TEXAS INSTRUMENTS

SOFTWARE

TI-95 STATISTICS LIBRARY

GUIDEBOOK

TEXAS INSTRUMENTS

TI-95 STATISTICS LIBRARY

GUIDEBOOK

Manual developed by:

The staff of Texas Instruments
Instructional Communications and
Design Communications
TI Corporate Design Center

Jacquelyn F. Quiram
Joseph L. Willard
De Warden
Kenneth E. Heichelheim
Michael T. Keller
Chris M. Alley

With contributions by:

Robert A. Pollan
S.S. Millwright
Jerome H. Puckett
Robert E. Whitsitt, II

Important

Texas Instruments makes no warranty, either expressed or implied, including but not limited to any implied warranties of merchantability and fitness for a particular purpose, regarding these programs or book materials and makes such materials available solely on an "as-is" basis. In no event shall Texas Instruments be liable to anyone for special, collateral, incidental, or consequential damages in connection with or arising out of the purchase or use of these materials, and the sole and exclusive liability of Texas Instruments, regardless of the form of action, shall not exceed the purchase price of this cartridge. Moreover, Texas Instruments shall not be liable for any claim of any kind whatsoever against the user of these programs or book materials by any other party.

Table of Contents

This guidebook provides instructions for using the TI-95 Statistics library. Before using this guidebook, you should already be familiar with the scientific calculator functions described in the *TI-95 User's Guide*.

Contents of This Guidebook

This guidebook describes the contents and use of the TI-95 Statistics library. The guidebook is organized to help you use the programs in the library.

Organization of the Guidebook

The guidebook includes eight chapters.

Chapter 1 gives a brief description of each program in the library, the general use and care of the cartridge, how to save data for later use, and how to use an optional printer.

Chapters 2 through 8 provide detailed information about each program in the library. The discussion of each program includes:

- A brief presentation of general information about the program and the inputs required by the program.
- Step-by-step instructions for using the program.
- An example application demonstrating the use of the program.

Two appendixes are included at the end of the guidebook.

Appendix A contains a list showing the data registers used with each Statistics program. This is useful when storing or retrieving data from one of these programs. Appendix A also includes a list of all flags used in each program.

Appendix B contains service and warranty information that may be useful in case of difficulty.

Chapter 1: Getting Started

This chapter describes the handling, installation, and use of the TI-95 Statistics cartridge. It also introduces you to the programs available on the cartridge.

Table of Contents

Installing the Statistics Cartridge

You should become familiar with the proper handling and installation of the Statistics cartridge before using the programs.

Handling the Cartridge

Handle the cartridge with the same care you would give any other electronic equipment.

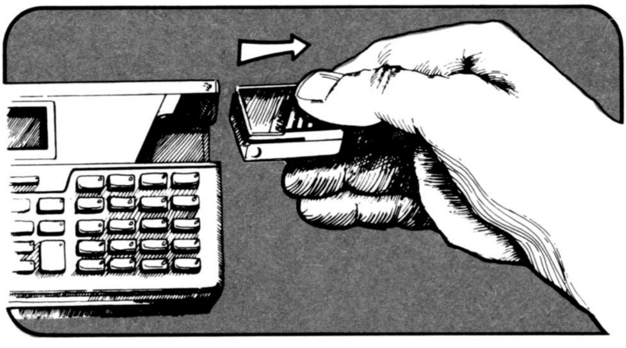
- Avoid static electricity. Before handling the cartridge, you should touch a metal object to discharge any static electricity.
- Store the cartridge in its original container or in the cartridge port on the upper right side of the TI–95.

Installing the Cartridge

The calculator is shipped with a port protector installed in the cartridge port. This protector resembles a cartridge and is installed to prevent dust from accumulating on the electrical contacts inside the port. (It is a good practice to always keep a cartridge or the port protector in the port.)

To install the Statistics cartridge:

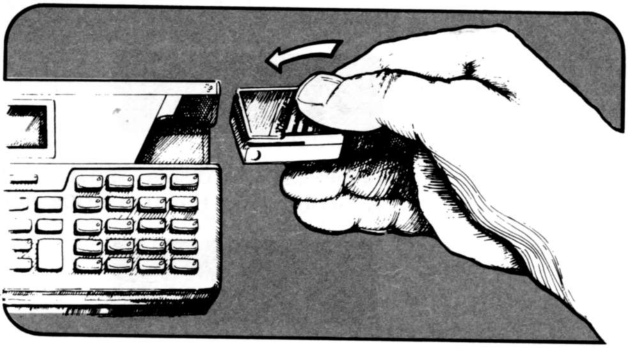
1. **Turn the calculator off.** Installing a cartridge while the TI–95 is on may result in loss of stored information.
2. If the port protector or another cartridge is already installed, remove it as shown below. Place your thumb on the ridged area at the top of the cartridge and slide it to the right.



After you remove a cartridge, be sure to store it properly.

Installing the Cartridge (Continued)

3. Turn the Statistics cartridge so that the ridges are facing upward and insert it into the port, small end first.



4. Slide the cartridge to the left until it snaps into place.

Displaying the Statistics Menu

After installing the cartridge, you can then display the STATISTICS menu. Each selection on this menu represents a different type of Statistics calculation. For each type of calculation, the cartridge contains either a single program or a "family" of related programs.

Accessing the Statistics Cartridge

To access the cartridge and display the **STATISTICS** menu:

1. Turn the calculator on and press **RUN**.

   The calculator displays:

   ```
       SELECT:
   PGM  MEM  STA        ESC
   ```

2. Select <STA> to display the first of two groups of selections from the **STATISTICS** menu.

   ```
       STATISTICS
   MNT  DST  AOV  RGR  -->
   ```

The Statistics Menu

The **STATISTICS** menu, which is described on the following pages, enables you to select the type of Statistics calculation you want to perform. Depending on the type you select, the calculator either runs a program or displays another menu.

- If there is only one program that performs that type of calculation, the calculator runs the program.
- If there are two or more programs that perform the same general type of calculation, the calculator displays a menu that lets you choose the specific program you want to run.

The Statistics Menu (Continued)

When you press **RUN** ⟨STA⟩, the calculator displays the first group of selections available from the menu.

```
   STATISTICS
MNT  DST  AOV  RGR  -->
```

⟨MNT⟩ Selects the Means and Moments program.

⟨DST⟩ Selects the **DISTRIBUTIONS** menu consisting of the following programs.

Normal Distribution (and the inverse)
Student's t-Distribution
F-Distribution
Chi-Square Distribution
Weibull Distribution (and the inverse)
Binomial Distribution
Poisson Distribution
Hypergeometric Distribution

⟨AOV⟩ Selects the Analysis of Variance (**ANOVA**) menu consisting of the following programs.

One-Way Analysis of Variance
Two-Way Analysis of Variance
Two-Way Analysis of Variance with Replication

⟨RGR⟩ Selects the **REGRESSION** menu consisting of the following programs.

Multiple Regression
Bivariate Regression

⟨-->⟩ Displays additional selections (shown on the next page).

(continued)

The Statistics Menu (Continued)

When you select ⟨-->⟩ from the first group of **STATISTICS** selections, the calculator displays the second group.

```
   STATISTICS
TST  HST  NPS  -->
```

⟨TST⟩ Selects the **HYPOTHESIS TESTS** menu consisting of the following programs:

Unpaired t-Test
Paired t-Test

⟨HST⟩ Selects the Histogram program.

⟨NPS⟩ Selects the **NONPARAMETRIC** menu consisting of the following programs.

Friedman Test
Runs Test
Kruskal-Wallis Test
R × C Contingency Table
Tolerance Limits
Kendall's Tau
Rank Function
Mann-Whitney Test

⟨-->⟩ Displays the previous selections (shown on the previous page).

Exiting from a Cartridge Program

At any point in a program, you can stop using the program and start using the calculator's built-in functions. You do not need to press any special keys to exit the program. In some instances, however, you may want to return to the same program later or run another program.

When You Finish a Program

When you finish using a program, the last menu selections used by the program usually remain in the display. You can clear these selections by pressing the key sequence [2nd] [F:CLR].

When You Want to Return to a Program

When you leave a program temporarily to perform other calculations, you can easily return to the program at the same point from which you left it.

- If the program's menu selections are still in the display, you can proceed with the program by pressing the applicable key on the menu.
- If your calculations involved a function such as [CONV], which displays its own menu, you can return to the previous program menu by pressing the [OLD] key on the calculator.

  Note: If you leave a program and then run another program that redefines the function keys, you cannot use the [OLD] key to return to the previous program.

When You Want to Run Another Program

When you want to exit a program and run another one, use one of the methods given below.

- If you want to exit a program and run another in the same "family," you can use the <ESC> key included on the program menus. Press <ESC> until the calculator displays the menu that lets you select the other program.
- If you want to run another program that is not in the same family, press [RUN] <STA> to display the **STATISTICS** menu. Then select the new program.

Using an Optional Printer with the Programs

If you run a Statistics program when a printer is connected to the calculator, the program automatically gives you a printed record of all calculations. (For information on setting up a printer, refer to "Printer Device Numbers" and "Setting the Printer Format" in Chapter 6 of the *TI-95 User's Guide*.)

Advantages of Using a Printer

A printer gives you a convenient method of reviewing the results of your calculations. The printout includes:

- The name of the program.
- The data values you entered. (This also enables you to see if you entered the values correctly.)
- Any options you selected.
- The results of the calculations, along with labels that identify each result.

With a printer, the program does not stop to display individual results. (Without a printer, you need to press a key to display each result.) Instead, the program prints a continuous list of results until the output is complete.

When to Connect a Printer

When you select a program, the calculator immediately checks to see if a printer is connected.

- If you want a printout, connect the printer and turn it on before selecting the program.
- If you do not want a printout, be sure to turn the printer off or disconnect it before selecting the program.

Precaution When Using a Printer

When you are using a printer with a cartridge program, be sure the calculator is not in the Trace mode. In the Trace mode, the calculator prints each program step as it is executed. This slows the operation of the program and uses a large amount of paper.

Using Data Stored in a File

Some of the programs in the Statistics cartridge allow you to use data that has been saved as a file. For a substantial amount of data, fewer keystrokes are required to load the data file into the appropriate registers than to enter all the individual data values.

Storage Considerations

You should save data when you intend to use the data set with the same program in the future. A data set entered for one program is not usually transferable to another program.

Each program that uses old data requires the data set to occupy specific registers. Appendix A of this guidebook contains a listing of the register assignments associated with each program.

Sequence for Saving Data

The following sequence outlines the procedure you use to save data. You must stop at the proper point to save data because proceeding with results causes the program to change the data. After the data set changes, the values you entered are no longer present.

1. Run the part of the program that enters the data set. You can edit the data but do not proceed with results.
2. Save the data as a file in file space, on cassette tape, or in a memory cartridge. Refer to the *TI–95 Programming Guide* for information on saving files.
3. Return to the point at which you left the program by pressing the [OLD] key on the calculator. You can then proceed with results.

Sequence for Using Stored Data

The following sequence outlines the procedure for using stored data.

1. Load the data into the appropriate registers before running the program. Refer to the *TI–95 Programming Guide* for information on retrieving files.
2. Run the program. Select the program's ⟨OLD⟩ option to bypass the data entry stage.
3. Edit the data or proceed with results.

Chapter 2: Means and Moments

This chapter assists you in using the Means and Moments program, which calculates the means, central moments, and skewness and kurtosis coefficients of a sample.

Table of Contents

The Means and Moments Program

Using the Means and Moments program, you can determine the means, central moments, skewness, and kurtosis for a set of sample data.

Introduction to the Program

Given a set of sample data, this program calculates:

- Arithmetic mean (mn)
- Geometric mean (Gmn)
- Harmonic mean (Hmn)
- Variance (m2—second central moment)
- m3—third central moment
- m4—fourth central moment
- Skewness coefficient (a3)
- Kurtosis coefficient (a4)

Reference

Handbook of Probability and Statistics, Richard S. Burington and Donald C. May Jr., Handbook Publishers Inc., Sandusky, Ohio, 1958, pp. 9–13.

Starting the Program

Select ⟨MNT⟩ from the **STATISTICS** menu to display the **MEANS AND MOMENTS** menu.

```
MEANS & MOMENTS
CLR  FRQ  ENT  DEL  EOD
```

⟨CLR⟩	Clears data registers.
⟨FRQ⟩	Specifies the frequency of a data value.
⟨ENT⟩	Enters a data value.
$\boxed{\text{INV}}$ ⟨ENT⟩	Deletes last data value entered.
⟨DEL⟩	Deletes a data value.
⟨EOD⟩	Indicates the end of a data set and calculates results.

Clearing the Data Registers

Before entering a new data set, press <CLR> on the **MEANS AND MOMENTS** menu. This clears the data registers associated with the Means and Moments program.

Once you have entered a data set, it remains in the data registers until you press <CLR>. Therefore, if you do not press <CLR>, you can recalculate the means and moments or modify the data.

Entering Single Data Values

To enter single data values:

1. Enter a value and press <ENT>.

2. Repeat the above step for all single data values.

Entering Several Identical Data Values

To enter two or more identical data values at one time:

1. Enter the frequency of the value and press <FRQ>.

2. Enter the value and press <ENT>.

Note: The program continues to use the last frequency entered. You must enter a 1 and press <FRQ> to return to the entry of single data values.

Deleting Incorrect Entries

There are two ways to delete an incorrect entry.

- To delete your most recent entry, press INV <ENT>.

- To delete an earlier entry, enter the frequency of occurrence, press <FRQ>, enter the value as it was previously entered, and press <DEL>.

Calculating Results

1. Press ⟨EOD⟩ to calculate the Means and Moments results.

2. Select the appropriate key from the following menu.

```
n=
mn    m2    m3    m4    -->
```

⟨mn⟩	Arithmetic mean
⟨m2⟩	Variance
⟨m3⟩	Third moment
⟨m4⟩	Fourth moment
⟨-->⟩	Displays the additional selections shown below

```
n=
a3    a4    Gmn   Hmn   -->
```

⟨a3⟩	Skewness coefficient
⟨a4⟩	Kurtosis coefficient
⟨Gmn⟩	Geometric mean *
⟨Hmn⟩	Harmonic mean **
⟨-->⟩	Displays the previous selections shown above

*The geometric mean is not defined if there is a negative number or zero in the data set.

**The harmonic mean is not defined if there is a zero in the data set.

Example: The Means and Moments Program

This example illustrates how you use this program to obtain information about a probability distribution from a relative frequency histogram.

Example

Given the mass function for the binomial with $n = 4$, $p = .2$, and $q = (1 - p) = .8$:

x	f(x) = frequency
0	.4096
1	.4096
2	.1536
3	.0256
4	.0016

It is known from statistical theory that the mean, central moments, skewness coefficient, and kurtosis coefficient for the binomial distribution with $n = 4$ and $p = .2$ are as follows:

$mn = np = .8$
$m2 = npq = .64$
$m3 = npq(q - p) = .384$
$m4 = npq(1 + 3pq(n - 2)) = 1.2544$
$a3 = (q - p)/(npq)^{.5} = .75$
$a4 = 3 - 6/n + 1/npq = 3.0625$

Verify the above facts using this program.

Procedure	Press		Display
Select the program from the **STATISTICS** menu	⟨MNT⟩		MEANS & MOMENTS
Clear the registers	⟨CLR⟩		0.
Enter the first frequency	.4096 ⟨FRQ⟩ 0 ⟨ENT⟩	frq = n =	0.4096 0.4096

Example (Continued)

Procedure	Press		Display
Enter the second frequency	.4096 ⟨FRQ⟩ 1 ⟨ENT⟩	frq = n =	0.4096 0.8192
Enter the third frequency incorrectly	.1535 ⟨FRQ⟩ 2 ⟨ENT⟩	frq = n =	0.1535 0.9727
Enter the fourth frequency	.0256 ⟨FRQ⟩ 3 ⟨ENT⟩	frq = n =	0.0256 0.9983
Enter the last frequency	.0016 ⟨FRQ⟩ 4 ⟨ENT⟩	frq = n =	0.0016 0.9999
Delete the third frequency	.1535 ⟨FRQ⟩ 2 ⟨DEL⟩	frq = n =	0.1535 0.8464
Reenter the third frequency	.1536 ⟨FRQ⟩ 2 ⟨ENT⟩	frq = n =	0.1536 1.
Indicate end of data	⟨EOD⟩	n =	1.
Select all desired results in any order	⟨mn⟩ ⟨m2⟩ ⟨m3⟩ ⟨m4⟩ ⟨a3⟩ ⟨a4⟩ ⟨Gmn⟩ ⟨Hmn⟩	mn = m2 = m3 = m4 = a3 = a4 = * *	0.8 0.64 0.384 1.2544 0.75 3.0625

* The geometric mean (Gmn) and harmonic mean (Hmn) are not defined because the data set contains a zero.

Chapter 3: Theoretical Distributions

This chapter describes the Theoretical Distributions programs, which eliminate the need for probability tables.

Table of Contents

The Theoretical Distributions menu offers you a selection of programs for eight commonly-used distributions.

The Distribution Menu

Select ⟨DST⟩ from the **STATISTICS** menu to display the following menu.

```
DISTRIBUTIONS
NML  t   F   CHI  -->
```

⟨NML⟩	Normal Distribution
INV ⟨NML⟩	Inverse Normal Distribution
⟨t⟩	Student's t-Distribution
⟨F⟩	F-Distribution
⟨CHI⟩	Chi-Square Distribution
⟨-->⟩	Displays the menu selections shown below

```
DISTRIBUTIONS
WEI  BIN  POI  HYP  -->
```

⟨WEI⟩	Weibull Distribution
INV ⟨WEI⟩	Inverse Weibull Distribution
⟨BIN⟩	Binomial Distribution
⟨POI⟩	Poisson Distribution
⟨HYP⟩	Hypergeometric Distribution
⟨-->⟩	Displays the previous selections shown above

The Normal Distribution Program

This program actually consists of two programs: the Normal distribution program and the Inverse Normal distribution program. This section describes the use of both of these programs.

Introduction to the Programs

The Normal distribution program can be used in two ways.

- If you know z, the number of standard deviations a value is away from the mean, this program calculates:

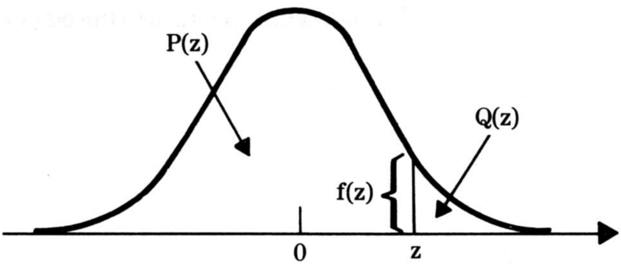
  The right-tail area, Q(z).

  The height of the curve at z, f(z).

- If you know the value of Q(z), this program calculates z, the number of standard deviations a value is away from the mean.

These programs assume the standard unit normal distribution. You can obtain the z value using the equation:

$z = (x - \mu)/\sigma$



Reference

Handbook of Mathematical Functions, edited by Milton Abramowitz and Irene A. Stegun, National Bureau of Standards, Washington, D.C., 1970, pp. 932–933.

Calculating Q(z) and f(z)

To calculate Q(z) and f(z):

1. Select ⟨DST⟩ from the **STATISTICS** menu.
2. Select ⟨NML⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the value of z and press ⟨Qz⟩.

   The value of Q(z) is displayed.

4. Press $\boxed{x\sim t}$ to display the value of f(z).
5. Repeat steps 3 and 4 for other values of z, if desired.
6. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

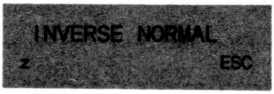
Calculating z

To calculate the value of z:

1. Select ⟨DST⟩ from the **STATISTICS** menu.

2. Select **INV** ⟨NML⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the probability, Q(z), and press ⟨z⟩.

   The value of z is displayed.

4. Repeat step 3 for other probabilities, if desired.

5. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

The following examples use the Normal distribution program. The first example illustrates the use of the Normal distribution program in the calculation of alpha risks in hypothesis testing. The second example illustrates how to obtain critical z values which are required in running hypothesis tests using the Inverse Normal distribution.

Example 1

In the example given in the Runs Test program (page 8–16), the expected number of runs (MNr) was 20.8. The standard deviation (Sr) was 3.089436095. The observed number of runs (#r) was 20. For this set of data, compute the standard normal deviate, and then determine the two-tailed alpha risk taken if the null hypothesis were rejected. The standard normal deviate is computed using the equation zr = (#r – MNr)/Sr.

Procedure	Press	Display
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS
Select the program	⟨NML⟩	NORMAL
Compute zr	$\boxed{(}$ 20 $\boxed{-}$ 20.8 $\boxed{)}$ $\boxed{\div}$ 3.089436095 $\boxed{=}$ $\boxed{+/-}$	.2589469325
Find value of Q(z)	⟨Qz⟩	Qz = .3978381478
Calculate the two-tailed alpha risk	$\boxed{\times}$ 2 $\boxed{=}$	.7956762957

Conclusion

The rejection of the null hypothesis in the Runs Test example implies an alpha risk of approximately .796.

Example 2

Calculate the critical z values for the 95% two-tailed z-test which is used in the Runs Test example. Find that value of z which leaves an area $Q(z) = .025$ in the right tail under the Normal distribution. Then, the other critical value will be $-z$ and will leave an equal area in the left tail.

Procedure	Press	Display
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS
Select the program	[INV] ⟨NML⟩	INVERSE NORMAL
Enter the probability and calculate z	.025 ⟨z⟩	z= 1.960394917

Conclusion

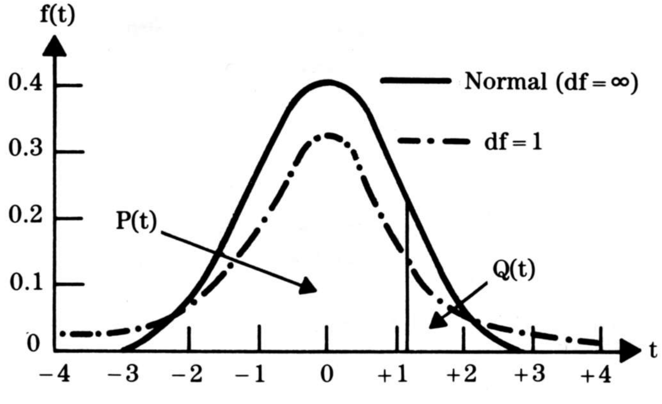
The required critical values of z are approximately ± 1.96.

The Student's t-Distribution Program

This program calculates Student's t probabilities.

Introduction to the Program

Given the t-statistic (t) resulting from a test of a hypothesis and the degrees of freedom (df) of the sample population, this program calculates the left-tailed area under the Student's t-distribution.



Reference

Handbook of Mathematical Functions, edited by Milton Abramowitz and Irene A. Stegun, National Bureau of Standards, Washington, D.C., 1970, pp. 947–948.

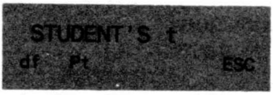
Calculating Pt

To calculate Pt:

1. Select ⟨DST⟩ from the **STATISTICS** menu.

2. Select ⟨t⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the number of degrees of freedom and press ⟨df⟩.

4. Enter the value of t and press ⟨Pt⟩.

   The value of Pt is displayed.

5. Repeat steps 3 and 4 using other values, if desired.

6. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

Examples: The Student's t-Distribution Program

The following examples illustrate the use of the Student's t-distribution program in the calculation of alpha risks for hypothesis testing.

Example 1

Referring to the example given in the Unpaired t-Test program (page 6–9), a t-statistic of −3.459182584 with 23 degrees of freedom was observed. Calculate the two-tailed alpha risk taken for rejection of the null hypothesis.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	〈DST〉	DISTRIBUTIONS	
Select the program	〈t〉	STUDENT'S t	
Enter the degrees of freedom of the sample	23 〈df〉	df =	23.
Enter the value of t and calculate Pt	3.459182584 [+/−] 〈Pt〉	Pt =	0.001064753
Calculate the two-tailed alpha risk	[×] 2 [=]		0.002129506

Conclusion

The rejection of the hypothesis in the Unpaired t-Test example implies an alpha risk of approximately .002.

Example 2

Verify that the critical values of ± 2.069 used in the Unpaired t-Test example imply a two-tailed alpha risk of .05.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS	
Select the program	⟨t⟩	STUDENT'S t	
Enter the degrees of freedom of the sample	23 ⟨df⟩	df =	23.
Enter the value of t and calculate Pt	2.069 [+/−] ⟨Pt⟩	Pt =	.0249825698
Calculate the two-tailed alpha risk	[×] 2 [=]		.0499651395

Conclusion

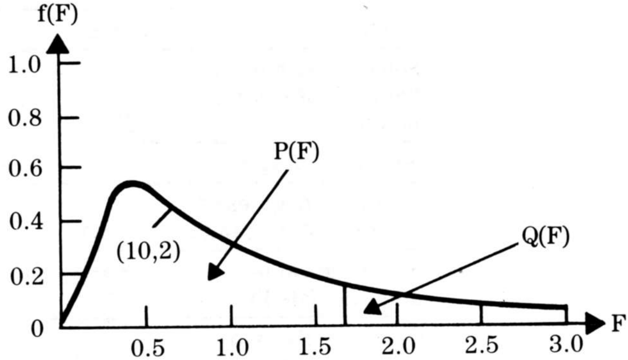
The use of ± 2.069 as critical values for a two-tailed t-test with 23 degrees of freedom implies a 95% significance level.

The F-Distribution Program

This program calculates F-distribution probabilities.

Introduction to the Program

Given the degrees of freedom of both samples (df1 and df2) and the F-statistic, this program calculates Q(F), the area under the curve to the right of the F-statistic.



Reference

Handbook of Mathematical Functions, edited by Milton Abramowitz and Irene A. Stegun, National Bureau of Standards, Washington, D.C., 1970, pp. 946–947.

Calculating Q(F)

To calculate Q(F):

1. Select ⟨DST⟩ from the **STATISTICS** menu.
2. Select ⟨F⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

   ```
   F
   df1  df2  QF            ESC
   ```

3. Enter the number of degrees of freedom for the first sample set and press ⟨df1⟩.
4. Enter the number of degrees of freedom for the second sample set and press ⟨df2⟩.
5. Enter the value of F and press ⟨QF⟩.

   The value of Q(F) is displayed.

6. Repeat steps 3 through 5 using other values, if desired.
7. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

Examples: The F-Distribution Program

The following examples illustrate the use of the F-distribution program in establishing alpha risks for hypothesis testing.

Example 1

The test for equality of variance in the Unpaired t-Test example (page 6–9) resulted in an F-statistic of .5253045597 with 12 and 11 degrees of freedom. Calculate the alpha risk of rejection for this F-statistic.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS	
Select the program	⟨F⟩	F	
Enter df1	12 ⟨df1⟩	df1 =	12.
Enter df2	11 ⟨df2⟩	df2 =	11.
Enter the value of F and calculate Q(F)	.5253045597 ⟨QF⟩	QF =	.8580878726

Conclusion

The rejection of the equal variances hypothesis in the Unpaired t-Test example would entail an alpha risk of approximately .858.

Example 2

Verify that the critical F value of 2.79 used in the Unpaired t-Test example is the correct rejection value to use for a 95% significance level.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS	
Select the program	⟨F⟩	F	
Enter df1	12 ⟨df1⟩	df1 =	12.
Enter df2	11 ⟨df2⟩	df2 =	11.
Enter the value of F and calculate Q(F)	2.79 ⟨QF⟩	QF =	.0498617135

Conclusion

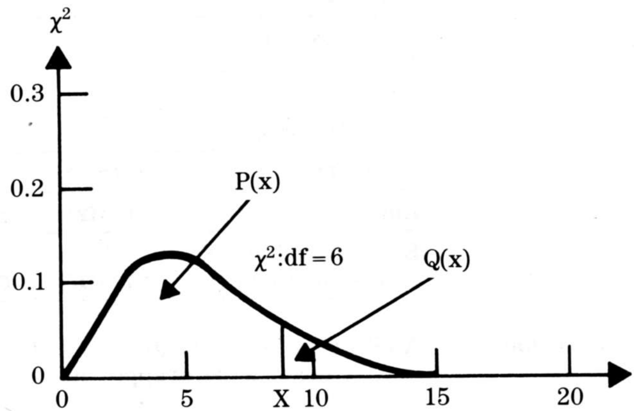
An F-statistic of 2.79 with 12 and 11 degrees of freedom implies an alpha risk of approximately .05.

The Chi-Square Distribution Program

This program calculates Chi-square probabilities.

Introduction to the Program

Given the degrees of freedom (df) and the Chi-square statistic (χ^2) of a sample population, this program calculates Q(x), the right-tailed area under the Chi-square distribution.



Reference

Handbook of Mathematical Functions, edited by Milton Abramowitz and Irene A. Stegun, National Bureau of Standards, Washington, D.C., 1970, pp. 940–941.

Calculating Qx

To calculate Qx:

1. Select <DST> from the **STATISTICS** menu.
2. Select <CHI> from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the number of degrees of freedom and press <df>.
4. Enter the value of Chi-square and press <Qx>.

   The value of Qx is displayed.

5. Repeat steps 3 and 4 using other values, if desired.
6. Press <ESC> to return to the **DISTRIBUTIONS** menu.

Examples: The Chi-Square Distribution Program

These examples illustrate the use of the Chi-square distribution program in establishing alpha risks for hypothesis tests.

Example 1

In the first example for the Histogram program (page 7–21), a Chi-square statistic of 4.75 with 4 degrees of freedom was obtained from the Goodness-of-Fit test. Calculate the alpha risk if the null hypothesis were rejected.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS	
Select the program	⟨CHI⟩	CHI-SQUARE	
Enter df	4 ⟨df⟩	df =	4.
Enter Chi-square and find the value of Qx	4.75 ⟨Qx⟩	Qx =	.3139239011

Conclusion

The alpha risk for rejection of the null hypothesis in this Goodness-of-Fit test is approximately .314.

Example 2

Verify that the critical Chi-square value of 9.488 with 4 degrees of freedom used in the same test implies an alpha risk of approximately .05.

Procedure	Press	Display	
Select the program	⟨DST⟩ ⟨CHI⟩	CHI-SQUARE	
Enter df	4 ⟨df⟩	df =	4.
Enter Chi-square and find the value of Qx	9.488 ⟨Qx⟩	Qx =	.0499944056

Conclusion

9.488 is the correct critical value of Chi-square to use for this 95% Goodness-of-Fit test.

The Weibull Distribution Program

This program consists of two programs: the Weibull distribution program and the Inverse Weibull distribution program. This section describes the use of both of these programs.

Introduction to the Program

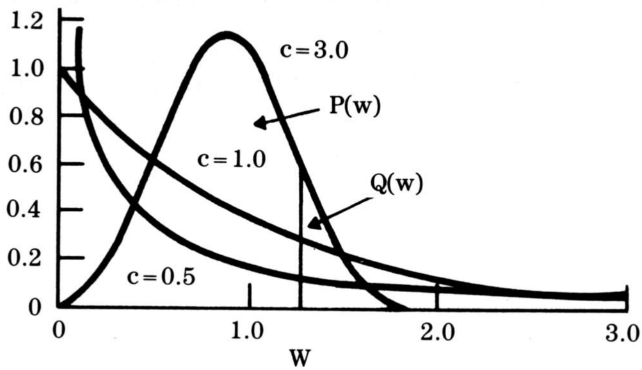
Given the scale parameter (b) and the shape parameter (c), the Weibull distribution program can be used in two ways.

- If you know the Weibull statistic (w) of a sample, this program calculates P(w).
- If you know the value of P(w), this program calculates the value of w.

A location parameter is sometimes specified for this distribution. In this program, this parameter is assumed to be zero. If your data suggest a non-zero location parameter, you can shift the sample data to location zero by subtracting the non-zero value from each observation.

The Histogram program can be used to estimate the values of b and c.

Note: If c is equal to 1, the Weibull distribution is the Exponential distribution and this program can be used to calculate Exponential probabilities.



Reference

Statistical Distributions, N. A. J. Hastings and J. B. Peacock, John Wiley & Sons, New York, 1975, pp. 124–129.

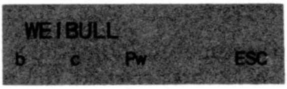
Calculating P(w)

To calculate P(w):

1. Select ⟨DST⟩ from the **STATISTICS** menu.

2. Select ⟨WEI⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.



3. Enter the value for the scale parameter and press ⟨b⟩.

4. Enter the value for the shape parameter and press ⟨c⟩.

5. Enter the value of the Weibull statistic and press ⟨Pw⟩.

   The value of P(w) is displayed.

6. Repeat steps 3 through 5 using other values, if desired.

7. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

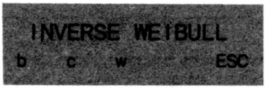
Calculating w

To calculate w:

1. Select ⟨DST⟩ from the **STATISTICS** menu.

2. Press $\boxed{\text{INV}}$ and select ⟨WEI⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the value for the scale parameter and press ⟨b⟩.

4. Enter the value for the shape parameter and press ⟨c⟩.

5. Enter the probability of P(w) and press ⟨w⟩.

   The value of w is displayed.

6. Repeat steps 3 through 5 using other values, if desired.

7. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

Examples: The Weibull Distribution Program

These examples illustrate the use of the Weibull distribution program and the Inverse Weibull distribution program.

Example 1

Given the Weibull parameters estimated in the second Histogram example (page 7–25), determine what percentage of defective product returns are likely to occur within four weeks of shipment.

b = 19.44126746
c = 1.298078809
w = 4

Procedure	Press	Display
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS
Select the program	⟨-->⟩ ⟨WEI⟩	WEIBULL
Enter the scale parameter (b)	19.44126746 ⟨b⟩	b= 19.44126746
Enter the shape parameter (c)	1.298078809 ⟨c⟩	c= 1.298078809
Enter the Weibull statistic (w) and calculate P(w)	4 ⟨Pw⟩	Pw= .1205219565

Conclusion

Approximately 12% of the product which is found defective can be expected to be returned within the first four weeks after shipment.

Example 2

Using the same Weibull distribution as in example 1, determine how many weeks after shipment the manufacturer can expect to have received 90% of all the items which will be returned as defective.

b = 19.44126746
c = 1.298078809
Pw = .9

Procedure	Press	Display
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS
Select the program	⟨-->⟩ $\boxed{\text{INV}}$ ⟨WEI⟩	INVERSE WEIBULL
Enter the scale parameter (b)	19.44126746 ⟨b⟩	b = 19.44126746
Enter the shape parameter (c)	1.298078809 ⟨c⟩	c = 1.298078809
Enter the Weibull probability P(w) and calculate w	.9 ⟨w⟩	w = 36.96276098

Conclusion

The manufacturer can expect to have received 90% of the returned defective items within approximately 37 weeks after shipment.

The Binomial Distribution Program

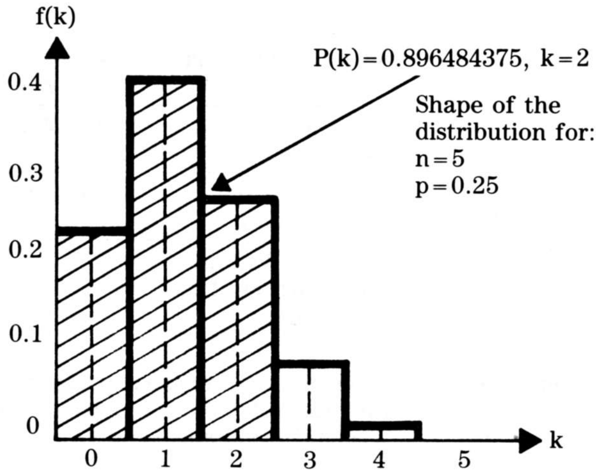
The Binomial distribution determines the probability that a discrete event will occur a certain number of times in a given number of trials. This model is applicable when the probability that the event will occur in a single trial is constant and the trials are independent.

Introduction to the Program

Given the number of trials (n), the probability that a success will occur in a single trial (p), and the number of successes (k), this program calculates:

- Probability of observing k or fewer successes, P(k)
- Probability of observing exactly k successes, f(k)

For example, the probability is illustrated below for drawing k or fewer spades when you draw a five-card hand from a 52-card deck with replacement. The probability is shaded for drawing two or fewer spades.



The Binomial distribution can sometimes be used to approximate the Hypergeometric distribution in those cases where the sampled population is large compared to the sample size.

Reference

Statistical Distributions, N. A. J. Hastings and J. B. Peacock, John Wiley & Sons, New York, 1975, pp. 36–41.

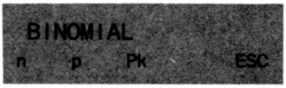
Calculating P(k) and f(k)

To calculate P(k) and f(k):

1. Select ⟨DST⟩ from the **STATISTICS** menu.

2. Select ⟨BIN⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the number of trials and press ⟨n⟩.

4. Enter the probability that a success will occur in any single trial and press ⟨p⟩.

5. Enter the number of successes desired (k) and press ⟨Pk⟩.

   The probability of k or fewer successes in n trials is calculated and displayed.

6. To display the probability of exactly k successes, f(k), press [x~t].

7. Repeat steps 3 through 6 using other values, if desired.

8. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

Example: The Binomial Distribution Program

The following example illustrates the use of the Binomial distribution program in the solution of a problem in acceptance sampling.

Example

Find the probability of acceptance of a lot of 5000 electronic parts based on a random sample of 75 items drawn from the lot with an assumed fraction defective of .08 where the lot is to be accepted if the number of defectives in the sample is 10 or less.

Referring to the example given for the Hypergeometric distribution (page 3–32), since the sample size of 75 is only .015 of the lot size of 5000, it can be assumed that the Binomial will serve as a good approximation of the Hypergeometric, even though the sample is drawn without replacement.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS	
Select the program	⟨-->⟩ ⟨BIN⟩	BINOMIAL	
Enter number of trials (sample size)	75 ⟨n⟩	n=	75.
Enter lot fraction defective	.08 ⟨p⟩	p=	0.08
Enter number of successes and calculate P(k)	10 ⟨Pk⟩	Pk=	.9640874205

Conclusion

The probability that the lot will be accepted under the stated sampling plan is approximately .964, which disagrees with the exact Hypergeometric probability by only .001.

The Poisson Distribution

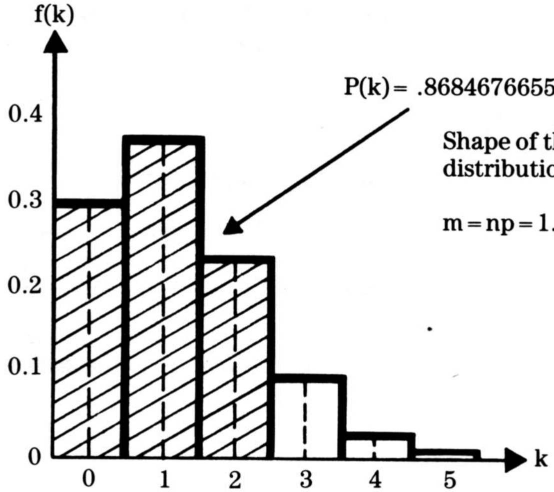
The Poisson distribution determines the probability that a discrete event will occur a certain number of times if the event is Poisson-distributed.

Introduction to the Program

Given the average number of successes (m) and the number of successes (k), this program calculates:

- Probability of observing k or fewer successes, P(k)
- Probability of observing exactly k successes, f(k)

The example below illustrates the use of this distribution as an approximation to the Binomial distribution, shown on page 3–24, for drawing k or fewer spades in a five-card hand from a 52-card deck. The probability is shaded for drawing two or fewer spades.



The Poisson distribution is often used as an approximation to the Binomial distribution where the number of trials is large and the probability of success in a single trial is small. If used for this purpose, the constant np is the value of m in the Poisson distribution.

Reference

Statistical Distributions, N. A. J. Hastings and J. B. Peacock, John Wiley & Sons, New York, 1975, pp. 108–113.

Calculating P(k) and f(k)

To calculate P(k) and f(k):

1. Select ⟨DST⟩ from the **STATISTICS** menu.

2. Select ⟨POI⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the average number of successful occurrences and press ⟨m⟩.

4. Enter the number of successes desired and press ⟨Pk⟩.

   The value of P(k) is displayed.

5. To display the value of f(k), press $\boxed{x\sim t}$.

6. Repeat steps 3 through 5 using other values, if desired.

7. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

Example: The Poisson Distribution Program

The following example illustrates the use of the Poisson distribution program in the solution of a problem in acceptance sampling.

Example

Find the probability of acceptance of a lot of 5000 electronic parts based on a random sample of 75 parts drawn from the lot with an assumed fraction defective of .08 where the lot is to be accepted if the number of defectives in the sample is 10 or less.

Referring to the example used in the Binomial (page 3–26) and Hypergeometric (page 3–32) distribution programs, since n is large and p is small, the Binomial probability can be adequately approximated by the Poisson with parameter m = np.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS	
Select the program	⟨-->⟩ ⟨POI⟩	POISSON	
Calculate the Poisson parameter	75 [×] .08 [=]		6.
Enter the value of m	⟨m⟩	m =	6.
Enter number of successes and calculate P(k)	10 ⟨Pk⟩	Pk =	.9573790764

Conclusion

The probability that the lot will be accepted under the stated sampling plan is approximately .957, which disagrees with the Binomial by .007 and disagrees with the exact Hypergeometric probability by .008.

The Hypergeometric Distribution Program

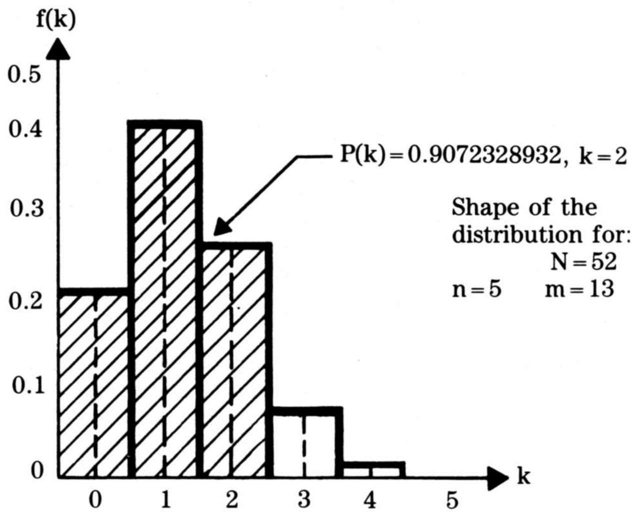
The Hypergeometric distribution determines the probability of obtaining a certain number of successes in a given sample, when the sample is taken from a population containing a specific number of successes. This model is appropriate when each element of the sample can be classified as a success or a failure and the samples are taken without replacement.

Introduction to the Program

Given the population size (N), the sample size (n), the number of successes in the population (m), and the number of successes in the sample (k), this program calculates:

- Probability of k or fewer successes, P(k)
- Probability of exactly k successes, f(k)

The example below illustrates the use of this distribution to determine the probability of drawing k number of spades in a five-card hand drawn without replacement from a 52-card deck. The probability is shaded for drawing two or fewer spades.



Reference

Statistical Distributions, N. A. J. Hastings and J. B. Peacock, John Wiley & Sons, New York, 1975, pp. 78–79.

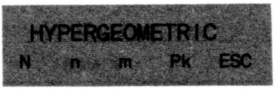
Calculating P(k) and f(k)

To calculate P(k) and f(k):

1. Select ⟨DST⟩ from the **STATISTICS** menu.

2. Select ⟨HYP⟩ from the **DISTRIBUTIONS** menu.

   The following display appears.

3. Enter the population size and press ⟨N⟩.

4. Enter the sample size and press ⟨n⟩.

5. Enter the number of successes in the population and press ⟨m⟩.

6. Enter the number of successes in the sample (k) and press ⟨Pk⟩.

   The value of P(k) is displayed.

7. To display the value of f(k), press $\boxed{x \sim t}$.

8. Repeat steps 3 through 7 using other values, if desired.

9. Press ⟨ESC⟩ to return to the **DISTRIBUTIONS** menu.

Example: The Hypergeometric Distribution Program

The following example illustrates the use of the Hypergeometric distribution program in the solution of a problem in acceptance sampling.

Example

A lot of 5000 electronic parts is to be accepted or rejected on the basis of the number of defectives found in a random sample of 75 items drawn from the lot. If the sample is found to contain 10 or less defectives, the lot will be accepted. If more than 10 defectives are found, the lot will be rejected. If the fraction of defectives in the lot is .08, find the probability that the lot will be accepted.

Procedure	Press	Display	
Select Distributions from the **STATISTICS** menu	⟨DST⟩	DISTRIBUTIONS	
Select the program	⟨-->⟩ ⟨HYP⟩	HYPERGEOMETRIC	
Enter population size	5000 ⟨N⟩	N =	5000.
Enter sample size	75 ⟨n⟩	n =	75.
Calculate number of defectives in the population (m)	5000 $\boxed{\times}$ .08 $\boxed{=}$		400.
Enter the value of m	⟨m⟩	m =	400.
Enter number of successes and calculate P(k)	10 ⟨Pk⟩	Pk =	.9652251319

Conclusion

The probability that the lot will be accepted under the stated sampling plan is approximately .965.

Chapter 4: Analysis of Variance

The Statistics cartridge provides analysis of variance for three experimental designs.

Table of Contents

Introduction

The Analysis of Variance menu offers you three types of ANOVA programs. The program you select depends on your experimental design.

The ANOVA Menu

Select ⟨AOV⟩ from the STATISTICS menu to display the following menu.

```
ANOVA
1    2    2R
```

⟨1⟩ One-Way ANOVA

⟨2⟩ Two-Way ANOVA

⟨2R⟩ Two-Way ANOVA with Replication

The One-Way ANOVA Program

A One-Way Analysis of Variance is used to test the hypothesis that the mean responses to more than two different treatments are identical against the alternative that at least one is different.

Introduction to the Program

Given the number of treatments (#Tr), the number of entries in each treatment (n), and the results of the observations (x), this program calculates:

- Sum of squares
- Mean squares
- Degrees of freedom
- F-statistic

The data for a one-way ANOVA can be arranged in a matrix such as the one shown below.

	Observations				
Treatment 1	x1,1	x1,2	x1,3	x1,4	x1,5
Treatment 2	x2,1	x2,2	x2,3	x2,4	x2,5
Treatment 3	x3,1	x3,2	x3,3	x3,4	

Reference

Statistics, An Introduction, Albert D. Rickmers and Hollis N. Todd, McGraw-Hill Book Company, New York, 1967, pp. 154–167.

Selecting the Program

To use the One-Way ANOVA program:

1. Select ⟨AOV⟩ from the **STATISTICS** menu.

2. Select ⟨1⟩ from the **ANOVA** menu.

   The following display appears.

```
ONE-WAY
#TR  EOD                ESC
```

Defining the Matrix

To define the matrix:

1. Enter the number of treatments and press ⟨#Tr⟩.

2. Press ⟨EOD⟩.

   The next series of displays requests the number of observations in each treatment, beginning with treatment 1.

```
n (   1)
ENT
```

3. Enter the number of observations in the first treatment and press ⟨ENT⟩.

4. Repeat this procedure until the number of observations for each treatment is entered.

   The **EDIT** menu shown on the next page appears when the number of observations for the last treatment is entered.

Editing the Matrix

The **EDIT** menu enables you to change any entry you made.

```
EDIT
i    ENT   EOD
```

- ► If you do not want to edit the matrix, press ⟨EOD⟩ and proceed to "Entering the Data."
- ► If you want to edit the matrix, follow the procedure below.

To edit an incorrect entry:

1. Enter the treatment you want to change and press ⟨i⟩. The number you entered is displayed.
2. Enter the correct number and press ⟨ENT⟩.
3. Repeat steps 1 and 2 until all corrections are made.
4. Press ⟨EOD⟩.

Entering the Data

The next display requests the data for treatment 1, observation 1.

```
x (   1,   1)
ENT
```

1. Enter the data for this observation and press ⟨ENT⟩.
2. Repeat this procedure, as prompted, until all observations for this treatment are entered.

   The **EDIT** menu shown on the next page appears when all treatment 1 observations are entered.

Editing the Data

The EDIT menu enables you to change any entry you made.

```
EDIT
j      ENT  EOD
```

- ► If you do not want to edit the data, press ⟨EOD⟩ and enter the data for the next treatment, as prompted.
- ► If you want to edit the data, follow the procedure below.

To edit an incorrect entry:

1. Specify the number of the observation in error and press ⟨j⟩. The value you entered previously is displayed.
2. Enter the correct value and press ⟨ENT⟩.
3. Repeat steps 1 and 2 until all corrections are made.
4. Press ⟨EOD⟩.

When you complete data entry for the last treatment and press ⟨EOD⟩, the analysis of variance is calculated and the display shown on the following page appears.

Obtaining the Results

Select the appropriate function key from the following menu to obtain the results.

```
ONE-WAY
MSR  dfR  MSE  dfE  -->
```

⟨MSR⟩	Mean Square of Rows
⟨MSR⟩ $\boxed{x\sim t}$	Sum of Squares of Rows (SSR)
⟨dfR⟩	Degrees of Freedom of Rows
⟨MSE⟩	Mean Square of Error
⟨MSE⟩ $\boxed{x\sim t}$	Sum of Squares of Error (SSE)
⟨dfE⟩	Degrees of Freedom of Error
⟨-->⟩	Displays the selections shown below

```
ONE-WAY
F    SST  dfT  -->  ESC
```

⟨F⟩	F-statistic for the data
⟨SST⟩	Sum of Squares of Treatment
⟨dfT⟩	Degrees of Freedom of Treatment
⟨-->⟩	Displays the previous selections shown above
⟨ESC⟩	Returns you to the **ANOVA** menu

Example: The One-Way ANOVA Program

The following example uses the One-Way ANOVA program to evaluate the results of three different teaching techniques.

Example Using the same data that are used in the Kruskal-Wallis example (comprehensive final examination scores—page 8–22), test the hypothesis that all teaching techniques are equally effective against the alternative that at least one of the techniques is more effective. Since the test will be run at the same 95% level, reject the null hypothesis if the observed F-statistic exceeds 3.32.

Class I 83, 82, 77, 83, 81, 92, 84, 85, 82, 80, 81, 79, 80

Class II 84, 85, 74, 88, 69, 84, 82, 81

Class III 89, 81, 85, 91, 85, 90, 86, 92, 86, 94, 98, 82

Procedure	Press	Display	
Select ANOVA from the **STATISTICS** menu	⟨AOV⟩	ANOVA	
Select the program	⟨1⟩	ONE WAY	
Enter number of treatment groups	3 ⟨#Tr⟩	#Tr =	3.
Indicate end of data	⟨EOD⟩	n(1)	
Enter number of observations in treatment (class) I	13 ⟨ENT⟩	n(2)	
Enter number of observations in treatment (class) II	8 ⟨ENT⟩	n(3)	

Example (Continued)

Procedure	Press	Display
Enter number of observations in treatment (class) III	12 ⟨ENT⟩	EDIT
Indicate end of data	⟨EOD⟩	x(1, 1)
Begin entering values for class I data	83 ⟨ENT⟩	x(1, 2)
	82 ⟨ENT⟩	x(1, 3)
	77 ⟨ENT⟩	x(1, 4)
	83 ⟨ENT⟩	x(1, 5)
	81 ⟨ENT⟩	x(1, 6)
	92 ⟨ENT⟩	x(1, 7)
	84 ⟨ENT⟩	x(1, 8)
	85 ⟨ENT⟩	x(1, 9)
	82 ⟨ENT⟩	x(1,10)
	80 ⟨ENT⟩	x(1,11)
	81 ⟨ENT⟩	x(1,12)
	79 ⟨ENT⟩	x(1,13)
	80 ⟨ENT⟩	EDIT

(continued)

Example (Continued)	Procedure	Press	Display
	Indicate end of class I data	⟨EOD⟩	x(2, 1)
	Begin entering class II data	84 ⟨ENT⟩	x(2, 2)
		85 ⟨ENT⟩	x(2, 3)
		74 ⟨ENT⟩	x(2, 4)
		88 ⟨ENT⟩	x(2, 5)
		69 ⟨ENT⟩	x(2, 6)
		84 ⟨ENT⟩	x(2, 7)
		82 ⟨ENT⟩	x(2, 8)
		81 ⟨ENT⟩	EDIT
	Indicate end of class II data	⟨EOD⟩	x(3, 1)
	Begin entering class III data	89 ⟨ENT⟩	x(3, 2)
		81 ⟨ENT⟩	x(3, 3)
		85 ⟨ENT⟩	x(3, 4)
		91 ⟨ENT⟩	x(3, 5)
		85 ⟨ENT⟩	x(3, 6)

Example (Continued)

Procedure	Press	Display	
	90 ⟨ENT⟩	x(3, 7)	
	86 ⟨ENT⟩	x(3, 8)	
	92 ⟨ENT⟩	x(3, 9)	
	86 ⟨ENT⟩	x(3,10)	
	94 ⟨ENT⟩	x(3,11)	
	98 ⟨ENT⟩	x(3,12)	
	82 ⟨ENT⟩	EDIT	
Indicate end of class III data	⟨EOD⟩	ONE-WAY	
Select ANOVA values	⟨MSR⟩	MSR =	167.6472902
	$\boxed{x\sim t}$		335.2945804
	⟨dfR⟩	dfR =	2.
	⟨MSE⟩	MSE =	23.71442308
	$\boxed{x\sim t}$		711.4326923
	⟨dfE⟩	dfE =	30.
	⟨F⟩	F =	7.069423096
	⟨SST⟩	SST =	1046.727273
	⟨dfT⟩	dfT =	32.

Conclusion

Since the observed F-statistic of 7.069423096 is greater than the critical value of 3.32, we reject the null hypothesis and conclude that there is evidence that at least one of the treatments yields a higher average response. Note that this result is consistent with the Kruskal-Wallis test result.

The Two-Way ANOVA Program

The Two-Way Analysis of Variance is used to simultaneously test the hypothesis that there is no significant effect due to either row treatment or column treatment.

Introduction to the Program

Given the number of treatments, the number of groups receiving the treatments (j), and the results of the observations, this program calculates:

- Sum of squares
- Mean squares
- Degrees of freedom
- F-statistics

The data for a two-way ANOVA can be arranged in a matrix such as the one shown below.

		Column Treatment (column 1)	Column Treatment (column 2)
Row Treatment	(row 1)	x1,1	x1,2
	(row 2)	x2,1	x2,2
	(row 3)	x3,1	x3,2

Reference

Statistics, An Introduction, Albert D. Rickmers and Hollis N. Todd, McGraw-Hill Book Company, New York, 1967, pp. 167–172.

Selecting the Program

To use the Two-Way ANOVA program:

1. Select ⟨AOV⟩ from the **STATISTICS** menu.

2. Select ⟨2⟩ from the **ANOVA** menu.

   The following display appears.

```
TWO-WAY
ROW  COL  EOD        ESC
```

Defining the Matrix

To define the matrix:

1. Enter the number of rows and press ⟨ROW⟩.

2. Enter the number of columns and press ⟨COL⟩.

3. Press ⟨EOD⟩.

Entering the Data

The next series of displays prompts you to enter data column by column, beginning with row 1, column 1.

```
x (  1,  1)
ENT
```

1. Enter the data for this observation and press ⟨ENT⟩.

2. Repeat this procedure, entering data as prompted. The program proceeds column by column through the matrix until all data are entered.

When all data are entered, the **EDIT** menu shown on the next page is displayed.

The Edit Menu

The **EDIT** menu appears after the last data entry is made to enable you to change any entry you made.

```
EDIT
i-j  ENT  EOD
```

- ► If you do not want to edit, press <EOD> and proceed to "Obtaining the Results" on the following page.
- ► If you want to edit, use the procedure below.

Editing the Data

To edit an incorrect entry:

1. Enter the row number of the error and press [x~t].
2. Enter the column number of the error and press <i-j>. The value originally entered is displayed.
3. Enter the correct value and press <ENT>.
4. Repeat this procedure until all corrections are made.
5. Press <EOD>.

When you complete data entry for the last treatment and press <EOD>, the analysis of variance is calculated and the display shown on the following page appears.

Obtaining the Results

Select the appropriate function keys from the following menu to obtain the results.

```
TWO-WAY
MSR  dfR  MSC  dfC  -->
```

<MSR>		Mean Square of Rows
<MSR>	$\boxed{x\sim t}$	Sum of Squares of Rows (SSR)
<dfR>		Degrees of Freedom of Rows
<MSC>		Mean Square of Columns
<MSC>	$\boxed{x\sim t}$	Sum of Squares of Columns (SSC)
<dfC>		Degrees of Freedom of Columns
<-->>		Displays the selections shown below

```
TWO-WAY
MSE  dfE  FR   FC   -->
```

<MSE>		Mean Square of Error
<MSE>	$\boxed{x\sim t}$	Sum of Squares of Error (SSE)
<dfE>		Degrees of Freedom of Error
<FR>		F-statistic for Rows
<FC>		F-statistic for Columns
<-->>		Displays the selections shown on the next page

(continued)

Obtaining the Results (Continued)

```
TWO-WAY
SST  dfT  -->        ESC
```

⟨SST⟩	Sum of Squares of Total
⟨dfT⟩	Degrees of Freedom of Total
⟨-->⟩	Displays the previous selections (shown at the top of the previous page)
⟨ESC⟩	Returns to the Two-Way **ANOVA** menu

Example: The Two-Way ANOVA Program

The following example illustrates the use of the Two-Way ANOVA program in the analysis of a randomized complete block design.

Example

The data below represents the number of defective items produced per shift by three operators on five machines.

		Operator 1	2	3
Machine	1	34	28	33
	2	30	24	35
	3	27	20	40
	4	28	29	30
	5	30	25	34

Produce the ANOVA table and test the hypotheses that there is no difference in the number of defectives produced by operators and there is no difference in the number of defectives produced by machines. At the 95% level, the critical F-statistic for operators (columns) is 4.46 and the critical F-statistic for machines (rows) is 3.84.

Procedure	Press	Display	
Select ANOVA from the **STATISTICS** menu	〈AOV〉	ANOVA	
Select the program	〈2〉	TWO-WAY	
Enter number of rows	5 〈ROW〉	ROW =	5.
Enter number of columns	3 〈COL〉	COL =	3.
Indicate end of data	〈EOD〉	x(1, 1)	
Begin entry of column 1 data	34 〈ENT〉	x(2, 1)	

(continued)

Example (Continued)

Procedure	Press	Display	
Continuing entering column 1 data	30 ⟨ENT⟩	x(3, 1)	
	27 ⟨ENT⟩	x(4, 1)	
	28 ⟨ENT⟩	x(5, 1)	
	30 ⟨ENT⟩	x(1, 2)	
Begin entry of column 2 data	28 ⟨ENT⟩	x(2, 2)	
	24 ⟨ENT⟩	x(3, 2)	
Enter incorrect value	22 ⟨ENT⟩	x(4, 2)	
	29 ⟨ENT⟩	x(5, 2)	
	25 ⟨ENT⟩	x(1, 3)	
Begin entry of column 3 data	33 ⟨ENT⟩	x(2, 3)	
	35 ⟨ENT⟩	x(3, 3)	
	40 ⟨ENT⟩	x(4, 3)	
	30 ⟨ENT⟩	x(5, 3)	
	34 ⟨ENT⟩	EDIT	
Specify row and column where error occurs	3 $\boxed{x\sim t}$ 2 ⟨i-j⟩	x =	22.
Enter correct data	20 ⟨ENT⟩	x =	20.

Example (Continued)

Procedure	Press	Display	
Indicate end of data	⟨EOD⟩	TWO-WAY	
Select ANOVA values	⟨MSR⟩	MSR =	3.6
	$\boxed{x \sim t}$		14.4
	⟨dfR⟩	dfR =	4.
	⟨MSC⟩	MSC =	105.8
	$\boxed{x \sim t}$		211.6
	⟨dfC⟩	dfC =	2.
	⟨MSE⟩	MSE =	14.8
	$\boxed{x \sim t}$		118.4
	⟨dfE⟩	dfE =	8.
	⟨FR⟩	FR =	.2432432432
	⟨FC⟩	FC =	7.148648649
	⟨SST⟩	SST =	344.4
	⟨dfT⟩	dfT =	14.

Conclusion

Because FR is less than 3.84, we fail to reject the hypothesis for machines. However, because FC is greater than 4.46, we reject the hypothesis for operators. It appears that the operators produce a different average number of defectives, but no evidence was found that there is a difference in the number of defectives produced by machines.

The Two-Way ANOVA with Replication Program

The Two-Way Analysis of Variance with Replication program is used to simultaneously test the hypothesis that there is no significant effect due to either row treatment or column treatment and no significant effect due to row-column interaction.

Introduction to the Program

Given the number of treatments (i), the number of groups receiving the treatments (j), and the results of the observations from each replication (k), this program calculates:

- Sum of squares
- Mean squares
- Degrees of freedom
- F-statistics

The data for a two-way ANOVA with replication can be arranged in a matrix such as the one shown below.

		Column Treatment 1	Column Treatment 2
Row Treatment	1	$x_{1,1}(1)$ $x_{1,1}(2)$	$x_{1,2}(1)$ $x_{1,2}(2)$
	2	$x_{2,1}(1)$ $x_{2,1}(2)$	$x_{2,2}(1)$ $x_{2,2}(2)$
	3	$x_{3,1}(1)$ $x_{3,1}(2)$	$x_{3,2}(1)$ $x_{3,2}(2)$

Reference

Statistics, An Introduction, Albert D. Rickmers and Hollis N. Todd, McGraw-Hill Book Company, New York, 1967, pp. 172–177.

Selecting the Program

To use the Two-Way ANOVA with Replication program:

1. Select ⟨AOV⟩ from the **STATISTICS** menu.
2. Select ⟨2R⟩ from the **ANOVA** menu.

   The following display appears.

   ```
   TWO-WAY (REPL)
   ROW  COL  REP  EOD  ESC
   ```

Defining the Matrix

To define the matrix:

1. Enter the number of rows and press ⟨ROW⟩.
2. Enter the number of columns and press ⟨COL⟩.
3. Enter the number of replications and press ⟨REP⟩.
4. Press ⟨EOD⟩.

   The data entry display, shown on the next page, appears.

Entering the Data

The next series of displays prompts you to enter data in row 1, column 1, beginning with row 1, column 1, replication 1.

```
x ( 1, 1, 1)
ENT
```

1. Enter the data for this observation and press ⟨ENT⟩.

2. Repeat this procedure until all of the observations for this row and column are entered. All replications in one cell of the matrix must be entered before you proceed to the next cell.

   The program then prompts you to begin entering data for row 1, column 2.

```
x ( 1, 2, 1)
ENT
```

3. Enter the observation for this row, column, and replication, and press ⟨ENT⟩.

4. Continue entering data, as prompted, for each row, column, and replication in row 1.

The data entry procedure is repeated for each row in the matrix. The **EDIT** display, shown on the next page, appears after the data for each row are entered.

Editing the Data

The **EDIT** display appears after the data for each row are entered to enable you to change any entry you made.

```
EDIT
j-k  ENT  EOD
```

- ► If you do not want to edit, press ⟨EOD⟩. If you have more rows of data to enter, the program returns the data entry display to enable you to enter the next row. If you have entered the last treatment, proceed to "Obtaining the Results" on the following page.

- ► If you want to edit, use the procedure below.

To edit an incorrect entry:

1. Enter the column number where the error occurs and press $\boxed{x{\sim}t}$.

2. Enter the replication number and press ⟨j-k⟩. The value originally entered is displayed.

3. Enter the correct value and press ⟨ENT⟩.

4. When all entries are correct, press ⟨EOD⟩.

The data entry procedure is repeated for each row in the matrix. The **EDIT** display appears after the data for each row are entered.

When you complete the last data entry and press ⟨EOD⟩, the display shown on the following page appears.

Obtaining the Results

Select the appropriate function keys from the menu below to obtain the results.

```
TWO-WAY (REPL)
MSR  dfR  MSC  dfC  -->
```

⟨MSR⟩	Mean Square of Rows
⟨MSR⟩ [x~t]	Sum of Squares of Rows (SSR)
⟨dfR⟩	Degrees of Freedom of Rows
⟨MSC⟩	Mean Square of Columns
⟨MSC⟩ [x~t]	Sum of Squares of Columns (SSC)
⟨dfC⟩	Degrees of Freedom of Columns
⟨-->⟩	Displays the selections shown below

```
TWO-WAY (REPL)
MSI  dfI  SST  dfT  -->
```

⟨MSI⟩	Mean Square of Interaction
⟨MSI⟩ [x~t]	Sum of Squares of Interaction (SSI)
⟨dfI⟩	Degrees of Freedom of Interaction
⟨SST⟩	Total Sum of Squares
⟨dfT⟩	Total Degrees of Freedom
⟨-->⟩	Displays the selections shown on the next page

Obtaining the Results (Continued)

```
TWO-WAY (REPL)
MSE  dfE  -->
```

⟨MSE⟩	Mean Square of Error
⟨MSE⟩ [x~t]	Sum of Squares of Error (SSE)
⟨dfE⟩	Degrees of Freedom of Error
⟨-->⟩	Displays the selections shown below

```
TWO-WAY (REPL)
FR   FC   FI  E+I  -->
```

⟨FR⟩	F-Statistic for Rows
⟨FC⟩	F-Statistic for Columns
⟨FI⟩	F-Statistic for Interaction
⟨E + I⟩	Pool Error and Interaction Sum-of-Squares When you select this option, the program recalculates the analysis of variance using pooled data. You can obtain the pooled results by selecting the appropriate function keys from the menu.
⟨-->⟩	Displays the previous menu selections (shown at the top of the previous page)

The following example illustrates the use of this program in the analysis of a twice-replicated randomized complete block designed experiment.

Example

The experiment in the Two-Way ANOVA example (page 4–17) was replicated to test for the possibility of a machine/operator interaction. The results of this replication are shown below.

		Operator 1	2	3
Machine	1	34 35	28 24	33 34
	2	30 30	24 29	35 31
	3	27 30	20 28	40 29
	4	28 30	29 29	30 28
	5	30 30	25 26	34 31

Construct the ANOVA table and test the same hypotheses that were tested in the Two-Way example. In addition, test the hypothesis that there is no difference in the average number of defectives produced as a result of an interaction between operators and machines. At the 95% level, the critical values are FR = 3.06, FC = 3.68, and FI = 2.64.

If you fail to reject the hypothesis for interaction, pool the error and interaction sum-of-squares and rerun the tests for operators and machines at the 95% level. In this case, the critical values will be FR = 4.26 and FC = 5.66.

Example (Continued)

Procedure	Press	Display	
Select ANOVA from the **STATISTICS** menu	⟨AOV⟩	ANOVA	
Select the program	⟨2R⟩	TWO-WAY (REPL)	
Enter number of rows	5 ⟨ROW⟩	ROW =	5.
Enter number of columns	3 ⟨COL⟩	COL =	3.
Enter number of replications	2 ⟨REP⟩	REP =	2.
Indicate end of data	⟨EOD⟩	x(1, 1, 1)	
Enter row 1, column 1, replicate 1 data	34 ⟨ENT⟩	x(1, 1, 2)	
Enter row 1, column 1, replicate 2 data	35 ⟨ENT⟩	x(1, 2, 1)	
Enter row 1, column 2 data	28 ⟨ENT⟩	x(1, 2, 2)	
	24 ⟨ENT⟩	x(1, 3, 1)	
Enter row 1, column 3 data	33 ⟨ENT⟩	x(1, 3, 2)	
	34 ⟨ENT⟩	EDIT	
Indicate end of row 1 data	⟨EOD⟩	x(2, 1, 1)	

(continued)

Example (Continued)

Procedure	Press	Display
Begin entry of row 2 data	30 ⟨ENT⟩	x(2, 1, 2)
	30 ⟨ENT⟩	x(2, 2, 1)
	24 ⟨ENT⟩	x(2, 2, 2)
	29 ⟨ENT⟩	x(2, 3, 1)
	35 ⟨ENT⟩	x(2, 3, 2)
	31 ⟨ENT⟩	EDIT
Indicate end of row 2 data	⟨EOD⟩	x(3, 1, 1)
Begin entry of row 3 data	27 ⟨ENT⟩	x(3, 1, 2)
	30 ⟨ENT⟩	x(3, 2, 1)
	20 ⟨ENT⟩	x(3, 2, 2)
	28 ⟨ENT⟩	x(3, 3, 1)
	40 ⟨ENT⟩	x(3, 3, 2)
	29 ⟨ENT⟩	EDIT
Indicate end of row 3 data	⟨EOD⟩	x(4, 1, 1)

Example (Continued)

Procedure	Press	Display
Begin entry of row 4 data	28 ⟨ENT⟩	x(4, 1, 2)
	30 ⟨ENT⟩	x(4, 2, 1)
	29 ⟨ENT⟩	x(4, 2, 2)
	29 ⟨ENT⟩	x(4, 3, 1)
	30 ⟨ENT⟩	x(4, 3, 2)
	28 ⟨ENT⟩	EDIT
Indicate end of row 4 data	⟨EOD⟩	x(5, 1, 1)
Begin entry of row 5 data	30 ⟨ENT⟩	x(5, 1, 2)
Enter incorrect data	31 ⟨ENT⟩	x(5, 2, 1)
	25 ⟨ENT⟩	x(5, 2, 2)
	26 ⟨ENT⟩	x(5, 3, 1)
	34 ⟨ENT⟩	x(5, 3, 2)
	31 ⟨ENT⟩	EDIT

(continued)

Example (Continued)

Procedure	Press	Display	
Specify column and replication of incorrect data	1 [x~t] 2 ⟨j-k⟩	x =	31.
Enter correct data	30 ⟨ENT⟩	x =	30.
Indicate end of data	⟨EOD⟩	TWO-WAY (REPL)	
Select the results from the ANOVA table	⟨MSR⟩	MSR =	5.7
	[x~t]		22.8
	⟨dfR⟩	dfR =	4.
	⟨MSC⟩	MSC =	102.9
	[x~t]		205.8
	⟨dfC⟩	dfC =	2.
	⟨MSI⟩	MSI =	10.525
	[x~t]		84.2
	⟨dfI⟩	dfI =	8.
	⟨SST⟩	SST =	448.3
	⟨dfT⟩	dfT =	29.
	⟨MSE⟩	MSE =	9.033333333
	[x~t]		135.5
	⟨dfE⟩	dfE =	15.
	⟨FR⟩	FR =	0.63099631
	⟨FC⟩	FC =	11.39114391
	⟨FI⟩	FI =	1.165129151

Because FR is less than 3.06 and FI is less than 2.64, no evidence is found that would indicate a difference in machines or a difference due to an operator/machine interaction. Because FC is greater than 3.68, we reject the hypothesis for operators and conclude that there is a significant effect due to operators.

The procedure on the next page pools the error and interaction sum-of-squares to test for operator/machine interaction.

Example (Continued)

Procedure	Press		Display
Pool error and interaction sum-of-squares	⟨E + I⟩		0.
Select results of pooling error and interaction	⟨MSR⟩	MSR =	5.7
	$\boxed{x\sim t}$		22.8
	⟨dfR⟩	dfR =	4.
	⟨MSC⟩	MSC =	102.9
	$\boxed{x\sim t}$		205.8
	⟨dfC⟩	dfC =	2.
	⟨MSI⟩	MSI =	0.
	$\boxed{x\sim t}$		0.
	⟨dfI⟩	dfI =	0.
	⟨SST⟩	SST =	448.3
	⟨dfT⟩	dfT =	29.
	⟨MSE⟩	MSE =	9.552173913
	$\boxed{x\sim t}$		219.7
	⟨dfE⟩	dfE =	23.
	⟨FR⟩	FR =	.5967228038
	⟨FC⟩	FC =	10.77241693
	⟨FI⟩	FI =	0.

Conclusion

After pooling error and interaction, the conclusions are the same. However, pooling provides more degrees-of-freedom for error. Therefore, this is a more powerful test than the test using unpooled data. Note that we would have failed to reject the null hypothesis for operators at the 99% level (critical value FC = 8.65), but we can reject the same hypothesis using the replicated design at the 99% level.

Chapter 5: Regression Analysis

This chapter describes two programs which enable you to perform Multiple Linear Regression Analysis and Bivariate Data Transforms.

Table of Contents

Introduction

The two Regression Analysis programs assist you in forming mathematical models from observed data.

The Regression Menu

Select ⟨RGR⟩ from the **STATISTICS** menu to display the following menu.

```
 REGRESSION
MLT  BI
```

⟨MLT⟩	Multiple Regression
⟨BI⟩	Bivariate Models

The Bivariate Models program contains the following transformation models.

- ► The Power Model
- ► The Exponential Model
- ► The Reciprocal Model

The Multiple Regression Program

The Multiple Regression program assists you in finding an adequate model for a given a set of data consisting of more than one possible predictor and a response to those predictors.

Introduction to the Program

Given a set of data consisting of more than one possible predictor (x) and a response to those predictors (y), this program assists you in the selection of a ''best'' multiple-predictor regression model by supplying:

- The analysis of variance table
- The correlation matrix
- The least-squares estimates of the coefficients
- The standard errors of the coefficients
- The coefficient of determination (r^2)

Once all predictor data have been entered, you may select any ordered set of predictors to be included in the analysis.

References

Handbook of Tables for Probability and Statistics, edited by Robert C. Weast, Chemical Rubber Co., Cleveland, Ohio, 1968, pp. 58–63.

Applied Regression Analysis, N. R. Draper and H. Smith, John Wiley & Sons, New York, 1966, pp. 132–134.

Selecting the Program

To use the Multiple Regression program:

1. Select <RGR> from the **STATISTICS** menu.
2. Select <MLT> from the **REGRESSION** menu.

   The following display appears.

```
 MULTIPLE REGR
NEW  OLD
```

- If you want to enter new data, use the procedure on page 5–6 to define the data set.
- If you want to use data you have saved, proceed to ''Using Old Data'' on the next page.

Using Old Data

If you ran the Multiple Regression program previously and saved the summed data to a file or tape, you can use the data again if you retrieve it before entering the program.

1. Select ‹OLD› from the **MULTIPLE REGR** menu.

   The following display appears.

   ```
   MORE POINTS?
   NO  m   EOD
   ```

- ► If you do not want to add points, press ‹NO› and proceed to "Viewing the Sums" on page 5–14.

- ► If you want to add points to your data set, enter the number of points you want to add, press ‹m› and ‹EOD›. Then go to "Entering the First Observation" on page 5–10.

Defining the Data Set

To define the data set:

1. Select ⟨NEW⟩ from the **MULTIPLE REGR** menu.

   The following display appears.

   ```
    MULTIPLE REGR
   p   n   EOD       ESC
   ```

2. Enter the number of predictors and press ⟨p⟩.

3. Enter the total number of observations and press ⟨n⟩.

4. Press ⟨EOD⟩.

After the data set is defined, the following display appears.

```
 INPUT SUMS?
YES NO
```

- If your data is in point form, proceed to "Entering the First Observation" on page 5–10.

- If your data is in sum form, proceed to the next page.

Entering Sums

When you select ⟨YES⟩ from the **INPUT SUMS?** menu, the display below appears to enable you to enter your data in sum form.

```
 s ( 1 )
ENT
```

Enter the sum of the first predictor and press ⟨ENT⟩. The display below appears.

```
 s ( 2 )
ENT
```

Enter the sum of the second predictor and press ⟨ENT⟩.

The series of displays continues until you have entered a sum for each predictor.

After you enter the last sum, the display below appears, requesting a sum for the response.

```
 s ( 1 )
ENT
```

Enter the sum for the response and press ⟨ENT⟩.

The display shown on the next page then appears.

(continued)

Entering Sums (Continued)

The display below requests the sum for the product of the predictors.

```
 s ( 1,   1)
ENT
```

Enter the product of the first set of predictors and press <ENT>.

The series of displays continues until you have entered a product for each set of predictors.

After you enter the last product, the display below appears, requesting a sum for the first set of predictors and the associated response.

```
 s ( 1,   1)
ENT
```

Enter the sum for this product and press <ENT>.

The series of displays continues until you have entered a product for each set of predictors and response.

After you enter the last product, the display shown on the next page appears.

Entering Sums (Continued)

After you enter the last product, the display below appears, requesting a sum for the square of the responses.

```
 s ( 1,  1)
ENT
```

Enter the sum for this product and press ⟨ENT⟩.

The following display appears after all the sums have been entered.

```
 MORE POINTS?
NO   m    EOD
```

- If you do not want to add points, press ⟨NO⟩ and proceed to "Viewing the Sums" on page 5–14.
- If you want to add point data to your data set, enter the number of points you want to add, press ⟨m⟩ and ⟨EOD⟩. Then proceed to "Entering the First Observation" on the next page.

Entering the First Observation

To enter the data for the first observation:

1. Press ‹NO› to indicate that your data is in points.

   The display below appears, requesting data for the first predictor in the first observation.

   ```
    x(   1,    1)
   ENT
   ```

2. Enter the value for this predictor and press ‹ENT›.

3. Repeat this procedure, as prompted, to enter values for each of the predictors in the observation.

   After you enter the value for the last predictor in the first observation, the display below appears.

   ```
    y(   1)
   ENT
   ```

4. Enter the value of the response to the first set of predictors, press ‹ENT›, and go to the next page.

The Edit Menu

After you enter all data for the first observation, the program displays an **EDIT?** menu that enables you to change any of the values.

```
 EDIT?
YES  NO
```

- ► If you do not want to edit, press ⟨NO⟩ and go to the next page to enter the next observation.
- ► If you want to edit, press ⟨YES⟩ and use the procedure below.

Editing the First Observation

When you select ⟨YES⟩ from the **EDIT?** menu, the program repeats the same series of displays that you used to enter the first observation data.

```
 x(  1,  1)
ENT
```

- ► To display the value of the first predictor, press [CE].
- ► To accept the current value and advance to the next predictor, press ⟨ENT⟩.
- ► To edit the current value, enter the correct value and press ⟨ENT⟩.

When you press ⟨ENT⟩ to accept or edit the last value in this observation, the program returns to the **EDIT?** menu. Select ⟨NO⟩ and proceed to the next page.

Entering the Remaining Observations

After you enter the first observation and select ⟨NO⟩ from the **EDIT?** menu, the program prompts you to enter the first predictor of the second observation.

```
 x(  2, 1)
ENT
```

Use the same procedure you used to enter the first observation.

After you have entered all data for the second observation, proceed to the next page.

Editing the Remaining Observations

After you enter all data for the second observation, the program displays an **EDIT?** menu that enables you to change any of the values.

```
EDIT?
YES  NO
```

- If you do not want to edit, press ⟨NO⟩ and follow the prompts to enter the next observation.
- If you want to edit, press ⟨YES⟩ and use the same procedure you used to edit the first observation data.

The **EDIT?** menu appears after the data for each observation is entered.

When you have edited the last observation, select ⟨NO⟩ from the **EDIT?** menu and proceed to ''Viewing the Sums'' on the next page.

Viewing the Sums

After you enter all the data and select ‹NO› from the last **EDIT?** menu, the program enables you to see the sums of your data.

```
SHOW SUMS?
YES  NO
```

Note: If you want to save the sums for future use, you must do so now, before you select ‹NO› from the **SHOW SUMS?** menu. Refer to Chapter 1 of this guide for information on saving data.

- If you do not want to see the sums, press ‹NO› and proceed to "Viewing the Correlation Matrix" on page 5-16.
- If you want to see the sums, press ‹YES›. You must view them at this point in the program. They are replaced in the data registers by other values at a later time in the program.

If you press ‹YES›, the program displays the sum of the first predictors as shown below.

```
s ( 1) =        xxx
NXT
```

(where xxx is the value)

Note: The sum number may scroll off the display to make room for the entire value. You can use the [←] key to redisplay the sum.

Press ‹NXT› to view each successive sum. The sums are displayed in the order shown on the next page.

The Order of the Sums

When you select ‹YES› from the **SHOW SUMS?** menu, the sums are displayed in the order illustrated below as you press ‹NXT› to see each successive sum. The p represents the last predictor.

s(1) s(2) ⋮ s(p)	(The sum of the predictors)
s(y)	(The sum of the responses)
s(1, 1) s(1, 2) ⋮ s(1, p)	(The sum of the cross products of the first predictors with other predictors)
s(1, y)	(The sum of the cross product of the first predictors and the responses)
s(2, 2) s(2, 3) ⋮ ⋮ s(p, p)	(The sum of the cross products of the remaining predictors)
s(p, y)	(The sum of the cross product of the remaining predictors and the responses)
s(y, y)	(The sum of the squares of the responses)

After you have seen all the sums, proceed to ''Viewing the Correlation Matrix'' on the next page.

Viewing the Correlation Matrix

The display below appears either after you have seen the sums or after you select ⟨NO⟩ from the **SHOW SUMS?** menu.

```
SEE r MATRIX?
YES  NO
```

- If you do not want to see the correlation matrix, press ⟨NO⟩ and proceed to "Changing the Model" on page 5-18.
- If you want to see the correlation matrix, press ⟨YES⟩. You must view the correlations at this point in the program. They are replaced in the data registers by other values at a later time in the program.

If you press ⟨YES⟩, the program displays the correlation of the first two predictors as shown below.

```
r ( 1, 2) =    xxx
NXT
```

(where xxx is the value)

Note: The sum number may scroll off the display to make room for the entire value. You can use the [←] key to redisplay the sum.

Press ⟨NXT⟩ to view each successive correlation. The correlations are displayed in the order shown on the next page.

The Order of Correlation

When you select ⟨YES⟩ from the **SHOW SUMS?** menu, the correlations are displayed in the order illustrated below as you press ⟨NXT⟩ to see each successive sum. The p represents the last predictor.

r(1, 2)
r(1, 3)
⋮
r(1, p) — (The correlation between the first predictor and each other predictor)

r(1, y) — (The correlation between the first predictor and the response)

r(2, 3)
⋮
r(2, p) — (The correlation between the second predictor and each other predictor)

r(2, y) — (The correlation between the second predictor and the response)

r(3, p) — (The correlation between the third predictor and each other predictor)

r(3, y) — (The correlation between the third predictor and the response)

r(p, y) — (The correlation between the last predictor and the response)

After you have seen all the correlations, proceed to "Changing the Model" on the next page.

Changing the Model

The display below appears either after you have seen the correlation matrix or after you select ⟨NO⟩ from the **SEE r MATRIX?** menu.

```
CHANGE MODEL?
NO  p   EOD      ESC
```

- ► If you do not want to change the model, press ⟨NO⟩ and proceed to "Obtaining the Results" on page 5–20.
- ► If you want to change the model by using only a portion of the predictors or by changing the order of the predictors, enter the number of predictors, press ⟨p⟩, and press ⟨EOD⟩.

The display below asks you to specify the predictors you want to use in your new model.

```
p (1)
ENT
```

Specify the first predictor and press ⟨ENT⟩. The display below appears.

```
p (2)
ENT
```

Specify the next predictor and press ⟨ENT⟩.

After you have specified all the predictors, the **EDIT?** menu shown on the next page appears.

Editing the Specified Predictors

After you have entered the specified predictors, the program displays the **EDIT?** menu to enable you to change any of the entries.

```
 EDIT?
YES  NO
```

- If you do not want to edit the predictors, press <NO> and proceed to the next page.
- If you want to edit the predictors, press <YES>.

The program repeats the previous series of displays so that you can reenter the values.

```
 p (1)
ENT
```

- To display the value of the first predictor, press $\boxed{\text{CE}}$.
- To accept the current value and advance to the next predictor, press <ENT>.
- To edit the current value, enter the correct value and press <ENT>.

When you press <ENT> to accept or edit the last value in this observation, the program returns to the **EDIT?** menu. Select <NO> and proceed to the next page.

Obtaining the Results

You can obtain the results of the ANOVA by selecting the appropriate function keys from the menu below.

```
ANOVA TABLE
MSR  dfR  MSE  dfE  -->
```

⟨MSR⟩	Mean Square of Rows
⟨MSR⟩ $\boxed{x\sim t}$	Sum of Squares of Rows (SSR)
⟨dfR⟩	Degrees of Freedom of Rows
⟨MSE⟩	Mean Square of Error
⟨MSE⟩ $\boxed{x\sim t}$	Sum of Squares of Error (SSE)
⟨dfE⟩	Degrees of Freedom of Error
⟨-->⟩	Displays the selections shown below

```
ANOVA TABLE
F    SST  dfT  r^2  -->
```

⟨F⟩	F-statistic
⟨SST⟩	Total Sum of Squares
⟨dfT⟩	Total Degrees of Freedom
⟨r^2⟩	Coefficient of determination
⟨r^2⟩ $\boxed{x\sim t}$	Mean of y (MNy)
⟨-->⟩	Displays the menu shown on the next page

Obtaining the Results (Continued)

The display below appears when you select ‹-->› from the second **ANOVA** menu.

```
 SEQUENTIAL F's?
YES  NO  AOV       ESC
```

- If you do not want to see the sequential F's, press ‹NO› and proceed to the next page.
- If you want to return to the **ANOVA** menu, press ‹AOV› and return to page 5–20.
- If you want to see the sequential F's, press ‹YES›.

If you press ‹YES›, the program displays the first sequential F value as shown below.

```
 F 1 =          xxx
ENT
```

(where xxx is the value)

Note: The F number may scroll off the display to make room for the entire value. You can use the ← key to redisplay the number.

Press ‹NXT› to display each successive F value.

The display that appears after you have seen the sequential F's is shown on the next page.

(continued)

Obtaining the Results (Continued)

The display below appears either after you have seen all the sequential F's or after you select ⟨NO⟩ from the **SEQUENTIAL F's?** menu.

```
SEE COEFF?
YES  NO
```

- If you do not want to see the coefficients, press ⟨NO⟩ and proceed to the next page.
- If you want to see the coefficients, press ⟨YES⟩.

If you press ⟨YES⟩, the program displays the first coefficient as shown below.

```
b 1 =          xxx
ENT
```

(where xxx is the value)

Note: The coefficient number may scroll off the display to make room for the entire value. You can use the [←] key to redisplay the number.

Press ⟨NXT⟩ to display each successive coefficient. To display the standard error of a coefficient, press the [x⇌t] key while that coefficient is displayed.

The display that appears after you have seen the coefficients is shown on the next page.

Obtaining the Results (Continued)

The display shown below appears after you see the coefficients or after you select ⟨NO⟩ from the **SEE COEFFICIENTS?** menu.

```
PREDICT y?
YES  NO
```

- If you do not want to predict y values, press ⟨NO⟩. The program returns you to the **CHANGE MODEL?** menu. You can leave the Multiple Regression program by pressing ⟨ESC⟩ on that menu, or you can repeat the series of displays using the same or a new model.

- If you want to predict y values, press ⟨YES⟩. The display below appears, prompting you to enter an x value for each predictor in your model.

```
x ( 1 )
ENT
```

Enter a value and press ⟨ENT⟩ for each predictor.

After you enter values for all the predictors, the display below appears, showing the value of y for the x values you entered.

```
y =            xxx
NXT
```

(where xxx is the value)

Press ⟨NXT⟩ to return to the **PREDICT y?** menu.

Example: The Multiple Regression Program

The following example uses the Multiple Regression program to predict gas mileage for automobiles.

Example

In an attempt to determine a model to predict gas mileage for automobiles, the following data were collected.

x1	x2	x3	y
104	66	2	21.8
161	77	20	19.0
237	65	7	15.2
102	75	10	19.3
195	45	5	20.2
111	59	6	21.0
86	67	22	21.6
91	52	7	21.4
103	59	9	22.0
164	41	14	20.2
219	86	15	12.9

Where: x1 = Horsepower
x2 = Average speed
x3 = Elapsed time since engine tune (months)
y = Gasoline consumption

Determine the coefficients of a model which fits these data, and then use the model to predict the gas mileage of a 150-horsepower automobile at an average speed of 55 mph.

Procedure	Press	Display	
Select Regression from **STATISTICS** menu	⟨RGR⟩	REGRESSION	
Select the program	⟨MLT⟩	MULTIPLE REGR	
Indicate new data	⟨NEW⟩	MULTIPLE REGR	
Enter number of predictors	3 ⟨p⟩	p =	3.

Example (Continued)

Procedure	Press	Display
Enter number of observations	11 ⟨n⟩	n = 11.
Indicate end of data	⟨EOD⟩	INPUT SUMS?
Indicate new data	⟨NO⟩	x(1, 1)
Enter first value for predictor 1	104 ⟨ENT⟩	x(1, 2)
Enter first value for predictor 2	66 ⟨ENT⟩	x(1, 3)
Enter first value for predictor 3	2 ⟨ENT⟩	y(1)
Enter first observation	21.8 ⟨ENT⟩	EDIT?
Continue to next data set	⟨NO⟩	x(2, 1)
Begin entering second data set	161 ⟨ENT⟩	x(2, 2)
	77 ⟨ENT⟩	x(2, 3)
	20 ⟨ENT⟩	y(2)
	19.0 ⟨ENT⟩	EDIT?
Continue to next data set	⟨NO⟩	x(3, 1)

(continued)

Example (Continued)

Procedure	Press	Display
Enter third data set	237 <ENT>	x(3, 2)
	65 <ENT>	x(3, 3)
	7 <ENT>	y(3)
	15.2 <ENT>	EDIT?
Continue to next data set	<NO>	x(4, 1)
Enter fourth data set	102 <ENT>	x(4, 2)
	75 <ENT>	x(4, 3)
	10 <ENT>	y(4)
	19.3 <ENT>	EDIT?
Continue to next data set	<NO>	x(5, 1)
Enter fifth data set	195 <ENT>	x(5, 2)
	45 <ENT>	x(5, 3)
	5 <ENT>	y(5)
	20.2 <ENT>	EDIT?
Continue to next data set	<NO>	x(6, 1)

Example (continued)

Procedure	Press	Display
Enter sixth data set	111 ⟨ENT⟩	x(6, 2)
	59 ⟨ENT⟩	x(6, 3)
	6 ⟨ENT⟩	y(6)
	21.0 ⟨ENT⟩	EDIT?
Continue to next data set	⟨NO⟩	x(7, 1)
Enter seventh data set	86 ⟨ENT⟩	x(7, 2)
Enter incorrect value	76 ⟨ENT⟩	x(7, 3)
	22 ⟨ENT⟩	y(7)
	21.6 ⟨ENT⟩	EDIT?
Edit seventh data set	⟨YES⟩	x(7, 1)
Accept correct data point	⟨ENT⟩	x(7, 2)
Correct error entry	67 ⟨ENT⟩	x(7, 3)
Accept remaining data points	⟨ENT⟩	y(7)
	⟨ENT⟩	EDIT?

(Continued)

Example (Continued)

Procedure	Press	Display
Continue to next data set	⟨NO⟩	x(8, 1)
Enter eighth data set	91 ⟨ENT⟩	x(8, 2)
	52 ⟨ENT⟩	x(8, 3)
	7 ⟨ENT⟩	y(8)
	21.4 ⟨ENT⟩	EDIT?
Continue to next data set	⟨NO⟩	x(9, 1)
Enter ninth data set	103 ⟨ENT⟩	x(9, 2)
	59 ⟨ENT⟩	x(9, 3)
	9 ⟨ENT⟩	y(9)
	22.0 ⟨ENT⟩	EDIT?
Continue to next data set	⟨NO⟩	x(10, 1)
Enter tenth data set	164 ⟨ENT⟩	x(10, 2)
	41 ⟨ENT⟩	x(10, 3)
	14 ⟨ENT⟩	y(10)
	20.2 ⟨ENT⟩	EDIT?

Example (Continued)

Procedure	Press	Display	
Continue to next data set	⟨NO⟩	x(11, 1)	
Enter eleventh data set	219 ⟨ENT⟩	x(11, 2)	
	86 ⟨ENT⟩	x(11, 3)	
	15 ⟨ENT⟩	y(11)	
	12.9 ⟨ENT⟩	EDIT?	
Select results	⟨NO⟩	SHOW SUMS?	
	⟨NO⟩	SEE r MATRIX?	
	⟨NO⟩	CHANGE MODEL?	
	⟨NO⟩	ANOVA TABLE	
Select the ANOVA values in any order	⟨MSR⟩	MSR =	25.33270517
	$\boxed{x\sim t}$		75.9981155
	⟨dfR⟩	dfR =	3.
	⟨MSE⟩	MSE =	1.304425059
	$\boxed{x\sim t}$		9.130975413
	⟨dfE⟩	dfE =	7.
	⟨F⟩	F =	19.4205907
	⟨SST⟩	SST =	85.12909091
	⟨dfT⟩	dfT =	10.
	⟨r^2⟩	r^2 =	.8927396579
	$\boxed{x\sim t}$		19.50909091
Select Sequential F values	⟨-->⟩	SEQUENTIAL F's?	
	⟨YES⟩	F 1 =	44.173326

(continued)

Example (Continued)

Procedure	Press	Display	
Select next F value	⟨NXT⟩	F 2=	14.08106963
	⟨NXT⟩	F 3=	.0073764618
	⟨NXT⟩	SEQUENTIAL F's?	
	⟨NO⟩	SEE COEFF?	
Select Coefficients	⟨YES⟩	b 0=	31.69310598
	⟨NXT⟩ $\boxed{x\sim t}$	b 1=	– 0.041189595 .0066517673
	⟨NXT⟩ $\boxed{x\sim t}$	b 2=	– 0.100938979 .0288049036
	⟨NXT⟩ $\boxed{x\sim t}$	b 3=	.0052721412 0.061385103
	⟨NXT⟩	SEE COEFF?	
	⟨NO⟩	PREDICT y?	
	⟨NO⟩	CHANGE MODEL?	

The hypothesis that B3 = 0 can be tested against the alternative that B3 ≠ 0. F3 = .0073764618 with 1 and 7 degrees-of-freedom from the ANOVA table implies an alpha risk of rejection of approximately 93%. Therefore, we fail to reject the null hypothesis and decide to fit the simpler model $y = B_0 + B_1 x_1 + B_2 x_2$.

Example (Continued)

The following procedure changes the model to include only horsepower (x_1) and average speed (x_2).

Procedure	Press	Display	
Enter number of predictors	2 ⟨p⟩ ⟨EOD⟩	p(1)	
Specify first predictor	1 ⟨ENT⟩	p(2)	
Specify second predictor	2 ⟨ENT⟩	EDIT?	
Indicate predictors are defined	⟨NO⟩	ANOVA TABLE	
Select the ANOVA values in any order	⟨MSR⟩	MSR =	37.99424673
	[x~t]		75.98849345
	⟨dfR⟩	dfR =	2.
	⟨MSE⟩	MSE =	1.142574682
	[x~t]		9.140597455
	⟨dfE⟩	dfE =	8.
	⟨F⟩	F =	33.25318452
	⟨SST⟩	SST =	85.12909091
	⟨dfT⟩	dfT =	10.
	⟨r^2⟩	r^2 =	.8926266291
	[x~t]		19.50909091

(continued)

Example (Continued)

Procedure	Press	Display	
Select Sequential F values	⟨-->⟩	SEQUENTIAL F's?	
	⟨YES⟩	F 1=	50.43065831
	⟨NXT⟩	F 2=	16.07571074
	⟨NXT⟩	SEQUENTIAL F's?	
	⟨NO⟩	SEE COEFF?	
Select Coefficients	⟨YES⟩	b 0=	31.69239896
	⟨NXT⟩ $\boxed{x \sim t}$	b 1=	–.0412056288 .0062229838
	⟨NXT⟩ $\boxed{x \sim t}$	b 2=	–.0999999052 .0249410364
	⟨NXT⟩	SEE COEFF?	
	⟨NO⟩	PREDICT y?	
Predict y value	⟨YES⟩	x(1)	
	150 ⟨ENT⟩	x(2)	
	55 ⟨ENT⟩	y=	20.01155985

Conclusion

The estimated coefficients predict 20.01 mpg for a 150 hp automobile at an average speed of 55 mph.

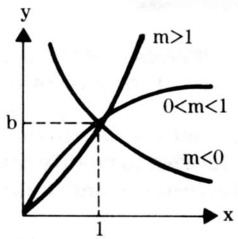
The Bivariate Models Program

The Bivariate Models program offers three ways to transform nonlinear data to a linear form. The programs then perform a linear regression and transform the coefficients back into the original nonlinear form.

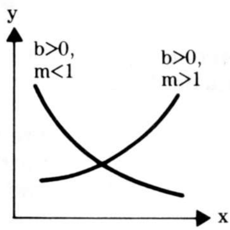
Introduction to the Program

The characteristics of your data should suggest a particular transformation model. This program performs power, exponential, and reciprocal transformations.

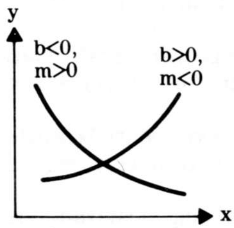
Given your set of nonlinear data and the model that appears to be most appropriate, this program provides the coefficient of determination (r^2), and the values of m and b for the selected model. You may then use the model to project a y value for a given x or an x value for a given y.



Power Curves



Exponential Curves



Reciprocal Curves

Note that these graphs represent x versus y, not the transformed data points.

The power model, $y = bx^m$, is appropriate when there is a linear relationship between log x and log y.

The exponential model, $y = bm^x$, is appropriate when there is a linear relationship between x and log y.

The reciprocal model, $y = (mx + b)^{-1}$, applies when there is a linear relationship between x and 1/y.

Reference

Applied Regression Analysis, N. R. Draper and H. Smith, John Wiley & Sons, New York, 1966, pp. 132–134.

Selecting the Program

To use the Bivariate Models program:

1. Select ⟨REG⟩ from the **STATISTICS** menu.

2. Select ⟨BI⟩ from the **REGRESSION** menu.

   The following display appears.

```
BIVARIATE MODELS
PWR EXP RCP CLR ESC
```

Clearing the Data Registers

Press ⟨CLR⟩ on the **BIVARIATE MODELS** menu to clear the data registers before entering a new data set.

Previously entered data remain in the data registers until cleared. If you wish to modify the existing data set and recalculate the results using the same model, do not press ⟨CLR⟩.

Selecting the Model

Select the model from the **BIVARIATE MODELS** menu.

⟨PWR⟩	The power transformation model: Transforms (x,y) → (lnx, lny)
⟨EXP⟩	The exponential transformation model: Transforms (x,y) → (x, lny)
⟨RCP⟩	The reciprocal transformation model: Transforms (x,y) → (x, 1/y)

The display shows the transformation process you select. (The power model is shown here as an example.)

```
(x,y)--> (lnx, lny)
ENT FRQ DEL EOD ESC
```

Entering a Data Pair

To enter a data pair:

1. Enter the value of x and press $\boxed{x{\sim}t}$.
2. Enter the value of y and press ‹ENT›.

Repeat the above steps to enter other data pairs.

Entering Identical Data Pairs at the Same Time

To enter multiple sets of identical data pairs:

1. Enter the frequency of occurrence and press ‹FRQ›.
2. Enter the value of x and press $\boxed{x{\sim}t}$.
3. Enter the value of y and press ‹ENT›.

Note: The program continues to use the last frequency entered. You must enter a new frequency to change it.

Deleting Incorrect Entries

To delete your most recent entry, press $\boxed{INV}$ ‹ENT›.

To delete an earlier entry, follow this procedure.

1. Enter the frequency of occurrence and press ‹FRQ›.
2. Enter the value of x as it was previously entered and press $\boxed{x{\sim}t}$.
3. Enter the value of y as it was previously entered and press ‹DEL›.

Calculating Results

When the data set is correctly entered, press ⟨EOD⟩ to calculate the results.

The following display appears.

```
BIVARIATE MODELS
m-b  r^2  y'  x'  ESC
```

⟨m-b⟩	m parameter of equation
⟨m-b⟩ $\boxed{x\sim t}$	b parameter of equation (b)
⟨r^2⟩	Coefficient of determination
⟨y'⟩	Projected y value (described below)
⟨x'⟩	Projected x value (described below)
⟨ESC⟩	Returns to the **BIVARIATE MODELS** menu

Projecting a y Value

To project a y value from the equation for the curve:

1. Enter the value for x at which you need y.
2. Press ⟨y'⟩.

Projecting an x Value

To project an x value from the equation for the curve:

1. Enter the value for y at which you need x.
2. Press ⟨x'⟩.

Notes:

1. The solution for x' given y' is based on the coefficients estimated with x as the predictor. This capability is only included as a convenience to the user and does not imply that the model may be used to predict x given y.

2. The coefficient of determination, r^2, is computed as the square of Pearson's product-moment coefficient of correlation for the transformed data and may not be valid for the untransformed data.

Example: The Bivariate Models Program

The following example illustrates the use of the Bivariate Models program to estimate the coefficients for a nonlinear model which can be transformed to linear form.

Example

The table below contains the United States census data for the years 1890 through 1970.

Year	Year Coded ($x = \text{Year} - 1900$)	Population (Millions)
1890	−10	62.9
1900	0	76.0
1910	10	92.0
1920	20	105.7
1930	30	122.8
1940	40	131.7
1950	50	150.7
1960	60	179.3
1970	70	203.2

Population growth is frequently exponential. If this is true for these data, a nonlinear model of the form $y = bm^x$ will fit these data well.

A plot of x versus log (y) for these data suggests a linear relationship, so the assumption of an exponential model appears to be valid.

Use the procedure on the next page to estimate the least-squares coefficients and calculate the coefficient of determination for this model. Then use the model to interpolate for the year 1947 ($x = 47$).

(continued)

Example (Continued)

Procedure	Press		Display
Select Regression from **STATISTICS** menu	⟨REG⟩	REGRESSION	
Select the program	⟨BI⟩	BIVARIATE	
Clear old data	⟨CLR⟩		0.
Select the Exponential model	⟨EXP⟩	(x,y)->(x,lny)	
Enter first data point	[+/–] 10 [x~t] 62.9 ⟨ENT⟩	n =	1.
Enter each data point	0 [x~t] 76.0 ⟨ENT⟩	n =	2.
	10 [x~t] 92.0 ⟨ENT⟩	n =	3.
	20 [x~t] 105.7 ⟨ENT⟩	n =	4.
	30 [x~t] 122.8 ⟨ENT⟩	n =	5.
	40 [x~t] 131.7 ⟨ENT⟩	n =	6.
	50 [x~t] 150.7 ⟨ENT⟩	n =	7.
	60 [x~t] 179.3 ⟨ENT⟩	n =	8.

Example (Continued)

Procedure	Press		Display
	70 $\boxed{x\sim t}$ 203.2 ‹ENT›	n =	9.
Indicate end of data entry	‹EOD›	BIVARIATE MODELS	
Estimate the least-squares coefficients	‹m–b› $\boxed{x\sim t}$	m =	1.01422098 76.63666071
Calculate coefficient of determination	‹r^2›	r^2 =	.9913769719

The value of r^2 is close to 1, which indicates that the exponential model fits these data well and will be useful for interpolation purposes.

The fitted model is $y = 76.63666071\ (1.01422098^x)$. To interpolate for the population in the year 1947, use this model as shown below.

Procedure	Press		Display
Enter the year coded	47 ‹y'›	y' =	148.8223986

Conclusion

The model estimates that the population of the United States in the year 1947 was approximately 148.8 million.

Chapter 6: Hypothesis Testing

This chapter contains two programs which enable you to test hypotheses concerning the difference between two population means and the mean difference between two populations.

Table of Contents

Introduction

The Hypothesis Testing programs include the Unpaired t-Test and the Paired t-Test programs.

The Test Menu

Select ⟨TST⟩ from the **STATISTICS** menu to display the following menu.

```
HYPOTHESIS TESTS
t    t-p
```

⟨t⟩ Unpaired t-Test

⟨t-p⟩ Paired t-Test

The Unpaired t-Test Program

The Unpaired t-Test program is used to test the null hypothesis that the means of two normal populations having equal variances are equal or differ by a constant. The test is based on two random independent samples, not necessarily of equal size, drawn from the two populations.

Introduction to the Program

Given the number of observations in each sample (nx and ny) and the data from these observations, this program calculates:

- Degrees of freedom
- Student's t-statistic
- F-statistic

Reference

Modern Elementary Statistics, John E. Freund, Prentice-Hall Inc., Englewood Cliffs, N. J., 1967, pp. 254–257.

Selecting the Program

To select the Unpaired t-Test program:

1. Select ⟨TST⟩ from the **STATISTICS** menu.

2. Select ⟨t⟩ from the **HYPOTHESIS TESTS** menu.

   The following display appears.

```
UNPAIRED t-TEST
nx   ny   EOD     ESC
```

Defining the Data Set

To define the data set:

1. Enter the number of observations in sample 1 and press ⟨nx⟩.

2. Enter the number of observations in sample 2 and press ⟨ny⟩.

3. Press ⟨EOD⟩.

The display shown on the following page requests the data for sample 1.

Entering Data (Sample 1)

The next series of displays requests data for a sample, beginning with observation 1 of the first sample (x).

```
 x (  1)
ENT
```

1. Enter the data for this observation and press ⟨ENT⟩.
2. Continue to enter data, as prompted, until all of the data for the sample are entered.

The Edit Display

After the last data entry for the sample is made, the **EDIT?** display shown below appears.

```
 EDIT?
i    ENT  EOD
```

- If you do not want to edit, press ⟨EOD⟩ and go to "Entering Data (Sample 2)" on the next page.
- If you want to edit, proceed to "Editing the Data" on the next page.

Editing the Data

To edit an incorrect entry:

1. Enter the observation number where the error occurs and press ⟨i⟩. The previously entered value is displayed.
2. Enter the correct value and press ⟨ENT⟩.
3. Repeat this procedure until all corrections are made.
4. When all entries are correct, press ⟨EOD⟩.

Entering Data (Sample 2)

When you press ⟨EOD⟩ on the **EDIT?** display after entering the sample 1 (x) data, the display begins prompting you to enter the sample 2 (y) data.

Enter the y values just as you entered the x values. The **EDIT?** display appears again after the data for the second sample are entered.

When you enter the last value and press ⟨EOD⟩ on the **EDIT?** menu, proceed to "Entering the Delta" on the next page.

Entering the Delta

When you complete data entry for the second sample and press ⟨EOD⟩, the following display appears requesting a delta value.

Note: The default delta in the program is 0. If your delta is 0, just press ⟨EOD⟩ when the **DELTA** display appears.

```
 DELTA
ENT  EOD              ESC
```

1. Enter the delta value from your hypothesis and press ⟨ENT⟩.

2. Press ⟨EOD⟩.

Obtaining the Results

The results of the Unpaired t-Test are obtained by selecting the appropriate function keys from the following menu.

```
UNPAIRED t-TEST
F    dfl  df2  -->  ESC
```

<F>	F-statistic
<df1>	Degrees of Freedom of Sample 1
<df2>	Degrees of Freedom of Sample 2
<-->>	Displays the additional selections shown below
<ESC>	Returns you to the **UNPAIRED t-TEST** menu

```
UNPAIRED t-TEST
t    dfT  -->        ESC
```

<t>	Student's t-statistic
<dfT>	Degrees of Freedom of Total
<-->>	Displays the previous selections shown above
<ESC>	Returns you to the **UNPAIRED t-TEST** menu

Example: The Unpaired t-Test Program

The following example illustrates the use of the Unpaired t-Test program in testing a hypothesis concerning population means.

Example

Evidence was found in the Kruskal-Wallis example (page 8–22) that there was a real difference in means between the test scores of students taught using teaching techniques 1 and 3. Using the data from the Kruskal-Wallis example, test the hypothesis (at the 95% level) that the variances of the two populations are equal using a critical F value of 2.79. If this hypothesis is not rejected, test the hypothesis that the mean of technique 1 is equal to the mean of technique 3 using a critical t value of ±2.069.

Class I 83, 82, 77, 83, 81, 92, 84, 85, 82, 80, 81, 79, 80

Class III 89, 81, 85, 91, 85, 90, 86, 92, 86, 94, 98, 82

Procedure	Press	Display	
Select Tests from the **STATISTICS** menu	⟨TST⟩	HYPOTHESIS TESTS	
Select the program	⟨t⟩	UNPAIRED t-TEST	
Enter # of observations in sample x (class 1)	13 ⟨nx⟩	nx =	13.
Enter # of observations in sample y (class 3)	12 ⟨ny⟩	ny =	12.

(continued)

Example (Continued)

Procedure	Press	Display
Indicate end of data	⟨EOD⟩	x(1)
Enter observation 1 for class 1	83 ⟨ENT⟩	x(2)
Enter observation 2 for class 1	82 ⟨ENT⟩	x(3)
Continue entering class 1 data	77 ⟨ENT⟩	x(4)
	83 ⟨ENT⟩	x(5)
	81 ⟨ENT⟩	x(6)
	92 ⟨ENT⟩	x(7)
	84 ⟨ENT⟩	x(8)
	85 ⟨ENT⟩	x(9)
	82 ⟨ENT⟩	x(10)
	80 ⟨ENT⟩	x(11)
	81 ⟨ENT⟩	x(12)
	79 ⟨ENT⟩	x(13)
	80 ⟨ENT⟩	EDIT?
Indicate end of class 1 data	⟨EOD⟩	y(1)
Begin entering class 3 data	89 ⟨ENT⟩	y(2)
	81 ⟨ENT⟩	y(3)
	85 ⟨ENT⟩	y(4)
	91 ⟨ENT⟩	y(5)
	85 ⟨ENT⟩	y(6)
Enter incorrect value	80 ⟨ENT⟩	y(7)
	86 ⟨ENT⟩	y(8)
	92 ⟨ENT⟩	y(9)
	86 ⟨ENT⟩	y(10)
	94 ⟨ENT⟩	y(11)
	98 ⟨ENT⟩	y(12)
	82 ⟨ENT⟩	EDIT?

Example (Continued)

Procedure	Press	Display	
Edit 6th point in class 3 data	6 ⟨i⟩	y =	80.
Enter correct value	90 ⟨ENT⟩	y =	90.
Indicate end of class 3 data	⟨EOD⟩	DELTA	
Indicate delta = 0	⟨EOD⟩	UNPAIRED t-TEST	
Select results of the t-test	⟨F⟩	F =	.5253045597
	⟨df1⟩	df1 =	12.
	⟨df2⟩	df2 =	11.
	⟨t⟩	t =	– 3.459182584
	⟨dfT⟩	dfT =	23.

Conclusion

Since the observed F is less than 2.79, we fail to reject the hypothesis of equal population variances. Then, since the observed t-statistic is less than –2.069, we conclude that there is a difference between the means of these two populations, which agrees with the Kruskal-Wallis result.

The Paired t-Test Program

The Paired t-Test program is designed to test the hypothesis that the mean difference of a set of paired data is zero or a constant.

Introduction to the Program

Given the number of subjects observed (n) and the data from these observations, this program calculates:

- Degrees of freedom
- Student's t-statistic

Reference

Statistics, An Introduction, Albert D. Rickmers and Hollis N. Todd, McGraw-Hill Book Company, New York, 1967, pp. 87–88.

Selecting the Program

To select the Paired t-Test program:

1. Select ⟨TST⟩ from the **STATISTICS** menu.

2. Select ⟨t-p⟩ from the **HYPOTHESIS TESTS** menu.

   The following display appears.

```
 PAIRED t-TEST
n    EOD            ESC
```

Defining the Data Set

To define the data set for the Paired t-Test program:

1. Enter the number of paired observations and press ⟨n⟩.

2. Press ⟨EOD⟩.

The display shown on the following page requests the observation data.

Entering the Data

After you press ‹EOD› on the **PAIRED t-TEST** menu, the display shown below appears to request the data for the first observation pair.

```
x,y (  1)
ENT
```

1. Enter the value of x for this data pair and press $\boxed{x{\sim}t}$.

2. Enter the value of y for this data pair and press ‹ENT›.

3. Repeat steps 1 and 2 to enter the remaining data pairs.

After you make the last data entry, the **EDIT** display appears.

The Edit Menu

The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.

```
EDIT
i    ENT  EOD
```

- If you do not want to edit, press ‹EOD› and proceed to "Entering the Delta" on the next page.

- If you want to edit, proceed to "Editing the Data" on the next page.

Editing the Data

To edit an incorrect entry:

1. Enter the observation number where the error occurs and press <i>. The x value originally entered is displayed.

2. If the x value is correct, press $\boxed{x\sim t}$. If the x value is incorrect, enter the correct value and press $\boxed{x\sim t}$. The y value you entered previously is displayed.

3. If the y value is correct, press <ENT>. If the y value is incorrect, enter the correct value and press <ENT>.

4. Repeat steps 1, 2, and 3 until all corrections are made.

5. Press <EOD>.

Entering the Delta

When you press <EOD>, the display that appears requests a delta value.

Note: The default delta in the program is 0. If your delta is 0, just press <EOD> when the **DELTA** display appears.

```
 DELTA
ENT  EOD            ESC
```

1. Enter the delta value from your hypothesis and press <ENT>.

2. Press <EOD>.

Obtaining the Results

The results of the Paired t-Test are obtained by selecting the appropriate function keys from the following menu.

```
PAIRED t-TEST
t    df              ESC
```

⟨t⟩	Student's t-statistic
⟨df⟩	Degrees of Freedom
⟨ESC⟩	Returns you to the **PAIRED t-TEST** menu

Example: The Paired t-Test Program

The following example uses the Paired t-Test program to test a hypothesis concerning the population differences between paired observations.

Example

Given the same data that is used in the Kendall's Tau example (page 8–42), test the hypothesis that the population difference between the grade a student makes in mathematics and the grade the same student makes in English is zero. Reject the null hypothesis (at the 99% level of significance) if the observed t-statistic falls outside of the range from −2.807 to 2.807.

Math	English	Math	English	Math	English
90	89	88	89	86	88
88	83	81	86	94	91
81	82	86	84	79	83
89	84	90	98	91	89
87	82	85	85	73	78
78	79	83	84	89	91
87	82	88	83	85	84
83	82	88	88	82	86

Run the Paired t-Test program using the above data.

Procedure	Press	Display	
Select Tests from the **STATISTICS** menu	⟨TST⟩	HYPOTHESIS TESTS	
Select the program	⟨t-p⟩	PAIRED t-TEST	
Enter # of observations in sample x	24 ⟨n⟩	n =	24.

(continued)

Example (Continued)

Procedure	Press	Display
Indicate end of data	⟨EOD⟩	x,y (1)
Begin entering data pairs	90 $\boxed{x\sim t}$ 89	
	⟨ENT⟩	x,y (2)
Continue entering data pairs	88 $\boxed{x\sim t}$ 83	
	⟨ENT⟩	x,y (3)
	81 $\boxed{x\sim t}$ 82	
	⟨ENT⟩	x,y (4)
	89 $\boxed{x\sim t}$ 84	
	⟨ENT⟩	x,y (5)
	87 $\boxed{x\sim t}$ 82	
	⟨ENT⟩	x,y (6)
	78 $\boxed{x\sim t}$ 79	
	⟨ENT⟩	x,y (7)
	87 $\boxed{x\sim t}$ 82	
	⟨ENT⟩	x,y (8)
	83 $\boxed{x\sim t}$ 82	
	⟨ENT⟩	x,y (9)
	88 $\boxed{x\sim t}$ 89	
	⟨ENT⟩	x,y (10)
	81 $\boxed{x\sim t}$ 86	
	⟨ENT⟩	x,y (11)
	86 $\boxed{x\sim t}$ 84	
	⟨ENT⟩	x,y (12)
	90 $\boxed{x\sim t}$ 98	
	⟨ENT⟩	x,y (13)
	85 $\boxed{x\sim t}$ 85	
	⟨ENT⟩	x,y (14)
	83 $\boxed{x\sim t}$ 84	
	⟨ENT⟩	x,y (15)

Example (Continued)

Procedure	Press	Display	
Continue entering data pairs	88 $\boxed{x\sim t}$ 83		
	⟨ENT⟩	x,y (16)	
	88 $\boxed{x\sim t}$ 88		
	⟨ENT⟩	x,y (17)	
	86 $\boxed{x\sim t}$ 88		
	⟨ENT⟩	x,y (18)	
	94 $\boxed{x\sim t}$ 91		
	⟨ENT⟩	x,y (19)	
	79 $\boxed{x\sim t}$ 83		
	⟨ENT⟩	x,y (20)	
	91 $\boxed{x\sim t}$ 89		
	⟨ENT⟩	x,y (21)	
	73 $\boxed{x\sim t}$ 78		
	⟨ENT⟩	x,y (22)	
	89 $\boxed{x\sim t}$		
Enter incorrect value	90 ⟨ENT⟩	x,y (23)	
	85 $\boxed{x\sim t}$ 84		
	⟨ENT⟩	x,y (24)	
Enter last data pair	82 $\boxed{x\sim t}$ 86		
	⟨ENT⟩	EDIT	
Edit 22nd data point	22 ⟨i⟩	x =	89.
Go to y value	$\boxed{x\sim t}$		90.
Enter correct y value	91 ⟨ENT⟩	x =	89.
Indicate end of data	⟨EOD⟩	DELTA	
Indicate no delta	⟨EOD⟩	PAIRED t-TEST	
Select results	⟨t⟩	t =	.0562427886
	⟨df⟩	df =	23.

Conclusion

Since $-2.807 < t < 2.807$, we fail to find evidence from this sample that there is any real difference between grades for an individual student.

Chapter 7: Histograms

The program described in this chapter enables you to construct or enter a histogram and to perform Goodness-of-Fit tests for any of six distributions.

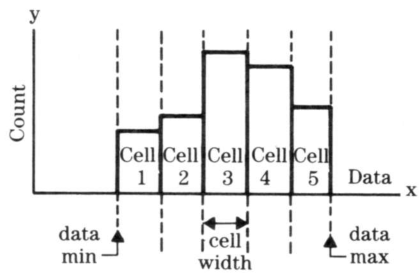
Table of Contents

The Histogram program enables you to perform two functions. You can first construct or enter a histogram. Then, you can perform Goodness-of-Fit tests on the histogram.

Introduction to the Program

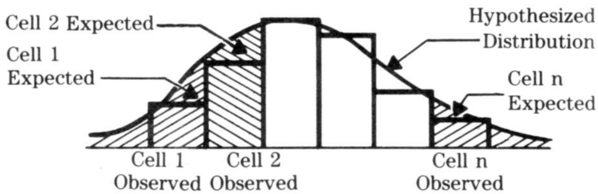
Given the definition of the histogram and the data points or cell frequencies, this program calculates:

- Cell frequency
- Number of data points
- Mean, variance
- 3rd central moment
- 4th central moment



In addition, you can test your histogram for Goodness-of-Fit against the Normal, Uniform, Weibull, Poisson, Binomial, and Exponential distributions.

This program uses the following rules.



- Data points which are less than the minimum cell boundary are included in the first cell.
- Data points which exceed the greatest cell are included in the last cell.
- Data points which fall on interior cell boundaries are included in the lower cell.

References

Handbook of Probability and Statistics, Richard S. Burington and Donald C. May Jr., Handbook Publishers Inc., Sandusky, Ohio, 1958, pp. 14–23.

Practical Nonparametric Statistics, 2nd Edition, W. J. Conover, John Wiley & Sons, New York, 1980, pp. 190–199.

Before Selecting the Program

If you want to use data you have previously saved, you must load the data into the data registers before selecting the Histogram program. Refer to Chapter 1 of this guide for information on loading old data.

The Histogram Menu

When you select ‹HST› from the **STATISTICS** menu, the menu below is displayed.

```
 HISTOGRAM
NEW  OLD
```

- If you want to construct a histogram using new data, press ‹NEW› and go to the next page.
- If you want to use data you have previously entered in the histogram program, press ‹OLD› and proceed.

Using Old Data

When you select ‹OLD› from the **HISTOGRAM** menu, the following menu appears to enable you to add points.

```
 ADD POINTS ?
YES  NO
```

- If you do not want to add points, press ‹NO› and proceed to ''Obtaining the Results'' on page 7–12.
- If you want to add points, proceed to ''Entering Additional Points'' on page 7–10.

After defining the histogram, you can enter data in either grouped or ungrouped form. The program then calculates the mean and moments for that histogram.

Defining the Histogram Parameters

If you select ⟨NEW⟩ from the **HISTOGRAM** menu, the following display appears requesting the definition of the histogram you want to construct.

```
 HISTOGRAM
#C  WID  MIN  EOD
```

To define the histogram parameters:

1. Enter the number of cells and press ⟨#C⟩.
2. If the cell width is constant, enter the cell width and press ⟨WID⟩.

   If the cell width is variable, do not enter a cell width at this time.
3. Enter the minimum data value and press ⟨MIN⟩.
4. Press ⟨EOD⟩. If you entered a cell width, go to "Selecting the Type of Data" on page 7-6. If not, proceed to "Defining Variable Cell Widths" below.

Defining Variable Cell Widths

If you did not enter a cell width above, the following display appears to enable you to define the cell widths.

```
 WIDTH (   1)
ENT
```

To define variable cell widths for your data:

1. Enter the first cell width and press ⟨ENT⟩.
2. Repeat step 1 for each cell as prompted and proceed to the next page.

The Edit Menu

After you enter all the cell widths, the program displays an **EDIT?** menu that enables you to change any of the values.

```
EDIT?
YES  NO
```

- If you do not want to edit, press ‹NO› and go to the next page.
- If you want to edit, press ‹YES› and use the procedure below.

Editing the Cell Widths

When you select ‹YES› from the **EDIT?** menu, the program displays the same menu that you used to enter the cell widths.

```
WIDTH (   1)
ENT
```

- To display the first cell width, press [CE].
- To accept the current value and proceed to the next cell width, press ‹ENT›.
- To edit the current value, enter the correct value and press ‹ENT›.

When you press ‹ENT› to accept or edit the value of the last cell width, the program returns to the **EDIT?** menu. Select ‹NO› and proceed to the next page.

Selecting the Type of Data

The next display requests the type of data you intend to enter.

```
 TYPE OF DATA
PTS  FRQ
```

- ► If you want to enter ungrouped data points, proceed to the next page.
- ► If you want to enter grouped data, proceed to ''Entering Grouped Data'' on page 7–8.

Entering Ungrouped Data

To enter ungrouped data:

1. Select <PTS> as the type of data you want to enter.

   The next series of displays requests the value for each observation, beginning with observation 1.

   ```
   x (   1)
   ENT DEL EOD
   ```

2. Enter the value for this observation and press <ENT>.

3. Repeat step 2 until all observations are entered.

If an error occurs during data entry, delete the value by entering the value as it was incorrectly entered and pressing <DEL>. Reenter the value correctly using the procedure outlined above.

After all data points have been correctly entered, press <EOD> and proceed to ''Obtaining the Results'' on page 7–12.

Entering Grouped Data

To enter grouped data:

1. Select ⟨FRQ⟩ as the type of data you want to enter.

   The next series of displays requests the frequency for each cell, beginning with cell 1.

   ```
    f (   1)
   ENT
   ```

2. Enter the frequency for this cell and press ⟨ENT⟩.

3. Repeat step 2 as prompted until all frequencies are entered.

The program then displays the menu shown on the following page.

The Edit Menu

After you enter all the frequencies, the program displays an **EDIT?** menu that enables you to change any of the values.

```
 EDIT?
YES  NO
```

- If you do not want to edit, press ⟨NO⟩ and go to the next page.
- If you want to edit, press ⟨YES⟩ and use the procedure below.

Editing the Frequencies

When you select ⟨YES⟩ from the **EDIT?** menu, the program displays the same menu that you used to enter the cell frequencies.

```
 f (  1)
ENT
```

- To display the first frequency, press **CE**.
- To accept the current value and proceed to the next frequency, press ⟨ENT⟩.
- To edit the current value, enter the correct value and press ⟨ENT⟩.

When you press ⟨ENT⟩ to accept or edit the value of the last frequency, the program returns to the **EDIT?** menu. Select ⟨NO⟩ and proceed to the next page.

Entering Additional Points

The display shown below enables you to add more points to your data.

```
ADD POINTS ?
YES  NO
```

- If you do not want to add points, press ⟨NO⟩ and proceed to the section entitled "Obtaining the Results" on page 7–12.
- If you want to add points, use the procedure below.

1. Select ⟨YES⟩ from the **ADD POINTS?** menu.

   The program displays a series of prompts requesting the value for each added point.

```
x (     )
ENT  DEL  EOD
```

2. Enter the value of the first point and press ⟨ENT⟩.
3. Repeat step 2 until all additional points are entered.

After you have entered all additional points, the program enables you to correct any errors you made when you entered the additional data. The procedure for making these corrections is provided on the next page.

Editing the Added Points

If you enter an erroneous value during data entry, the program enables you to edit the data using the same display you used to enter the data.

```
  x (    )
ENT  DEL  EOD
```

To correct an erroneous value you entered as an additional point:

1. Enter the value as it was incorrectly entered.
2. Press ‹DEL› to delete the erroneous value you identified in step 1.
3. Enter the value correctly and press ‹ENT›.
4. Repeat steps 1 through 3 to replace any other erroneous entry.

After all erroneous entries have been corrected, press ‹EOD› and proceed to ''Obtaining the Results'' on the next page.

Obtaining the Results

The results of the histogram are obtained by selecting the appropriate function keys from the following menu.

```
HISTOGRAM
FRQ  n   mn   -->  ESC
```

⟨FRQ⟩	Frequency of occurrence within each cell
⟨FRQ⟩ $\boxed{x{\sim}t}$	The cell value
⟨n⟩	Number of data points in the histogram
⟨mn⟩	Mean of the histogram
⟨-->⟩	Displays the selections shown below
⟨ESC⟩	Returns to the **HISTOGRAM** menu

```
HISTOGRAM
m2   m3   m4   FIT  -->
```

⟨m2⟩	Variance of the histogram
⟨m3⟩	Third moment of the histogram
⟨m3⟩ $\boxed{x{\sim}t}$	Skewness coefficient (a3)
⟨m4⟩	Fourth moment of the histogram
⟨m4⟩ $\boxed{x{\sim}t}$	Kurtosis coefficient (a4)
⟨FIT⟩	Selects the Goodness-of-Fit test (shown on next page)
⟨-->⟩	Displays the previous selections shown above

The Goodness-of-Fit Test

The Goodness-of-Fit test produces Chi-square, degrees of freedom, and the expected values. You may choose to provide the required parameters or you may elect to have them automatically estimated from the data.

Testing for Goodness-of-Fit

When you select ⟨FIT⟩ from the **HISTOGRAM** results menu, the following display appears.

```
GOODNESS-OF-FIT
NML  UNI  WEI  -->  ESC
```

⟨NML⟩	Normal distribution fit
⟨UNI⟩	Uniform distribution fit
⟨WEI⟩	Weibull distribution fit
⟨-->⟩	Displays the additional selections shown below
⟨ESC⟩	Returns to the **HISTOGRAM** menu

```
GOODNESS-OF-FIT
POI  BIN  EXP  -->
```

⟨POI⟩	Poisson distribution fit
⟨BIN⟩	Binomial distribution fit
⟨EXP⟩	Exponential distribution fit
⟨-->⟩	Displays the previous selections shown above

The Poisson and Binomial fits are available only when all cell boundaries have a fractional portion of .5 and the minimum cell boundary is at least -0.5.

The Test Method

To test against a distribution using parameters you specify, proceed to the next page. To test using estimated parameters, proceed to page 7–17.

Testing with Specified Parameters

You can perform the Goodness-of Fit test using specified parameters by making a selection from the distributions displayed on the **GOODNESS-OF-FIT** menu. When you make a selection, a menu is displayed to prompt you for the required parameters.

Note: The Uniform distribution does not require any inputs; therefore, no menu is displayed. To test against a Uniform distribution, press ‹UNI› and proceed to page 7–20.

For any other menu selection, one of the following menus will be displayed. Follow the steps that apply to your selection.

To test for fit against the Normal distribution:

```
 NORMAL
mn   EOD
```

1. Select ‹NML› from the **GOODNESS-OF-FIT** menu.

2. Enter the standard deviation and press $\boxed{x{\sim}t}$.

3. Enter the value of mn and press ‹mn›.

4. Press ‹EOD› and proceed to page 7–20.

Testing with Specified Parameters (Continued)

To test for fit against the Weibull distribution:

```
WEIBULL
b     EOD
```

1. Select ⟨WEI⟩ from the **GOODNESS-OF-FIT** menu.
2. Enter the value of c and press $\boxed{x \sim t}$.
3. Enter the value of b and press ⟨b⟩.
4. Press ⟨EOD⟩ and proceed to page 7–20.

To test for fit against the Poisson distribution:

```
POISSON
m     EOD
```

1. Select ⟨POI⟩ from the **GOODNESS-OF-FIT** menu.
2. Enter the value of m and press ⟨m⟩.
3. Press ⟨EOD⟩ and proceed to page 7–20.

(continued)

Testing with Specified Parameters (Continued)

To test for fit against the Binomial distribution:

```
BINOMIAL
n    p    EOD
```

1. Select ⟨BIN⟩ from the **GOODNESS-OF-FIT** menu.
2. Enter the value of n and press ⟨n⟩.
3. Enter the value of p and press ⟨p⟩.
4. Press ⟨EOD⟩ and proceed to page 7–20.

To test for fit against the Exponential distribution:

```
EXPONENTIAL
b    EOD
```

1. Select ⟨EXP⟩ from the **GOODNESS-OF-FIT** menu.
2. Enter the value of b and press ⟨b⟩.
3. Press ⟨EOD⟩ and proceed to page 7–20.

Testing with Estimated Parameters

You can perform the Goodness-of Fit test using parameters estimated from your histogram data by making a selection from the distributions displayed on the **GOODNESS-OF-FIT** menu. When you make a selection, a menu is displayed to prompt you for the required parameters.

Note: The Uniform distribution does not require any inputs; therefore, no menu is displayed. To test against the Uniform distribution, press ⟨UNI⟩ and proceed to page 7–20.

For any other menu selection, one of the following menus will be displayed. Follow the steps that apply to your selection.

To test for fit against the Normal distribution:

```
NORMAL
mn    EOD
```

1. Select ⟨NML⟩ from the **GOODNESS-OF-FIT** menu.
2. Press [INV].
3. Enter the standard deviation and press [x~t].
4. Enter the value of mn and press ⟨mn⟩.
5. Press ⟨EOD⟩ and proceed to page 7–20.

(continued)

Testing with Estimated Parameters (Continued)

To have the program generate the parameters required for the distribution, select the distribution from the **GOODNESS-OF-FIT** menu.

To test for fit against the Weibull distribution:

```
 WEIBULL
b     EOD
```

1. Select ⟨WEI⟩ from the **GOODNESS-OF-FIT** menu.
2. Press [INV].
3. Enter the value of c and press [x~t].
4. Enter the value of b and press ⟨b⟩.
5. Press ⟨EOD⟩ and proceed to page 7–20.

To test for fit against the Poisson distribution:

```
 POISSON
m     EOD
```

1. Select ⟨POI⟩ from the **GOODNESS-OF-FIT** menu.
2. Press [INV].
3. Enter the value of m and press ⟨m⟩.
4. Press ⟨EOD⟩ and proceed to page 7–20.

Testing with Estimated Parameters (Continued)

To test for fit against the Binomial distribution:

```
BINOMIAL
n    p    EOD
```

1. Select ⟨BIN⟩ from the **GOODNESS-OF-FIT** menu.
2. Press **[INV]**.
3. Enter the value of n and press ⟨n⟩.
4. Enter the value of p and press ⟨p⟩.
5. Press ⟨EOD⟩ and proceed to page 7–20.

To test for fit against the Exponential distribution:

```
EXPONENTIAL
b    EOD
```

1. Select ⟨EXP⟩ from the **GOODNESS-OF-FIT** menu.
2. Press **[INV]**.
3. Enter the value of b and press ⟨b⟩.
4. Press ⟨EOD⟩ and proceed to page 7–20.

Obtaining the Results

The results of the Goodness-of-Fit test are obtained by selecting the appropriate function keys.

```
GOODNESS-OF-FIT
CHI df  exp FIT ESC
```

⟨CHI⟩	Chi-square
⟨df⟩	Degrees of freedom
⟨exp⟩	Expected values (the expected values are displayed in a series of displays)
⟨FIT⟩	Returns to the **GOODNESS-OF-FIT** menu
⟨ESC⟩	Returns to the **HISTOGRAM** menu

Examples: The Histogram Program

The following examples illustrate the use of the Histogram program for two purposes. The first example uses the program in testing a sample of random numbers for uniformity. The second example uses the program in estimating parameters for a histogram.

Example 1

Given the following sample of 40 random numbers, construct a histogram and perform a Goodness-of-Fit test to test the hypothesis that they were drawn from a population that is uniformly distributed.

.04	.82	.56	.37	.98
.43	.22	.02	.41	.99
.38	.10	.98	.47	.67
.06	.61	.47	.57	.88
.74	.57	.82	.55	.45
.24	.94	.97	.04	.96
.52	.37	.26	.71	.51
.01	.51	.48	.72	.67

In order to perform a valid Goodness-of-Fit test, the expected value in every cell of a histogram must be at least 5. If a histogram is constructed for these data containing five cells of width 0.2 with a minimum cell boundary of 0, the expected value in each cell is 40/5 = 8 for an assumed uniform distribution.

Construct the histogram and test the hypothesis that this sample was drawn from a population which is uniformly distributed against the alternative that the population is not uniform. This Goodness-of-Fit test will be run at the 95% confidence level, so you will reject the null hypothesis if Chi-square exceeds 9.488.

Procedure	Press	Display	
Select the program from the **STATISTICS** menu	⟨HST⟩	HISTOGRAM	
Indicate new data	⟨NEW⟩	HISTOGRAM	
Enter # of cells	5 ⟨#C⟩	#C =	5.

(continued)

Example 1 (Continued)

Procedure	Press	Display	
Enter the cell width	.2 ⟨WID⟩	WID =	2.
Enter minimum value	0 ⟨MIN⟩	MIN =	0.
Indicate end of data	⟨EOD⟩	TYPE OF DATA	
Indicate ungrouped data	⟨PTS⟩	x(1)	
Begin entering data	.04 ⟨ENT⟩	x(2)	
	.43 ⟨ENT⟩	x(3)	
	.38 ⟨ENT⟩	x(4)	
	.06 ⟨ENT⟩	x(5)	
	.74 ⟨ENT⟩	x(6)	
	.24 ⟨ENT⟩	x(7)	
	.52 ⟨ENT⟩	x(8)	
	.01 ⟨ENT⟩	x(9)	
	.82 ⟨ENT⟩	x(10)	
	.22 ⟨ENT⟩	x(11)	
	.10 ⟨ENT⟩	x(12)	
	.61 ⟨ENT⟩	x(13)	
	.57 ⟨ENT⟩	x(14)	
	.94 ⟨ENT⟩	x(15)	
	.37 ⟨ENT⟩	x(16)	
	.51 ⟨ENT⟩	x(17)	
	.56 ⟨ENT⟩	x(18)	
	.02 ⟨ENT⟩	x(19)	
	.98 ⟨ENT⟩	x(20)	
	.47 ⟨ENT⟩	x(21)	
	.82 ⟨ENT⟩	x(22)	
	.97 ⟨ENT⟩	x(23)	
	.26 ⟨ENT⟩	x(24)	
	.48 ⟨ENT⟩	x(25)	
	.37 ⟨ENT⟩	x(26)	
	.41 ⟨ENT⟩	x(27)	
	.47 ⟨ENT⟩	x(28)	
	.57 ⟨ENT⟩	x(29)	

Example 1 (Continued)

Procedure	Press	Display	
	.55 ⟨ENT⟩	x(30)	
	.04 ⟨ENT⟩	x(31)	
	.71 ⟨ENT⟩	x(32)	
	.72 ⟨ENT⟩	x(33)	
	.98 ⟨ENT⟩	x(34)	
	.99 ⟨ENT⟩	x(35)	
Enter incorrect value	.76 ⟨ENT⟩	x(36)	
Delete incorrect value	.76 ⟨DEL⟩	x(35)	
Enter correct value	.67 ⟨ENT⟩	x(36)	
	.88 ⟨ENT⟩	x(37)	
	.45 ⟨ENT⟩	x(38)	
	.96 ⟨ENT⟩	x(39)	
	.51 ⟨ENT⟩	x(40)	
	.67 ⟨ENT⟩	x(41)	
Indicate end of data	⟨EOD⟩	HISTOGRAM	
Select the frequencies of each cell	⟨frq⟩	f 1=	6.
	$\boxed{x{\sim}t}$		0.1
	⟨NXT⟩	f 2=	6.
	$\boxed{x{\sim}t}$		0.3
	⟨NXT⟩	f 3=	13.
	$\boxed{x{\sim}t}$		0.5
	⟨NXT⟩	f 4=	6.
	$\boxed{x{\sim}t}$		0.7
	⟨NXT⟩	f 5=	9.
	$\boxed{x{\sim}t}$		0.9
	⟨NXT⟩	HISTOGRAM	
Select the remaining results	⟨n⟩	n =	40.
	⟨mn⟩	mn =	0.53
	⟨m2⟩	m2 =	0.0711
	⟨m3⟩	m3 =	– 0.001626
	$\boxed{x{\sim}t}$		–.0857661944
	⟨m4⟩	m4 =	0.00989037
	$\boxed{x{\sim}t}$		1.956470651

(continued)

Example 1 (Continued)

To determine if your data fit a Uniform distribution, use the Goodness-of-Fit test offered in the **HISTOGRAM** results menu.

Procedure	Press	Display	
Select Goodness-of-Fit from the results menu	⟨FIT⟩	GOODNESS-OF-FIT	
Select the distribution	⟨UNI⟩	GOODNESS-OF-FIT	
Select results of the Goodness-of-Fit	⟨CHI⟩ ⟨df⟩	CHI = df =	4.75 4.

Conclusion

Since 4.75 is less than 9.488, we fail to reject the null hypothesis and conclude that we have found no evidence that the population is not uniformly distributed between 0 and 1.

Example 2

Given the following histogram, test these data for Goodness-of-Fit to the Weibull distribution using the parameters estimated from the data. If the Weibull fits these data adequately, use the estimated parameters in the examples for the Weibull distribution program. The 95% Chi-square critical value is 11.07.

Weeks Elapsed Since Shipment	Number of Defective Items Returned
5	12
10	13
15	24
20	16
25	10
30	7
35	5
40	13

Follow the procedure below to perform the Goodness-of-Fit test.

Procedure	Press	Display	
Select the program from the **STATISTICS** menu	⟨HST⟩	HISTOGRAM	
Indicate new data	⟨NEW⟩	HISTOGRAM	
Enter # of cells	8 ⟨#C⟩	#C =	8.
Enter the cell width	5 ⟨WID⟩	WID =	5.
Enter minimum value	0 ⟨MIN⟩	MIN =	0.
Indicate end of data	⟨EOD⟩	TYPE OF DATA	
Indicate grouped data	⟨FRQ⟩	f(1)	

(continued)

Example 2 (Continued)

Procedure	Press	Display	
Begin entering data	12 ⟨ENT⟩	f(2)	
	13 ⟨ENT⟩	f(3)	
	24 ⟨ENT⟩	f(4)	
	16 ⟨ENT⟩	f(5)	
	10 ⟨ENT⟩	f(6)	
	7 ⟨ENT⟩	f(7)	
	5 ⟨ENT⟩	f(8)	
	13 ⟨ENT⟩	EDIT?	
Indicate no edit	⟨NO⟩	ADD POINTS?	
Indicate end of data	⟨NO⟩	HISTOGRAM	
Select the results	⟨n⟩	n =	100.
	⟨mn⟩	mn =	17.75
	⟨m2⟩	m2 =	118.6875
	⟨m3⟩	m3 =	637.21875
	$\boxed{x\sim t}$		.4928117717
	⟨m4⟩	m4 =	30937.01953
	$\boxed{x\sim t}$		2.196182908

Example 2 (Continued)

To determine if your data fit a Weibull distribution, use the Goodness-of-Fit test offered in the **HISTOGRAM** results menu.

Procedure	Press	Display	
Select Goodness-of-Fit from the results menu	⟨FIT⟩	GOODNESS-OF-FIT	
Select the distribution	⟨WEI⟩	WEIBULL	
Select estimated parameters	INV ⟨b⟩	b =	19.44126746
	x~t		1.298078809
Select Goodness-of-Fit	⟨EOD⟩	GOODNESS-OF-FIT	
Select results of the Goodness-of-Fit	⟨CHI⟩	CHI =	6.632402891
	⟨df⟩	df =	5.
	⟨exp⟩	e 1 =	15.76622712
	⟨NXT⟩	e 2 =	18.65401654
	⟨NXT⟩	e 3 =	16.61923911
	⟨NXT⟩	e 4 =	13.5253305
	⟨NXT⟩	e 5 =	10.42838605
	⟨NXT⟩	e 6 =	7.735399695
	⟨NXT⟩	e 7 =	5.566253775
	⟨NXT⟩	e 8 =	11.70514722

Conclusion

Since 6.63 is less than 11.07, we conclude that these data fit the Weibull adequately, so the estimated parameters may be used in the Weibull distribution examples.

Chapter 8: Nonparametric Statistics

This chapter describes the eight nonparametric statistics programs included in the Statistics Library.

Table of Contents

The eight nonparametric statistics programs in this chapter serve a broad range of statistical applications.

The Nonparametric Menu

Select ⟨NPS⟩ from the **STATISTICS** menu to display the following menu.

```
 NONPARAMETRIC
FMN  RUN  K-W  RxC  -->
```

⟨FMN⟩	Friedman Test
⟨RUN⟩	Wald-Wolfowitz Runs Test
⟨K-W⟩	Kruskal-Wallis Test
⟨R x C⟩	Rows and Columns Contingency Table
⟨-->⟩	Displays the additional selections shown below

```
 NONPARAMETRIC
TOL  TAU  RNK  M-W  -->
```

⟨TOL⟩	Tolerance Limits
⟨TAU⟩	Kendall's Tau
⟨RNK⟩	Rank Function
⟨M-W⟩	Mann-Whitney Test
⟨-->⟩	Displays the previous selections shown above

The Friedman Test Program

The Friedman Test is similar to the Two-Way Analysis of Variance but does not assume population normality.

Introduction to the Program

Given the number of blocks, number of treatments, and the response to each treatment, this program calculates:

- F-statistic
- Degrees of freedom

In addition, the Friedman Test program enables you to perform treatment tests using your data. The treatment test calculates:

- Student's t-statistic
- Degrees of freedom

The Friedman Test uses the randomized block design, where the treatments are assumed to be random within each block.

		Treatment a	b	c	d	e
Block	A	3	1	2	5	4
	B	4	3	1	2	5
	C	2	5	3	1	4

The program generates results based on ranked data. You may enter your data and allow the program to rank it for you, or you may enter a ranking that is representative of your data.

Reference

Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, John Wiley & Sons Inc., New York, 1980, pp. 299–305.

Selecting the Program

To select the Friedman Test program:

1. Select <NPS> from the **STATISTICS** menu.

2. Select <FMN> from the **NONPARAMETRICS** menu.

   The following display appears.

```
 FRIEDMAN TEST
TRT  BLK  EOD        ESC
```

Defining the Data Set

To define the data set:

1. Enter the number of treatments and press <TRT>.

2. Enter the number of blocks per treatment and press <BLK>.

3. Press <EOD>.

Entering the Data

The next series of displays requests the data for each treatment, beginning with block 1, treatment 1.

```
 x (  1,   1)
ENT
```

1. Enter the data for this treatment and press <ENT>.

2. Repeat step 1 until all data for this block are entered.

   The **EDIT** display shown on the next page appears when all the treatments for a block are entered.

Entering the Data (Continued)

The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.

```
EDIT
j     ENT   EOD
```

If the entries are correct, proceed to step 4 of the editing procedure given below.

Editing the Data

To edit an incorrect entry:

1. Specify the number of the treatment in error and press ⟨j⟩. The data you entered previously is displayed.

2. Enter the correct data and press ⟨ENT⟩.

3. Repeat steps 1 and 2 until all corrections are made.

4. Press ⟨EOD⟩.

   The data entry procedure is repeated for each block. The **EDIT** display appears after each block is entered.

   When you complete editing the last block and press ⟨EOD⟩, the display shown on the following page appears.

Obtaining the Results

Select the appropriate function key from the following menu to obtain the results.

```
FRIEDMAN TEST
F   df1  df2  TRT  ESC
```

⟨F⟩	F-statistic
⟨df1⟩	Degrees of Freedom of numerator for F-statistic
⟨df2⟩	Degrees of Freedom of denominator for F-statistic
⟨TRT⟩	Selects the **TREATMENT TEST** menu (shown on the next page)
⟨ESC⟩	Returns to the **NONPARAMETRICS** menu

The Treatment Test

If the F-statistic is significant when you perform the Friedman Test, you can use the Treatment Test to compare any two of the treatments.

Using the Treatment Test

When you select ⟨TRT⟩ from the **FRIEDMAN TEST** results menu, the menu below is displayed.

```
 TREATMENT TEST
T1   T2   EOD        ESC
```

To perform the Treatment Test using any two treatments used in the Friedman Test:

1. Enter the number of the treatment you want to designate as treatment 1 and press ⟨T1⟩.

2. Enter the number of the treatment you want to designate as treatment 2 and press ⟨T2⟩.

3. Press ⟨EOD⟩ to indicate the end of treatment data.

   The results menu shown on the next page is displayed. (The t-statistic is also displayed.)

Obtaining the Results

Select the appropriate function key from the menu below to obtain the results of the Treatment Test.

```
t    df    -->
```

⟨t⟩ t-statistic

⟨df⟩ Degrees of freedom

⟨-->⟩ Returns to the **TREATMENT TEST** menu (shown on the previous page)

To perform the Treatment Test using two different treatments:

1. Press ⟨-->⟩. The **TREATMENT TEST** menu is displayed.
2. Perform steps 1, 2, and 3 on page 8–7.
3. When you complete the treatment tests you want to run, press ⟨ESC⟩ on the **TREATMENT TEST** menu to return to the **FRIEDMAN TEST** menu.

Example: The Friedman Test Program

The following example uses the Friedman Test program to perform a nonparametric analysis of a randomized complete block design experiment.

Example

Using the same data that was used in the Two-Way Analysis of Variance example (page 4–17), test the hypothesis that there is no difference in the average number of defectives produced by the three operators against the alternative that at least one of the operators produces more defectives. Use a critical F value of 4.46 for a 95% level test.

If the null hypothesis is rejected, compare all three pairs of operators to determine which one(s) tend to produce a different number of defectives. Use critical t values of ±2.306 for a 95% level test.

Procedure	Press	Display	
Select Nonparametrics from **STATISTICS** menu	⟨NPS⟩	NONPARAMETRIC	
Select the program from the **NPS** menu	⟨FMN⟩	FRIEDMAN TEST	
Enter the number of treatments	3 ⟨TRT⟩	TRT =	3.
Enter the number of blocks	5 ⟨BLK⟩	BLK =	5.
Indicate end of data	⟨EOD⟩	x(1, 1)	
Begin entry of block 1 data	34 ⟨ENT⟩	x(1, 2)	

(continued)

Example (Continued)

Procedure	Press	Display
	28 ⟨ENT⟩	x(1, 3)
	33 ⟨ENT⟩	EDIT
Indicate end of block 1 data	⟨EOD⟩	x(2, 1)
Begin entry of block 2 data	30 ⟨ENT⟩	x(2, 2)
	24 ⟨ENT⟩	x(2, 3)
	35 ⟨ENT⟩	EDIT
Indicate end of block 2 data	⟨EOD⟩	x(3, 1)
Begin entering block 3 data	27 ⟨ENT⟩	x(3, 2)
	20 ⟨ENT⟩	x(3, 3)
	40 ⟨ENT⟩	EDIT
Indicate end of block 3 data	⟨EOD⟩	x(4, 1)
Begin entry of block 4 data	28 ⟨ENT⟩	x(4, 2)

Example (Continued)

Procedure	Press	Display	
Enter incorrect value	28 ⟨ENT⟩	x(4, 3)	
	30 ⟨ENT⟩	EDIT	
Specify treatment where error occurred	2 ⟨j⟩	x =	28.
Enter correct value	29 ⟨ENT⟩	x =	29.
Indicate end of block 4 data	⟨EOD⟩	x(5, 1)	
Begin entry of block 5 data	30 ⟨ENT⟩	x(5, 2)	
	25 ⟨ENT⟩	x(5, 3)	
	34 ⟨ENT⟩	EDIT	
Indicate end of data	⟨EOD⟩	FRIEDMAN TEST	
Select test results	⟨F⟩ ⟨df1⟩ ⟨df2⟩	F = df1 = df2 =	7.111111111 2. 8.

Because the observed F is greater than the critical F value, the null hypothesis is rejected and we conclude that there is evidence that the operators do not produce the same average number of defectives.

To determine which operator(s) produce a different number of defectives, perform the Treatment Test illustrated on the next page.

(continued)

Example (Continued)

Procedure	Press	Display	
Select Treatment Test from the results menu	⟨TRT⟩	TREATMENT TEST	
Enter number of first treatment to be compared	1 ⟨T1⟩	T1 =	1.
Enter number of second treatment to be compared	2 ⟨T2⟩	T2 =	2.
Indicate end of data and show t-statistic	⟨EOD⟩		1.885618083
Show degrees of freedom	⟨df⟩	df =	8.
Enter another set of treatments to be compared	⟨-->⟩ 1 ⟨T1⟩ 3 ⟨T2⟩	TREATMENT TEST T1 = T2 =	 1. 3.
Indicate end of data and show t-statistic	⟨EOD⟩		1.885618083
Show degrees of freedom	⟨df⟩	df =	8.

Example (Continued)

Procedure	Press	Display	
Enter another set of treatments to be compared	⟨-->⟩	TREATMENT TEST	
	2 ⟨T1⟩	T1 =	2.
	3 ⟨T2⟩	T2 =	3.
Indicate end of data and show t-statistic	⟨EOD⟩		3.771236166
Show degrees of freedom	⟨df⟩	df =	8.

Conclusion

The treatment tests indicate that there is a significant difference between operators 2 and 3.

The Runs Test Program

The Wald-Wolfowitz Runs Test program is used to check for randomness by testing the hypothesis that all outcomes are equally likely.

Introduction to the Program

The data for this program are generated through a sequence of observations that are of two different types. Given the number of observations of each type (n and m) and the number of runs in the sequence (#r), this program calculates:

- Mean of the number of runs (MNr)
- Standard deviation of the number of runs (Sr)
- Normal deviate associated with the observed number of runs (zr)

A run in an observation sequence begins when data switches types, or at the beginning of the data set. For example, the data set MMMMMNNMMM has three runs, while the sequence MNMNMNMNNMM has nine runs.

Reference

Modern Elementary Statistics, John E. Freund, Prentice-Hall Inc., Englewood Cliffs, N. J., 1967, pp. 326–328.

Selecting the Program

To select the Runs Test program:

1. Select ⟨NPS⟩ from the **STATISTICS** menu.

2. Select ⟨RUN⟩ from the **NONPARAMETRICS** menu.

   The following display appears.

```
 RUNS TEST
n1   n2   #r   EOD  ESC
```

Entering the Data

To enter the data into the program:

1. Enter the number of observations of the first type and press ⟨n1⟩.

2. Enter the number of observations of the second type and press ⟨n2⟩.

3. Enter the number of runs and press ⟨#r⟩.

4. Press ⟨EOD⟩.

Obtaining the Results

Select the appropriate function keys from the following menu to obtain the results.

```
 RUNS TEST
MNr  Sr   zr        ESC
```

⟨MNr⟩	The mean of the number of runs
⟨Sr⟩	The standard deviation of the number of runs
⟨zr⟩	The normal deviate of the number of runs
⟨ESC⟩	Returns to the **NONPARAMETRICS** menu

Example: The Runs Test Program

The following example uses the Runs Test program to test a sample of numbers for randomness.

Example

In the sample of 40 numbers used in example 1 of the Histogram program (page 7–21), there are 18 numbers less than .5, 22 numbers greater than .5, and the sequence contains 20 runs. Determine whether this observed number of runs supports the hypothesis that this sample was randomly drawn from a uniformly distributed population. Test at the 95% confidence level and reject the null hypothesis if either zr > 1.96 or zr < −1.96.

Procedure	Press	Display	
Select the program from the **STATISTICS** menu	⟨NPS⟩	NONPARAMETRICS	
Select the program from the **NPS** menu	⟨RUN⟩	RUNS TEST	
Enter the number of type 1 observations	18 ⟨n1⟩	n1 =	18.
Enter the number of type 2 observations	22 ⟨n2⟩	n2 =	22.
Enter number of runs	20 ⟨#r⟩	#r =	20.
Indicate end of data	⟨EOD⟩	RUNS TEST	
Select results of the test	⟨MNr⟩ ⟨Sr⟩ ⟨zr⟩	MNr = Sr = zr =	20.8 3.089436095 −.2589469325

Conclusion

Since −1.96 < zr < 1.96, we fail to reject the null hypothesis. That is, no evidence was found that these numbers were not randomly drawn.

The Kruskal-Wallis Test Program

The Kruskal-Wallis Test is similar to the One-Way Analysis of Variance except it does not require the assumption of population normality.

Introduction to the Program

Given the number of samples (#s), the number of entries in each sample (n), and the results of the observations (x), this program calculates:

- Chi-square
- degrees of freedom

	Observations				
Sample 1	x1,1	x1,2	x1,3	x1,4	x1,5
2	x2,1	x2,2	x2,3	x2,4	x2,5
3	x3,1	x3,2	x3,3	x3,4	

Reference

Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, John Wiley & Sons Inc., New York, 1980, pp. 229–327.

Selecting the Program

To use the Kruskal-Wallis Test program:

1. Select ⟨NPS⟩ from the **STATISTICS** menu.
2. Select ⟨K-W⟩ from the **NONPARAMETRICS** menu.

   The following display appears.

   ```
    KRUSKAL-WALLIS
   #s  EOD              ESC
   ```

Defining the Matrix

To define the matrix:

1. Enter the number of samples and press ⟨#s⟩.
2. Press ⟨EOD⟩.

   The next series of displays requests the number of entries in each sample, beginning with sample 1.

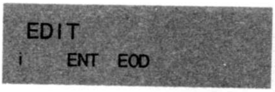
   ```
    n (   1)
   ENT
   ```

3. Enter the number of observations in the sample and press ⟨ENT⟩.
4. Repeat step 3 until the number of observations for each sample is entered.

   The **EDIT** display shown on the next page appears when all the observations for a group are entered.

Defining the Matrix (Continued)

The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.



If the entries are correct, proceed to step 4 of the editing procedure given below.

Editing the Matrix

To edit an incorrect entry:

1. Specify the sample where the error occurred and press <i>. The value you entered is displayed.

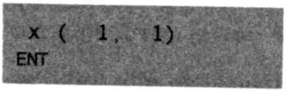
2. Enter the correct number and press <ENT>.

3. Repeat steps 1 and 2 until all corrections are made.

4. Press <EOD>.

Entering the Data

The next series of displays requests the data for each observation in a sample, beginning with sample 1, observation 1.



1. Enter the value for this observation and press <ENT>.

2. Repeat step 1 until all observations for this sample are entered.

   The **EDIT** display shown on the next page appears when all the observations for a sample are entered.

(continued)

Entering the Data (Continued)

The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.

```
EDIT
j    ENT  EOD
```

If the entries are correct, proceed to step 4 of the editing procedure given below.

Editing the Data

To edit an incorrect entry:

1. Specify the number of the observation in error and press ⟨j⟩. The value you entered previously is displayed.

2. Enter the correct value and press ⟨ENT⟩.

3. Repeat steps 1 and 2 until all corrections are made.

4. Press ⟨EOD⟩.

   The data entry procedure is repeated for each sample. The **EDIT** display appears after the data in each sample are entered. When all data are entered, the results are calculated.

   When you complete editing the last sample and press ⟨EOD⟩, the Kruskal-Wallis test is performed and the display shown on the following page appears.

Obtaining the Results

Select the appropriate function key to display the results.

```
KRUSKAL-WALLIS
CHI  df  POP        ESC
```

⟨CHI⟩	Chi-square
⟨df⟩	Degrees of freedom
⟨POP⟩	Selects the **POPULATION TEST** menu shown below
⟨ESC⟩	Returns to the **KRUSKAL-WALLIS** menu

```
POPULATION TEST
P1  P2  EOD        ESC
```

Using the Population Test

If the value of Chi-square is significant, you can use the Population Test to compare the means of any two of the sample populations.

1. Enter the number of the sample you want to designate as population 1 and press ⟨P1⟩.

2. Enter the number of the sample you want to designate as population 2 and press ⟨P2⟩.

3. Press ⟨EOD⟩ to indicate the end of population data.

   The results of the Population Test are displayed.

4. Press ⟨ESC⟩ to return to the **POPULATION TEST** menu.

Example: The Kruskal-Wallis Test Program

The following example uses the Kruskal-Wallis Test program to evaluate the results of three different teaching techniques.

Example

Three classes of students were taught the same subject using three different techniques. At semester end, all students were given the same comprehensive final examination. The results of the final examination are as follows.

Class I 83, 82, 77, 83, 81, 92, 84, 85, 82, 80, 81, 79, 80

Class II 84, 85, 74, 88, 69, 84, 82, 81

Class III 89, 81, 85, 91, 85, 90, 86, 92, 86, 94, 98, 82

Test the hypothesis that all teaching techniques are equally effective against the alternative that at least one of the techniques is more effective. Run the test at the 95% level and therefore use a critical Chi-square value of 5.991.

Procedure	Press	Display	
Select Nonparametrics from the **STATISTICS** menu	⟨NPS⟩	NONPARAMETRICS	
Select the program from the **NPS** menu	⟨K-W⟩	KRUSKAL-WALLIS	
Enter the number of samples	3 ⟨#s⟩	#s =	3.

Example (Continued)

Procedure	Press	Display
Indicate end of data	⟨EOD⟩	n(1)
Enter the number of sample 1 observations	13 ⟨ENT⟩	n(2)
Enter the number of sample 2 observations	8 ⟨ENT⟩	n(3)
Enter the number of sample 3 observations	12 ⟨ENT⟩	EDIT
Indicate end of data	⟨EOD⟩	x(1, 1)
Begin entering values for sample 1 data	83 ⟨ENT⟩	x(1, 2)
	82 ⟨ENT⟩	x(1, 3)
	77 ⟨ENT⟩	x(1, 4)
	83 ⟨ENT⟩	x(1, 5)
	81 ⟨ENT⟩	x(1, 6)
	92 ⟨ENT⟩	x(1, 7)
	84 ⟨ENT⟩	x(1, 8)
	85 ⟨ENT⟩	x(1, 9)
	82 ⟨ENT⟩	x(1, 10)
	80 ⟨ENT⟩	x(1, 11)
	81 ⟨ENT⟩	x(1, 12)

(continued)

Example (Continued)

Procedure	Press	Display
	79 ⟨ENT⟩	x(1, 13)
	80 ⟨ENT⟩	EDIT
Indicate end of sample 1 data	⟨EOD⟩	x(2, 1)
Begin entering sample 2 data	84 ⟨ENT⟩	x(2, 2)
	85 ⟨ENT⟩	x(2, 3)
	74 ⟨ENT⟩	x(2, 4)
	88 ⟨ENT⟩	x(2, 5)
	69 ⟨ENT⟩	x(2, 6)
	84 ⟨ENT⟩	x(2, 7)
	82 ⟨ENT⟩	x(2, 8)
	81 ⟨ENT⟩	EDIT
Indicate end of sample 2 data	⟨EOD⟩	x(3, 1)
Begin entering sample 3 data	89 ⟨ENT⟩	x(3, 2)
	81 ⟨ENT⟩	x(3, 3)
	85 ⟨ENT⟩	x(3, 4)

Example (Continued)

Procedure	Press	Display	
	91 <ENT>	x(3, 5)	
	85 <ENT>	x(3, 6)	
	90 <ENT>	x(3, 7)	
	86 <ENT>	x(3, 8)	
	92 <ENT>	x(3, 9)	
	86 <ENT>	x(3, 10)	
Enter incorrect value	95 <ENT>	x(3, 11)	
	98 <ENT>	x(3, 12)	
	82 <ENT>	EDIT	
Edit 10th data point	10 <j>	x=	95.
Enter correct value	94 <ENT>	x=	94.
Indicate end of sample 3 data	<EOD>	KRUSKAL-WALLIS	
Select results of the test	<CHI> <df>	CHI= df=	11.09873477 2.

Conclusion

Since the observed Chi-square is greater than 5.991, we must reject the null hypothesis and conclude that there is evidence that at least one of the teaching techniques is more effective. We can then use the Population Test, as illustrated on the next page, to determine which ones are different.

(continued)

Example (Continued)

Since the null hypotheses is rejected, test the hypothesis that the mean of population i is equal to the mean of population j for all three possible pairings of data. The population test will be run at the same 95% level, which implies the rejection of the null hypothesis if the observed t-statistic lies outside the range from −2.042 to 2.042.

Procedure	Press	Display	
Select Population Test from the results menu	⟨POP⟩	POPULATION TEST	
Enter number of first population to be compared	1 ⟨P1⟩	P1 =	1.
Enter number of second population to be compared	2 ⟨P2⟩	P2 =	2.
Indicate end of data	⟨EOD⟩		.2912323911
Show degrees of freedom	⟨df⟩	df =	30.
Enter number of first population to be compared	⟨-->⟩ 1 ⟨P1⟩	POPULATION TEST P1 =	 1.
Enter number of second population to be compared	3 ⟨P2⟩	P2 =	3.
Indicate end of data	⟨EOD⟩		3.722864955
Show degrees of freedom	⟨df⟩	df =	30.

Example (Continued)

Procedure	Press	Display
Enter number of first population to be compared	⟨-->⟩ 2 ⟨P1⟩	POPULATION TEST P1 = 2.
Enter number of second population to be compared	3 ⟨P2⟩	P2 = 3.
Indicate end of data	⟨EOD⟩	2.978451677
Show degrees of freedom	⟨df⟩	df = 30.

Conclusion

Since $-2.042 < .2912323911 < 2.042$, no significant difference is found between method I and method II. However, since 3.722864955 and 2.978451677 are both greater than 2.042, there is evidence that method III yields better average results than the other two methods.

The R × C Contingency Table Program

The R × C Contingency Table program enables you to test the hypothesis that row-column occurrences of an event are independent of one another.

Introduction to the Program

Given the number of rows, the number of columns, and the value of the data in each cell of the array, this program calculates:

- Value of the test statistic (x^2)
- Degrees of freedom (df)
- Pearson's Contingency Coefficient (CC)

Reference

Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, John Wiley & Sons Inc., New York, 1980, pp. 153–169.

Selecting the Program

To use the R × C Contingency Table program, follow these steps.

1. Select ⟨NPS⟩ from the **STATISTICS** menu.

2. Select ⟨R × C⟩ from the **NONPARAMETRICS** menu.

   The following display appears.

```
 RxC CONTINGENCY
ROW  COL  EOD          ESC
```

Defining the Matrix

To define the matrix:

1. Enter the number of rows and press ⟨ROW⟩.

2. Enter the number of columns and press ⟨COL⟩.

3. Press ⟨EOD⟩.

Entering the Data

The next series of displays requests the data for each observation, beginning with row 1, column 1.

```
 x (  1,   1)
ENT
```

1. Enter the value for this observation and press ⟨ENT⟩.

2. Repeat step 1 until all observations are entered.

   The **EDIT** display shown on the next page appears when all the observations are entered.

The Edit Menu

The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.

```
EDIT
i-j  ENT  EOD
```

If the entries are correct, proceed to step 5 of the editing procedure given below.

Editing the Data

To edit an incorrect entry:

1. Specify the row of the observation in error and press [x~t].

2. Specify the column of the observation in error and press ⟨i-j⟩. The value you entered previously is displayed.

3. Enter the correct value and press ⟨ENT⟩.

4. Repeat steps 1, 2, and 3 until all corrections are made.

5. Press ⟨EOD⟩.

   When you complete data entry for the observation and press ⟨EOD⟩, the contingency table is calculated and the display shown on the following page appears.

Obtaining the Results

Select the appropriate function keys from the following menu to obtain the results.

```
RxC CONTINGENCY
CHI  df   CC         ESC
```

⟨CHI⟩	Chi-square
⟨df⟩	Degrees of freedom
⟨CC⟩	Pearson's Contingency Coefficient
⟨ESC⟩	Returns to the **R × C CONTINGENCY** menu

Example: The R × C Contingency Table Program

The following example illustrates a test for mutual independence of bivariate data using an R × C Contingency table.

Example

A contingency table was constructed from the bivariate sample used in the Kendall's Tau example (page 8-42). The ordered grades in mathematics were divided into four columns of six points each. The ordered grades in English were divided into three rows of eight points each. This resulted in the table below with all row totals = 8, all column totals = 6, and all cell expected values = 2.

		Column 1	2	3	4
Row	1	0	1	2	5
	2	2	4	1	1
	3	4	1	3	0

Test the hypothesis (at the 97.5% level) that a student's grade in mathematics is independent of his grade in English against the alternative that the grades are correlated. The critical value of Chi-square with 6 degrees of freedom is 14.449.

Procedure	Press	Display	
Select the program from the **STATISTICS** menu	⟨NPS⟩	NONPARAMETRICS	
Select the program from the **NPS** menu	⟨R × C⟩	R × C CONTINGENCY	
Enter the number of rows	3 ⟨ROW⟩	ROW =	3.
Enter the number of columns	4 ⟨COL⟩	COL =	4.
Indicate end of data	⟨EOD⟩	x(1, 1)	
Begin entering column 1 data	0 ⟨ENT⟩	x(2, 1)	

Example (Continued)

Procedure	Press	Display	
	2 ⟨ENT⟩	x(3, 1)	
	4 ⟨ENT⟩	x(1, 2)	
Enter column 2 data	1 ⟨ENT⟩	x(2, 2)	
	4 ⟨ENT⟩	x(3, 2)	
	1 ⟨ENT⟩	x(1, 3)	
Enter column 3 data	2 ⟨ENT⟩	x(2, 3)	
Enter incorrect value	3 ⟨ENT⟩	x(3, 3)	
	3 ⟨ENT⟩	x(1, 4)	
Enter column 4 data	5 ⟨ENT⟩	x(2, 4)	
	1 ⟨ENT⟩	x(3, 4)	
	0 ⟨ENT⟩	EDIT	
Edit entry in row 2, column 3	2 $\boxed{x{\sim}t}$ 3 ⟨i–j⟩	x =	3.
Enter correct value	1 ⟨ENT⟩	x =	1.
Indicate end of data	⟨EOD⟩	R × C CONTINGENCY	
Select results of the test	⟨CHI⟩	CHI =	15.
	⟨df⟩	df =	6.
	⟨CC⟩	CC =	.6201736729

Conclusion

Since Chi-square > 14.449, we reject the null hypothesis and conclude that there is evidence that grades in mathematics are correlated with grades in English. Note that this result is consistent with the results obtained from the Kendall's Tau test at the same level of significance.

The Tolerance Limits Program

The Tolerance Limits program determines one- or two-sided tolerance limits.

Introduction

Given a probability (p), a pair of positive integers (r and m), and a fraction (q) between zero and one, this program calculates the size (n) of a random sample $X_1 < X_2 < \ldots X_n$, for which the following statement can be made.

> "The probability is p that the interval from $X_{(r)}$ to $X_{(n+1-m)}$ inclusive, contains a proportion q or more of the population."

The program uses the convention $X_{(0)} = -\infty$ and $X_{(n+1)} = +\infty$, so that one-sided tolerance limits may be obtained by setting either n + 1 or m equal to zero.

The program accommodates probability values between 0.5 and 1.0 and population fractions between 0.0 and 1.0.

Reference

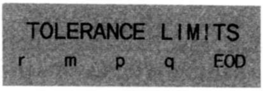
Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, John Wiley & Sons Inc., New York, 1980, pp. 118–121.

Selecting the Program

To use the Tolerance Limits program, follow these steps.

1. Select ⟨NPS⟩ from the **STATISTICS** menu.
2. Select ⟨TOL⟩ from the **NONPARAMETRICS** menu.

   The following display appears.



Entering the Data

3. Enter the value of r and press ⟨r⟩.
4. Enter the value of m and press ⟨m⟩.
5. Enter the probability and press ⟨p⟩.
6. Enter the fraction and press ⟨q⟩.
7. Press ⟨EOD⟩.

   The sample size is displayed.

8. Press $\boxed{\text{INV}}$ and ⟨EOD⟩ to return to the **NONPARAMETRICS** menu.

Example: The Tolerance Limits Program

The following example illustrates the use of the Tolerance Limits program in establishing sample sizes.

Example

Find the sample sizes required such that we can be 99% certain that at least 75% of the population from which the samples were drawn lies within the range of the sample, and that at least 75% of the population is greater than the smallest observation in the sample. Draw a random sample from a known population and verify the results.

To find the sample size required in order to be 99% certain that at least 75% of the population lies within the range of the sample, follow this procedure.

Procedure	Press	Display	
Select the program from the **STATISTICS** menu	<NPS>	NONPARAMETRICS	
Select the program from the **NPS** menu	<-->> <TOL>	TOLERANCE LIMITS	
Enter the value of r	1 <r>	r=	1.
Enter the value of m	1 <m>	m=	1.
Enter the probability	.99 <p>	p=	0.99
Enter the fraction	.75 <q>	q=	0.75
Indicate end of data	<EOD>	n=	24.

The result indicates that in any random sample of size 24 drawn from any population, you can be 99% certain that at least 75% of the population lies in the sample range.

Example (Continued)

To find the required sample size to assert that at least 75% of the population is greater than the smallest observation in the sample, follow this procedure.

Procedure	Press		Display
Enter a new value for m	0 ⟨m⟩	m =	0.
Indicate end of data	⟨EOD⟩	n =	17.

This result indicates that in any random sample of size 17, you can be 99% certain that at least 75% of the population is greater than the smallest observation in the sample.

Verifying the Results

To verify the results, a sample of 24 random numbers was drawn from a standard normal population. The smallest number drawn was −2.756 and the largest was 1.706. The fraction of the standard normal distribution which lies in this range is .953, which is greater than .75. Another sample of 17 random numbers was drawn. The smallest number in this sample was −1.805. The fraction of the standard normal greater than −1.805 is .964, which is greater than .75.

The Kendall's Tau Program

The Kendall's Tau is a nonparametric correlation coefficient for a sample of bivariate observations. This statistic can be used to test the hypothesis that the observations are mutually independent. This test applies to non-numeric as well as numeric data providing the data can be expressed in ordinal scale.

Introduction to the Program

Given the number of data pairs and their coordinate values, this program calculates:

- Kendall's Tau
- Standard-unit normal variate implied by the statistic

Reference

Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, John Wiley & Sons Inc., New York, 1980, pp. 256–260.

Selecting the Program

To select the Kendall's Tau program:

1. Select ⟨NPS⟩ from the **STATISTICS** menu.

2. Select ⟨TAU⟩ from the **NONPARAMETRICS** menu.

   The following display appears.

```
  KENDALL'S TAU
n    EOD                ESC
```

Defining the Data Set

To define the data set:

1. Enter the number of pairs and press ⟨n⟩.

2. Press ⟨EOD⟩.

Entering the Data

The next series of displays requests the data pair for each observation, beginning with observation 1.

```
 x,y (   1)
ENT
```

1. Enter the x value for this observation and press [x~t].

2. Enter the y value for this observation and press ⟨ENT⟩.

3. Repeat steps 1 and 2 until all pairs are entered.

   The **EDIT** display shown on the next page appears when all the observations are entered.

The Edit Menu

The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.

```
EDIT
i    ENT  EOD
```

- If you do not want to edit, press ⟨EOD⟩ and proceed to "Obtaining the Results" on the next page.
- If you want to edit, follow the procedure below.

Editing the Data

To edit an incorrect entry:

1. Specify the number of the observation in error and press ⟨i⟩. The x value you entered previously is displayed.
2. If the x value is correct, press [x~t]. If the x value is incorrect, enter the correct value and press [x~t]. The y value you entered previously is displayed.
3. If the y value is correct, press ⟨ENT⟩. If the y value is incorrect, enter the correct value and press ⟨ENT⟩.
4. Repeat steps 1, 2, and 3 until all corrections are made.
5. Press ⟨EOD⟩.

   When you complete data entry and press ⟨EOD⟩, Kendall's Tau is calculated and the display shown on the following page appears.

Obtaining the Results

Select the appropriate function keys from the menu to obtain the results.

```
 KENDALL'S TAU
TAU  zt           ESC
```

⟨TAU⟩	Kendall's Tau statistic
⟨zt⟩	Standard-unit normal variate
⟨ESC⟩	Returns to the **KENDALL'S TAU** entry menu

Example: The Kendall's Tau Program

The following example uses the Kendall's Tau program to test for correlation in a sample of paired data.

Example

The final grades in mathematics and English for a class of 24 students were as follows:

Math	English	Math	English	Math	English
90	89	88	89	86	88
88	83	81	86	94	91
81	82	86	84	79	83
89	84	90	98	91	89
87	82	85	85	73	78
78	79	83	84	89	91
87	82	88	83	85	84
83	82	88	88	82	86

Calculate Kendall's Tau for these data and test the hypothesis that the grade a student earns in math is not correlated with the grade he earns in English against the alternative that the grades are correlated. Assume that evidence of correlation has been found (at the 97.5% level) if zt > 2.24 or zt < −2.24.

Procedure	Press	Display	
Select the program from the **STATISTICS** menu	⟨NPS⟩	NONPARAMETRICS	
Select the program from the **NPS** menu	⟨-->⟩ ⟨TAU⟩	KENDALL'S TAU	
Enter the number of pairs	24 ⟨n⟩	n =	24.
Indicate end of data	⟨EOD⟩	x,y (1)	
Begin entering data pairs	90 $\boxed{x{\sim}t}$ 89 ⟨ENT⟩	x,y (2)	

Example (Continued)	Procedure	Press		Display
	Continue entering data pairs	88 $\boxed{x\sim t}$		
		83 ⟨ENT⟩	x,y (3)	
		81 $\boxed{x\sim t}$		
		82 ⟨ENT⟩	x,y (4)	
		89 $\boxed{x\sim t}$		
		84 ⟨ENT⟩	x,y (5)	
		87 $\boxed{x\sim t}$		
		82 ⟨ENT⟩	x,y (6)	
		78 $\boxed{x\sim t}$		
		79 ⟨ENT⟩	x,y (7)	
		87 $\boxed{x\sim t}$		
		82 ⟨ENT⟩	x,y (8)	
		83 $\boxed{x\sim t}$		
		82 ⟨ENT⟩	x,y (9)	
		88 $\boxed{x\sim t}$		
		89 ⟨ENT⟩	x,y (10)	
		81 $\boxed{x\sim t}$		
		86 ⟨ENT⟩	x,y (11)	
		86 $\boxed{x\sim t}$		
		84 ⟨ENT⟩	x,y (12)	
		90 $\boxed{x\sim t}$		
		98 ⟨ENT⟩	x,y (13)	
		85 $\boxed{x\sim t}$		
		85 ⟨ENT⟩	x,y (14)	
		83 $\boxed{x\sim t}$		
		84 ⟨ENT⟩	x,y (15)	
		88 $\boxed{x\sim t}$		
		83 ⟨ENT⟩	x,y (16)	
		88 $\boxed{x\sim t}$		
		88 ⟨ENT⟩	x,y (17)	
		86 $\boxed{x\sim t}$		
		88 ⟨ENT⟩	x,y (18)	

(continued)

Example (Continued)

Procedure	Press	Display	
Continue entering data pairs	94 [x~t]		
	91 <ENT>	x,y (19)	
	79 [x~t]		
	83 <ENT>	x,y (20)	
	91 [x~t]		
	89 <ENT>	x,y (21)	
	73 [x~t]		
Enter incorrect value	73 <ENT>	x,y (22)	
	89 [x~t]		
	91 <ENT>	x,y (23)	
	85 [x~t]		
	84 <ENT>	x,y (24)	
Enter last data pair	82 [x~t]		
	86 <ENT>	EDIT	
Edit 21st data set	21 <i>	x =	73.
Go to y value	[x~t]		73.
Enter correct y value	78 <ENT>	x =	78.
Indicate end of data	<EOD>	KENDALL'S TAU	
Select results	<TAU>	TAU =	0.5
	<zt>	zt =	3.423007615

Conclusion

Since zt > 2.24, we reject the null hypothesis at the 97.5% level and assume that there is a positive correlation between the grades in the two courses.

The Rank Function Program

This program allows you to replace elements with their ranks.

Introduction to the Program

Given the number of elements in an array and the values of those elements, this program determines the rank order of the elements.

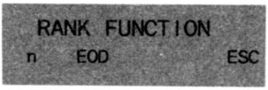
Selecting the Program

To select the Rank Function program:

1. Select ⟨NPS⟩ from the **STATISTICS** menu.

2. Select ⟨RNK⟩ from the **NONPARAMETRICS** menu.

   The following display appears.



Defining the Matrix

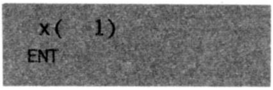
To define the matrix:

1. Enter the number of items and press ⟨n⟩.

2. Press ⟨EOD⟩.

Entering the Data

The next series of displays requests the value for each item, beginning with item 1.



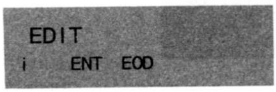
1. Enter the value for this item and press ⟨ENT⟩.

2. Repeat step 1 until all items are entered.

   The **EDIT** display shown on the next page appears when all the observations are entered.

Entering the Data (Continued)

The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.



If the entries are correct, proceed to step 4 of the editing procedure given below.

Editing the Data

To edit an incorrect entry:

1. Specify the number of the item in error and press ⟨i⟩. The value you entered previously is displayed.

2. Enter the correct value and press ⟨ENT⟩.

3. Repeat steps 1 and 2 until all corrections are made.

4. Press ⟨EOD⟩.

   When you complete data entry and press ⟨EOD⟩, the display shown on the following page appears.

Obtaining the Results

The display shown below requests ranking information.

```
RANK FUNCTION
#R  1st  EOD       ESC
```

To obtain the ranking for the elements in your array:

1. Enter the number of elements to be ranked and press ⟨#R⟩.

2. Enter the index of the first element and press ⟨1st⟩.

3. Press ⟨EOD⟩. The display below appears.

   ```
   R =              xxx
   NXT
   ```

   (where xxx is the value)

   The rank of the first element appears in the display. If you want to see the index of the first rank, press [x~t].

4. Repeat step 3 until the ranks of all selected elements have been displayed.

   After the ranks of all selected elements have been displayed, the **RANK FUNCTION** display shown above reappears.

5. Repeat steps 1 through 4 to repeat the rank function.

Example: The Rank Function Program

The following example uses the Rank Function program to rank two subsets of an array of numbers.

Example

Given the following array of ten numbers, rank the first five numbers and then rank the last five numbers.

86, 68, 77, 68, 91, 72, 77, 91, 70, 77

Procedure	Press	Display
Select the program from the **STATISTICS** menu	<NPS>	NONPARAMETRICS
Select the program from the **NPS** menu	<-->> <RNK>	RANK FUNCTION
Enter the number of elements	10 <n>	n = 10.
Indicate end of data	<EOD>	x (1)
Begin entering data	86 <ENT>	x (2)
	68 <ENT>	x (3)
	77 <ENT>	x (4)
	68 <ENT>	x (5)
Enter incorrect value	90 <ENT>	x (6)
	72 <ENT>	x (7)
	77 <ENT>	x (8)
	91 <ENT>	x (9)
	70 <ENT>	x (10)
	77 <ENT>	EDIT

(continued)

Example (Continued)

Procedure	Press		Display
Edit 5th data point	5 ⟨i⟩	x=	90.
Enter correct value	91 ⟨ENT⟩	x=	91.
Indicate end of element data	⟨EOD⟩	RANK FUNCTION	

To rank the first set of five elements in the array, follow the procedure below.

Procedure	Press		Display
Enter number of elements to be ranked	5 ⟨#R⟩	#R=	5.
Enter index of first element	1 ⟨1st⟩	1st=	1.
Indicate end of data and show first rank	⟨EOD⟩	R=	4.
Show value of first rank	[x~t]		1.
Select remaining ranks of the first set	⟨NXT⟩	R=	1.5
	[x~t]		2.
	⟨NXT⟩	R=	3.
	[x~t]		3.
	⟨NXT⟩	R=	1.5
	[x~t]		4.
	⟨NXT⟩	R=	5.
	[x~t]		5.

To rank the second set of five elements, follow the procedure on the following page.

Example (Continued)

To rank the second set of five elements in the array, follow the procedure below.

Procedure	Press	Display	
Enter number of elements to be ranked	⟨NXT⟩	RANK FUNCTION	
	5 ⟨#R⟩	#R =	5.
Enter index of first element	6 ⟨1st⟩	1st =	6.
Indicate end of data and show first rank	⟨EOD⟩	R =	2.
	$\boxed{x\sim t}$		6.
Select remaining ranks of the second set	⟨NXT⟩	R =	3.5
	$\boxed{x\sim t}$		7.
	⟨NXT⟩	R =	5.
	$\boxed{x\sim t}$		8.
	⟨NXT⟩	R =	1.
	$\boxed{x\sim t}$		9.
	⟨NXT⟩	R =	3.5
	$\boxed{x\sim t}$		10.

The Mann-Whitney Test Program

The Mann-Whitney Test program is similar to the Unpaired t-Test program, but it does not assume population normality. It tests the hypothesis that the means of the two populations are equal.

Introduction to the Program

Given the number of observations in each of the two samples (nx and ny) and the data from these observations, this program provides the standard-unit normal statistic (z) required to test the hypothesis.

The data consist of two mutually independent random samples, not necessarily of the same size, drawn from the two populations.

Reference

Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, John Wiley & Sons Inc., New York, 1980, pp. 216–233.

Selecting the Program

To select the Mann-Whitney Test program:

1. Select ⟨TST⟩ from the **STATISTICS** menu.
2. Select ⟨M-W⟩ from the **NONPARAMETRICS** menu.

   The following display appears.

```
MANN-WHITNEY
nx   ny   EOD       ESC
```

Defining the Data Set

To define the data set:

1. Enter the number of observations in sample 1 and press ⟨nx⟩.
2. Enter the number of observations in sample 2 and press ⟨ny⟩.
3. Press ⟨EOD⟩.

Entering the Data

The next series of displays requests the value for each observation of a sample, beginning with observation 1 of the first sample.

```
 x (   1)
ENT
```

1. Enter the value for this observation and press ⟨ENT⟩.

2. Repeat step 1 until all values for the sample are entered.

   The **EDIT** display appears when all the observations for a sample are entered. The **EDIT** menu gives you the choice of correcting an entry or continuing with the program.

   ```
    EDIT
   i    ENT  EOD
   ```

   If the entries are correct, proceed to step 4 of the editing procedure given on the next page.

Editing the Data

To edit an incorrect entry:

1. Specify the number of the observation in error and press ⟨i⟩. The value you entered previously is displayed.

2. Enter the correct value and press ⟨ENT⟩.

3. Repeat steps 1 and 2 until all corrections are made.

4. Press ⟨EOD⟩.

   The data entry procedure is repeated for the second sample using a "y" prompt in the display. The **EDIT** display appears again after the data for the second sample are entered.

Obtaining the Results

When you complete data entry for the second sample and press ⟨EOD⟩, the value of z is displayed.

Example: The Mann-Whitney Test Program

The following example illustrates the use of the Mann-Whitney Test program in testing a hypothesis concerning population means.

Example

Evidence was found in the Kruskal-Wallis example (comprehensive final examination scores—page 8–22) that there was a real difference in means between teaching techniques 1 and 3. The Unpaired t-Test example also detected a difference. Using the Mann-Whitney test program on the same data, test the hypothesis (at the 95% level) that the mean of technique 1 is equal to the mean of technique 3. The correct critical values of z are ± 1.96.

Class I 83, 82, 77, 83, 81, 92, 84, 85, 82, 80, 81, 79, 80

Class II 84, 85, 74, 88, 69, 84, 82, 81

Class III 89, 81, 85, 91, 85, 90, 86, 92, 86, 94, 98, 82

Procedure	Press	Display	
Select the program from the **STATISTICS** menu	⟨NPS⟩	NONPARAMETRICS	
Select the program from the **NPS** menu	⟨-->⟩ ⟨M-W⟩	MANN-WHITNEY	
Enter # of observations in sample (class) 1	13 ⟨nx⟩	nx =	13.
Enter # of observations in sample (class) 3	12 ⟨ny⟩	ny =	12.
Indicate end of data	⟨EOD⟩	x(1)	
Begin entering class 1 data	83 ⟨ENT⟩ 82 ⟨ENT⟩ 77 ⟨ENT⟩	x(2) x(3) x(4)	

Example (Continued)

Procedure	Press	Display	
Continue entering class 1 data	83 <ENT>	x(5)	
	81 <ENT>	x(6)	
	92 <ENT>	x(7)	
	84 <ENT>	x(8)	
	85 <ENT>	x(9)	
	82 <ENT>	x(10)	
	80 <ENT>	x(11)	
	81 <ENT>	x(12)	
	79 <ENT>	x(13)	
	80 <ENT>	EDIT	
Indicate end of data	<EOD>	y(1)	
Begin entering class 3 data	89 <ENT>	y(2)	
	81 <ENT>	y(3)	
	85 <ENT>	y(4)	
	91 <ENT>	y(5)	
	85 <ENT>	y(6)	
	90 <ENT>	y(7)	
	86 <ENT>	y(8)	
	92 <ENT>	y(9)	
	86 <ENT>	y(10)	
Enter incorrect value	92 <ENT>	y(11)	
	98 <ENT>	y(12)	
	82 <ENT>	EDIT	
Edit 10th data point	10 <i>	y=	92.
Enter correct value	94 <ENT>	y=	94.
Indicate end of data	<EOD>	z=	–3.028133741

Conclusion

Since the observed z is less than -1.96, we reject the null hypothesis and conclude that there is a real difference between the means of the two populations. This result is consistent with the result obtained using the parametric test.

Appendix A: Registers and Flags Used

The register contents provided in this chapter are important when you need to save and retrieve data. The list of flags used in each program is important during programming and debugging.

Table of Contents

Register Contents

The following table lists the contents of each data register. Using these tables, you can determine which data register is occupied by any value a program generates. You can also determine the block of registers to save for those programs that can use stored data.

	Program Name	Register	Contents
Means and Moments	Means and Moments	t-register	used
		000	Last x
		001	Last frq
		002	Sum of fx
		003	Sum of fx^2
		004	Sum of fx^3
		005	Sum of fx^4
		006	Sum of flnx
		007	Sum of f/x
		008	n = Sum of f
Distributions	Normal	t-register	used
		000	z
		001	used
	Inverse Normal	000	Qz
	Student's t	t-register	used
		000	used
		001	df
		002	used
		003	used
		004	used
		005	used
		006	used
		007	used
		008	used
		009	used
		010	used
		011	used
		012	used
		013	used

Distributions (Continued)

Program Name	Register	Contents
F	000	df1
	001	df2
	002	F
	003	used
	004	used
	005	used
	006	used
	007	used
	008	used
	009	used
	010	used
	011	used
	012	used
	013	used
Chi-Square	t-register	used
	000	used
	001	used
	002	used
	003	chi
	004	used
	005	used
	006	used
	007	df
Weibull	000	b
	001	c
	002	w
Inverse Weibull	t-register	used
	000	b
	001	c
Binomial	t-register	used
	000	n
	001	p
	002	used
	003	used

(continued)

	Program Name	Register	Contents
Distributions (Continued)	Poisson	t-register	used
		000	m
		001	used
		002	used
	Hypergeometric	t-register	used
		000	n
		001	N
		002	m
		003	k
		004	used
		005	used
		006	used
		007	used
		008	used
		009	used
ANOVA	One-Way	t-register	used
		000	SSE
		001	MSR
		002	MSE
		003	F
		004	SSR
		005	SST
		006	Sum of x(i, j)
		007	used
		008	dfE
		009	dfT
		010	dfR
		011	# of obs. in tmt. 1
		012	# of obs. in tmt. 2
		:	:
		010 + n	# of obs. in tmt. n
		011 + n	x(1,1)
		012 + n	x(1,2)
		:	:
		010 + Sum of t(i)	x(n,tn)

	Program Name	Register	Contents
ANOVA (Continued)	Two-Way	t-register	used
		000	used
		001	used
		002	ROW − 1
		003	COL − 1
		004	used
		:	:
		008 + (ROW + 1) × (COL + 1)	used
	Two-Way with Replication	t-register	used
		000	used
		001	used
		002	used
		003	ROW = n
		004	COL = m
		005	REP = k
		006	used
		:	:
		013 + m(k + 1) + n	used

	Program Name	Register	Contents
Regression	Multiple	t-register	used
		000	# of active pred., PP
		001	n
		002	Total # of pred., P
		003	used
		:	:
		(P+1)(P+2)/2+ 3P+17	Last reg. of sums
		:	:
		(P+4)(P+5)/2+ (PP+1)(PP+6)+8	used
	Bivariate	t-register	used
		000	x(i)
		001	y(i)
		002	frq(i)
		003	m
		004	b
		005	r^2
		006	Transform type: 1=PWR, 2=EXP, 3=RCP

	Program Name	Register	Contents
t-Test	Unpaired	t-register	used
		000	used
		001	used
		002	$\bar{x}$
		003	s_x^2
		004	$\bar{y}$
		005	s_y^2
		006	F
		007	Δ
		008	x(1)
		009	x(2)
		:	:
		7 + nx	x(nx)
		8 + nx	y(1)
		9 + nx	y(2)
		:	:
		7 + nx + ny	y(ny)
	Paired	t-register	used
		000	n
		001	used
		002	used
		003	Δ
		004	t
		005	y(1)
		006	x(1) − y(1)
		007	y(2)
		008	x(2) − y(2)
		:	:
		2n + 3	y(n)
		2n + 4	x(n) − y(n)

Histogram

Program Name	Register	Contents
Histogram	t-register	used
	000	used
	001	used
	002	used
	003	used
	004	used
	005	used
	006	df
	007	Chi
	008	N
	009	used
	010	used
	011	used
	012	used
	013	used
	014	# of cells = C
	015	Mean
	016	2nd moment
	017	3rd moment
	018	4th moment
	019	Min
	020	Cell(1) upper limit
	021	Cell(2) upper limit
	:	:
	19 + C	Cell(C) upper limit
	20 + C	Cell(1) mid x
	21 + C	Cell(2) mid x
	:	:
	19 + 2C	Cell(C) mid x
	20 + 2C	f(1)
	21 + 2C	f(2)
	:	:
	19 + 3C	f(C)
	20 + 3C	e(1)
	21 + 3C	e(2)
	:	:
	19 + 4C	e(C)

	Program Name	Register	Contents
Nonparametric	Friedman Test	000	used
		001	used
		002	used
		003	t
		004	T2
		005	T1
		006	A2 – B2
		007	F
		008	df2
		009	df1
		010	# of tmts = k
		011	# of blocks = b
		012	B2
		013	A2
		014	Sum of ranks(1)
		015	Sum of ranks(2)
		:	:
		13 + k	Sum of ranks(k)
		14 + k	used
		:	:
		13 + 2k	used
	Runs Test	000	n1
		001	n2
		002	# of runs
		003	Mean
		004	s
		005	z

(continued)

	Program Name	Register	Contents
Nonparametric (Continued)	Kruskal-Wallis Test	t-register	used
		000	used
		001	used
		002	used
		003	used
		004	used
		005	Chi
		006	P1
		007	P2
		008	t
		009	Total # of obs.
		010	# of samp. = k = df + 1
		011	n(1)
		012	n(2)
		:	:
		10 + k	n(k)
		11 + k	Mean rank(1)
		12 + k	Mean rank(2)
		:	:
		10 + 2k	Mean rank(k)
		11 + 2k	obs. 1 of ith sample
		12 + 2k	obs. 2 of ith sample
		:	:
		10 + 2k + n(max)	obs. n of largest sample

	Program Name	Register	Contents
Nonparametric (Continued)	R×C Contingency Table	t-register	used
		000	CC
		001	used
		002	Row
		003	Column
		004	used
		005	df
		006	used
		007	used
		008	Chi
		009	used
		:	:
		8+(Row+1)× (Col+1)	used
	Tolerance Limits	000	used
		001	r
		002	m
		003	p
		004	q
		005	used
		006	used
		007	n
		008	used
		009	used
		010	used
		011	used
	Kendall's Tau	t-register	used
		000	n
		001	zt
		002	used
		003	used
		004	Tau
		005	y(1)
		006	x(1)
		007	y(2)
		008	x(2)
		:	:
		2n+3	y(n)
		2n+4	x(n)

(continued)

	Program Name	Register	Contents
Nonparametric (Continued)	Rank Function	t-register	used
		000	1st element to rank
		001	Last element to rank
		002	used
		003	used
		004	used
		005	used
		006	used
		007	used
		008	used
		009	used
		010	n
		011	Rank(1) or x(1)
		012	Rank(2) or x(2)
		:	:
		10 + n	Rank(n) or x(n)
	Mann-Whitney Test	t-register	used
		000	used
		001	used
		002	used
		003	used
		004	used
		005	used
		006	used
		007	used
		008	Sum of ranks (sample 1)
		009	Sum of ranks (sample 2)
		010	n1
		011	n2
		012	Rank of x(1)
		013	Rank of x(2)
		:	:
		11 + n1	Rank of x(n1)
		12 + n1	Rank of y(1)
		13 + n1	Rank of y(2)
		:	:
		11 + n1 + n2	Rank of y(n2)

Flags Used

Some of the programs in the Statistics library use one or more flags. If you write a program that uses a flag and then run a program in the library, the status of the flag may change if it is one of the flags in the list below.

List of Flags

Programs in the Statistics library that use flags are listed below.

Program Name	Flag 16	Flag 17	Flag 18
Means and Moments	x	x	x
Normal Distribution	x		
Inverse Normal	x		
t-Distribution	x		
Two-way ANOVA	x		
Histogram	x	x	x
R × C Contingency	x		

Appendix B: Service and Warranty Information

This appendix describes the service provided by Texas Instruments and the warranty for the cartridge.

Table of Contents

Service Information

If you experience a problem with your cartridge, please call or write Consumer Relations to discuss the problem.

For Service and General Information

If you have questions about service or the general use of your cartridge, please call Consumer Relations **toll-free** within the United States at:

1–800–TI CARES (842–2737).

From outside the United States, call 1–806–741–4800. (We cannot accept collect calls at this number.)

You may also write to the following address:

Texas Instruments Incorporated
Consumer Relations
P.O. Box 53
Lubbock, Texas 79408

Please contact Consumer Relations:

- Before returning the cartridge for service.
- For general information about using the cartridge.

For Technical Information

If you have technical questions about the operation of the product or programming applications, call 1–806–741–2663. We regret that we cannot accept collect calls at this number. As an alternative, you can write Consumer Relations at the address given above.

Express Service

Texas Instruments offers an express service option for fast return delivery. Please call Consumer Relations at 1–800–TI CARES (842–2737) for information.

Calculator Accessories

If you are unable to purchase calculator accessories (such as carrying cases or adapters) from your local dealer, you may order them from Texas Instruments. Please call Consumer Relations at 1–800–TI CARES (842–2737) for information.

Returning Your Cartridge for Service

A defective cartridge will be either repaired or replaced with the same or comparable reconditioned model (at TI's option) when it is returned postage prepaid to a Texas Instruments Service Facility.

Texas Instruments cannot assume responsibility for loss or damage during incoming shipment. For your protection, carefully package the cartridge for shipment and insure it with the carrier. Be sure to enclose the following items with your cartridge:

- Your full return address
- Any accessories related to the problem
- A note describing the problem you experienced
- A copy of your sales receipt or other proof of purchase to determine warranty status

Please ship the cartridge postage prepaid; COD shipments cannot be accepted.

In-Warranty Service

For a cartridge covered under the warranty period, no charge is made for service.

Out-of-Warranty Service

A flat-rate charge by model is made for out-of-warranty service. To obtain the service charge for a particular model, call Consumer Relations at 1–800–TI CARES (842–2737) **before** returning the product for service. (We cannot hold products in the Service Facility while providing charge information.)

Texas Instruments Service Facilities

U.S. Residents
(U.S. Postal Service)
Texas Instruments
P.O. Box 2500
Lubbock, Texas 79408

U.S. Residents
(other carriers)
Texas Instruments
2305 N. University
Lubbock, Texas 79415

Canadian Residents Only
Texas Instruments
41 Shelley Road
Richmond Hill, Ontario, Canada L4C 5G4

One-Year Limited Warranty

This Texas Instruments software cartridge warranty extends to the original consumer purchaser of the product.

Warranty Duration

This cartridge is warranted to the original consumer purchaser for a period of one (1) year from the original purchase date.

Warranty Coverage

This cartridge is warranted against defective materials and construction. This warranty covers the electronic and case components of the software cartridge. These components include all semiconductor chips and devices, plastics, boards, wiring, and all other hardware contained in this cartridge (''the Hardware''). This limited warranty does not extend to the programs contained in the cartridge and the accompanying book materials (''the Programs''). **The warranty is void if the cartridge has been damaged by accident or unreasonable use, neglect, improper service, or other causes not arising out of defects in materials or construction.**

Warranty Disclaimers

Any implied warranties arising out of this sale, including but not limited to the implied warranties of merchantability and fitness for a particular purpose, are limited in duration to the above one-year period. Texas Instruments shall not be liable for loss of use of the cartridge or other incidental or consequential costs, expenses, or damages incurred by the consumer or any other user.

Some states do not allow the exclusion or limitations of implied warranties or consequential damages, so the above limitations or exclusions may not apply to you.

Legal Remedies

This warranty gives you specific legal rights, and you may also have other rights that vary from state to state.

Warranty Performance

During the above one-year warranty period, your TI cartridge will be either repaired or replaced with a reconditioned comparable model (at TI's option) when the cartridge is returned, postage prepaid, to a Texas Instruments Service Facility. The repaired or replacement cartridge will be in warranty for the remainder of the original warranty period or for six months, whichever is longer. Other than the postage requirement, no charge will be made for such repair or replacement. Texas Instruments strongly recommends that you insure the product for value prior to mailing.

TEXAS INSTRUMENTS

Printed in Taiwan

1061439-0101