	RAD	□	ENG
						3	1	---	---	n

Chi-Square Evaluation

001 *LBLA 002 CF0 003 CF1 004 0 005 ST01 006 ST02 007 ST03 008 RTN 009 *LBLC 010 F0? 011 GSB9 012 ST03 013 - 014 X ² 015 RCL3 016 = 017 ST+2 018 RCL1 019 1 020 + 021 ST01 022 GSB8 023 RTN 024 *LBLB 025 F1? 026 GT01 027 RCL2 028 GSB7 029 GSB8 030 GSB7 031 RTN 032 *LBL1 033 1 034 RCL1 035 RCL3 036 x 037 RCL2 038 = 039 RCL2 040 - 041 GSB7 042 GSB8 043 RTN 044 *LBLd 045 RCL2 046 RCL1 047 = 048 GSB8 049 GSB7 050 RTN 051 *LBLD 052 F0? 053 GSB9 054 ST03 055 - 056 X ²	Initialize	057 RCL3 058 = 059 ST-2 060 RCL1 061 1 062 - 063 ST01 064 GSB8 065 RTN 066 *LBLa 067 GSB8 068 ST+2 069 X ² 070 ST+3 071 RCL1 072 1 073 + 074 ST01 075 GSB8 076 GSB7 077 SF1 078 RTN 079 *LBLb 080 GSB8 081 ST-2 082 X ² 083 ST-3 084 RCL1 085 1 086 - 087 ST01 088 GSB8 089 GSB7 090 RTN 091 *LBLB 092 SF0 093 1 094 RTN 095 *LBL9 096 SPC 097 X ² Y 098 PRTX 099 X ² Y 100 PRTX 101 RTN 102 *LBLc 103 SF1 104 GT0E 105 RTN 106 *LBL8 107 F0? 108 PRTX 109 RTN 110 *LBL7 111 F0? 112 SPC	For equal expected frequency.						
For correction O _j , E _j .	X ₁ ²	082 X ² 083 ST-3 084 RCL1 085 1 086 - 087 ST01 088 GSB8 089 GSB7 090 RTN 091 *LBLB 092 SF0 093 1 094 RTN 095 *LBL9 096 SPC 097 X ² Y 098 PRTX 099 X ² Y 100 PRTX 101 RTN 102 *LBLc 103 SF1 104 GT0E 105 RTN 106 *LBL8 107 F0? 108 PRTX 109 RTN 110 *LBL7 111 F0? 112 SPC	Set flag 0 for print.						
		092 X ² 093 ST-3 094 RCL1 095 1 096 - 097 ST01 098 GSB8 099 GSB7 010 RTN 011 *LBLB 012 SF0 013 1 014 RTN 015 *LBL9 016 SPC 017 X ² Y 018 PRTX 019 X ² Y 020 PRTX 021 RTN 022 *LBLc 023 SF1 024 GT0E 025 RTN 026 *LBL8 027 F0? 028 PRTX 029 RTN 030 *LBL7 031 F0? 032 SPC							
For correction O _j , E _j .	X ₂ ²	093 ST-3 094 RCL1 095 1 096 - 097 ST01 098 GSB8 099 GSB7 100 RTN 101 *LBLB 102 SF0 103 1 104 RTN 105 *LBL9 106 SPC 107 X ² Y 108 PRTX 109 X ² Y 110 PRTX 111 RTN 112 *LBLc 113 SF1 114 GT0E 115 RTN 116 *LBL8 117 F0? 118 PRTX 119 RTN 120 *LBL7 121 F0? 122 SPC	Set flag 1 for equally expected frequency.						
REGISTERS									
0	1 n	2 Used	3 Used	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

113 RTN

LABELS		FLAGS		SET STATUS		
A Start	B Print	C $O_i \uparrow E_i \rightarrow$	D $O_k \uparrow E_k$	E χ_1^2	F Print	G
^a $O_j (\Sigma+)$	^b $O_h (\Sigma-)$	^c χ_2^2	^d E	e	^f Equal E_i	
0	1 χ_2^2	2	3	4	2	
5	6	7 Space	8 Print	9 Print	3	
FLAGS		TRIG		DISP		
ON OFF		DEG	x	FIX	x	
0 <input type="checkbox"/>	<input checked="" type="checkbox"/>	GRAD	<input type="checkbox"/>	SCI	<input type="checkbox"/>	
1 <input type="checkbox"/>	<input checked="" type="checkbox"/>	RAD	<input type="checkbox"/>	ENG	<input type="checkbox"/>	
2 <input type="checkbox"/>	<input checked="" type="checkbox"/>			n	<u>2</u>	
3 <input type="checkbox"/>	<input checked="" type="checkbox"/>					

Contingency Table

001 *LBLA 002 CLRG 003 CF0 004 CF1 005 θ 006 RTN 007 *LBLB 008 F0? 009 GSB9 010 θ 011 ST07 012 R↓ 013 GSB8 014 RTN 015 *LBLD 016 RCL0 017 RCL4 018 × 019 RCL1 020 ÷ 021 RCL0 022 RCL5 023 RCL2 024 ÷ 025 × 026 + 027 RCL0 028 - 029 ST00 030 GSB7 031 R/S 032 RCLD 033 RCL0 034 RCLD 035 + 036 ÷ 037 √X 038 GSB7 039 GSB6 040 RTN 041 *LBLE 042 RCL1 043 GSB7 044 R/S 045 RCL2 046 GSB7 047 R/S 048 + 049 GSB? 050 GSB6 051 RTN 052 *LBLC 053 SF1 054 GSB8 055 CF1 056 RTN		Initialize Input x_{ij}, x_{2j} for $2 \times k$. $2 \times k$ χ^2 $2 \times k$ C_c $2 \times k$ R_1, R_2, T $2 \times k$ correction.	057 *LBLA 058 SF0 059 1 060 RTN 061 *LBL9 062 X?Y 063 PRTX 064 X?Y 065 PRTX 066 RTN 067 *LBLb 068 F0? 069 GSB8 070 ST0C 071 F1? 072 CHS 073 ST+3 074 ST00 075 ST07 076 ENT↑ 077 × 078 ST08 079 R↓ 080 *LBL0 081 ST0B 082 F1? 083 CHS 084 ST+2 085 ST+0 086 ST+7 087 ENT↑ 088 × 089 ST09 090 R↓ 091 ST0A 092 F1? 093 CHS 094 ST+1 095 ST+0 096 ST+7 097 ENT↑ 098 × 099 RCL7 100 ÷ 101 ST+4 102 RCL9 103 RCL7 104 ÷ 105 ST+5 106 RCL8 107 RCL7 108 ÷ 109 ST+6 110 1 111 F1? 112 CHS	Set flag for print. Print x_{ij}, x_{2j} . $3 \times k$ Input x_{ij}, x_{2j}, x_{3j} .
REGISTERS				
0 T	1 R ₁	2 R ₂	3 R ₃	4 $\Sigma x_{ij}/C_j$
S0	S1	S2	S3	S4
A x_{1j}	B x_{2j}	C x_{3j}	D χ^2	E k
				I

113 RCL _E		169 RCL _B			
114 +		170 GSB ₇			
115 STO _E		171 RTN			
116 GSB ₇		172 *LBL _C		3 x k correction.	
117 GSB ₆		173 SF1			
118 CF1		174 GSB _b			
119 R/S		175 CF1			
120 RCL ₇		176 RTN			
121 GSB ₇		177 *LBL ₈		Print x_{ij}, x_{2j}, x_{3j} .	
122 GSB ₆		178 R ₄			
123 RTN		179 R ₄			
124 *LBL _D		180 PRTX			
125 RCL ₁		181 R ₁			
126 RCL ₂		182 PRTX			
127 RCL ₃		183 R ₁			
128 +		184 PRTX			
129 +		185 RTN			
130 STO _B	3 x k	186 *LBL ₇			
131 RCL ₄	χ^2	187 FB?		Subroutine for print.	
132 RCL ₁		188 PRTX			
133 ÷		189 RTN			
134 STO ₉		190 *LBL ₆			
135 RCL ₅		191 FB?		Subroutine for space.	
136 RCL ₂		192 SPC			
137 ÷		193 RTN			
138 ST+9					
139 RCL ₆					
140 RCL ₃					
141 ÷					
142 ST+9					
143 RCL ₉					
144 -1					
145 -					
146 RCL ₀					
147 x					
148 GSB ₇					
149 R/S					
150 ENT ₁	3 x k				
151 ENT ₁	C _c				
152 RCL ₀					
153 +					
154 ÷					
155 JX					
156 GSB ₇					
157 GSB ₆					
158 R/S					
159 *LBL _e	3 x k				
160 RCL ₁	R ₁ , R ₂ , R ₃ , T				
161 GSB ₇					
162 R/S					
163 RCL ₂					
164 GSB ₇					
165 R/S					
166 RCL ₃					
167 GSB ₇					
168 R/S					
LABELS					
^a Start	^b x _{ij} , x _{2j}	^c Correction	^d χ^2 ; C _c	^e R ₁ , R ₂ ; T	
^a Print	^b Input 3 x k	^c Correction	^d χ^2 ; C _c	^e R ₁ , R ₂	
^d Used	1	2	3	4	
^e Space	7 Print	8 Print	9 Print	3	
FLAGS					
0	Print	1 Correction	0	Print	
SET STATUS					
FLAGS		TRIG		DISP	
0	ON	OFF	X	DEG	X
1	ON	OFF	X	GRAD	□
2	ON	OFF	X	RAD	□
3	ON	OFF	X	ENG	□
				n	2

Spearman's Rank Correlation Coefficient

001	#LBL4				057	X>ZY				
002	CLR6				058	PRTX				
003	CF0				059	X>ZY				
004	CF1				060	PRTX				
005	0				061	RTN				
006	RTN				062	#LBL0				
007	#LBLC				063	F0?				
008	F0?				064	PRTX				
009	GSB9				065	RTN				
010	-				066	#LBL1				
011	X^2				067	F0?				
012	F1?				068	SPC				
013	CHS				069	RTN				
014	ST+2									
015	RCL1									
016	1									
017	F1?									
018	CHS									
019	+									
020	ST01									
021	GSB0									
022	GSB1									
023	RTN									
024	#LBL4									
025	1									
026	RCL2									
027	6									
028	X									
029	RCL1									
030	X^2									
031	1									
032	-									
033	RCL1									
034	X									
035	÷									
036	-									
037	GSB0									
038	R/S									
039	RCL1									
040	1									
041	-									
042	JX									
043	X									
044	GSB0									
045	GSB1									
046	RTN									
047	#LBLD									
048	SF1									
049	GSBC									
050	CF1									
051	RTN									
052	#LBLB									
053	SF0									
054	1									
055	RTN									
056	#RTN9									
REGISTERS										
0	1 n	2 $\sum D_i^2$	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 Start	B Print	C $(\Sigma+)$	D $(\Sigma-)$	E $\rightarrow r_s, z$	F Print	G Flags	H Trig	I Disp	
a	b	c	d	e	f	ON OFF	DEG x	FIX x	
0	1	2	3	4	2	0 <input type="checkbox"/> x	GRAD <input type="checkbox"/>	SCI <input type="checkbox"/>	
5	6	7	8	9	3	1 <input type="checkbox"/> x	RAD <input type="checkbox"/>	ENG <input type="checkbox"/>	
						2 <input type="checkbox"/> x		n <u>2</u>	

\bar{x} and R Control Chart

001 *LELA 002 CLR6 003 CF0 004 CF1 005 0 006 RTN 007 *LBLB 008 1 009 ST0E 010 RTN 011 *LBLC 012 ST00 013 RCL4 014 ST0A 015 RCL5 016 ST0B 017 RCL0 018 GSB9 019 F1? 020 GT01 021 0 022 ST01 023 ST02 024 ST03 025 X2Y 026 ST04 027 ST05 028 SF1 029 *LBL1 030 RCL4 031 X2Y 032 X?Y? 033 ST04 034 RCL5 035 X?Y 036 X?Y? 037 ST05 038 F0? 039 CHS 040 ST+2 041 X? 042 F0? 043 CHS 044 ST+3 045 RCL1 046 1 047 F0? 048 CHS 049 + 050 ST01 051 GSB9 052 RTN 053 *LBLB 054 GSB7 055 RCL4 056 GSB9		Initialize Store 1 in R_E for print. Input x _{ij} . Xmax, Xmin		057 R/S 058 *LBLB 059 RCL5 060 GSB9 061 RTN 062 *LBLB 063 CF1 064 RCL6 065 1 066 + 067 ST06 068 RCL2 069 RCL1 070 ÷ 071 GSB9 072 ST+7 073 R/S 074 *LBLB 075 RCL4 076 RCL5 077 - 078 ST+8 079 GSB9 080 GSB7 081 R/S 082 *LBLB 083 RCL7 084 RCL6 085 ÷ 086 GSB9 087 RTN 088 *LBLB 089 RCL8 090 RCL6 091 ÷ 092 ST03 093 GSB9 094 GSB7 095 R/S 096 *LBLB 097 RCL3 098 X 099 RCL7 100 RCL6 101 ÷ 102 X?Y 103 - 104 GSB5 105 R/S 106 *LBLB 107 LSTX 108 2 109 X 110 + 111 GSB9 112 GSB7	\bar{x}_i R_i \bar{x} \bar{R} L_x $U_{\bar{x}}$
REGISTERS					
0 x _{ij}	1 n	2 Σx_{ij}	3 Σx_{ij}^2 , \bar{R}	4 x _{max}	
S0	S1	S2	S3	S4	
A Last x _{max}	B Last x _{min}	C	D	E 1 for print	
				I	

LABELS						FLAGS			SET STATUS		
A Start	B Print	C $x_{ij} (\Sigma+)$	D $x_{ik} (\Sigma-)$	E x_{\max}, x_{\min}	F Correction	G	H	I	J	K	
^a \bar{x}_{ij}, R_i	^b \bar{x}, \bar{R}	^c L_x, U_x	^d L_R	^e U_R	^f 1 st data	0 ON	ON	OFF	DEG	X	FIX
0	^g $j > 1$	2	3	4	2	1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	GRAD	<input type="checkbox"/>	SCI
5	6	7 Space	8 Print	9 Print?	3	2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	RAD	<input type="checkbox"/>	ENG
						3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	n	<u>2</u>	

Operating Characteristic Curves

<pre> 001 *LBLA 002 CFB 003 CLR6 004 0 005 RTN 006 *LBLB 007 SF0 008 1 009 RTN 010 *LBLC 011 GSB3 012 ST01 013 RTN 014 *LBLD 015 ST03 016 X#Y 017 ST02 018 GSB3 019 X#Y 020 GSB3 021 RTN 022 *LBLE 023 GSB4 024 GSB3 025 RCL1 026 X 027 INT 028 ST04 029 RCL1 030 RCL2 031 GSBa 032 RCL1 033 RCL4 034 - 035 RCL2 036 GSBa 037 RT 038 ÷ 039 ST05 040 ST06 041 ST07 042 RCL3 043 0 044 ST08 045 X=Y? 046 GSB5 047 *LBL0 048 RCL4 049 - 050 RCL8 051 RCL2 052 - 053 X 054 RCL8 055 1 056 + </pre>		<pre> Initialize Set flag 0 for print. Store N. Store n, c for finite lot size. Finite lot size. Registers </pre>		<pre> 057 ÷ 058 LSTX 059 RCL1 060 RCL4 061 - 062 RCL2 063 - 064 + 065 ÷ 066 RCL6 067 X 068 ST06 069 ST+7 070 RCL3 071 1 072 RCL8 073 + 074 ST08 075 X#Y? 076 GT08 077 ! 078 RCL7 079 X>Y? 080 X=Y 081 GSB3 082 P/S 083 *LBL0 084 - 085 LSTX 086 X≤Y? 087 GSB9 088 ST05 089 1 090 ST07 091 + 092 ST06 093 CLX 094 X=1? 095 GT08 096 *LBL1 097 RT 098 1 099 RCL7 100 + 101 ST07 102 X>Y? 103 GT07 104 RCL5 105 X#Y 106 + 107 LSTX 108 ÷ 109 RCL6 110 X 111 ST06 112 GT01 </pre>					
0	¹ N, n	² n, p	³ c, f(0)	⁴ M	⁵ f(0)	⁶ , c	⁷ , counter	⁸ Used	⁹
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	

113 RTN		169 RCL8	
114 *LBL7		170 X	
115 RCL6		171 RCL4	
116 RTN		172 X	
117 *LBL8		173 ST04	
118 1		174 ST+5	
119 GSB3		175 RCL7	
120 RTN		176 1	
121 *LBL9		177 *	
122 ST06		178 ST07	
123 X ² Y		179 RCL6	
124 RTN		180 XY?	
125 *LBL0	Input n, c for infinite lot size.	181 GT02	
126 ST06		182 1	
127 X ² Y		183 RCL5	
128 ST01		184 X>Y?	
129 GSB3		185 X ² Y	
130 X ² Y		186 GSB3	
131 GSB3		187 R/S	
132 RTN		188 *LBL6	
133 *LBL6		189 RCL3	
134 ST02		190 GSB3	
135 GSB4		191 R/S	
136 GSB3		192 RTN	
137 ST02		193 *LBL5	
138 RCL2		194 RCL5	
139 1		195 GSB3	
140 -		196 R/S	
141 CHS		197 RTN	
142 ÷		198 *LBL3	
143 ST08		199 F09	
144 LSTX		200 PRTX	
145 RCL1		201 RTN	
146 Y ^x		202 *LBL4	
147 ST03		203 F09	
148 RCL6		204 SPC	
149 0		205 RTN	
150 ST07			
151 X=Y?			
152 GSB6			
153 CLX			
154 RCL1			
155 X ² Y			
156 X>Y?			
157 GT06			
158 RCL3			
159 ST04			
160 ST05			
161 *LBL2			
162 RCL1			
163 RCL7			
164 -			
165 RCL7			
166 1			
167 +			
168 ÷			
LABELS			
A Start	B Print	C N	D nfc→
a f(x)	b	c	d nfc→
0 P _a	1 f(x + 1)	2 Used	3 Print
5 c, f(0)	6 f(0)	7 c	8 1
			9 STO 6
FLAGS			
0 Print	1	2	3
SET STATUS			
FLAGS		TRIG	
0	1	2	3
ON OFF	DEG X	FIX X	
1	GRAD	SCI	
2	RAD	ENG	
3	n ₂		

Single- and Multi-Server Queues

001 *LBLA			057 RCL1						
002 GS89			058 RCL3						
003 ST01			059 -						
004 ST01			060 ÷						
005 R↓			061 ST04		Lq, L				
006 ST02			062 SPC						
007 X \neq Y			063 PRTX						
008 ST05			064 R/S						
009 ÷			065 *LBLC						
010 ST03			066 RCL3						
011 PRTX			067 +						
012 R/S			068 ST06						
013 *LBLB			069 PRTX						
014 1			070 R/S						
015 ST04			071 *LBLD						
016 0			072 RCL4						
017 *LBL1			073 RCL2		Tq, T				
018 RCL4			074 ÷						
019 +			075 SPC						
020 LSTX			076 PPTX						
021 RCL3			077 R/S						
022 x			078 *LBLD						
023 RCLI			079 RCL6						
024 RCLI			080 RCL2						
025 -			081 ÷						
026 1			082 PRTX						
027 +			083 R/S						
028 ÷			084 *LBLE						
029 ST04			085 SPC		P(t)				
030 R↓			086 PRTX						
031 DS2I			087 RCL1						
032 GT01			088 RCL5						
033 1			089 x						
034 RCL3			090 RCL2						
035 RCL1			091 -						
036 ÷			092 x						
037 -			093 CHS						
038 RCL4			094 e ^x						
039 X \neq Y			095 RCLI						
040 ÷			096 x						
041 ST01			097 PRTX						
042 +			098 SPC						
043 1/X			099 R/S						
044 SPC			100 *LBL9		Print u, λ, n.				
045 PRTX			101 R↓						
046 R/S			102 R↓						
047 *LBLB			103 SPC						
048 RCLI			104 PRTX						
049 x			105 R↑						
050 ST01			106 PRTX						
051 PPTX			107 R↑						
052 R/S			108 PPTX						
053 *LBLC			109 RTN						
054 . RCLI			110 *LBLa						
055 RCL3			111 GSBB						
056 x			112 ST02		m, n				
REGISTERS									
0	1 n, m	2 λ, n	3 ρ	4 Lq, k	5 μ, Qk, L	6 L, ΣQk	7 ΣkQk, -F	8 a	9 Used
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E				I Used, P _b	

113	R4			169	ST05				
114	ST01			170	SPC				
115	R/S			171	PRTX				
116	*LBL6			172	R/S				
117	6SB8			173	*LBL6				
118	ST08			174	RCL8				
119	÷			175	X				
120	ST03			176	PRTX				
121	PRTX			177	R/S				
122	R/S			178	*LBLd				
123	*LBLd			179	RCL5				
124	CLX			180	RCL1				
125	ST07			181	÷				
126	1			182	1				
127	ST04			183	-				
128	ST05			184	RCL3				
129	ST06			185	1				
130	*LBL2			186	+				
131	RCL2			187	X				
132	RCL4			188	ST07				
133	X?Y?			189	1				
134	X?Y			190	+				
135	RCL3			191	RCL1				
136	X?Y			192	X				
137	÷			193	SPC				
138	RCL1			194	PRTX				
139	RCL4			195	R/S				
140	-			196	*LBLd				
141	1	L		197	RCL8				
142	+			198	X				
143	X			199	PRTX				
144	RCL5			200	R/S				
145	X			201	*LBLe				
146	ST05			202	RCL7				
147	EEX			203	CHS				
148	CHS			204	SPC		F		
149	9			205	PRTX				
150	0			206	SPC				
151	X?Y?			207	R/S				
152	GT02			208	*LBL8				
153	R4			209	R↓				
154	ST+6			210	SPC				
155	RCL4			211	PRTX				
156	X			212	R↑				
157	ST+7			213	PRTX				
158	RCL1			214	RTH				
159	RCL4								
160	1								
161	+								
162	ST04								
163	X?Y?								
164	GT03								
165	*LBL2								
166	RCL7								
167	RCL6								
168	÷								
LABELS					FLAGS		SET STATUS		
A ... → p	B → P ₀ , → P _b	C → L _q , → L	D → T _q , → T	E t → P(t)	0		FLAGS	TRIG	DISP
^a m:n→	^b STa → p	^c → L, → T	^d → L _q , → T _q	^e → F	1		ON OFF		
0	^f P ₀ , P _b	^g L	^h K	ⁱ			1 <input type="checkbox"/> X	DEG <input checked="" type="checkbox"/> x	FIX <input type="checkbox"/> x
5	⁶	⁷	⁸ Print	⁹ Print	3		2 <input type="checkbox"/> X	GRAD <input type="checkbox"/> □	SCI <input type="checkbox"/> □
							3 <input type="checkbox"/> X	RAD <input type="checkbox"/> □	ENG <input type="checkbox"/> □
								n <u>2</u>	

Appendix A

MAGNETIC CARD

SYMBOLS AND CONVENTIONS

SYMBOL OR CONVENTION	INDICATED MEANING
White mnemonic: x A	White mnemonics are associated with the user-definable key they are above when the card is inserted in the calculator's window slot. In this case the value of x could be input by keying it in and pressing A.
Gold mnemonic: y x f E	Gold mnemonics are similar to white mnemonics except that the gold f key must be pressed before the user-definable key. In this case y could be input by pressing f E.
x ↑ y A	↑ is the symbol for ENTER. In this case ENTER is used to separate the input variables x and y. To input both x and y you would key in x, press ENTER, key in y and press A.
x A	The box around the variable x indicates input by pressing STO A.
(x) A	Parentheses indicate an option. In this case, x is not a required input but could be input in special cases.
→ x A	→ is the symbol for calculate. This indicates that you may calculate x by pressing key A.
→ x, y, z A	This indicates that x, y, and z are calculated by pressing A once. The values would be printed in x, y, z order.
→ x; y; z A	The semi-colons indicate that after x has been calculated using A, y and z may be calculated by pressing R/S.
→ "x ", y A	The quote marks indicate that the x value will be "paused" or held in the display for one second. The pause will be followed by the display of y.
↔ x A	The two-way arrow ↔ indicates that x may be either output or input when the associated user-definable key is pressed. If numeric keys have been pressed between user-definable keys, x is stored. If numeric keys have not been pressed, the program will calculate x.

SYMBOLS AND CONVENTIONS (Continued)

SYMBOL OR CONVENTION	INDICATED MEANING
P? █ A	The question mark indicates that this is a mode setting, while the mnemonic indicates the type of mode being set. In this case a print mode is controlled. Mode settings typically have a 1.00 or 0.00 indicator displayed after they are executed. If 1.00 is displayed, the mode is on. If 0.00 is displayed, it is off.
START █ A	The word START is an example of a command. The start function should be performed to begin or start a program. It is included when initialization is necessary.
DEL █ A	This special command indicates that the last value or set of values input may be deleted by pressing █ A.
→ x; ... █ A	Three dots (...) indicate that additional output follows. See User Instructions for complete description of variables output.



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