TI-84 Calculator Instructions

Adapted from:
The Practice of Statistics 4e
by Starnes, Yates, and Moore
Histograms on the Calculator

You can construct histograms using your TI-84. We will use the following example to illustrate the process:

*What percent of your home state’s residents were born outside the United States? The country as a whole has 12.5% foreign-born residents, but the states vary from 1.2% in West Virginia to 27.2% in California. The table below presents the data for all 50 states.*

<table>
<thead>
<tr>
<th>State</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>2.6</td>
</tr>
<tr>
<td>Alaska</td>
<td>7.0</td>
</tr>
<tr>
<td>Arizona</td>
<td>15.1</td>
</tr>
<tr>
<td>Arkansas</td>
<td>3.8</td>
</tr>
<tr>
<td>California</td>
<td>27.2</td>
</tr>
<tr>
<td>Colorado</td>
<td>10.3</td>
</tr>
<tr>
<td>Connecticut</td>
<td>12.9</td>
</tr>
<tr>
<td>Delaware</td>
<td>8.1</td>
</tr>
<tr>
<td>Florida</td>
<td>18.9</td>
</tr>
<tr>
<td>Georgia</td>
<td>9.2</td>
</tr>
<tr>
<td>Hawaii</td>
<td>16.3</td>
</tr>
<tr>
<td>Idaho</td>
<td>5.6</td>
</tr>
<tr>
<td>Illinois</td>
<td>13.8</td>
</tr>
<tr>
<td>Indiana</td>
<td>4.2</td>
</tr>
<tr>
<td>Iowa</td>
<td>3.8</td>
</tr>
<tr>
<td>Kansas</td>
<td>6.3</td>
</tr>
<tr>
<td>Kentucky</td>
<td>2.7</td>
</tr>
<tr>
<td>Louisiana</td>
<td>2.9</td>
</tr>
<tr>
<td>Maine</td>
<td>3.2</td>
</tr>
<tr>
<td>Maryland</td>
<td>12.2</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>14.1</td>
</tr>
<tr>
<td>Michigan</td>
<td>5.9</td>
</tr>
<tr>
<td>Minnesota</td>
<td>6.6</td>
</tr>
<tr>
<td>Mississippi</td>
<td>1.8</td>
</tr>
<tr>
<td>Missouri</td>
<td>3.3</td>
</tr>
<tr>
<td>Montana</td>
<td>1.9</td>
</tr>
<tr>
<td>Nebraska</td>
<td>5.6</td>
</tr>
<tr>
<td>Nevada</td>
<td>19.1</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>5.4</td>
</tr>
<tr>
<td>New Jersey</td>
<td>20.1</td>
</tr>
<tr>
<td>New Mexico</td>
<td>10.1</td>
</tr>
<tr>
<td>New York</td>
<td>21.6</td>
</tr>
<tr>
<td>North Carolina</td>
<td>6.9</td>
</tr>
<tr>
<td>North Dakota</td>
<td>2.1</td>
</tr>
<tr>
<td>Ohio</td>
<td>3.6</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>4.9</td>
</tr>
<tr>
<td>Oregon</td>
<td>9.7</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>5.1</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>12.6</td>
</tr>
<tr>
<td>South Carolina</td>
<td>4.1</td>
</tr>
<tr>
<td>South Dakota</td>
<td>2.2</td>
</tr>
<tr>
<td>Tennessee</td>
<td>3.9</td>
</tr>
<tr>
<td>Texas</td>
<td>15.9</td>
</tr>
<tr>
<td>Utah</td>
<td>8.9</td>
</tr>
<tr>
<td>Vermont</td>
<td>3.9</td>
</tr>
<tr>
<td>Virginia</td>
<td>10.1</td>
</tr>
<tr>
<td>Washington</td>
<td>12.4</td>
</tr>
<tr>
<td>West Virginia</td>
<td>1.2</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>4.4</td>
</tr>
<tr>
<td>Wyoming</td>
<td>2.7</td>
</tr>
</tbody>
</table>

1. Enter the data for the percent of state residents born outside the United States in your Statistics/List Editor.
   - Press STAT and choose 1: Edit...
   - Type the values into list L1.

2. Set up a histogram in the Statistics Plots menu.
   - Press 2nd Y= (STAT PLOT).
   - Press ENTER or 1 to go into Plot1

3. Use ZoomStat to let the calculator choose classes and make a histogram.
• Press ZOOM and choose 9:ZoomStat.
• Press TRACE and the left and right arrow keys to examine the classes.

4. Adjust the classes to match those in the below figure:

then graph the histogram.

• Press WINDOW and enter the values shown.
• Press GRAPH
• Press TRACE and the left and right arrow keys to examine the classes.

5. See if you can match the histogram below:
Making Calculator Boxplots

The TI-89 can plot up to three boxplots in the same viewing window. Let’s use the calculator to make side-by-side boxplots of the travel time to work data for the samples from North Carolina and New York shown below:

1. Enter the travel time data for North Carolina in L1 and for New York in L2.

2. Set up two statistics plots: Plot1 to show a boxplot of the North Carolina data and Plot2 to show a boxplot of the New York data.

Note: The calculator offers two types of boxplots: a “modified” boxplot that shows outliers and a standard boxplot that doesn’t. We’ll always use the modified boxplot.

3. Use the calculator’s Zoom feature to display the side-by-side boxplots. Then Trace to view the five-number summary.
   - Press ZOOM and select 9: ZoomStat.
   - Press TRACE..
Computing numerical summaries with technology

Let’s find numerical summaries for the travel times of North Carolina and New York workers. We’ll start by showing you the necessary calculator techniques and then look at output from computer software.

One-variable statistics on the calculator Enter the North Carolina data in L1 and the New York data in L2.

1. Find the summary statistics for the North Carolina travel times.
   - Press STAT, Right Arrow (CALC tab); choose 1:1-Var Stats.
   - Press ENTER. Now press 2nd 1 (L1) and ENTER.
   - Press the down arrow key to see the rest of the one-variable statistics for North Carolina.

2. Repeat Step1 using list2 to find the summary statistics for the New York travel times.

Output from statistical software We Used Minitab statistical software to produce descriptive statistics for the New York and North Carolina travel time data. Minitab allows you to choose which numerical summaries are included in the output.
<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>Minimum</th>
<th>Q1</th>
<th>Median</th>
<th>Q3</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>NY Time</td>
<td>20</td>
<td>31.25</td>
<td>21.88</td>
<td>5.00</td>
<td>15.00</td>
<td>22.50</td>
<td>43.75</td>
<td>85.00</td>
</tr>
<tr>
<td>NC Time</td>
<td>15</td>
<td>22.47</td>
<td>15.23</td>
<td>5.00</td>
<td>10.00</td>
<td>20.00</td>
<td>30.00</td>
<td>60.00</td>
</tr>
</tbody>
</table>
The standard Normal curve

The TI-84 can be used to draw and find areas under a standard Normal curve.

To draw a standard Normal curve: First, turn off all statistics plots.

1. Enter the formula for the standard Normal density curve in Y1.
   - Define \( Y_1 = \text{normalpdf}(x, 0, 1) \).
   - Press \( \text{Y=} \). With the cursor next to \( Y_1 = \), press 2\(^{nd}\) \( \text{VARS (DISTR)} \) and choose 1:normalpdf(.
   - Press \( X,T,Θ,n,0,1 \), to complete the formula.

2. Adjust windows settings and graph.
   - Press \( \text{WINDOW} \). Enter \( \text{Xmin} = -4, \text{Xmax} = 4, \text{Xscl} = 1, \text{Ymin} = -1, \text{Ymax} = .5, \text{Yscl} = .1 \).
   - Press \( \text{GRAPH} \) to display the curve.

To find areas under the standard Normal curve: Go to the home screen. Use the shadeNorm command to find the desired area.

TI-84: Press 2\(^{nd}\) \( \text{VARS (DISTR)} \), arrow right to \( \text{DRAW} \), and choose 1:Shade-Norm(. Complete the command \( \text{shadeNorm(lower bound, upper bound, } μ, \sigma) \).

Note: After each time you use \( \text{shadeNorm} \), execute the command \( \text{clrDraw} \) to remove the shading. (\( \text{clrDraw} \) can be found in the \( \text{DRAW} \) menu).

To find
   - The area to the left of \( z = 2.22 \), use -100 for the lower bound: \( \text{shadeNorm(-100, 2.22, 0, 1)} \).
• The area to the right of $z = -1.78$, use 100 for the upper bound: `shadeNorm (-1.78, 100, 0, 1).

• The area between $z = -1.25$ and $z = 0.81$:
  `shadeNorm (-1.25, 0.81, 0, 1).`
From z-scores to areas, and vice versa

Finding areas: The normalcdf command on the TI-84 can be used to find areas under a Normal curve. This method is quicker than shadeNorm but has the disadvantage of not providing a picture of the area it is finding. The syntax is familiar: normalcdf(lower bound, upper bound, μ, σ). Let’s use the following example to illustrate this process:

On the driving range, Tiger Woods practices his swing with a particular club by hitting many, many balls. When Tiger hits his driver, the distance the ball travels follows a Normal distribution with mean 304 yards and standard deviation 8 yards.

Recall that μ = 304 yards and σ = 8 yards.

1. What proportion of Tiger’s drives on the range travel at least 290 yards?
   - Press 2nd VARS (DISTR) and choose 2:normcdf.
   - Complete the command normcdf(290, 400, 304, 8) and press ENTER.

   ![normalcdf(290,400,304,8) 0.9599408865]

   Note: We chose 400 as the upper bound because it’s many, many standard deviations above the mean. These results agree with our previous answer using the z-table: 0.9599.

2. What percent of Tiger’s drives travel between 305 and 325 yards? The screen shots below indicate that our earlier result of 0.4440 using the was a little off. This discrepancy was caused by the fact that we rounded our z-scores to two decimal places in order to use the table.

   ![normalcdf(290,400,304,8) normalcdf(305,325,304,8) 0.4459292478]

   Work backward: The TI-84 invNorm function calculates the value corresponding to a given percentile in a Normal distribution. For this command, the syntax is invNorm(percentile, μ, σ). Let’s illustrate this process with the following example:
High levels of cholesterol in the blood increase the risk of heart disease. For 14-year-old boys, the distribution of blood cholesterol is approximately Normal with mean $\mu = 170$ milligrams of cholesterol per deciliter of blood (mg/dl) and standard deviation $\sigma = 30$ mg/dl.

Recall that $\mu = 170$ mg/dl and $\sigma = 30$ mg/dl.

3. What is the first quartile of the distribution of blood cholesterol?
   - Press $2^{nd}$ VARS (DISTR) and choose 3:invNorm(.25).
   - Complete the command $\text{invNorm}(.25, 170, 30)$ and press ENTER.
   - Compare this with the result of $\text{invNorm}(.25)$. 

   ![invNorm(.25, 170, 30) and invNorm(.25)]

   TECHNOLOGY TIP: For normpdf, shadeNorm, normcdf, and invNorm, the default values are $\mu = 0$ and $\sigma = 1$.

   The first command shows that the first quartile ($25^{th}$ quartile) of the cholesterol distribution for 14 year-old males is 149.8 mg/dl. (Our answer using the z-table is 149.9 mg/dl.) The second command shows that in the standard Normal distribution, 25% of the observations fall below $z = -0.067449$. (We used $z = -0.67$ for our previous calculations, which explains the small discrepancy.)
Normal probability plots

The TI-84 can construct a normal probability plot. We will use the following example to illustrate this process:

*Here are the unemployment rates in the 50 states in November 2009. The data is arranged from lowest (North Dakota’s 4.1%) to highest (Michigan’s 14.7%)*

<table>
<thead>
<tr>
<th>4.1</th>
<th>4.5</th>
<th>5.0</th>
<th>6.3</th>
<th>6.3</th>
<th>6.4</th>
<th>6.4</th>
<th>6.6</th>
<th>6.7</th>
<th>6.7</th>
<th>6.9</th>
<th>7.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0</td>
<td>7.2</td>
<td>7.4</td>
<td>7.4</td>
<td>7.4</td>
<td>7.8</td>
<td>8.0</td>
<td>8.0</td>
<td>8.2</td>
<td>8.2</td>
<td>8.4</td>
<td>8.5</td>
</tr>
<tr>
<td>8.6</td>
<td>8.7</td>
<td>8.8</td>
<td>8.9</td>
<td>9.1</td>
<td>9.2</td>
<td>9.5</td>
<td>9.6</td>
<td>9.7</td>
<td>10.2</td>
<td>10.3</td>
<td>10.5</td>
</tr>
<tr>
<td>10.6</td>
<td>10.6</td>
<td>10.8</td>
<td>10.9</td>
<td>11.1</td>
<td>11.5</td>
<td>12.3</td>
<td>12.3</td>
<td>12.3</td>
<td>12.7</td>
<td>14.7</td>
<td></td>
</tr>
</tbody>
</table>

To make a Normal probability plot for a set of quantitative data:
- Enter the data values in L1.
- Define Plot1 as shown.
- Use zoomStat to see the finished graph.

*Interpretation:* The Normal probability plot is quite linear, so it is reasonable to believe that the data follow a Normal distribution.
Scatterplots on the calculator

Making scatterplots with technology is much easier than constructing them by hand. We’ll use the following example to show how to construct a scatterplot on a TI-84:

*Ninth-grade students at the Webb Schools go on a backpacking trip each fall. Students are divided into hiking groups of size 8 by selecting names from a hat. Before leaving, students and their backpacks are weighed. Here are data from one hiking group in a recent year:*

<table>
<thead>
<tr>
<th>Body weight (lb):</th>
<th>120</th>
<th>187</th>
<th>109</th>
<th>103</th>
<th>131</th>
<th>165</th>
<th>158</th>
<th>116</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backpack weight (lb):</td>
<td>26</td>
<td>30</td>
<td>26</td>
<td>24</td>
<td>29</td>
<td>35</td>
<td>31</td>
<td>28</td>
</tr>
</tbody>
</table>

- Enter the data values into your lists. Clear lists: L1 and L2. Put the body weights in L1 and the backpack weights in L2.
- Define a scatterplot in the statistics plot menu. Specify the settings shown.

- Use ZoomStat to obtain a graph. The calculator will set the window dimensions automatically by looking at the values in L1 and L2.

Notice that there are no scales on the axes and that the axes are not labeled. If you copy a scatterplot from your calculator onto your paper, make sure that you scale and label the axes. You can use TRACE to help you get started (like we did).
Least-squares regression lines on the calculator

Let’s use the fat gain and NEA data to show how to find the equation of the least-squares regression line on the TI-84. Here is the data:

<table>
<thead>
<tr>
<th>NEA change (cal):</th>
<th>-94</th>
<th>-57</th>
<th>-29</th>
<th>135</th>
<th>143</th>
<th>151</th>
<th>245</th>
<th>355</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat gain (kg):</td>
<td>4.2</td>
<td>3.0</td>
<td>3.7</td>
<td>2.7</td>
<td>3.2</td>
<td>3.6</td>
<td>2.4</td>
<td>1.3</td>
</tr>
<tr>
<td>NEA change (cal):</td>
<td>392</td>
<td>473</td>
<td>486</td>
<td>555</td>
<td>571</td>
<td>580</td>
<td>620</td>
<td>690</td>
</tr>
<tr>
<td>Fat gain (kg):</td>
<td>3.8</td>
<td>1.7</td>
<td>1.6</td>
<td>2.2</td>
<td>1.0</td>
<td>0.4</td>
<td>2.3</td>
<td>1.1</td>
</tr>
</tbody>
</table>

1. Enter the NEA change data into L1 and the fat gain data into L2. Then make a scatterplot. Refer to “Scatterplots on the calculator.”

2. To determine the least-squares regression line:
   - Press STAT; choose CALC and then 8:LinReg(a+bx). Finish the command to read LinReg(a+bx)L1,L2,Y1 and press ENTER. (Y1 is found under VARS/Y-VARS/1:Function.)

   ![LinReg screenshot]

   

3. Graph the regression line. Turn off all other equations in the Y= screen and press GRAPH to add the least-squares line to the scatterplot.

   ![Regression graph screenshot]

4. Save these lists for later use. On the home screen, L1→NEA:L2→FAT.

   Although the calculator will report the values for $a$ and $b$ to nine decimal places, we usually round off to fewer decimal places. You would write the equation as $y = 3.505 - 0.00344x$. 

16
Note: The TI-84 command tells the calculator to compute the equation of the least-squares regression line using L1 as the explanatory variable and L2 as the response variable and then to store the result in slot Y1. This method is useful if you want to graph the regression line or use its equation to make predictions. If you’re interested in only the equation of the line, LinReg(a+bx)L1,L2 will do.

If $r^2$ and $r$ do not appear on the TI-84 screen, do this one-time series of keystrokes: Press 2^{nd} 0 (CATALOG), scroll down to DiagnosticOn, and press ENTER. Press ENTER again to execute the command. The screen should say “Done.” Then press 2^{nd} ENTER (ENTRY) to recall the regression command and ENTER again to calculate the least-squares line. The $r^2$ and $r$ values should now appear.
Residual plots and $s$ on the calculator

We want to calculate residuals and make a residual plot on the TI-84 using the following example:

You should have already made a scatter-plot, calculated the equation of the least-squares regression line, and graphed the line on your plot.

Earlier, we found that $\hat{y} = 3.505 - 0.00344x$.

1. Define L3 as the predicted values from the regression equation.
   - With L3 highlighted, enter the command $3.505 - 0.00344 \times L1$ and press ENTER

2. Define L4 as the observed $y$-value minus the predicted $y$-value.
   - With L4 highlighted, enter the command $L2 - L3$ and press ENTER to show the residuals.

3. Turn off Plot1 and the regression equation. Specify Plot2 with L1 as the $x$ variable and L4 as the $y$ variable. Use ZoomStat to see the residual plot.

The $x$ axis in the residual plot serves as a reference line: points above this line correspond to positive residuals and points below the line correspond to negative residuals. We used TRACE to see the residual for the individual with an NEA change of $-94$ calories.
4. Finally, we want to compute the standard deviation $s$ of the residuals. Calculate one-variable statistics on the residuals list (L4). The mean of the residuals is 0 (up to roundoff error). The sum of the squared residuals is $\Sigma x^2 = 7.663$. To find $s$, use the formula:

$$s = \sqrt{\frac{\Sigma \text{residuals}^2}{n-2}} = \sqrt{\frac{7.663}{14}} = 0.74 \text{ kg}$$

```
1-Var Stats
\bar{x}=-1.63125E-12
\Sigma x=-2.61E-11
\Sigma x^2=7.66335185
S\bar{x}=.714765782
\sigma x=.6920689925
\n=16
```
Analyzing random variables on the calculator

Let’s explore what the calculator can do using the random variable $X =$ Apgar score of a randomly selected newborn.

1. Start by entering the values of the random variable in L1 and the corresponding probabilities in L2. Use the following table:

<table>
<thead>
<tr>
<th>Value $x_i$:</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability $p_i$:</td>
<td>0.001</td>
<td>0.006</td>
<td>0.007</td>
<td>0.008</td>
<td>0.012</td>
<td>0.020</td>
<td>0.038</td>
<td>0.099</td>
<td>0.319</td>
<td>0.437</td>
<td>0.053</td>
</tr>
</tbody>
</table>

2. To graph a histogram of the probability distribution:
   - Set up a statistics plot with Xlist: L1 and Freq: L2.
   - Adjust your window settings as follows: Xmin = −1, Xmax = 11, Xscl = 1, Ymin = −0.1, Ymax = 0.5, Yscl = 0.1.
3. To calculate the mean and standard deviation of the random variable, use one-variable statistics with the values in L1 and the probabilities (relative frequencies) in L2.

**TI-84:** Execute the command 1-Var Stats L1,L2.

![1-Var Stats result](image)
Simulating with randNorm

The randNorm command on the TI-84 allows you to simulate observations from a Normal distribution with a specified mean and standard deviation. This process will be illustrated using the following example:

The diameter $C$ of a randomly selected large drink cup at a fast-food restaurant follows a Normal distribution with a mean of 3.96 inches and a standard deviation of 0.01 inches. The diameter $L$ of a randomly selected large lid at this restaurant follows a Normal distribution with mean 3.98 inches and standard deviation 0.02 inches.

For a lid to fit on a cup, the value of $L$ has to be bigger than the value of $C$, but not by more than 0.06 inches.

You can find randNorm under MATH/PRB. For instance, randNorm(3.98,.02) will randomly select a value from the Normal distribution with mean 3.98 and standard deviation 0.02. This simulates choosing a large cup lid at random from the fast-food restaurant of the prior example and measuring its diameter (in inches). To simulate choosing a large drink cup and measuring its width, you can use randNorm(3.96,.01).

To estimate the probability that a randomly selected lid will fit on a randomly chosen cup:

1. Simulate choosing 100 large cup lids at random, and store their widths in L1:
   
   randNorm(3.98,.02,100)→L1

2. Simulate choosing 100 large drink cups at random, and store their diameters in L2:
   
   randNorm(3.96,.01,100)→L2

3. Compute the difference between the lid and cup diameters for these 100 pairs of values:
   
   L1-L2→L3

4. Count the number of values in L3 that are between 0 and 0.06. (You may want to sort the values in L3 first!) This number divided by 100 is your estimate of the probability.

![1-Var Stats](image)
Binomial coefficients on the calculator

To calculate a binomial coefficient like \( \binom{5}{2} \) on the TI-84, proceed as follows:

Type 5, press MATH, arrow over to PRB, choose 3:nCr, and press ENTER. Then type 2 and press ENTER again to execute the command 5 nCr 2.

\[
\begin{array}{c}
5 \text{ nCr } 2 \\
10
\end{array}
\]
Binomial probability on the calculator

There are two handy commands on the TI-84 for finding binomial probabilities:

\[
\text{binompdf}(n,p,k) \text{ computes } P(X = k)
\]
\[
\text{binomcdf}(n,p,k) \text{ computes } P(X \leq k)
\]

These two commands can be found in the distributions menu (2^{nd}/VARS) on the TI-84. This will be illustrated using the following example:

*Each child of a particular pair of parents has probability 0.25 of having type O blood. Genetics says that children receive genes from each of their parents independently. If these parents have 5 children, the count \( X \) of children with type O blood is a binomial random variable with \( n = 5 \) trials and probability \( p = 0.25 \) of a success on each trial. In this setting, a child with type O blood is a “success” (S) and a child with another blood type is a “failure” (F).*

For the parents having \( n = 5 \) children, each with probability \( p = 0.25 \) of type O blood:

\[
P(X = 3) = \text{binompdf}(5,0.25,3) = 0.08789
\]

To find \( P(X > 3) \), we used the complement rule:

\[
P(X > 3) = 1 - P(X \leq 3)
\]
\[
= 1 - \text{binomcdf}(5,0.25,3)
\]
\[
= 0.01563
\]

Of course, we could also have done this as

\[
P(X > 3) = P(X = 4) + P(X = 5)
\]
\[
= \text{binompdf}(5,0.25,4) + \text{binompdf}(5,0.25,5)
\]
\[
= 0.01465 + 0.00098 = 0.01563
\]
Geometric probability on the calculator

There are two handy commands on the TI-84 for finding geometric probabilities:

\[ \text{geometpdf}(p,k) \] computes \( P(Y = k) \)

\[ \text{geometcdf}(p,k) \] computes \( P(Y \leq k) \)

These two commands can be found in the distributions menu (2nd/VARS) on the TI-84. We will illustrate the use of these commands using the following example:

Your teacher is planning to give you 10 problems for homework. As an alternative, you can agree to play the Birth Day Game. Here’s how it works. A student will be selected at random from your class and asked to guess the day of the week (for instance, Thursday) on which one of your teacher’s friends was born. If the student guesses correctly, then the class will have only one homework problem.

If the student guesses the wrong day of the week, your teacher will once again select a student from the class at random. The chosen student will try to guess the day of the week on which a different one of your teacher’s friends was born. If this student gets it right, the class will have two homework problems. The game continues until a student correctly guesses the day on which one of your teacher’s (many) friends was born. Your teacher will assign a number of homework problems that is equal to the total number of guesses made by members of your class.

For the Birth Day Game, with probability of success \( p = 1/7 \) on each trial:

\[ P(Y = 10) = \text{geometpdf}(1/7,10) = 0.0357 \]

To find \( P(Y < 10) \), use geometcdf:

\[ P(Y < 10) = P(Y \leq 9) = \text{geometcdf}(1/7,9) = 0.7503 \]
Confidence interval for a population proportion

The TI-84 can be used to construct a confidence interval for an unknown population proportion. We’ll demonstrate using the following example:

The Gallup Youth Survey asked a random sample of 439 U.S. teens aged 13 to 17 whether they thought young people should wait to have sex until marriage. Of the sample, 246 said “Yes.” Construct and interpret a 95% confidence interval for the proportion of all teens who would say “Yes” if asked this question.

Of n = 439 teens surveyed, X = 246 said they thought that young people should wait to have sex until after marriage. To construct a confidence interval:

- Press STAT, then choose TESTS and A:1-PropZInt.
- When the 1-PropZInt screen appears, enter x = 246, n = 439, and confidence level 0.95.

```
1-PropZInt
x:246
n:439
C-Level:.95
```

- Highlight “Calculate” and press ENTER. The 95% confidence interval for p is reported, along with the sample proportion p-hat and the sample size, as shown here.

```
1-PropZInt
(0.51333, 0.60679)
p=.5603644647
n=439
```
Inverse t on the calculator

Most newer TI-84 calculators allow you to find critical values t* using the inverse t command. As with the calculator’s inverse Normal command, you have to enter the area to the left of the desired critical value. We will use the following example to illustrate this process.

Suppose you want to construction a 95% confidence interval for the mean \( \mu \) of a Normal population based on an SRS of size \( n = 12 \). What critical value \( t^* \) should you use?

Press 2\(^{nd}\) VARS (DISTR) and choose 4:invT(. Then complete the command invT(.975,11) and press ENTER.

![invT(0.975,11)
2.200985143](image)
One-sample t intervals for $\mu$ on the calculator

Confidence intervals for a population mean using $t$ procedures can be constructed on the TI-84, thus avoiding the use of a $z$-table. Here is a brief summary of the techniques when you have the actual data values and when you have only numerical summaries. We will use the following example(s) to illustrate the process.

1. Using raw data:

A manufacturer of high-resolution video terminals must control the tension on the mesh of fine wires that lies behind the surface of the viewing screen. Too much tension will tear the mesh, and too little will allow wrinkles. The tension is measured by an electrical device with output readings in millivolts (mV). Some variation is inherent in the production process. Here are the tension readings from a random sample of 20 screens from a single day’s production.

269.5 297.0 269.6 283.3 304.8 280.4 233.5 257.4 317.5 327.4
264.7 307.7 310.0 343.3 328.1 342.6 338.8 340.1 374.6 336.1

Construct and interpret a 90% confidence interval for the mean tension $\mu$ of all the screens produced on this day.

Enter the 20 video screen tension readings data in L1.

From the home screen,
- Press STAT, arrow over to TESTS, and choose 8:TInterval....
- On the TInterval screen, adjust your settings as shown and choose Calculate.

2. Using summary statistics:
Environmentalists, government officials, and vehicle manufacturers are all interested in studying the auto exhaust emissions produced by motor vehicles.

The major pollutants in auto exhaust from gasoline engines are hydrocarbons, carbon monoxide, and nitrogen oxides (NOX). Researchers collected data on the NOX levels (in grams/mile) for a random sample of 40 light-duty engines of the same type. The mean NOX reading was 1.2675 and the standard deviation was 0.3332.

Construct and interpret a 95% confidence interval for the mean amount of NOX emitted by light-duty engines of this type.

This time, we have no data to enter into a list. Proceed to the TInterval screen as in Step 1, but choose Stats as the data input method. When you get to the TInterval screen, enter the inputs shown and calculate the interval.
One-proportion z test on the calculator

The TI-84 can be used to test a claim about a population proportion. We’ll demonstrate using the following example:

A potato-chip producer has just received a truckload of potatoes from its main supplier. If the producer determines that more than 8% of the potatoes in the shipment have blemishes, the truck will be sent away to get another load from the supplier. A supervisor selects a random sample of 500 potatoes from the truck. An inspection reveals that 47 of the potatoes have blemishes. Carry out a significance test at the \( \alpha = 0.10 \) significance level. What should the producer conclude?

In a random sample of size \( n = 500 \), the supervisor found \( X = 47 \) potatoes with blemishes. To perform a significance test:

Press STAT, then choose TESTS and 5:1-PropZTest.

On the 1-PropZTest screen, enter the values shown: \( p_0 = 0.08 \), \( x = 47 \), and \( n = 500 \). Specify the alternative hypothesis as “prop > \( p_0 \).” Note: \( x \) is the number of successes and \( n \) is the number of trials. Both must be whole numbers!

If you select the “Calculate” choice and press ENTER, you will see that the test statistic is \( z = 1.15 \) and the \( P \)-value is 0.1243.

If you select the “Draw” option, you will see the screen shown here. Compare these results with those in the example.
Computing P-values from t distributions on the calculator

You can use the tcdf command on the TI-84 to calculate areas under a t distribution curve. The syntax is tcdf(lower bound, upper bound, df). To access this command:

Press 2nd VARS ([DISTR]) and choose tcdf.

Let’s use the tcdf command to compute the P-values from the following examples:

**Better batteries**

The battery company wants to test \( H_0: \mu = 30 \) versus \( H_A: \mu > 30 \) based on an SRS of 15 new AAA batteries with mean lifetime \( \bar{x} = 33.9 \) hours and standard deviation \( s_x = 9.8 \) hours.

**Two-sided test**

What if you were performing a test of \( H_0: \mu = 5 \) versus \( H_A: \mu \neq 5 \) based on a sample size of \( n = 37 \) and obtained \( t = -3.17 \)? Since this is a two-sided test, you are interested in the probability of getting a value of \( t \) less than \(-3.17\) or greater than \(3.17\).

- **Better batteries**: To find \( P(t \geq 1.54) \), execute the command tcdf (1.54,100,14).
- **Two-sided test**: To find the P-value for the two-sided test with df = 36 and \( t = -3.17 \), execute the command 2*tcdf(-100, -3.17,36).

\[
\begin{align*}
tcdf(1.54,100,14) \quad & \approx 0.0729268628 \\
2*tcdf(-100, -3.17,36) \quad & \approx 0.0031080065
\end{align*}
\]
One-sample t test on the calculator

You can perform a one-sample t test using either raw data or summary statistics on the TI-84. Let’s use the calculator to carry out the test of $H_0: \mu = 5$ versus $H_A: \mu < 5$ from the following dissolved oxygen example:

The level of dissolved oxygen (DO) in a stream or river is an important indicator of the water’s ability to support aquatic life. A researcher measures the DO level at 15 randomly chosen locations along a stream. Here are the results in milligrams per liter (mg/l):

| A dissolved oxygen level below 5 mg/l puts aquatic life at risk. |

Start by entering the sample data in L1. Then, to do the test:

- Press STAT, choose TESTS and 2:T-test.
- Adjust settings as shown.

If you select “Calculate,” the following screen appears:
The test statistic is $t = -0.94$ and the $P$-value is 0.1809.

If you specify “Draw,” you see a $t$ distribution curve (df = 14) with the lower tail shaded.

If you are given summary statistics instead of the original data, you would select the option “Stats” instead of “Data.”
Confidence interval for a difference in proportions

The TI-84 can be used to construct a confidence interval for $p_1 - p_2$. We’ll demonstrate using the following example:

As part of the Pew Internet and American Life Project, researchers conducted two surveys in late 2009. The first survey asked a random sample of 800 U.S. teens about their use of social media and the Internet. A second survey posed similar questions to a random sample of 2253 U.S. adults. In these two studies, 73% of teens and 47% of adults said that they use social-networking sites. Use these results to construct and interpret a 95% confidence interval for the difference between the proportion of all U.S. teens and adults who use social-networking sites.

Of $n_1 = 800$ teens surveyed, $X = 584$ said they used social-networking sites. Of $n_2 = 2253$ adults surveyed, $X = 1059$ said they engaged in social networking. To construct a confidence interval:

Press STAT, then choose TESTS and B:2-PropZInt.

When the 2-PropZInt screen appears, enter the values shown.

Highlight “Calculate” and press ENTER.

Highlight “Calculate” and press ENTER.
Significance test for a difference in proportions

The TI-84 can be used to perform significance tests for comparing two proportions. Here, we use the data following example:

*High levels of cholesterol in the blood are associated with higher risk of heart attacks. Will using a drug to lower blood cholesterol reduce heart attacks?* The Helsinki Heart Study recruited middle-aged men with high cholesterol but no history of other serious medical problems to investigate this question. The volunteer subjects were assigned at random to one of two treatments: 2051 men took the drug gemfibrozil to reduce their cholesterol levels, and a control group of 2030 men took a placebo. During the next five years, 56 men in the gemfibrozil group and 84 men in the placebo group had heart attacks. *Is the apparent benefit of gemfibrozil statistically significant? Perform an appropriate test to find out.*

To perform a test of \( H_0: p_1 - p_2 = 0: \)

Press STAT, then choose TESTS and 6:2-PropZTest.

- When the 2-PropZTest screen appears, enter the values \( x_1 = 56, n_1 = 2051, x_2 = 84, n_2 = 2030. \) Specify the alternative hypothesis \( p_1 < p_2, \) as shown.

- If you select "Calculate" and press \(<\text{ENTER}\), you are told that the \( z \) statistic is \( z = -2.47 \) and the \( P \)-value is 0.0068, at top right. These results agree with those from the previous example. Do you see the combined proportion of heart attacks?

- If you select the "Draw" option, you will see the screen shown here.
Two-sample t intervals on the calculator

You can use the two-sample t interval command on the TI-84 to construct a confidence interval for the difference between two means. We’ll show you the steps using the summary statistics from the following example:

The Wade Tract Preserve in Georgia is an old-growth forest of long-leaf pines that has survived in a relatively undisturbed state for hundreds of years. One question of interest to foresters who study the area is “How do the sizes of longleaf pine trees in the northern and southern halves of the forest compare?” To find out, researchers took random samples of 30 trees from each half and measured the diameter at breast height (DBH) in centimeters. Comparative boxplots of the data and summary statistics from Minitab are shown below.

<table>
<thead>
<tr>
<th>Descriptive Statistics: North, South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>North</td>
</tr>
<tr>
<td>South</td>
</tr>
</tbody>
</table>

Press STAT, then choose TESTS and 0:2-SampTInt....
- Choose Stats as the input method and enter the summary statistics as shown.

- Enter the confidence level: C-level: .90. For Pooled: choose “No.” We’ll discuss pooling later.
- Highlight Calculate and press ENTER.
2-SampTInt
(3.9362, 17.724)
df=55.7276914
\( \bar{x}_1 = 34.53 \)
\( \bar{x}_2 = 23.7 \)
\( S_{x_1} = 14.26 \)
\( S_{x_2} = 17.5 \)
Two-sample \( t \) tests with computer software and calculators

Technology gives smaller \( P \)-values for two-sample \( t \) tests than the conservative method. That’s because calculators and software use the more complicated formula on page 637 of your textbook to obtain a larger number of degrees of freedom. The below figure gives computer output from Fathom and Minitab for the two-sample \( t \) test from the calcium experiment. The \( P \)-values differ slightly because Fathom uses 15.59 degrees of freedom while Minitab truncates to \( df = 15 \).

Let’s look at what the calculator does.

- Enter the Group 1 (calcium) data in list1 and the Group 2 (placebo) data in list2.
- To perform the significance test, go to STAT and choose 4:2-SampTTest.

\[ \begin{align*}
\text{Test of Blood pressure experiment} & \quad \text{Compare Means} \\
\text{First attribute (numeric): BChange} \\
\text{Second attribute (numeric or categorical): Group} \\
\text{Ho: Population mean of BChange for Calcium equals that for Placebo} \\
\text{Ha: Population mean of BChange for Calcium is greater than that for Placebo} \\
\text{Count:} & \quad 10 \quad 11 \\
\text{Mean:} & \quad 5 \quad -0.272727 \\
\text{Stdev:} & \quad 0.74525 \quad 0.50069 \\
\text{Std error:} & \quad 2.73486 \quad 1.77953 \\
\text{Using unpooled variances} \\
\text{Student's \( t \):} & \quad 1.604 \quad 15.5905 \\
\text{\( df \):} & \quad 15.59 \quad 15.5905 \\
\text{\( P \)-value:} & \quad 0.064 \quad 0.065 \\
\end{align*} \]

- In the 2-SampTTest screen, specify “Data” and adjust your other settings as shown.

\[ \text{2-SampTTest} \]
\[ \text{Inpt: Use Stats} \]
\[ \text{List1: L1} \]
\[ \text{List2: L2} \]
\[ \text{Freq1: 1} \]
\[ \text{Freq2: 1} \]
\[ \mu_1: \neq \mu_2 \quad \mu_2 \text{ } \checkmark \]
\[ \downarrow \text{Pooled: No Yes} \]

- Highlight “Calculate” and press ENTER.
The results tell us that the two-sample $t$ test statistic is $t = 1.604$, and the $P$-value is 0.0644. There is enough evidence against $H_0$ to reject it at the 10% significance level, but not at the 5% or 1% significance levels.

If you select “Draw” instead of “Calculate,” the appropriate $t$ distribution will be displayed, showing the test statistic and the shaded area corresponding to the $P$-value.

Note: The calculator’s 90% confidence interval for the true difference is (-0.4767, 11.022). This is quite a bit narrower than (-0.754, 11.300).
Finding *P*-values for chi-square tests on the calculator

To find the *P*-value in the following M&M’S example with your calculator:

*The table shows the observed and expected counts for Jerome’s random sample of 60 M&M’S Milk Chocolate Candies.*

<table>
<thead>
<tr>
<th>Color</th>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>9</td>
<td>14.40</td>
</tr>
<tr>
<td>Orange</td>
<td>8</td>
<td>12.00</td>
</tr>
<tr>
<td>Green</td>
<td>12</td>
<td>9.60</td>
</tr>
<tr>
<td>Yellow</td>
<td>15</td>
<td>8.40</td>
</tr>
<tr>
<td>Red</td>
<td>10</td>
<td>7.80</td>
</tr>
<tr>
<td>Brown</td>
<td>6</td>
<td>7.80</td>
</tr>
</tbody>
</table>

Use the $\chi^2$cdf command. You’ll find this command in the distributions (DISTR) menu on the TI-84. We ask for the area between $\chi^2 = 10.180$ and a very large number (we’ll use 1000) under the chi-square density curve with 5 degrees of freedom. The command that does this is $\chi^2$cdf(10.180,1000,5). As the calculator screen shots show, this method gives a more precise *P*-value than the chi square table.
Chi-square goodness-of-fit test on the calculator

You can use the TI-84 to perform the calculations for a chi-square goodness-of-fit test. We’ll use the data from the following example to illustrate the steps:

*The table shows the observed and expected counts for Jerome’s random sample of 60 M&M’S Milk Chocolate Candies.*

<table>
<thead>
<tr>
<th>Color</th>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>9</td>
<td>14.40</td>
</tr>
<tr>
<td>Orange</td>
<td>8</td>
<td>12.00</td>
</tr>
<tr>
<td>Green</td>
<td>12</td>
<td>9.60</td>
</tr>
<tr>
<td>Yellow</td>
<td>15</td>
<td>8.40</td>
</tr>
<tr>
<td>Red</td>
<td>10</td>
<td>7.80</td>
</tr>
<tr>
<td>Brown</td>
<td>6</td>
<td>7.80</td>
</tr>
</tbody>
</table>

1. Enter the observed counts and expected counts in two separate lists.
   - Clear L1 and L2.
   - Enter the observed counts in L1. Calculate the expected counts separately and enter them in L2.
2. Perform a chi-square goodness-of-fit test.

Press STAT, arrow over to TESTS and choose D:χ²GOF-Test....

Enter the inputs shown. If you choose Calculate, you’ll get a screen with the test statistic, P-value, and df. If you choose the Draw option, you’ll get a picture of the appropriate chi-square distribution with the test statistic marked and shaded area corresponding to the P-value.
Chi-square tests for two-way tables on the calculator

You can use the TI-89 to perform calculations for a chi-square test for homogeneity. We’ll use the data from the following example to illustrate the process:

Market researchers suspect that background music may affect the mood and buying behavior of customers. One study in a supermarket compared three randomly assigned treatments: no music, French accordion music, and Italian string music. Under each condition, the researchers recorded the numbers of bottles of French, Italian, and other wine purchased. Here is a table that summarizes the data:

<table>
<thead>
<tr>
<th>Wine</th>
<th>None</th>
<th>French</th>
<th>Italian</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
<td>30</td>
<td>39</td>
<td>30</td>
<td>99</td>
</tr>
<tr>
<td>Italian</td>
<td>11</td>
<td>1</td>
<td>19</td>
<td>31</td>
</tr>
<tr>
<td>Other</td>
<td>43</td>
<td>35</td>
<td>35</td>
<td>113</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>75</td>
<td>84</td>
<td>243</td>
</tr>
</tbody>
</table>

1. Enter the observed counts in matrix [A].
   • Press 2^{nd} X^{-1} (MATRIX), arrow to EDIT, and choose 1:A.
   • Enter the dimensions of the matrix: 3 x 3.

   ![Matrix Input Screen]

   • Enter the observed counts from the two-way table in the same locations in the matrix.
2. Specify the chi-square test, the matrix where the observed counts are found, and the matrix where the expected counts will be stored.
   - Press STAT, arrow to TESTS, and choose C:χ²Test.
   - Adjust your settings as shown.

3. Choose “Calculate” or “Draw” to carry out the test. If you choose “Calculate,” you should get the test statistic, P-value, and df shown below. If you specify “Draw,” the chi-square distribution with 4 degrees of freedom will be drawn, the area in the tail will be shaded, and the P-value will be displayed.

4. To see the expected counts, go to the home screen and ask for a display of the matrix [B].
   - Press 2^{nd} x⁻¹ (MATRIX), and choose 2:[B].
Regression inference on the calculator

Let’s use the data from the following example to illustrate significance tests and confidence intervals on the TI-84.

<table>
<thead>
<tr>
<th>NEA change (cal):</th>
<th>-94</th>
<th>-57</th>
<th>-29</th>
<th>135</th>
<th>143</th>
<th>151</th>
<th>245</th>
<th>355</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat gain (kg):</td>
<td>4.2</td>
<td>3.0</td>
<td>3.7</td>
<td>2.7</td>
<td>3.2</td>
<td>3.6</td>
<td>2.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NEA change (cal):</th>
<th>392</th>
<th>473</th>
<th>486</th>
<th>535</th>
<th>571</th>
<th>580</th>
<th>620</th>
<th>690</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat gain (kg):</td>
<td>3.8</td>
<td>1.7</td>
<td>1.6</td>
<td>2.2</td>
<td>1.0</td>
<td>0.4</td>
<td>2.3</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Enter the x-values (NEA change) into L1 and the y-values (Fat gain) into L2.

To do a significance test:

• Press STAT, then choose TESTS and F:LinRegTTest....
• In the LineRegTTest Screen, adjust the input as shown. Then highlight “Calculate” and press ENTER.

The linear regression t test results take two screens to present.

\[
\begin{align*}
\text{LinRegTTest} \\
\text{Xlist: L1} \\
\text{Ylist: L2} \\
\text{Freq: 1} \\
\beta \neq 0 \text{ and } \rho \neq 0 \\
\text{RegEQ: } y = a + bx \\
\text{Calculate}
\end{align*}
\]

\[
\begin{align*}
\text{LinRegTTest} \\
y &= a + bx \\
\beta \neq 0 \text{ and } \rho \neq 0 \\
t &= -4.641816035 \\
p &= 3.8095431 \times 10^{-4} \\
\text{df} &= 14 \\
a &= 3.505122916 \\
b &= -0.003441487 \\
s &= 0.7398528737 \\
r^2 &= 0.6061492049 \\
r &= 0.7785558457
\end{align*}
\]
Compare these results with the Minitab regression output below.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.5051</td>
<td>0.3036</td>
<td>11.54</td>
<td>0.000</td>
</tr>
<tr>
<td>NEA change</td>
<td>-0.0034415</td>
<td>0.0007414</td>
<td>-4.64</td>
<td>0.000</td>
</tr>
<tr>
<td>$S = 0.739853$</td>
<td>$R-Sq = 60.6%$</td>
<td>$R-Sq(adj) = 57.8%$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To construct a confidence interval:

- Press STAT, then choose TESTS and G:LinRegTInt....
- In the LinRegTInt screen, adjust the inputs as shown. Then highlight “Calculate” and press ENTER.

The linear regression $t$ interval results take two screens to present. We show only the first screen.
Transforming to achieve linearity on the calculator

We’ll use data from the following example to illustrate a general strategy for performing transformations with logarithms on the TI-84. A similar approach could be used for transforming data with powers and roots.

On July 31, 2005, a team of astronomers announced that they had discovered what appeared to be a new planet in our solar system. They had first observed this object almost two years earlier using a telescope at Caltech’s Palomar Observatory in California. Originally named UB313, the potential planet is bigger than Pluto and has an average distance of about 9.5 billion miles from the sun. (For reference, Earth is about 93 million miles from the sun.) Could this new astronomical body, now called Eris, be a new planet?

At the time of the discovery, there were nine known planets in our solar system. Here are data on the distance from the sun and period of revolution of those planets. Note that distance is measured in astronomical units (AU), the number of earth distances the object is from the sun.
(a) plots the natural logarithm of period against distance from the sun for all 9 planets.

(b) Plots the natural logarithm of period against the natural logarithm of distance from the sun for the 9 planets.

• Enter the values of the explanatory variable in L1 and the values of the response variable in L2. Make a scatterplot of $y$ versus $x$ and confirm that there is a curved pattern.

• Define L3 to be the logarithm (base 10 or $e$) of L1 and L4 to be the logarithm (same base) of L2. To see whether an exponential model fits the original data, make a plot of L4 versus L1 and look for linearity. To see whether a power model fits the original data, make a plot of L4 versus L3 and look for linearity. (We used $\ln$ to match the example.)

• If a linear pattern is present, calculate the equation of the least-squares regression line and store it in Y1. For the planet data, we executed the command LinReg(a+bx)L3,L4,Y1.
• Construct a residual plot to look for any departures from the linear pattern. For Xlist, enter the list you used as the explanatory variable in the linear regression calculation. For Ylist, use the RESID list stored in the calculator. For the planet data, we used L3 as the Xlist.

• To make a prediction for a specific value of the explanatory variable \( x = k \), modify the regression equation in Y1 by changing \( x \) to \( \log x \) or \( \ln x \), if appropriate. Then use Y1(\( k \)) to obtain the predicted value of \( \log y \) or \( \ln y \). To get the predicted value of \( y \), use \( 10^{\text{Ans}} \) or \( e^{\text{Ans}} \) to undo the
logarithm transformation. Here’s our prediction of the period of revolution for Eris, which is at a distance of 102.15 AU from the sun:

\[
Y_1(102.15) = 6.939274784
\]
\[e^{(\text{Ans})} = 1032.021505\]