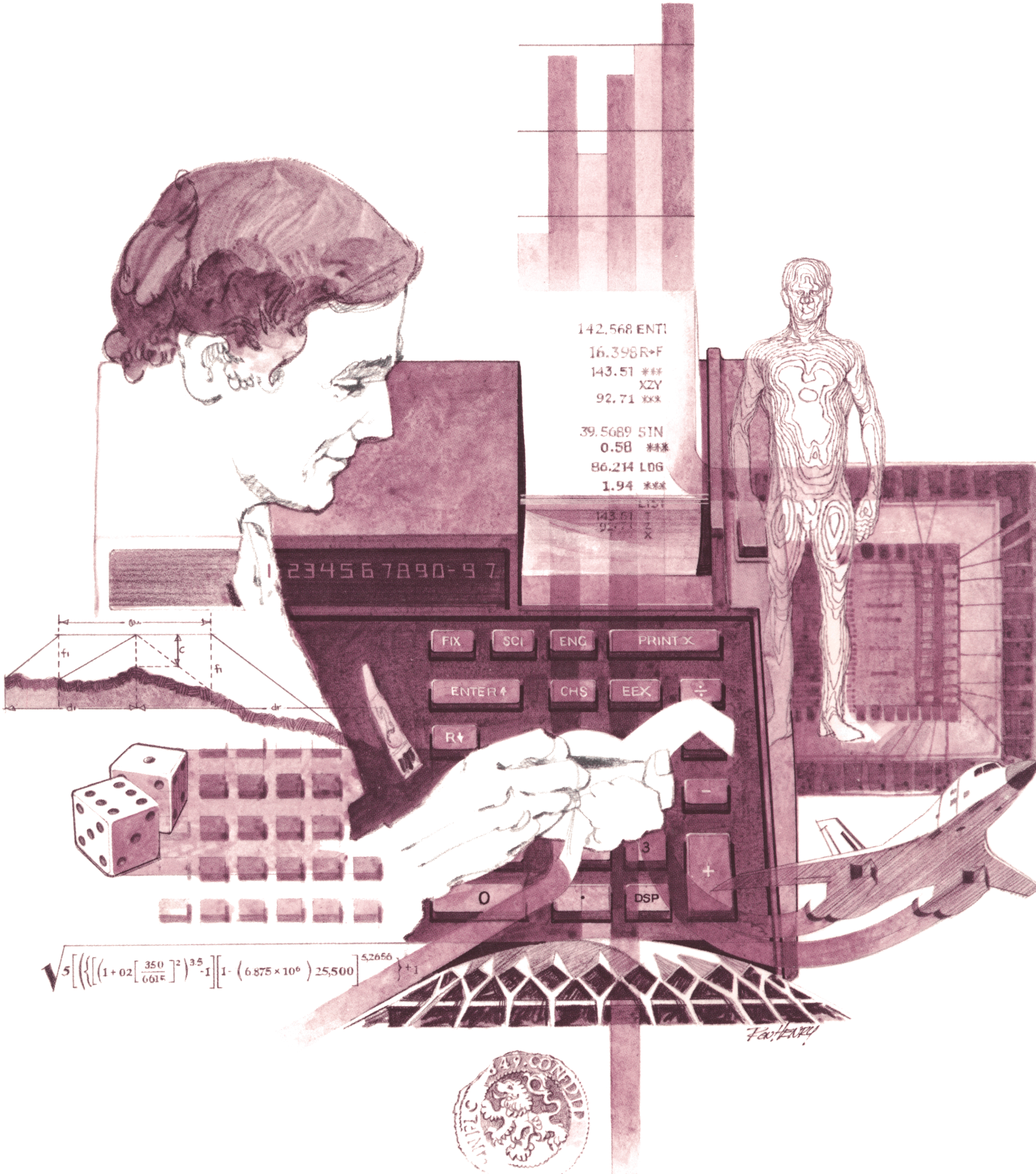
HEWLETT-PACKARD

HP-67/HP-97

Users' Library Solutions

Test Statistics



INTRODUCTION

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

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

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

A WORD ABOUT PROGRAM USAGE

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

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

> The Set Status section indicates the status of flags, angular mode, and display setting. After keying in your program, review the status section and set the conditions as indicated before using or permanently recording the program.
>
> REMEMBER! To save the program permanently, **clip** the corners of the magnetic card once you have recorded the program. This simple step will protect the magnetic card and keep the program from being inadvertently erased.

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

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Program Description I

Program Title ONE SAMPLE TEST STATISTICS FOR THE MEAN

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Suppose $\{x_1, x_2, ..., x_n\}$ is a sample from a normal population with a known variance σ^2 and unknown mean μ. A test of the null hypothesis

$$H_0: \mu = \mu_0$$

is based on the z statistic which has a standard normal distribution.

If the variance σ^2 is unknown then the t statistic, which has the t distribution with n – 1 degrees of freedom, is used instead.

Equations:

$$z = \frac{\sqrt{n}(\bar{x} - \mu_0)}{\sigma}$$

$$t = \frac{\sqrt{n}\ (\bar{x} - \mu_0)}{s}$$

where $\bar{x}$ and s are sample mean and sample standard deviation.

Operating Limits and Warnings

Remark:

$n > 1$.

Program Description II

Sketch(es)

Sample Problem(s)

Example:

Compute the z and the t statistics for the following set of data if $\mu_0 = 2$ and $\sigma = 1$.

{2.73, 0.45, 2.52, 1.19, 3.51, 2.75, 1.79, 1.83, 1, 0.87, 1.9, 1.62, 1.74, 1.92, 1.24, 2.68}

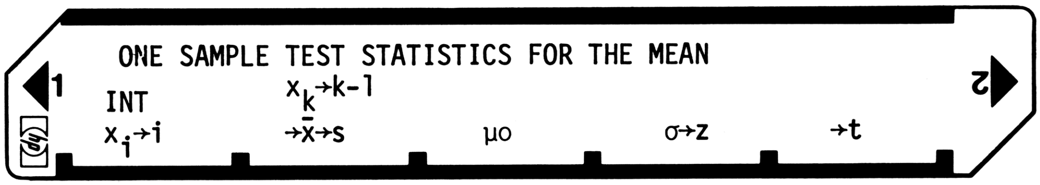
Keystrokes:

[f] [A] ——→ 0.00
2.73 [A] .45 [A] . . . 2.68 [A] ——→ 16.00
[B] ——→ 1.86 ($\bar{x}$)
[B] ——→ 0.82 (s)
2 [C] ——→ 2.00
1 [D] ——→ –0.57 (z)
[E] ——→ –0.69 (t)

Solution(s)

Reference(s) This program is a translation of the HP-65 Stat Pac 2 program.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	If $\bar{x}$ and s are known, go to 8			
3	Initialize		RTN R/S	0.00
4	Perform 4 for i = 1, 2,..., n	x_i	A	i
5	Optional—delete erroneous			
	data x_k ($k \neq 1$)	x_k	f A	
6	Compute $\bar{x}$ and s		B	$\bar{x}$
			B	s
7	Go to 9			
8	Store $\bar{x}$ and s	$\bar{x}$	STO 2	
		s	STO 5	
9	Input μ_0	μ_0	C	
10	Input σ and compute z	σ	D	z
	or			
	Compute t		E	t
11	For a new case, go to 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	
002	CLRG	16-53	Initialize
003	RTN	24	
004	*LBLA	21 11	
005	RCL2	36 02	
006	-	-45	Accumulate sums
007	RCL4	36 04	for the mean and
008	-	-45	the standard
009	RCL1	36 01	deviation
010	1	01	
011	+	-55	
012	÷	-24	
013	ENT↑	-21	
014	ENT↑	-21	
015	RCL4	36 04	
016	+	-55	
017	ENT↑	-21	
018	ENT↑	-21	
019	RCL2	36 02	
020	+	-55	
021	STO2	35 02	
022	LSTX	16-63	
023	-	-45	
024	-	-45	
025	STO4	35 04	
026	R↓	-31	
027	×	-35	
028	RCL1	36 01	
029	×	-35	
030	1	01	
031	LSTX	16-63	
032	+	-55	
033	ABS	16 31	
034	STO1	35 01	
035	×	-35	
036	ST+3	35-55 03	
037	RCL1	36 01	
038	RTN	24	
039	*LBLB	21 12	Display the mean
040	RCL2	36 02	
041	R/S	51	
042	*LBLB	21 12	
043	RCL3	36 03	Compute the
044	RCL1	36 01	standard deviation
045	1	01	
046	-	-45	
047	÷	-24	
048	√X	54	
049	STO5	35 05	Store s
050	RTN	24	
051	*LBLC	21 13	
052	STO6	35 06	Store μ_0
053	RTN	24	
054	*LBLD	21 14	
055	RCL2	36 02	
056	RCL6	36 06	
057	-	-45	
058	X⇄Y	-41	$\bar{x}-\mu_0$
059	÷	-24	
060	RCL1	36 01	
061	√X	54	
062	×	-35	
063	RTN	24	Display z
064	*LBLE	21 15	
065	RCL2	36 02	
066	RCL6	36 06	
067	-	-45	$\bar{x}-\mu_0$
068	RCL5	36 05	
069	÷	-24	
070	RCL1	36 01	
071	√X	54	
072	×	-35	Display t
073	RTN	24	
074	*LBLb	21 16 12	Delete data
075	RCL1	36 01	
076	CHS	-22	
077	STO1	35 01	
078	R↓	-31	
079	GSBA	23 11	
080	R/S	51	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	n(or-n)	running mean	sum of squares	Used	s	μ_0			

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title TEST STATISTICS FOR THE CORRELATION COEFFICIENT

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Under the assumptions of normal correlation analysis, the t statistic, which has the t distribution with n – 2 degrees of freedom, can be used to test the null hypothesis that the true correlation coefficient $\rho = 0$.

To test the null hypothesis $\rho = \rho_0$, where ρ_0 is a given number, the z statistic is used. z has approximately the standard normal distribution.

Equations:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

$$z = \frac{\sqrt{n-3}}{2} \ln\left[\frac{(1+r)(1-\rho_0)}{(1-r)(1+\rho_0)}\right]$$

where r is an estimate (based on a sample of size n) of the correlation coefficient ρ.

Operating Limits and Warnings

Remarks:

1. This program requires that $n > 3$, $|r| < 1$ and $|\rho_0| < 1$; otherwise, flashing zeros will result.
2. Usually, the z statistic is used when the sample size is large.

Program Description II

Sketch(es)

Sample Problem(s)

Example:

Given r = 0.12, n = 31, and $\rho_0 = 0$, find t and z.

Keystrokes:

.12 **A** 31 **B** **C** ⟶ 0.65 (t)

0 **D** **E** ⟶ 0.64 (z)

Solution(s)

Reference(s)

1. Hogg and Craig, Introduction to Mathematical Statistics, Macmillan Co., 1970.
2. J. Freund, Mathematical Statistics, Prentice-Hall, 1971.
3. This program is a translation of the HP-65 Stat Pac 2 program.

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Input r and n in any order	r	A	
		n	B	
3	Compute t		C	t
	or			
	Input ρ_0 and compute z	ρ_0	D	
			E	z
4	For a new case, go to 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO1	35 01	Store r
003	*LBL0	21 00	
004	ABS	16 31	Test if r or ρ_0 has
005	1	01	absolute value less
006	X⇄Y	-41	than or equal to 1
007	X>Y?	16-34	
008	GTO9	22 09	
009	LSTX	16-63	
010	RTN	24	
011	*LBLB	21 12	
012	STO2	35 02	Store n
013	3	03	
014	X⇄Y	-41	Test if n > 3
015	X≤Y?	16-35	
016	GTO9	22 09	
017	RTN	24	
018	*LBLC	21 13	Compute t
019	RCL2	36 02	
020	2	02	
021	-	-45	n-2
022	1	01	
023	RCL1	36 01	
024	X²	53	$(n-2)/(1-r^2)$
025	-	-45	
026	÷	-24	
027	√X	54	
028	RCL1	36 01	
029	×	-35	
030	RTN	24	
031	*LBLD	21 14	
032	STO3	35 03	Store ρ_0
033	GTO0	22 00	
034	*LBLE	21 15	Test if $\lvert\rho_0\rvert \leq 1$
035	RCL1	36 01	Compute z
036	1	01	
037	+	-55	
038	1	01	
039	RCL1	36 01	
040	-	-45	(1+4)/(1-r)
041	÷	-24	
042	1	01	
043	RCL3	36 03	
044	-	-45	
045	×	-35	
046	1	01	
047	RCL3	36 03	
048	+	-55	
049	÷	-24	
050	LN	32	
051	RCL2	36 02	
052	3	03	n-3
053	-	-45	
054	√X	54	
055	×	-35	
056	2	02	
057	÷	-24	
058	RTN	24	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	r	n	ρ_0						

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title **DIFFERENCES AMONG PROPORTIONS**

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Suppose $x_1, x_2, ..., x_k$ are observed values of a set of independent random variables having binomial distributions with parameters n_i and θ_i $(i = 1, 2, ..., k)$.

A chi-square statistic χ^2 can be used to test the null hypothesis $\theta_1 = \theta_2 = ... = \theta_k$. The χ^2 statistic has the chi-square distribution with $k - 1$ degrees of freedom.

Equation:

$$\chi^2 = \sum_{i=1}^{k} \frac{(x_i - n_i\hat{\theta})^2}{n_i\hat{\theta}(1-\hat{\theta})} = \sum_{i=1}^{k} n_i \left[\frac{1}{\sum_{i=1}^{k} x_i} \sum_{i=1}^{k} \frac{x_i^2}{n_i} + \frac{1}{\sum_{i=1}^{k} (n_i - x_i)} \sum_{i=1}^{k} \frac{(n_i - x_i)^2}{n_i} - 1 \right]$$

where

$$\hat{\theta} = \sum_{i=1}^{k} x_i \Big/ \sum_{i=1}^{k} n_i$$

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Example:

	n_i	x_i
Sample 1	400	232
Sample 2	500	260
Sample 3	400	197

Keystrokes:

[A] 400 [↑] 232 [B] 500 [↑] 260 [B] 400 [↑] 197 [B] ⟶ 3.00 (k)

[C] ⟶ 6.47 (χ^2)

[D] ⟶ 2.00 (df)

[E] ⟶ 0.53 ($\hat{\theta}$)

Solution(s)

Reference(s)

1. J. Freund, Mathematical Statistics, Prentice-Hall, 1971.
2. This program is a translation of the HP-65 Stat Pac 2 program.

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		A	0.00
3	Perform 3 for i = 1, 2,..., k	n_i	↑	
		x_i	B	i
4	Compute χ^2 statistic		C	χ^2
5	Compute df		D	df
6	Compute $\hat{\theta}$		E	$\hat{\theta}$
7	For a new case, go to 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	CLRG	16-53	Initialize
003	0	00	
004	RTN	24	
005	*LBLB	21 12	
006	ST+1	35-55 01	Accumulate sums
007	-	-45	
008	STO4	35 04	$n_i - x_i$
009	ST+2	35-55 02	
010	LSTX	16-63	
011	+	-55	
012	LSTX	16-63	x_i
013	ENT↑	-21	
014	×	-35	n_i
015	X⇄Y	-41	x_i^2
016	÷	-24	
017	ST+5	35-55 05	x_i^2/n_i
018	LSTX	16-63	
019	RCL4	36 04	n_i
020	ENT↑	-21	
021	×	-35	$(n_i - x_i)^2$
022	X⇄Y	-41	
023	÷	-24	
024	ST+6	35-55 06	
025	1	01	
026	RCL3	36 03	
027	+	-55	
028	STO3	35 03	
029	RTN	24	
030	*LBLC	21 13	Compute χ^2
031	RCL5	36 05	
032	RCL1	36 01	
033	÷	-24	
034	RCL6	36 06	
035	RCL2	36 02	
036	÷	-24	
037	+	-55	
038	1	01	
039	-	-45	
040	RCL1	36 01	
041	RCL2	36 02	
042	+	-55	
043	×	-35	
044	RTN	24	
045	*LBLD	21 14	Compute df
046	RCL3	36 03	
047	1	01	
048	-	-45	
049	RTN	24	
050	*LBLE	21 15	Compute θ
051	RCL1	36 01	
052	RCL1	36 01	
053	RCL2	36 02	
054	+	-55	
055	÷	-24	
056	RTN	24	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	Σx_i	$\Sigma(n_i - x_i)$	k	$n_i - x_i$	$\Sigma(x_i^2/n_i)$	$\Sigma(n_i - x_i)^2/n_i$			

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title BEHRENS-FISHER STATISTIC

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Suppose $\{x_1, x_2, ..., x_{n_1}\}$ and $\{y_1, y_2, ..., y_{n_2}\}$ are independent random samples from two normal populations having means μ_1, μ_2 (unknown). If the variances $\sigma_1{}^2, \sigma_2{}^2$ cannot be assumed equal, then the Behrens-Fisher statistic d is used instead of the t statistic to test the null hypothesis

$$H_0: \mu_1 - \mu_2 = D.$$

Equation:

$$d = \frac{\bar{x} - \bar{y} - D}{\sqrt{\dfrac{s_1{}^2}{n_1} + \dfrac{s_2{}^2}{n_2}}}$$

where $\bar{x}, \bar{y}$ and $s_1{}^2, s_2{}^2$ are sample means and variances.

Critical values of this test are tabulated in the Fisher-Yates Tables for various values of n_1, n_2, α and θ, where α is the level of significance and

$$\theta = \tan^{-1}\left(\frac{s_1}{s_2}\sqrt{\frac{n_2}{n_1}}\right).$$

Operating Limits and Warnings

Remark:

$n_1 > 1, n_2 > 1.$

Program Description II

Sketch(es)

Sample Problem(s)

Example:

Compute the Behrens-Fisher statistic for D = 0.

x:	79, 84, 108, 114, 120, 103, 122, 120
y:	91, 103, 90, 113, 108, 87, 100, 80, 99, 54

Keystrokes:

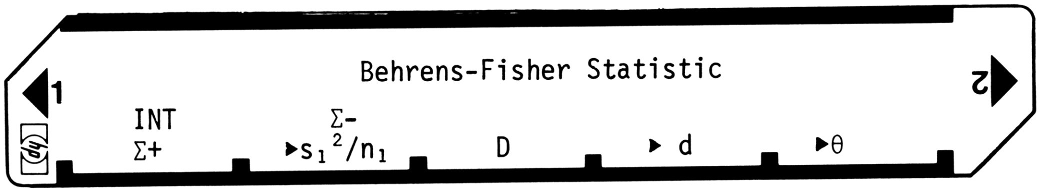
[f] [A] 79 A 84 A ... 120 A	→ 8.00 (n_1)
B	→ 34.60 (s_1^2/n_1)
[f] [A] 91 A 103 A ... 54 A	→ 10.00 (n_2)
0 C D	→ 1.73 (d)
E	→ 47.88° (θ) or 0.84 radians or 53.20 grads

Solution(s)

Reference(s)

1. Fisher and Yates, Statistical Tables for Biological, Agricultural and Medical Research, Hafner, Publishing Co., 1970.
2. This program is a translation of the HP-65 Stat Pac 2 program.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	If $\bar{x}$, $\bar{y}$ and s_1, s_2 are known, go				
	to 11				
3	Initialize		f	A	0.00
4	Perform 4 for i = 1, 2,..., n_1	x_i	A		i
5	Optional—delete erroneous x_k	x_k	f	B	
	($k \neq 1$)				
6	Compute and store $\bar{x}$, $s_1{}^2/n_1$		B		$s_1{}^2/n_1$
7	Initialize		f	A	0.00
8	Perform 8 for i = 1, 2,..., n_2	y_i	A		i
9	Optional—delete erroneous y_h	y_h	f	B	
	($h \neq 1$)				
10	Go to 12				
11	Store $\bar{x}$, $\bar{y}$ and $s_1{}^2/n_1$, $s_2{}^2/n_2$				
	in any order	$\bar{x}$	STO	5	
		$s_1{}^2/n_1$	STO	6	
		$\bar{y}$	STO	2	
		$s_2{}^2/n_2$	STO	3	
12	Input D	D	C		
13	Compute d and θ		D		d
			E		θ
14	Optional—recall means		RCL	5	$\bar{x}$
			RCL	2	$\bar{y}$
15	For a different D, go to 12				
16	For a new case, go to 2				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLa	21 16 11	
002	0	00	
003	STO1	35 01	Initialize
004	STO2	35 02	
005	STO3	35 03	
006	STO4	35 04	
007	RTN	24	
008	*LBLA	21 11	
009	RCL2	36 02	Accumulate sums
010	-	-45	
011	RCL4	36 04	
012	-	-45	
013	RCL1	36 01	
014	1	01	
015	+	-55	
016	÷	-24	
017	ENT↑	-21	
018	ENT↑	-21	
019	RCL4	36 04	
020	+	-55	
021	ENT↑	-21	
022	ENT↑	-21	
023	RCL2	36 02	
024	+	-55	
025	STO2	35 02	
026	LSTX	16-63	
027	-	-45	
028	-	-45	
029	STO4	35 04	
030	R↓	-31	
031	x	-35	
032	RCL1	36 01	
033	x	-35	
034	1	01	
035	LSTX	16-63	
036	+	-55	
037	ABS	16 31	
038	STO1	35 01	
039	x	-35	
040	ST+3	35-55 03	
041	RCL1	36 01	
042	RTN	24	
043	*LBLB	21 12	Store $\bar{x}$
044	RCL2	36 02	
045	STO5	35 05	
046	RCL3	36 03	
047	RCL1	36 01	
048	1	01	$n_i - 1$
049	-	-45	
050	÷	-24	
051	RCL1	36 01	
052	÷	-24	
053	STO6	35 06	Store s_1^2/n_1
054	RTN	24	
055	*LBLC	21 13	Store D
056	STO7	35 07	
057	RTN	24	
058	*LBLD	21 14	
059	RCL5	36 05	Compute d
060	RCL2	36 02	
061	-	-45	
062	RCL7	36 07	
063	-	-45	
064	RCL3	36 03	
065	RCL1	36 01	
066	1	01	
067	-	-45	
068	÷	-24	
069	RCL1	36 01	
070	÷	-24	
071	STO8	35 08	Store s_2^2/n_2
072	RCL6	36 06	
073	+	-55	
074	√X	54	
075	÷	-24	
076	RTN	24	
077	*LBLE	21 15	
078	RCL6	36 06	Compute θ
079	RCL8	36 08	
080	÷	-24	
081	√X	54	
082	TAN⁻¹	16 43	
083	RTN	24	
084	*LBLb	21 16 12	
085	RCL1	36 01	
086	CHS	-22	Delete erroneous data
087	STO1	35 01	
088	R↓	-31	
089	GTOA	22 11	
090			
100			
110			

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	n	running mean	sum of squares	Used	$\bar{x}$	s_1^2/n_1	D	s_2^2/n_2	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title KRUSKAL-WALLIS STATISTIC

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Suppose we want to test the null hypothesis that k independent random samples of sizes $n_1, n_2, \ldots, n_k$ come from identical continuous populations.

Arrange all values from k samples jointly (as if they were one sample) in an increasing order of magnitude. Let R_{ij} ($i = 1, 2, \ldots, k, j = 1, 2, \ldots, n_i$) be the rank of the j^{th} value in the i^{th} sample.

The Kruskal-Wallis statistic H can be used to test the null hypothesis.

When all sample sizes are large (> 5), H is distributed approximately as the chi-square with k − 1 degrees of freedom. For small samples, the test is based on special tables.

Equation:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{\left(\sum_{j=1}^{n_i} R_{ij}\right)^2}{n_i} - 3(N+1)$$

where

$$N = \sum_{i=1}^{k} n_i$$

Operating Limits and Warnings

Program Description I

Program Title KRUSKAL-WALLIS STATISTIC

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Table for small samples (k = 3):

Alexander and Quade, *On the Kruskal-Wallis Three Sample H-statistic,* University of North Carolina, Department of Biostatistics, Inst. Statistics Mimeo Ser. 602, 1968.

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Example:

i \ j	1	2	3	4	5	6	7	8	9	10
	Ranks R_{ij}									
1	29	5	26	10	33	30				
2	11	12	9	7	20	18	19	21		
3	14	28	8	25	17	15	32	4	2	
4	6	27	3	16	24	13	1	31	22	23

Keystrokes:

A 29 B 5 B ... 30 B → 6.00
C → 1.00
11 B 12 B ... 21 B C → 2.00
14 B 28 B ... 2 B C → 3.00
6 B 27 B ... 23 B C → 4.00
D → 2.29 (H)
E → 3.00 (df)

Solution(s)

Reference(s)

1. W.J. Conover, Practical Nonparametric Statistics, John Wiley and Sons, 1971.
2. This program is a translation of the HP-65 Stat Pac 2 program.

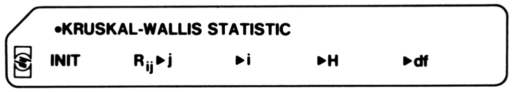
User Instructions

Kruskal-Wallis Statistic

INT	R_{ih}▸h-1 R_{ij}▸j	▸i	▸H	▸df

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Enter program				
2.	Initialize		A		0.00
3.	Perform 3-6 for i-1,2,...,k				
4.	Perform 4 for j-1,2,...n_i	R_{ij}	B		j
5.	Optional-delete erroneous R_{ih}	R_{jh}	f	B	
6.	End of the ith sample		C		i
7.	Compute H statistic		D		H
8.	Compute df		E		df
9.	Optional-recall N		RCL	5	N
10.	For a new case, go to 2				

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		A	0.00
3	Perform 3-6 for i = 1, 2,..., k			
4	Perform 4 for j = 1, 2,..., n_i	R_{ij}	B	j
5	Optional—delete erroneous R_{ih}	R_{ih}	GTO 1	
			R/S	
6	End of the ith sample		C	i
7	Compute H statistic		D	H
8	Compute df		E	df
9	Optional—recall N		RCL 5	N
10	For a new case, go to 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	CLRG	16-53	Initialize
003	0	00	
004	RTN	24	
005	*LBLB	21 12	Accumulate sums
006	ST+2	35-55 02	
007	RCL1	36 01	
008	1	01	
009	+	-55	
010	STO1	35 01	
011	RTN	24	
012	*LBLC	21 13	Prepare for a new
013	RCL1	36 01	sample
014	ST+5	35-55 05	
015	RCL2	36 02	
016	X^2	53	$(\Sigma R_{ij})^2$
017	X⇄Y	-41	
018	÷	-24	
019	ST+3	35-55 03	
020	RCL4	36 04	
021	1	01	
022	+	-55	
023	STO4	35 04	Reinitialize regist-
024	0	00	ers R_1,R_2
025	STO1	35 01	Display sample
026	STO2	35 02	number
027	RCL4	36 04	
028	RTN	24	
029	*LBLD	21 14	Compute H
030	RCL3	36 03	
031	4	04	
032	×	-35	
033	RCL5	36 05	
034	÷	-24	
035	RCL5	36 05	
036	1	01	
037	+	-55	
038	÷	-24	
039	LSTX	16-63	N + 1
040	-	-45	
041	3	03	
042	×	-35	
043	RTN	24	
044	*LBLE	21 15	Compute df
045	RCL4	36 04	
046	1	01	
047	-	-45	
048	RTN	24	
049	*LBLb	21 16 12	Delete erroneous
050	ST-2	35-45 02	data
051	RCL1	36 01	
052	1	01	
053	-	-45	
054	STO1	35 01	
055	RTN	24	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	n_i	ΣR_{ij}	$\Sigma[(\Sigma R_{ij})^2/n_i]$	k	N				

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title **MEAN-SQUARE SUCCESSIVE DIFFERENCE**

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

When test and estimation techniques are used, the method of drawing the sample from the population is specified to be random in most cases. If observations are chosen in sequence $x_1, x_2, \ldots, x_n$, the mean-square successive difference η can be used to test for randomness.

If the sample size n is large (say, greater than 20) and the population is normal, then a z statistic has approximately the standard normal distribution. Long trends are associated with large positive values of z and short oscillations with large negative values.

Equations:

$$\eta = \sum_{i=2}^{n} (x_i - x_{i-1})^2 \Bigg/ \sum_{i=1}^{n} (x_i - \overline{x})^2$$

$$= \sum_{i=2}^{n} (x_i - x_{i-1})^2 \Bigg/ \left[\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i \right)^2}{n} \right]$$

$$z = \frac{1 - \eta/2}{\sqrt{\frac{n-2}{n^2-1}}}$$

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Example:

Find the mean-square successive difference for the following set of data:

{0.53, 0.52, 0.39, 0.49, 0.97, 0.29, 0.65, 0.30, 0.40, 0.06, 0.14, 0.16, 0.68, 0.22, 0.68, 0.08, 0.52, 0.50, 0.63, 0.20, 0.67, 0.44, 0.64, 0.40, 0.97, 0.03, 0.73, 0.24, 0.57, 0.35}

Keystrokes:

A .53 B ⟶ 1.00

.52 C .39 C ... .35 C ⟶ 30.00

D ⟶ 2.81 (η)

E ⟶ −2.29 (z)

Solution(s)

Reference(s)

1. This program is a translation of the HP-65 Stat Pac 2 program.
2. Dixon and Massey, Introduction to Statistical Analysis, McGraw-Hill, 1969.

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		A	0.00
3	Input x_1	x_1	B	1.00
4	Perform 4 for i = 2, 3,..., n	x_i	C	i
5	Compute η		D	η
6	Compute z		E	z
7	For a new case, go to 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	CLRG	16-53	Initialize
003	0	00	
004	RTN	24	
005	*LBLB	21 12	
006	STO5	35 05	Store x_1 and
007	ST+2	35-55 02	accumulate sums
008	ENT↑	-21	
009	x	-35	x_1^2
010	ST+3	35-55 03	
011	RCL1	36 01	
012	1	01	
013	+	-55	
014	STO1	35 01	
015	RTN	24	
016	*LBLC	21 13	
017	RCL5	36 05	Store x_i
018	X⇄Y	-41	
019	STO5	35 05	
020	-	-45	$x_i - x_{i-1}$
021	ENT↑	-21	
022	x	-35	
023	ST+4	35-55 04	
024	RCL5	36 05	
025	GTOB	22 12	
026	*LBLD	21 14	
027	RCL4	36 04	Compute η
028	RCL3	36 03	
029	RCL2	36 02	
030	ENT↑	-21	
031	x	-35	$(\Sigma x_i)^2$
032	RCL1	36 01	
033	÷	-24	
034	-	-45	
035	÷	-24	
036	STO5	35 05	η
037	RTN	24	
038	*LBLE	21 15	Compute z
039	1	01	
040	RCL5	36 05	
041	2	02	
042	÷	-24	
043	-	-45	
044	RCL1	36 01	
045	2	02	
046	-	-45	
047	RCL1	36 01	
048	ENT↑	-21	
049	x	-35	
050	1	01	
051	-	-45	
052	÷	-24	
053	√X	54	
054	÷	-24	z
055	RTN	24	

STEP	KEY ENTRY	KEY CODE	COMMENTS
060			
070			
080			
090			
110			

LABELS

A INT	B x_1	C x_i	D η	E z
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS	SET STATUS		
0	FLAGS (ON / OFF)	TRIG	DISP
1	0 ☐ ☑	DEG ☑	FIX ☑
2	1 ☐ ☑	GRAD ☐	SCI ☐
3	2 ☐ ☑	RAD ☐	ENG ☐
	3 ☐ ☑		n 2

REGISTERS

0	1	2	3	4	5	6	7	8	9
	n	Σx_i	Σx_i^2	$\Sigma(x_i - x_{i-1})^2$	x_i, η				
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title THE RUN TEST FOR RANDOMNESS

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Consider a sequence of symbols such that the symbols are of two types only. A run is a continuous string of identical symbols preceded and followed by a different symbol or no symbol at all. For example, the sequence 1110100011 has five runs.

Let the total number of runs in a given sequence be u, and let n_1 and n_2 represent the number of symbols of type 1 and type 2 respectively. If the sample sizes are large (say, n_1 and n_2 are both greater than 10), then the randomness of the sequence may be tested using a z statistic which has the standard normal distribution.

Equations:

The sample distribution of the run has the mean μ and the standard deviation σ.

$$\mu = \frac{2 n_1 n_2}{n_1 + n_2} + 1$$

$$\sigma = \sqrt{\frac{2 n_1 n_2 (2 n_1 n_2 - n_1 - n_2)}{(n_1 + n_2)^2 (n_1 + n_2 - 1)}}$$

The test is based on the statistic

$$z = \frac{u - \mu}{\sigma}$$

Operating Limits and Warnings

Program Description I

Program Title THE RUN TEST FOR RANDOMNESS

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Remarks:

1. For small samples, the test is based on special tables.
2. This program can also be used for other tests involving runs. For example, one might want to test runs of scores above and below the median based on the order in which the scores were obtained. In this case, a sequence could be constructed in which each score would be replaced by a 1 if it was above the median or a 0, if below the median.

   The run test for randomness can then be applied to the sequence of 0's and 1's.

   Another use might be for Wald-Wolfowitz run test, which tests the null hypothesis that two random samples have been drawn from identical populations. The data from both groups are combined into one sequence according to magnitude. Each value may be assigned a 0 or 1 depending on which population it came from, and the run test for randomness then performed on the resulting sequence.

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Example:

A statistician sits by the roulette table one night in a Las Vegas casino, suspiciously watching the house rake in stake upon stake. To test the null hypothesis that the sequence of numbers is random, the statistician observes the following sequence of red (R) and black (B) numbers (ignoring 0 and 00):

RRRR B RRR BBBBB RR BBB RR BB RRR

In the sequence are 14 R's, 11B's, and a total of 9 runs. Find the mean and standard deviation of the sampling distribution and the z statistic.

Keystrokes:

14 [↑] 11 [A] 9 [B] [C] ⟶ 13.32 (μ)

[D] ⟶ 2.41 (σ)

[E] ⟶ –1.79 (z)

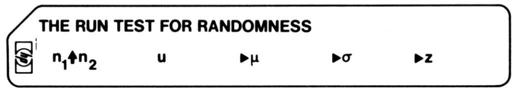
(His suspicion is not entirely unjustified.)

Solution(s)

Reference(s)

1. Freund and Williams, <u>Dictionary/Outline of Basic Statistics</u>, McGraw-Hill, 1966.
2. This program is a translation of the HP-65 Stat Pac 2 program.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Input			
	number of symbols of type 1	n_1	↑	
	number of symbols of type 2	n_2	A	n_1
3	Input number of runs	u	B	u
4	Compute the mean		C	μ
5	Compute the standard de-			
	viation		D	σ
6	Compute the z statistic		E	z
7	For a new case, go to 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO2	35 02	
003	R↓	-31	Store n_2
004	STO1	35 01	Store n_1
005	RTN	24	
006	*LBLB	21 12	
007	STO3	35 03	Store u
008	RTN	24	
009	*LBLC	21 13	
010	RCL1	36 01	Compute the mean
011	RCL2	36 02	
012	×	-35	
013	2	02	
014	×	-35	
015	STO7	35 07	
016	RCL1	36 01	
017	RCL2	36 02	
018	+	-55	
019	STO8	35 08	
020	÷	-24	
021	1	01	
022	+	-55	
023	STO4	35 04	
024	RTN	24	
025	*LBLD	21 14	
026	RCL7	36 07	Compute the
027	RCL8	36 08	standard deviation
028	-	-45	
029	RCL7	36 07	
030	×	-35	$(n_1+n_2)^2$
031	RCL8	36 08	
032	ENT↑	-21	
033	×	-35	
034	RCL8	36 08	
035	1	01	n_1+n_2-1
036	-	-45	
037	×	-35	
038	÷	-24	
039	√X	54	
040	STO5	35 05	
041	RTN	24	
042	*LBLE	21 15	
043	RCL3	36 03	Compute the z
044	RCL4	36 04	statistic
045	-	-45	
046	RCL5	36 05	
047	÷	-24	
048	STO6	35 06	
049	RTN	24	

060
070
080
090
100

LABELS

A	B	C	D	E
n_1 n_2	u	μ	σ	z
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	n_1	n_2	u	μ	σ	z	$\Sigma n_1 n_2$	n_1+n_2	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title **INTRACLASS CORRELATION COEFFICIENT**

Contributor's Name Hewlett-Packard
Address 1000 N.E. Circle Blvd.
City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

The intraclass correlation coefficient r_I measures the degree of association among individuals within classes or groups.

		Observations			
	1	x_{11}	x_{12}	...	x_{1n}
	2	x_{21}	x_{22}	...	x_{2n}
Groups	.	.	.		.
	.	.	.		.
	.	.	.		.
	k	x_{k1}	x_{k2}	...	x_{kn}

The coefficient is most easily calculated using the analysis of variance techniques. r_I is the sample estimate of the population intraclass correlation coefficient ρ_I. If we can assume that the individuals within groups are random samples from normal populations with the same variance, then the hypothesis $\rho_I = 0$ can be tested using the F statistic.

Equations:

1. Sums

   Group $$T_i = \sum_{j=1}^{n} x_{ij} \qquad i = 1, 2, ..., k$$

   Total $$T = \sum_{i=1}^{k} T_i$$

2. Sums of squares

   Mean

$$MSS = T^2/k\,n$$

Operating Li

Program Description I

Program Title INTRACLASS CORRELATION COEFFICIENT

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Among groups

$$ASS = \sum_{i=1}^{k} T_i^2/n - MSS$$

Within groups

$$WSS = \sum_{i=1}^{k} \sum_{j=1}^{n} x_{ij}^2 - MSS - ASS$$

3. Intraclass correlation coefficient

$$r_I = \left(\frac{ASS}{k-1} - \frac{WSS}{k(n-1)}\right) \Big/ \left(\frac{ASS}{k-1} + \frac{WSS}{k}\right)$$

4. F statistic

$$F = \frac{ASS}{k-1} \Big/ \frac{WSS}{k(n-1)}$$

with $df_1 = k - 1$ and $df_2 = k(n-1)$ degrees of freedom.

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Example:

		Observations	
Groups	1	71	71
	2	69	72
	3	59	65
	4	65	64
	5	66	60
	6	73	72
	7	68	67
	8	70	68

Solution

Keystrokes:

f REG 71 A 71 A B ——→ 142.00 (T_1)

69 A 72 A B ——→ 141.00 (T_2)

.
.
.

70 A 68 A B ——→ 138.00 (T_8)

C ——→ 0.70 (r_I)

D ——→ 5.61 (F)

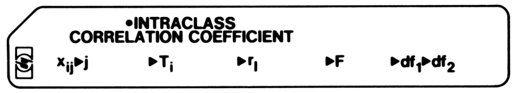
E ——→ 7.00 (df_1)

E ——→ 8.00 (df_2)

Reference(s) 1. This program is a translation of the HP-65 Stat Pac 2 program.

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

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		f REG	
3	Perform 3-5 for i = 1, 2,..., k			
4	Perform 4 for j = 1, 2,..., n	x_{ij}	A	j
5	Compute the group mean		B	T_i
6	Compute the coefficient		C	r_I
7	Compute the F statistic		D	F
8	Compute the degrees of freedom		E	df_1
			E	df_2
9	For a new case, go to 2			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	ST+6	35-55 06	x_{ij}
003	X^2	53	
004	ST+5	35-55 05	
005	1	01	
006	RCL1	36 01	Increase counter
007	+	-55	
008	ST01	35 01	
009	RTN	24	
010	*LBLB	21 12	Compute group sum
011	RCL6	36 06	
012	ST08	35 08	
013	ST+3	35-55 03	
014	X^2	53	
015	ST+4	35-55 04	
016	RCL1	36 01	
017	ST07	35 07	
018	0	00	
019	ST01	35 01	Reinitialize
020	ST06	35 06	
021	1	01	
022	RCL2	36 02	
023	+	-55	
024	ST02	35 02	
025	RCL8	36 08	Display sum
026	RTN	24	
027	*LBLC	21 13	
028	RCL4	36 04	Compute coefficient
029	RCL3	36 03	
030	X^2	53	
031	RCL2	36 02	
032	÷	-24	
033	-	-45	
034	RCL7	36 07	ASS/k-1
035	ST01	35 01	
036	÷	-24	
037	RCL2	36 02	
038	1	01	
039	-	-45	
040	÷	-24	
041	ST07	35 07	
042	RCL5	36 05	
043	RCL4	36 04	
044	RCL1	36 01	
045	÷	-24	
046	-	-45	
047	RCL2	36 02	
048	÷	-24	
049	ST08	35 08	
050	RCL1	36 01	
051	1	01	
052	-	-45	
053	ST01	35 01	
054	÷	-24	
055	-	-45	
056	RCL7	36 07	
057	RCL8	36 08	
058	+	-55	Display r_1
059	÷	-24	
060	RTN	24	
061	*LBLD	21 14	
062	RCL7	36 07	Compute F
063	RCL8	36 08	
064	RCL1	36 01	
065	÷	-24	
066	÷	-24	
067	RTN	24	
068	*LBLE	21 15	Compute degrees of freedom
069	RCL2	36 02	
070	1	01	
071	-	-45	
072	R/S	51	
073	*LBLE	21 15	
074	RCL1	36 01	
075	RCL2	36 02	
076	×	-35	
077	RTN	24	
080			
090			
100			

FLAGS	
0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☑
1	☐	☑
2	☐	☑
3	☐	☑

TRIG	
DEG	☑
GRAD	☐
RAD	☐

DISP	
FIX	☑
SCI	☐
ENG	☐
n	2

LABELS

A	B	C	D	E
$\Sigma +$	T_i	Y_1	F	df_1, df_2
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

REGISTERS

0	1	2	3	4	5	6	7	8	9
	n-1	k	ΣT_i	ΣT_i^2	Σx_{ij}^2	T_i	ASS/k-1	T_i WSS/k	0
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title FISHER'S EXACT TEST FOR A 2 x 2 CONTINGENCY TABLE

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

Fisher's exact probability test is used for analyzing a 2 x 2 contingency table when the two independent samples are small in size.

a	b
c	d

Suppose a, b, c, d are the frequencies and **a is the smallest frequency,** this program computes the following:

1. The exact probability p_0 of observing the given frequencies in a 2 x 2 table, when the marginal totals are regarded as fixed.
2. The exact probability p_i ($i = 1, 2, ..., a$) of each more extreme table having the same marginal totals.
3. The sum S_i of the probabilities of the first i + 1 tables.
4. The sum S of the probabilities of all tables with the same margins (i.e., $S = S_a$).

Equations:

1.

$$p_0 = \frac{(a+b)!\,(c+d)!\,(a+c)!\,(b+d)!}{N!\,a!\,b!\,c!\,d!}$$

where

$$N = a + b + c + d.$$

Operating Limits and Warnings

Program Description I

Program Title FISHER'S EXACT TEST FOR A 2 x 2 CONTINGENCY TABLE

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables

2. For the more extreme table (with the same margins)

a – i	b + i
c + i	d – i

$$p_i = \frac{(a+b)!\,(c+d)!\,(a+c)!\,(b+d)!}{N!\,(a-i)!\,(b+i)!\,(c+i)!\,(d-i)!}$$

where

i can be 1, 2, ... or a.

3.

$$S_n = \sum_{i=0}^{n} p_i$$

where

n can be 1, 2, ..., a.

4.

$$S = \sum_{i=0}^{a} p_i$$

Operating Limits and Warnings

Remarks:

1. a must be the smallest among the frequencies. Rearrange the table if necessary.
2. This program requires N ⩽ 69. However, Fisher's exact test is normally used for N ⩽ 30.

Program Description II

Sketch(es)

Sample Problem(s)

Example:

Compute p_0, p_1, p_2, S_4 and S for the following table

7	10
8	5

Note:

The table must be rearranged as

5	8
10	7

Keystrokes:

5 [↑] 8 [↑] 10 [↑] 7 [A] ——→ 0.16 (p_0)

[B] ——→ 0.06 (p_1)

[B] ——→ 0.01 (p_2)

[B] [B] [C] ——→ 0.23 (S_4)

[D] ——→ 0.23 (S)

Sol

Reference(s)

1. S. Siegel, *Nonparametric Statistics*, McGraw-Hill, 1956.
2. Sir R. A. Fisher, *Statistical Methods for Research Workers*, Oliver and Boyd, 1950.

This program is a translation of the HP-65 Stat Pac 2 program.

User Instructions

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Enter frequencies and compute			
	p_0	a	↑	
		b	↑	
		c	↑	
		d	A	p_0
3*	Optional—perform 3 or 3-4 for			
	i = 1, 2,..., a		B	p_i
4	Optional—recall current S_i		C	S_i
5	Compute the sum of all			
	probabilities		D	S
6	For a new case, go to 2			
	* It is not necessary to com-			
	plete the loop of 3 and 4. Go to			
	5 for S when desired.			

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO4	35 04	
003	R↓	-31	Stored, c,b,a
004	STO3	35 03	
005	R↓	-31	
006	STO2	35 02	
007	X⇄Y	-41	
008	STO1	35 01	
009	STO8	35 08	
010	+	-55	
011	STO5	35 05	
012	R↓	-31	
013	+	-55	
014	STO6	35 06	
015	N!	16 52	(c+d)!
016	RCL5	36 05	
017	N!	16 52	(a+b)!
018	×	-35	
019	RCL5	36 05	
020	RCL6	36 06	
021	+	-55	
022	N!	16 52	
023	÷	-24	
024	RCL1	36 01	
025	RCL3	36 03	
026	+	-55	(a+c)!
027	N!	16 52	
028	×	-35	
029	RCL2	36 02	
030	RCL4	36 04	
031	+	-55	
032	N!	16 52	(b+d)!
033	×	-35	
034	STO7	35 07	
035	0	00	
036	STO5	35 05	
037	R↓	-31	
038	*LBL0	21 00	
039	RCL1	36 01	Loop for computing
040	N!	16 52	probability
041	÷	-24	
042	RCL2	36 02	
043	N!	16 52	
044	÷	-24	
045	RCL3	36 03	
046	N!	16 52	
047	÷	-24	
048	RCL4	36 04	
049	N!	16 52	
050	÷	-24	
051	ST+5	35-55 05	Accumulate the sum
052	RTN	24	Display ρ_0
053	*LBLB	21 12	Compute ρ_i for
054	1	01	more extreme
055	ST-1	35-45 01	tables
056	ST+2	35-55 02	

STEP	KEY ENTRY	KEY CODE	COMMENTS
057	ST+3	35-55 03	
058	ST-4	35-45 04	
059	ST-8	35-45 08	
060	RCL7	36 07	
061	GTO0	22 00	
062	*LBLC	21 13	Recall the sum S_n
063	RCL5	36 05	
064	R/S	51	
065	*LBLD	21 14	Compute the sum S
066	RCL8	36 08	
067	0	00	
068	X=Y?	16-33	
069	GSB1	23 01	
070	GSBB	23 12	
071	GTOD	22 14	
072	*LBL1	21 01	
073	RCL5	36 05	
074	R/S	51	
075	RTN	24	

FLAGS	
0	
1	
2	
3	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
					a+b Used	c+d	Used	Used	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title BARTLETT'S CHI-SQUARE STATISTIC

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables, etc.

$$\chi^2 = \frac{f \ln s^2 - \sum_{i=1}^{k} f_i \ln s_i^2}{1 + \frac{1}{3(k-1)}\left[\left(\sum_{i=1}^{k} \frac{1}{f_i}\right) - \frac{1}{f}\right]}$$

where s_i^2 = sample variance of the i^{th} sample

f_i = degrees of freedom associated s_i^2

i = 1, 2, ..., k

k = number of samples

$$s^2 = \frac{\sum_{i=1}^{k} f_i s_i^2}{f}$$

$$f = \sum_{i=1}^{k} f_i$$

This χ^2 has a chi-square distribution (approximately) with $k - 1$ degrees of freedom which can be used to test the null hypothesis that $s_1^2, s_2^2, ..., s_k^2$ are all estimates of the same population variance σ^2; i.e. H_0: Each of $s_1^2, s_2^2, ..., s_k^2$ is an estimate of σ^2.

Note: Erroneous data can be corrected by using the [D] key.

Operating Limits and Warnings

Program Description II

Sketch(es)

Sample Problem(s)

Apply the program to the following data:

i	1	2	3	4	5	6
s_i^2	5.5	5.1	5.2	4.7	4.8	4.3
f_i	10	20	17	18	8	15

Solution(s)

Keystrokes:

```
[A]
5.5[ENT↑] 10[B], 5.1[ENT↑] 20[B], . . . .
4.3[ENT↑] 15[B] ---------------------------------> 6.00
[C] -------------------------------------------> 0.25 (χ²)
[R/S] -----------------------------------------> 5.00 (df)
```

Reference(s)

1. Statistical Theory with Engineering Applications, A. Hald, John Wiley and Sons, 1960.
2. This program is a translation of the HP-65 Stat Pac 1 program.

User Instructions

Bartlett's Chi-Square Statistic

1					2
INT	Σ+	χ^2	Σ-		

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2	Initialize		A	
3	Perform 3 for i = 1, 2, ..., k	s_i^2	↑	
		f_i	B	i
	(Correct erroneous data s_m^2, f_m)	s_m^2	↑	
		f_m	D	
4			C	χ^2
5			R/S	df

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	CLRG	16-53	Initialize
003	0	00	Clear storage registers
004	RTN	24	
005	*LBLB	21 12	
006	STO1	35 01	Accumulate sums
007	ST+3	35-55 03	
008	1/X	52	
009	ST+4	35-55 04	
010	R↓	-31	
011	ENT↑	-21	
012	ENT↑	-21	
013	RCL1	36 01	
014	×	-35	
015	ST+8	35-55 08	
016	X⇄Y	-41	
017	LN	32	
018	RCL1	36 01	
019	×	-35	
020	ST+7	35-55 07	
021	RCL5	36 05	
022	1	01	
023	+	-55	
024	STO5	35 05	
025	RTN	24	
026	*LBLC	21 13	Compute chi-square
027	RCL8	36 08	
028	RCL3	36 03	
029	÷	-24	
030	LN	32	
031	RCL3	36 03	
032	×	-35	
033	RCL7	36 07	
034	-	-45	
035	RCL4	36 04	
036	RCL3	36 03	
037	1/X	52	
038	-	-45	
039	RCL5	36 05	
040	1	01	
041	-	-45	
042	STO2	35 02	
043	3	03	
044	×	-35	
045	÷	-24	
046	1	01	
047	+	-55	
048	÷	-24	
049	R/S	51	Display chi-square
050	RCL2	36 02	
051	RTN	24	
052	*LBLD	21 14	
053	STO1	35 01	Error corrector
054	ST-3	35-45 03	
055	1/X	52	
056	ST-4	35-45 04	
057	R↓	-31	
058	ENT↑	-21	
059	ENT↑	-21	
060	RCL1	36 01	
061	×	-35	
062	ST-8	35-45 08	
063	X⇄Y	-41	
064	LN	32	
065	RCL1	36 01	
066	×	-35	
067	ST-7	35-45 07	
068	RCL5	36 05	
069	1	01	
070	-	-45	
071	STO5	35 05	
072	RTN	24	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	f_i	df	Σf_i	$\Sigma 1/f_i$	k	0	$\Sigma f_i \ln s_i^2$		0
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title MANN-WHITNEY STATISTIC

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvalli **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables, etc.

This program computes the Mann-Whitney test statistic on two independent samples of equal or unequal sizes. This test is designed for testing the null hypothesis of no difference between two populations.

Mann-Whitney test statistic is defined as

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - \sum_{i=1}^{n_1} R_i$$

where n_1 and n_2 are the sizes of the two samples. Arrange all values from both samples jointly (as if they were one sample) in an increasing order of magnitude, let R_i ($i = 1, 2, \ldots, n_1$) be the ranks assigned to the values of the first sample (it is immaterial which sample is referred to as the "first").

When n_1 and n_2 are small, the Mann-Whitney test bases on the exact distribution of U and specially constructed tables. When n_1 and n_2 are both large (say, greater than 8) then

$$z = \frac{U - \frac{n_1 n_2}{2}}{\sqrt{n_1 n_2 (n_1 + n_2 + 1)/12}}$$

is approximately a random variable having the standard normal distribution.

Operating Limits and Warnings

For small samples (say, less than or equal to 8) the specially constructed tables should be used. For example:

Handbook of Statistical Tables, D. B. Owen, Addison-Wesley, 1962

Program Description II

Sketch(es)

Sample Problem(s)

Find U and Z for the following data:

Sample 1	14.9	11.3	13.2	16.6	17	14.1	15.4	13	16.9
Rank R_i	7	1	4	12	14	5	10	3	13

Sample 2	15.2	19.8	14.7	18.3	16.2	21.1	18.9	12.2	15.3	19.4
Rank	8	18	6	15	11	19	16	2	9	17

Note: 1. $n_1 = 9, n_2 = 10$

2. The ranks have already been assigned in the example.

Solution(s)

```
Keystrokes:
10[A] 7[B] 1[B] 4[B] ---------
3[B] 13[B] ---------------------------------------->  9.00
[C] -----------------------------------------------> 66.00 (U)
[D] ----------------------------------------------->  1.71 (Z)
```

Reference(s)

1. Mathematical Statistics, J.E. Freund, Prentic Hall, 1962.
2. This progam is a translation of the HP-65 Stat Pac 1 program.

User Instructions

Mann-Whitney Statistic

1 ◀ ▶ 2

n_2 | Σ + | U | z | Σ -

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Enter program			
2		n_2	A	
3	Perform 3 for $i = 1, 2, \ldots, n_1$	R_i	B	i
	(Correct erroneous data R_k)	R_k	E	
4	Compute U		C	U
5	Compute z		D	z

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	STO2	35 02	
003	0	00	$n_2 \rightarrow R_2$
004	STO1	35 01	Store 0 in R_1,R_3
005	STO3	35 03	
006	RTN	24	
007	*LBLB	21 12	
008	ST+3	35-55 03	Accumulate sums
009	RCL1	36 01	
010	1	01	
011	+	-55	
012	STO1	35 01	
013	RTN	24	
014	*LBLC	21 13	Compute U
015	RCL2	36 02	
016	RCL1	36 01	
017	1	01	
018	+	-55	
019	2	02	
020	÷	-24	
021	+	-55	
022	x	-35	
023	RCL3	36 03	Display U
024	-	-45	
025	RTN	24	
026	*LBLD	21 14	Compute z
027	RCL1	36 01	
028	RCL2	36 02	
029	x	-35	
030	2	02	
031	÷	-24	
032	-	-45	
033	RCL1	36 01	
034	RCL2	36 02	
035	+	-55	
036	1	01	
037	+	-55	
038	RCL1	36 01	
039	x	-35	
040	RCL2	36 02	
041	x	-35	
042	1	01	
043	2	02	
044	÷	-24	
045	√X	54	
046	÷	-24	Display z
047	RTN	24	
048	*LBLE	21 15	Error corrector
049	ST-3	35-45 03	
050	RCL1	36 01	
051	1	01	
052	-	-45	
053	STO1	35 01	
054	RTN	24	

STEP	KEY ENTRY	KEY CODE	COMMENTS
060			
070			
080			
090			
100			
110			

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	n_1	n_2	ΣR_1						

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Description I

Program Title KENDALL'S COEFFICIENT OF CONCORDANCE

Contributor's Name Hewlett-Packard

Address 1000 N.E. Circle Blvd.

City Corvallis **State** Oregon **Zip Code** 97330

Program Description, Equations, Variables, etc.

Suppose n individuals are ranked from 1 to n according to some specified characteristic by k observers, the coefficient of concordance W measures the agreement between observers (or concordance between rankings).

$$W = \frac{12 \sum_{i=1}^{n} \left(\sum_{j=1}^{k} R_{ij} \right)^2}{k^2\ n(n^2 - 1)} - \frac{3(n + 1)}{n - 1}$$

Where R_{ij} is the rank assigned to the i^{th} individual by the j^{th} observer.

W varies from 0 (no community of preference) to 1 (perfect agreement). The null hypothesis that the observers have no community of preference may be tested using special tables, or if $n > 7$, by computing

$$\chi^2 = k\ (n - 1)\ W$$

which has approximately the chi-square distribution with n − 1 degrees of freedom (df).

Operating Limits and Warnings

For small samples (say, less than or equal to 7) the specially constructed tables should be used. For example:

Rank Correlation Methods, M.G. Kendall, Hafner Publishing Co., 1962

Program Description II

Sketch(es)

Sample Problem(s)

1. Find W, χ^2, and df for the following data:

Table for R_{ij} (n = 10, k = 3)

i \ j	1	2	3
1	6	7	3
2	1	4	2
3	9	3	5
4	2	6	1
5	10	8	9
6	3	2	6
7	5	9	8
8	4	1	4
9	8	10	10
10	7	5	7

Solution(s) Keystrokes:

```
[f] [CL REG]
6[A]  7[A] 3[A] [B],
1[A]  4[A] 2[A] [B]
. . . .
7[A]  5[A] 7[A] [B]
[C] -----------------------------------------------------> 0.69 (W)
[D] -----------------------------------------------------> 18.64 (χ²)
[R/S] ---------------------------------------------------> 9.00 (df)
```

Reference(s)

1. Nonparametric Statistical Inference, J.D. Gibbons, McGraw-Hill, 1971.
2. This program is a translation of the HP-65 Stat Pac 1 program.

User Instructions

Kendall's Coefficient of Concordance

$\Sigma+$ | $\Sigma\Sigma+$ | W | χ^2 ,df | $\Sigma-$

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Initialize		f	CL REG	
3	Perform 3-5 for i = 1, 2, ..., n				
4	Perform 4 for j = 1, 2, ..., k	R_{ij}	A		j
	(Correct erroneous data R_{im})	R_{im}	E		
5			B		i
6	Compute W		C		W
7	Compute χ^2 and df		D		χ^2
8			R/S		df
	(For a new case, go to 2.)				

97 Program Listing I

STEP	KEY ENTRY	KEY CODE	COMMENTS
001	*LBLA	21 11	
002	ST+2	35-55 02	Accumulate sums (i is fixed)
003	RCL1	36 01	
004	1	01	
005	+	-55	
006	STO1	35 01	Display current j
007	RTN	24	
008	*LBLB	21 12	Accumulate sum over i
009	RCL1	36 01	
010	STO5	35 05	
011	RCL2	36 02	
012	X²	53	
013	ST+3	35-55 03	
014	RCL4	36 04	
015	1	01	
016	+	-55	
017	STO4	35 04	
018	0	00	Reinitialize R_1,R_2
019	STO1	35 01	
020	STO2	35 02	
021	RCL4	36 04	Display current i
022	RTN	24	
023	*LBLC	21 13	Compute W
024	RCL3	36 03	
025	1	01	
026	2	02	
027	×	-35	
028	RCL5	36 05	
029	X²	53	
030	÷	-24	
031	RCL4	36 04	
032	÷	-24	
033	RCL4	36 04	
034	X²	53	
035	1	01	
036	-	-45	
037	÷	-24	
038	RCL4	36 04	
039	1	01	
040	+	-55	
041	3	03	
042	×	-35	
043	RCL4	36 04	
044	1	01	
045	-	-45	
046	÷	-24	
047	-	-45	Display answer W
048	RTN	24	
049	*LBLD	21 14	Compute χ^2 and df k
050	RCL5	36 05	
051	×	-35	
052	RCL4	36 04	
053	1	01	
054	-	-45	
055	×	-35	Display χ^2
056	R/S	51	
057	RCL4	36 04	
058	1	01	
059	-	-45	
060	RTN	24	
061	*LBLE	21 15	Error corrector (i is fixed)
062	ST-2	35-45 02	
063	RCL1	36 01	
064	1	01	
065	-	-45	
066	STO1	35 01	
067	RTN	24	

SET STATUS

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

REGISTERS

0	1	2	3	4	5	6	7	8	9
	j ΣR_{ij}		$\Sigma(\Sigma R_{ij})^2$	n	k				

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

NOTES

Hewlett-Packard Software

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

Application Pacs

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

You can choose from:

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Business Decisions
Clinical Lab and Nuclear Medicine
Mechanical Engineering
Surveying
Civil Engineering
Navigation
Games

Users' Library

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

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

Users' Library Solutions Books

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

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

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

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Home Management
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Industrial Engineering
Aeronautical Engineering
Control Systems
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Cardiac
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TEST STATISTICS FOR THE CORRELATION COEFFICIENT
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THE RUN TEST FOR RANDOMNESS
INTRACLASS CORRELATION COEFFICIENT
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