

# Using the TI-83+/84 Calculator for A.P. Statistics

There is a great amount of material here. You do not need to know all of it. Anything that is starred (\*) is vital to your being able to quickly generate meaningful statistics so you can spend your AP exam time explaining the meaning of your results rather than do a lot of number crunching.

For the hypothesis testing, there are specific examples for you to follow, sometimes several. You would be wise to go through the keystrokes, keeping in mind that your real job is to interpret this in English.

Please contact me at [sschwartz8128@verizon.net](mailto:sschwartz8128@verizon.net) when you spot mistakes, typos, or for anything you do not understand.

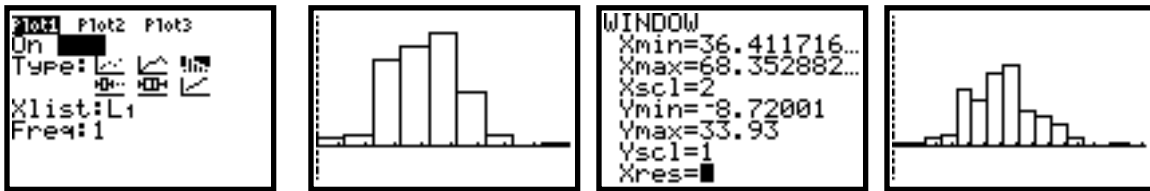
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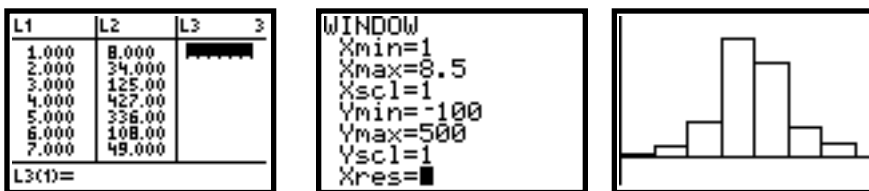
## A. Graphs

### \* 1. Histograms - **2nd** **Statplot** Select Plot

- data must be in a selected list. You should clear out anything in Y1 and use **ZOOM** **9** .
- you may adjust the window (Xscl) to change the bin width.



- If you have summary statistics, your methods are somewhat different. Example: Students were asked how many people live in their house. The summary of that data is in L1 (the number of people in the house) and L2 (how many students have that number).



### \* 2. Boxplots - **2nd** **Statplot** Select Plot

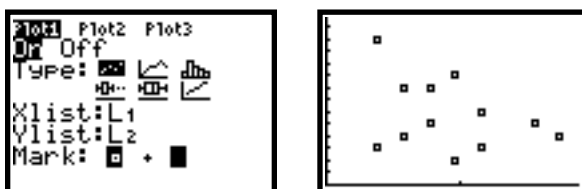
- data must be in a selected list. You should clear out anything in Y1 and use **ZOOM** **9** .
- modified boxplots (showing outliers) can be generated using the 3rd screen below:



- You may scroll through the 5 number summary by pressing **TRACE** . You may show up to 3 boxplots at one time.

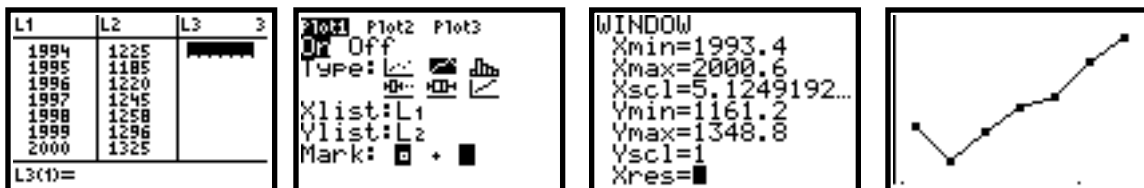
### \* 3. Scatterplots - **2nd** **Statplot** Select Plot

- bi-variate data should be in two lists. You should clear out anything in Y1 and use **ZOOM** **9** . Define the mark at the bottom. If you have many points, the dot is preferable. You can scroll through the points by pressing **TRACE** .



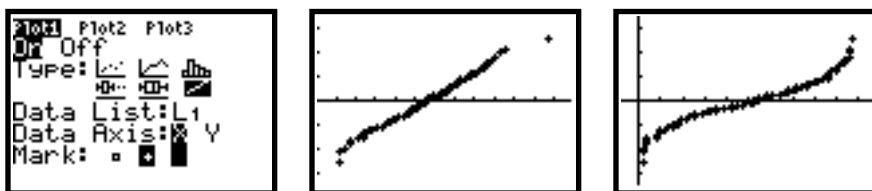
#### 4. Trendlines - $\boxed{2nd}$ $\boxed{Statplot}$ Select Plot

- When data is represented to show change over time, it is best to use a trendline. Bi-variate data should be in two lists. You should clear out anything in Y1 and use  $\boxed{ZOOM}$   $\boxed{9}$ . Define the mark at the bottom. If you have many points, the dot is preferable. You can scroll through the points by pressing  $\boxed{TRACE}$ .



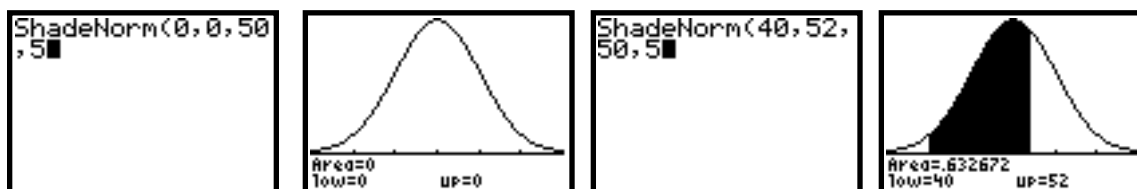
#### 5. Quantile Plots - $\boxed{2nd}$ $\boxed{Statplot}$ Select Plot

- You want to see if data is normally distributed. You can create a quantile plot by plotting the data versus its z-score. If the data plotted is pretty much in a straight line, the data is more or less normal. The first picture below is from normal data (note the outliers) while the second picture is clearly not normal.



#### 6. Drawing a Normal Curve $\boxed{2nd}$ $\boxed{DISTR}$ $\boxed{DRAW}$ ShadeNorm(lowerbound, upperbound $\mu$ , $\sigma$ )

- You know your mean  $\mu$  and your standard deviation  $\sigma$  and you wish to graph a normal distribution -  $N(\mu, \sigma)$ .
- You need to set up your window. In general, your XMIN should be  $\mu - 3\sigma$  and your XMAX should be  $\mu + 3\sigma$ . (3 standard deviations from the mean in each case).
- You will have to play with your YMAX. It should obviously be a decimal less than 1. The larger the standard deviation, the smaller it should be. You should leave room under the graph so YMIN should be negative. (A good rule of thumb is that YMIN should be 1/4 of YMAX)
- If you just want the curve, lower bound and upper bound should be the same.



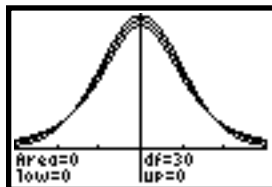
- Notes: If you do this repeatedly, you need to clear your drawing each time -  $\boxed{2nd}$   $\boxed{DRAW}$   $\boxed{ClrDraw}$ . If you want to shade the left or right tail of the normal curve, use an arbitrarily large number for lower bound or upper bound (4 standard deviations from the mean is fine).

7. Draw a  $t$ -Distribution Curve `2nd` `DISTR` `DRAW` `Shade_t(lowerbound, upperbound, df)`

- You know the degrees of freedom and want to show a  $t$ -distribution graph  $t(df)$ .
- This will rarely be done by you. It is used to show you how the degrees of freedom can change the distribution.
- Your window should be like the one below.
- Below are 3 different  $t$ -Distribution Curves with different degrees of freedom.

```
Shade_t(0,0,3):S
shade_t(0,0,6):Sh
ade_t(0,0,30
```

```
WINDOW
Xmin=-3
Xmax=3
Xscl=1
Ymin=-.1
Ymax=.4
Yscl=1
Xres=
```

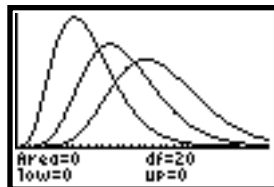


- Notes: If you do this repeatedly, you need to clear your drawing each time - `2nd` `DRAW` `ClrDraw`. If you want to shade the left or right tail of the normal curve, use an arbitrarily large number for lower bound or upper bound (4 standard deviations from the mean is fine).

8. Draw a  $\chi^2$  (Chi-Square) Distribution Curve `2nd` `DISTR` `DRAW` `Shade  $\chi^2$ (lowerbound, upperbound, df)`

- You know the degrees of freedom and want to show a  $\chi^2$  distribution graph  $\chi^2(df)$ .
- This will rarely be done by you. It is used to show you how the degrees of freedom can change the distribution.
- Your window should be like the one below.
- Below are 3 different  $\chi^2$  Distribution Curves with different degrees of freedom.

```
WINDOW
Xmin=0
Xmax=35
Xscl=1
Ymin=-.025
Ymax=.1
Yscl=1
Xres=
```



B. Probability and Random Numbers - `Math` `PRB`

\* 1. **rand** - will choose a random number between 0 and 1.

- to choose  $n$  random numbers between 0 and 1, use `rand(n)`. You will usually want to place these in a list. You can do it from the home screen by storing it into a list as shown below or do it from the `STAT` `EDIT` screen.

```
rand(100)→L1
```

L1	L2	L3	1
.69635	-----	-----	
.75738			
.05834			
.47685			
.71354			
.2275			
.1114			
L1 =rand(100)			

- to seed your random number generator (so that everyone gets the same order of random numbers),  
choose some number and store it into Rand. (Ex: 150  $\boxed{\text{STO}}$  rand).

2. **nPr** - calculate a permutation of  $n$  things taken  $r$  at a time. In permutations, order counts.

- If you have 30 people in a club and you wish to choose a president, vice-president, secretary, and treasurer, this would be a permutation of 30 things taken 4 at a time.

```
30 nPr 4
657720
```

The mathematical formula for  $nPr$  is  $\frac{n!}{(n-r)!}$

\* 3. **nCr** - calculate a combination of  $n$  things taken  $r$  at a time. In combinations, order do not count.

- If you have 30 people in a club and you wish to choose a 4 officers with equal rank, this would be a combination of 30 things taken 4 at a time.

```
30 nCr 4
27405
```

The mathematical formula for  $nCr$  is  $\frac{n!}{n!(n-r)!}$

- You need  $nCr$  as the coefficients of the terms in binomial distributions.

4. **!** - factorial -  $n!$  is defined as  $n(n-1)(n-2)\dots(2)(1)$ .  $0!$  is defined as 1.

\* 5. **RandInt** - generates  $n$  random integers between A and B

- form:  $\boxed{\text{RandInt}(A,B,n)}$  . You will usually want to place here in a list. You can do it from the home screen by storing it into a list as shown below or do it from the  $\boxed{\text{STAT}}\boxed{\text{EDIT}}$  screen.

```
randInt(1,5,9)→L
1
```

```
randInt(1,5,9)→L
1
```

\* 6. **RandNorm** - generates  $n$  random numbers with mean  $\mu$  and standard deviation  $\sigma$ .

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- form  $\text{randNorm}(\text{[ ]}, \text{[ ]}, n)$  . You will usually want to place these in a list. You can do it from.

the home screen by storing it into a list as shown below or do it from the  $\boxed{\text{STAT}}\boxed{\text{EDIT}}$  screen.

```
randNorm(50,5,10)
0)→L1
```

L1	L2	L3	1
43.716	-----	-----	
53.117			
48.417			
37.706			
47.063			
40.863			
55.218			

These examples choose 100 random numbers with a mean of 50 and standard deviation 5 that are distributed normally.

7. **randBin** - calculates the number of successes in a binomial experiment with  $n$  trials and probability of success  $p$ .

- form `randBin( $n, p$ )` .

```
randBin(50,.7)
37
35
34
```

This is several simulations of 50 trials with probability .7.

```
randBin(50,.7,5)
(33 40 33 34 43)
```

This will generate 5 simulations of 50 trials with probability of success .7. These can be stored in a list.

### C. Calculation of Statistics - `STAT` `CALC`

\* 1. **1-Var Stats** - used to find important statistical information with 1 variable

- assumes that the list that the data you want information about is in L1. If not, you must specify it (ex. 1-Var Stats L3)
- The following information is given:

$\bar{x}$  - the numerical mean (average)

$\sum x$  - the sum of your data

$\sum x^2$  - the sum of the squares of your data

$Sx$  - the sample standard deviation of your data:  $= \frac{\sum (x_i - \bar{x})^2}{n - 1}$

$\sigma x$  - the population standard deviation of your data:  $= \frac{\sum (x_i - \bar{x})^2}{n}$

$n$  - the number of data you have in your list

minX - the minimum value in your list

Q1 - the first quartile - 25% of the data is below this value

Med - the median of your data - 50% of the data is both below and above this value

Q3 - the third quartile - 25% of your data is above this value

maxX - the maximum value in your list

\* 2. **2-Var Stats** - use to find important statistical information with 2 variables.

- assumes that the lists that the data you want information about are in L1 and L2. If not, you must specify it (ex. 2-Var Stats L2, L3).  $x$  will be the first list,  $y$ , will be the second list.
- The following information is given:

$\bar{x}$  - the numerical mean (average) of  $x$

$\sum x$  - the sum of your  $x$  data

$\sum x^2$  - the sum of the squares of your  $x$  data

$S_x$  - the sample standard deviation of your  $x$  data:  $= \frac{\sum (x_i - \bar{x})^2}{n-1}$

$\sigma_x$  - the population standard deviation of your  $x$  data -  $= \frac{\sum (x_i - \bar{x})^2}{n}$

$n$  - the number of data points you have

$\bar{y}$  - the numerical mean (average) of  $y$

$\sum y$  - the sum of your  $y$  data

$\sum y^2$  - the sum of the squares of your  $y$  data

$\sum xy$  - the sum of the products of your data

$S_y$  - the sample standard deviation of your  $y$  data:  $= \frac{\sum (y_i - \bar{y})^2}{n-1}$

$\sigma_y$  - the population standard deviation of your  $y$  data:  $= \frac{\sum (y_i - \bar{y})^2}{n}$

minX - the smallest  $x$ - value

minY - the smallest  $y$ -value

maxX - the largest  $x$ - value

maxY - the largest  $y$ -value

3. **Med-Med** - performs linear regression using the median-median line - not covered in AP Stat.

\* 4 **LinReg(ax+b)** - performs linear regression using the least-squares regression line (LSRL).  $a$  will be the slope of the line and  $b$  will be the  $y$ -intercept.

- assumes the 2 lists on which you wish regression to be performed are L1 and L2. Otherwise you must specify. [LinReg(ax+B) L2, L3].

- If you wish the equation pasted into Y1 for graphing purposes, you have to specify that:

LinReg(ax+B) Y1. Y1 is found in the **VARs** **YVARs** **Function** **Y1** menu.

- If you wish to have the I-83 show the coefficient of correlation ( $r$ ), you must do the following:

**2nd** **Catalog** **Diagnostic On** . Once you are in the catalog, hit the **D** key to quickly get to Diagnostic On. This will stay in an on position until turned off.

- It is important to be in full float accuracy **MODE** **FLOAT** **ENTER** for all regressions.

The rest of the commands in this menu are not within the scope of the AP stat course but are listed. All information listed above about regression in general still apply.

5. **QuadReg** - performs quadratic regression in the form of  $y = ax^2 + bx + c$

6. **CubicReg** - performs cubic regression in the form of  $y = ax^3 + bx^2 + cx + d$

7. **QuartReg** - performs quartic regression in the form of  $y = ax^4 + bx^3 + cx^2 + dx + e$

8. **LinReg(a+bx)** - performs linear regression as in 4 above but the slope is now  $b$  and intercept  $a$

9. **LnReg** - performs logarithmic regression in the form of  $y = a + b \ln x$

0: **ExpReg** - performs exponential regression in the form of  $y = a \cdot b^x$

A. **PwrReg** - performs power regression in the form of  $y = a \cdot x^b$

B. **Logistic** - performs logistic regression in the form of  $y = \frac{c}{1 + ae^{-bx}}$

C. **SinReg** - performs sinusoidal regression in the form of  $y = a \sin(bx + c) + d$

D. **Distribution Statistics** - 2nd DISTR

1. **normalpdf** - computes the probability density function for the normal distribution at a specified  $x$  value. Since the probability of any particular  $x$ -value is zero in a normal distribution, then this function is used just in graphing a normal curve.

- form:  $\text{normalpdf}(x, \mu, \sigma)$ . To see a normal curve graphed, place this function into Y1 and graph using an X window from  $\mu - 3\sigma$  to  $\mu + 3\sigma$ .
- **Note: You will rarely use this function.**

\* 2. **normalcdf** - computes the normal distribution probability between *lowerbound* and *upperbound* for the specified mean and standard deviation.

- form:  $\text{normalcdf}(\text{lowerbound}, \text{upperbound}, \mu, \sigma)$ .
- if you want the tail of the normal distribution, you must use a small *lowerbound* or a large *upperbound*. 4 standard deviations from the mean is good enough.

Example: If refrigerated milk lasts an average of 15 days with a standard deviation of 0.7 days, find the probability that milk lasts: (assuming that this is a normal distribution)

- |                            |  |
|----------------------------|--|
| a) between 13 and 14 days: | Solution: $\text{normalcdf}(13, 14, 15, .7)$ : .074  |
| b) more than 16 days:      | Solution: $\text{normalcdf}(16, 999, 15, .7)$ : .077 |
| c) less than 15.5 days:    | Solution: $\text{normalcdf}(0, 15.5, 15, .6)$ : .762 |

\* 3. **invnorm** - computes the  $x$  value associated with a given area under a normal curve.

- form:  $\text{invnorm}(\text{percentage}, \mu, \sigma)$ .
- this calculation is the one to use if you know a percentile and you want to find the score associated with it.

Example: The scores in a large test are normally distributed with a mean of 74 and a standard deviation of 5. Find the score that represents:

- |                         |   |
|-------------------------|---|
| a) the 70th percentile: | Solution: $\text{invnorm}(.70, 74, 5) = 77.217$ |
| b) the top percentile:  | Solution: $\text{invnorm}(.99, 74, 5) = 85.632$ |

4. **tpdf** - computes the probability density function for the normal distribution at a specified  $x$  with a specified number of *degrees of freedom*. Since the probability of any particular  $x$ -value is zero in a t-distribution, then this function is used just in graphing a t-distribution.

- form:  $\text{tpdf}(x, df)$ . To see a t-distribution curve graphed, place this function into Y1 and graph using an X window from -3 to 3.

• **Note: You will very rarely use this function.**

5: **tcdf** - computes the t-distribution probability between *lowerbound* and *upperbound*



for the specified interval and *degrees of freedom*.

- form: tcdf (*lowerbound*, *upperbound*, *df*).
- **Note: You will never use this function.**

6.  $\chi^2$ pdf - computes the probability density function for the  $\chi^2$  distribution at a specified  $x$  with a specified number of *degrees of freedom*. Since the probability of any particular  $x$ -value is zero in a t-distribution, then this function is used just in graphing a t-distribution.

- form:  $\chi^2$ pdf ( $x$ ,  $df$ ). To see a  $\chi^2$ -distribution curve graphed, place this function into Y1 and graph using an X window from 0 to 30.
- **Note: You will very rarely use this function.**

\* 7.  $\chi^2$ cdf - computes the  $\chi^2$ -distribution probability between *lowerbound* and *upperbound* for the specified interval and *degrees of freedom*). We will use this when we do a  $\chi^2$  test for goodness of fit in the section on hypothesis testing.

- form:  $\chi^2$ cdf (*lowerbound*, *upperbound*, *df*).

8. **Fpdf** - not covered in this course.

9. **Fcdf** - not covered in this course.

\* 0. **binompdf** - computes a probability of  $r$  successes desired for the discrete binomial distribution with the specified number of trials  $n$  and probability of success  $p$  on each trial.

- form: binompdf( $n$ ,  $p$ ,  $r$ ) - this gives the mathematical formula:  $\binom{n}{r} p^r (1-p)^{n-r}$

Example: A basketball player shoots foul shots at 72% accuracy. If he shoots 20 foul shots, find the probability that he makes:

a. 17. Solution: binompdf(20, .72, 17) = .094

b. 18 or 19. Solution: binompdf(20, .72, 18) + binompdf(20, .72, 19) = .051

- Note: unless you want a specific value of  $r$ , it is best to use the binomcdf function below.

\* A. **binomcdf** - computes a cumulative probability of up to  $r$  successes desired for the discrete binomial distribution with the specified number of trials  $n$  and probability of success  $p$  on each trial.

- form: binomcdf( $n$ ,  $p$ ,  $r$ ) - this gives the binomial mathematical formula:

$$\binom{n}{0} p^0 (1-p)^n + \binom{n}{1} p^1 (1-p)^{n-1} + \dots + \binom{n}{r} p^r (1-p)^{n-r}$$

Example: A basketball player shoots foul shots at 72% accuracy. If he shoots 20 foul shots, find the probability that he makes:

a. fewer than 10: Solution: binomcdf(20, .72, 9) = .010

b. 15 or more: Solution: 1 - binomcdf(20, .72, 14) = .495

**B. poissonpdf** - not covered in this course

**C. poissoncdf** - not covered in this course

**D. geometpdf** - computes the probability that a success will occur on the  $r$ th trial given a geometric distribution with probability of success  $p$ .

- form:  $\text{geometpdf}(p, r)$  - this gives the mathematical formula  $(1 - p)^{r-1} \cdot p$

Example: A basketball player shoots foul shots at 72% accuracy. What is the probability that he will

- a) miss 2 straight and then make the 3rd:  $\text{geometpdf}(.72, 3) = .056 = .28^2 \cdot .72$
- b) make 5 straight and then miss:  $\text{geometpdf}(.28, 6) = .054 = .72^5 \cdot .28$

- **Note: using this function can be tricky. It is far easier to learn the mathematical formula**

**E. geometcdf** - computes the probability that a success will occur on the  $r$ th trial or before given a geometric distribution with probability of success  $p$ .

- form:  $\text{geometcdf}(p, r)$  - this gives the mathematical formula

$$p + (1 - p)^1 \cdot p + (1 - p)^2 \cdot p + \dots + (1 - p)^{r-1} \cdot p$$

Example: A basketball player shoots foul shots at 72% accuracy. What is the probability that he will take more than 4 shots before he makes his first shot?

Solution:  $1 - \text{geometcdf}(.72, 4) = .006 = .28^4$

- **Note: using this function can be tricky. It is easier to learn the mathematical formula.**

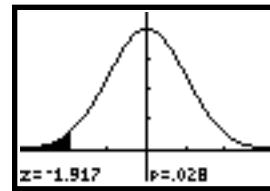
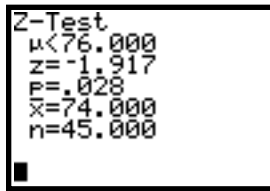
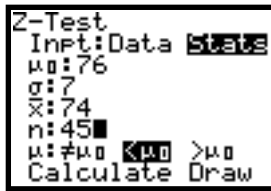
## E. Hypothesis Tests (Inference) and Confidence Intervals - STAT TESTS

\* **1. Z-Test** - performs a hypothesis test for single unknown population mean  $\mu$  when the population standard deviation  $\sigma$  is known.

- When to use: You know the population standard deviation  $\sigma$  (which is unusual, you usually do not know it). You have sample mean  $\bar{x}$  based on  $n$  subjects. You don't know the population mean  $\mu$ . You want to test your sample mean  $\bar{x}$  with some number  $\mu_0$ .
- the null hypothesis  $H_0$  will be that the unknown mean  $\mu$  is equal to  $\mu_0$ .
- the alternate hypothesis will be that either  $\mu \neq \mu_0, \mu > \mu_0$  or  $\mu < \mu_0$

Example: The standard deviation of a large group of students taking an exam is 7. 45 of my students take the exam and have a mean of 74. I believe that the scores are low. I believe they should have had a mean of 76. Test the hypothesis with 98% confidence.

You have summary statistics; use the Stats option. You want a one-sided test:  $\mu < \mu_0$ .

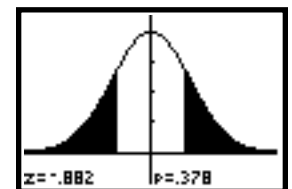
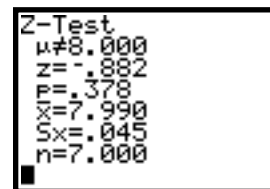
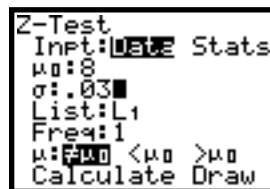
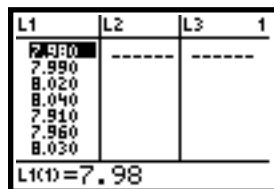


Conclusion: Since the  $p$ -value is less than 2%, you can reject the null hypothesis and infer that there is good evidence to suggest that your class has lower scores than 76. The screens above give you the  $z$ -statistic and the  $p$ -value. You can choose to calculate this material and graph it.

The  $z$ -statistic is given by  $z = \frac{\bar{x} - \mu_0}{\sigma/\sqrt{n}}$ .

Example: A popular brand of potato chips claim that a bag contains 8 ounces with a standard deviation of .03. You have a small sample of chips with weights as shown in list L1 on the left screen below. You want to test the hypothesis that your sample is different than the advertised mean with 95% confidence.

Since you have statistics, use the Data option. You want a two-sided test  $\mu \neq \mu_0$ .



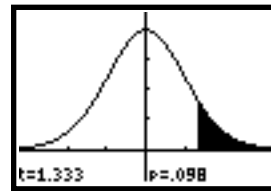
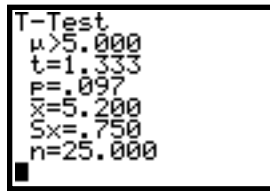
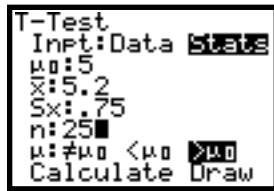
Conclusion: Since the  $p$ -value is so large (.378), well over .05, there is no evidence to suggest that the mean of your sample is different than 8.

\* **2. T-Test** - performs a hypothesis test for single unknown population mean  $\mu$  when the population standard deviation  $\sigma$  is unknown.

- When to use: You have sample mean  $\bar{x}$  based on  $n$  subjects and the sample standard deviation  $Sx$ . You don't know the population mean  $\mu$ . You want to test your sample mean  $\bar{x}$  with some number  $\mu_0$ . Be sure that the guidelines for using these procedures are in place (SRS, if sample size less than 15, it must be normal, sample size greater than 15, there are no outliers or strong skew, safe when sample size  $\geq 40$ )
- the null hypothesis  $H_0$  will be that the unknown mean  $\mu$  is equal to  $\mu_0$ .
- the alternate hypothesis will be that either  $\mu \neq \mu_0$ ,  $\mu > \mu_0$  or  $\mu < \mu_0$

Example: A weight loss system claims that a person will lose at least 5 pounds in the first week. 25 people enlisted in the program and lost an average of 5.2 lbs with a standard deviation of 0.7 lbs. Investigate the system's claim with 95% confidence.

Since you have summary statistics, use the  $t$ -option. You want a one-sided test:  $\mu > \mu_0$ . Note that it is safe to use the  $t$ -procedures because the sample size  $> 15$  with no evidence of outliers.

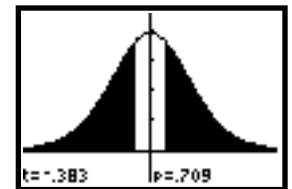
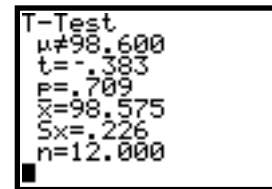
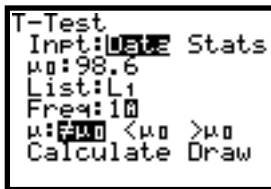
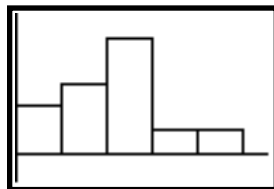


The  $t$ -statistic is given by  $t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}}$

Conclusion: Since the  $p$ -value is greater than .05, we do not reject the null hypothesis which means that there is no evidence to suggest that the weight system's claim is true.

Example: A thermometer reads "normal" at 98.6°F. A company wants to test its thermometers. It uses a sample size of 12 by placing the thermometers in 98.6° water and recording the temperatures: 98.6, 98.7, 98.4, 98.4, 98.3, 98.7, 98.8, 99.0, 98.6, 98.5, and 98.7.

Since you have statistics, use the Data option. You want a two-sided test  $\mu \neq \mu_0$ . Since the sample size is less than 15, you must assess normality of your data. A histogram is below. The data appears normal enough to use  $t$ -procedures.



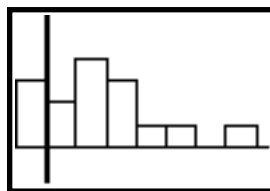
Conclusion: Since the  $p$ -value is so high ( $> .05$ ) we do not reject the null hypothesis meaning there is no reason to believe the thermometer readings are different than 98.6.

Example: A class of 15 students took a pre-exam and a post exam. Their scores are below. We want to test the hypothesis that the scores are better in the post exam at the 1% level.

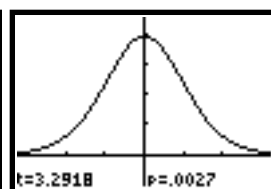
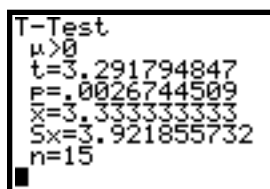
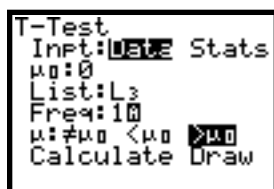
Pre	74	78	76	71	82	93	95	55	57	70	81	82	81	75	78
Post	77	78	75	73	83	92	94	64	62	77	79	85	86	80	90

L1	L2	L3	Freq
74	77	3	1
78	78	0	1
76	75	-1	1
71	73	2	1
82	83	1	1
93	92	-1	1
95	94	2	1

L3 = L2 - L1



This is a match pairs experiment so we look at  $L3 - L2$  and draw a histogram. Since there are  $\geq 15$  students, and there are no outliers or strong skew, we are safe.



Conclusion: Since the  $p$ -value is  $< .01$ , reject the null hypothesis that the two test results are the same. Thus there is good evidence that students do better on the post test.

Note that this is not a candidate for a 2-sample T test below because the two samples

are not independent.

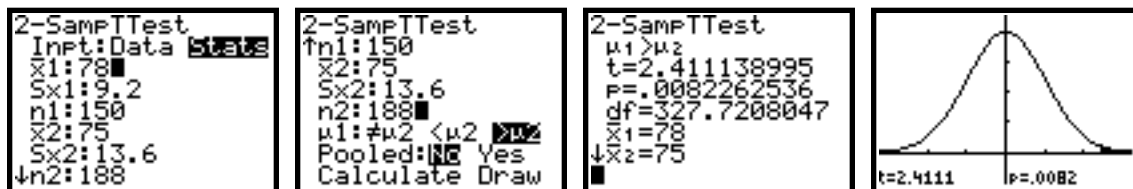
**3. 2-SampZtest** - 2 sample  $z$ -test. Although this test is similar to the one sample  $z$ -test above, it is not usually performed because we usually do not know the population standard deviation, much less both of them.

\* **4. 2-SampTTest** - 2 sample  $t$ -test. This tests the equality of the means of two population ( $\mu_1$  &  $\mu_2$ ) when neither population standard deviation ( $\sigma_1$  and  $\sigma_2$ ) is known.

- When to use: You have sample 2 means  $\bar{x}_1$  and  $\bar{x}_2$  based on  $n_1$  and  $n_2$  subjects and the sample standard deviations  $Sx_1$  and  $Sx_2$ . You don't know the population means  $\mu_1$  and  $\mu_2$ . You want to test your sample mean  $\bar{x}_1$  with some number  $\bar{x}_2$ . Remember the basic guidelines for this test: two SRSs that are independent. Matching violates independence. Both populations are normally distributed.
- the null hypothesis  $H_0$  will be that the unknown mean  $\mu_1$  is equal to  $\mu_2$ .
- the alternate hypothesis will be that either  $\mu_1 \neq \mu_2, \mu_1 > \mu_2$  or  $\mu_1 < \mu_2$
- you will use the unpooled option on the calculator.

Example: An experiment measures how much time students spend on average watching TV on a school night. Does the data below support the contention that boys watch more TV at the 2% level?

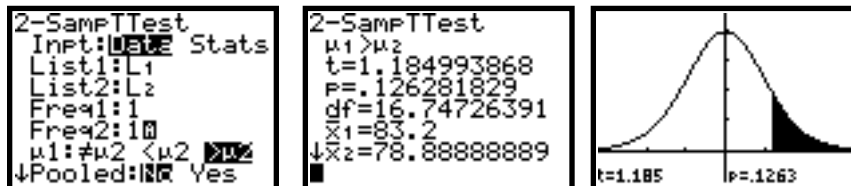
Sex	$n$	$\bar{x}$	$s$
Boys	150	78	9.2
Girls	188	75	13.6



Conclusion: Since  $p < .01$ , we reject the null hypothesis at the 1% level and conclude that there is evidence suggesting that boys watch more TV than girls.

Example: A researcher wants to determine how background music affects the grades on a standardized test. A stratified sample technique was used with the students having scores shown below. Does the data support the contention that background music gives students higher scores in this exam at the 5% level?

Music	85	84	88	72	79	90	91	80	93	70
Control	79	85	73	75	83	88	64	88	75	



Conclusion: Since  $p > .05$ , we do not reject the null hypothesis which means that there is no evidence to conclude that music gives students higher scores at the 5% level.

\* **5. 1-PropZTest** – one proportion Z test – performs a test for an unknown proportion of successes (prop). It uses a sample of  $n$  trials and  $x$  successes.

- When to use: you have a sample of  $n$  trials and  $x$  successes. You want to test the proportion of the sample successes to some unknown proportion  $p_0$ . Your data must have come from an SRS and the population size must be at least 10 times as large as the sample. Finally,  $np_0$  and  $n(1 - p_0)$  must both be greater than 10.

• Your null hypothesis is:  $H_0 : \text{prop} = p_0$

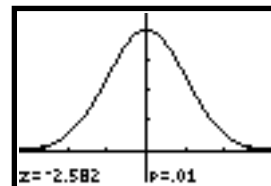
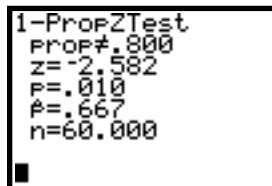
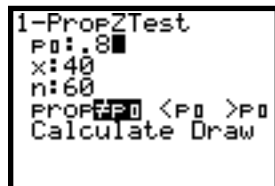
$$H_a : \text{prop} \neq p_0$$

• Your alternative hypotheses are:  $H_a : \text{prop} > p_0$

$$H_a : \text{prop} < p_0$$

• You are generating the z-statistic:  $z = \frac{\hat{p} - p_0}{\sqrt{\frac{p_0(1 - p_0)}{n}}}$  where  $\hat{p}$  is your sample proportion of success

Example: A commercial run nationally says that “4 out of every 5 dentists recommend Shmutz toothpaste.” A sample of 60 dentists finds that 40 dentists recommend Shmutz. Is there good evidence to believe that the commercial’s claims are faulty at the 2% level?



Conclusion: Since the  $p$ -value  $< .02$ , we reject the null hypothesis that there is no difference between our sample proportion and the commercial’s claim. We conclude that that there is enough evidence to say that the commercial’s claim is faulty.

Note that we should check whether we may use this test.  $60(.8)$  and  $60(.2)$  are both  $> 10$ . However, we are not sure of our population size. If this claim is about all dentists, we are certainly okay.

\* **6. 2-PropZTest** – 2 proportion Z tests – performs a test to compare the proportion of successes  $p_1$  and  $p_2$  from two populations.

- When to use – you have two populations with different values of  $n$  and you have a proportion of successes in each. You want to see if there is a statistical difference between the two. You may use this test when  $n_1\hat{p}$ ,  $n_1(1 - \hat{p}_1)$ ,  $n_2\hat{p}$ ,  $n_2(1 - \hat{p}_2)$  are all greater than 5.

• Your null hypothesis is:  $H_0 : p_1 = p_2$

$$H_a : p_1 \neq p_2$$

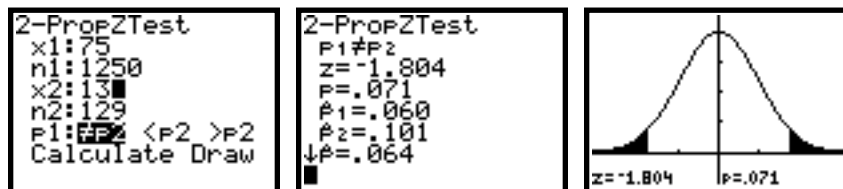
• Your alternative hypotheses are:  $H_a : p_1 > p_2$

$$H_a : p_1 < p_2$$

• The z-statistic is  $z = \frac{\hat{p} - p_0}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$  where  $\hat{p} = \frac{\# \text{ successes in both samples combined}}{\# \text{ observations in both samples combined}}$

Example: A study at Wissahickon High school asked students and teachers whether to keep classes at the standard 45 minute length or to make them longer. The results are below. Perform a test to determine whether there is a significant difference between the two groups at the 2% level.

	Teachers	Students
Lengthen them	19	75
Keep them the same	116	1175



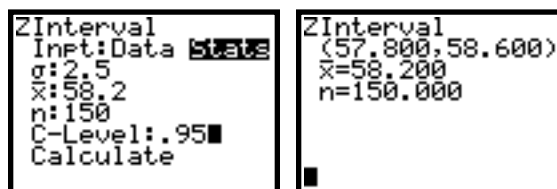
Since  $p > .02$ , we do not reject the null hypotheses and conclude that there is no evidence to believe that there is any difference between the way the teachers and students feel on the issue of class size.

\* **7. ZInterval** - Z confidence interval - finds the confidence interval from a sample size  $n$  from an unknown population mean  $\mu$  and known standard deviation  $\sigma$ .

• Conclusion: you have some sample with size  $n$ . You don't know the population mean but you do know the sample mean  $\bar{x}$  and the population standard deviation  $\sigma$  (not a normal situation). You want a confidence interval for  $\mu$ . It is assumed that the population distribution is normal.

• You are calculating  $\bar{x} \pm z * \frac{\sigma}{\sqrt{n}}$

Example: 150 light bulbs were tested. It was found that the mean life of the bulb was 58.2 hours with a standard deviation of 2.5 hours. If we assume that the population standard deviation is also 2.5 hours, find a 95% confidence interval for the life expectancy of the bulb.



This means: if you repeatedly sample 150 bulbs, 95% of the samples will have a mean between 57.8 and 58.6. The margin of error is  $58.6 - 58.2 = .4$  hours.

Example: 44 students took the monthly math contest. The results are below. L1 is the score and L2 are how many students received this score. The standard deviation for these exams over a long period of time is 1.22. Find a 99% confidence interval for the average score of this exam.

L1	L2	L3	3
0.000	1.000		
1.000	3.000		
2.000	5.000		
3.000	15.000		
4.000	14.000		
5.000	4.000		
6.000	2.000		

ZInterval
Inpt: Data Stats
$\sigma$ : 1.22
List: L1
Freq: L2
C-Level: .99
Calculate

ZInterval
(2.844, 3.792)
$\bar{x}$ : 3.318
Sx: 1.272
n: 44.000

Conclusion: if you repeated sample 44 students, 99% of the samples will have a mean between 2.844 and 3.792. The margin of error is  $3.792 - 3.318 = .474$ . The reason that the margin of error is so relatively large is because we want a 99% confidence interval and the sample size is not large.

\* **8. TInterval** - t confidence interval - finds the confidence interval from a sample size  $n$  from an unknown population mean  $\mu$  and unknown standard deviation  $\sigma$ .

- When to use: you have some sample with size  $n$ . You don't know the population mean but you do know the sample mean  $\bar{x}$  and the sample standard deviation  $s$ . You want a confidence interval for  $\mu$ . It is assumed that the population distribution is normal. If the sample size is less than 15, use only if the data is normal.
- You are calculating  $\bar{x} \pm t * \frac{s}{\sqrt{n}}$

Example: On a busy Saturday afternoon at a local supermarket, 25 people were timed as to the time they got in line until the times their groceries were bagged. The average time was 8.35 minutes with a standard deviation of 1.43 minutes. Construct a 95% confidence interval for the mean of time in line.

TInterval
Inpt: Data Stats
$\bar{x}$ : 8.35
Sx: 1.43
n: 25
C-Level: .95
Calculate

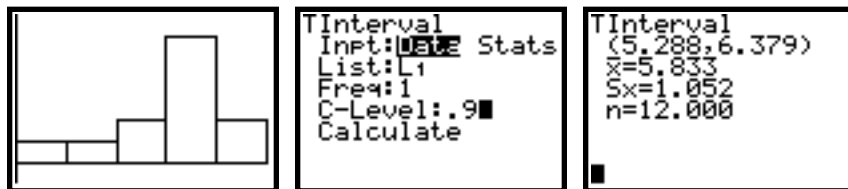
TInterval
(7.760, 8.940)
$\bar{x}$ : 8.350
Sx: 1.430
n: 25.000

Conclusion: if you repeatedly sample 25 people, 95% of these samples would have the mean between 7.760 minutes and 8.940 minutes. The margin of error is  $8.94 - 8.35 = .59$  minutes.

Example: 12 students who were taking a statistics final were polled as to how much sleep they got the night before. The results are below. Find a 90% confidence interval for the mean sleep time of statistics students before a final.

5	6.5	4.5	6.5	7	6.5	6	3.5	7	6	5.5	6
---	-----	-----	-----	---	-----	---	-----	---	---	-----	---





Conclusion: if we continually sample groups of 12 students, 90% of the samples will have a mean sleep time between 5.288 and 6.379 hours of sleep. The margin of error is  $6.379 - 5.833 = .545$  hours.

**9. 2-SampZInt** - z confidence interval for 2 samples - since this uses the premise that we have 2 population standard deviations (quite rare), we will not use this option.

\* **0. 2 SampleTInt** - t confidence intervals for 2 samples  $\mu_1 - \mu_2$ .

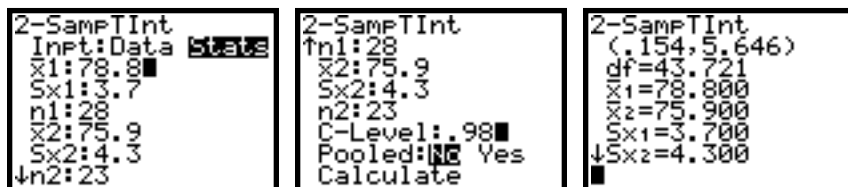
- When to use: you have 2 sample means and sample standard deviations with the same or different sizes and you wish to find a confidence interval for  $\mu_1 - \mu_2$ . It is assumed that both samples are normally distributed.

- You are calculating:  $(\bar{x}_1 - \bar{x}_2) \pm t * \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$

- Note that if you do this by hand, you will get a slightly different answer than the calculator answer because the hand method requires the *degrees of freedom* be found by subtracting 1 from the smaller of the two  $n$  values while the calculator uses a more exact method.

Example: Two groups took the same final exam, one using a calculator, the other not. The statistics are below. Construct a 98% confidence interval for the difference of the method averages.

	$n$	$\bar{x}$	$s$
With calculator	28	78.8	3.7
Without calculator	23	75.9	4.3



Conclusion: if we were to continually give this exam to the same sample sizes, 98% of the samples would have a difference between their averages to be .154 to 5.646. This is the same as saying that we are 98% confident that the mean difference between the two methods lies in the interval .154 to 5.646. The margin of error is  $5.646 - (78.8 - 75.9) = 2.746$

\* **A. 1-PropZInt** - confidence interval for an unknown proportion of successes.

- When to use: You have a sample size of  $n$  and have  $x$  successes. You want to predict the proportion of success to an indicated level of confidence. We assume that the data is from an

SRS, the population is at least 10 times the sample size and  $n\hat{p}$  and  $n(1 - \hat{p})$  are  $\geq 10$ .

- You are calculating  $\hat{p} \pm z^* \sqrt{\frac{\hat{p}(1 - \hat{p})}{n}}$  where  $\hat{p}$  is the proportion of success in your sample.

Example: In a poll of 1000 people taking from an SRS of the country, 634 said they watched the Super Bowl. Find a 95% confidence interval for the proportion of people watching the Super Bowl.

```
1-PropZInt
x:634
n:1000
C-Level:.95
Calculate
```

```
1-PropZInt
(.604,.664)
p=.634
n=1000.000
```

Conclusion: if we were to perform this survey repeatedly with sample sizes of 1000, 95% of them would have between 60.4% and 66.4% watching the Super Bowl. The margin of error is  $.664 - .634 = .03$  or 3%.

Note that we can perform this calculation because our population is well over 10 times our sample size, and  $1000(.634)$  and  $1000(.356)$  are well over 10.

\* **B. 2-PropZInt** - confidence interval for the difference between 2 unknown proportions of success.

- When to use: You have 2 samples having different number of successes. You want to predict the difference in the proportion of success to an indicated level of confidence. We assume that the data is from 2 SRSs, and  $n_1\hat{p}_1$ ,  $n_1(1 - \hat{p}_1)$ ,  $n_2\hat{p}_2$ ,  $n_2(1 - \hat{p}_2)$  are all greater than 5.

- You are calculating  $(\hat{p}_1 - \hat{p}_2) \pm z^* \sqrt{\frac{\hat{p}_1(1 - \hat{p}_1)}{n_1} + \frac{\hat{p}_2(1 - \hat{p}_2)}{n_2}}$

Example: A study is being done on the proportion of students drinking water at lunch. We want to construct a 90% confidence interval between the proportion of girls drinking water and boys. The data follows:

	Water	Other
Boys	18	51
Girls	28	25

```
2-PropZInt
x1:18
n1:69
x2:28
n2:53
C-Level:.9
Calculate
```

```
2-PropZInt
(-.410,-.125)
p1=.261
p2=.528
n1=69.000
n2=53.000
```

Conclusion: If we were to perform this study repeatedly, 90% of the time, the difference between the 2 proportions of water drinkers would be between 12.5% and 41%. The margin of error is  $.410 - (.528 - .261) = 14.3\%$ . It is so large because of the obvious difference in drinking habits between boys and girls.

\* C.  $\chi^2$ -Test - chi-square test on a two-way table of counts.

- There are two types of  $\chi^2$  tests, one for goodness of fit and the other for a two way table (sometimes called a test for independence).
- The calculator does not do a goodness of fit test directly. You have to put your data into a list, do some basic calculations, and then find a statistic. This method is outlined:

Example: Over the last 5 years, the population of Wissahickon High has been:

White: 75% Black 8% Asian: 14% Other: 3%

This year, our populations is:

White: 1009 Black: 85 Asian: 224 Other: 31

Perform a  $\chi^2$  test to see if this population is different from past years

Your null hypothesis is:  $H_o$  : The current pop. is the same as previous years

Your alternative hypothesis is:  $H_a$  : The current pop. is different than previous years

Put the observed (current numbers) in L1.

We have 1349 students in school. Use the percentages given to find the expected numbers. You can round. Put them in L2.

You need the formula:  $\frac{(\text{Obs} - \text{Exp})^2}{\text{Exp}}$  in your L3. Sum your L3. Then look

up the  $\chi^2$  statistic for the number of *degrees of freedom*. Since there are 4 rows, the *df* value is 3. The format is  $\chi^2\text{cdf}(\text{lowerbound}, \text{upperbound}, \text{df})$ . *Lowerbound* will be the sum you just got, *upperbound* will be any large number (1000 is fine).

L1	L2	L3
1009	1012	.00889
85	108	4.8981
224	189	6.4815
31	40	2.025
-----	-----	-----
L3 = (L1 - L2)² / L2		

sum(L3)	13.41352291
---------	-------------

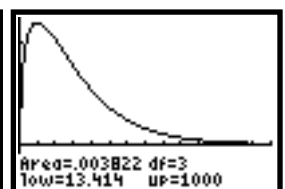
$\chi^2\text{cdf}(13.414, 1000, 3)$	.0038217095
-------------------------------------	-------------

Conclusion: Since the *p*-value is less than 1%, we can reject the null hypothesis. So we can conclude that this year's population is different than previous years. If you want to see the shading (there is very little here), go to the **2nd** **DISTR** menu:

DISTR	<b>2</b> <b>DISTR</b>
1:ShadeNorm(	
2:Shade_t(	
3:Shade $\chi^2$ (	
4:ShadeF(	

WINDOW	
Xmin=0	
Xmax=15	
Xscl=1	
Ymin=-.06	
Ymax=.24	
Yscl=.1	
Xres=	

Shade $\chi^2$ (13.414, 1000, 3)
----------------------------------



- $\chi^2$  test for 2-way tables. The calculator can handle this but in a slightly different way.

Example: We want to see if there is a relationship to the WHS population in regards to their breakfast eating habits. Here are the stats:

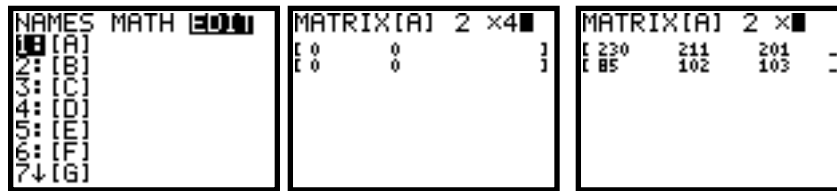
		Class			
		9	10	11	12
Breakfast Habits	Yes	230	211	201	195
	No	85	102	103	120

Your null hypothesis is:  $H_o$  : The proportion of breakfast eaters to non breakfast eaters are the same

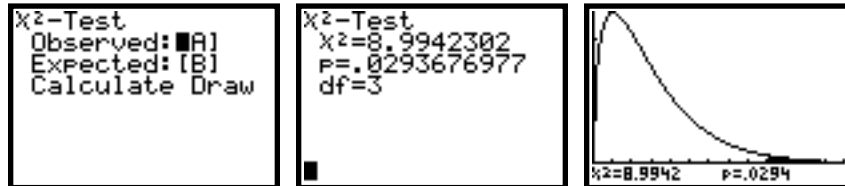
Your alternative hypothesis is:  $H_a$  : The proportion of breakfast eaters to non breakfast eaters are not the same

On the calculator, go to your matrix menu - **2nd** **MATRX** **EDIT**

Make Matrix A a 2x4 matrix (the same as your data above). Then type in your data.



Then go to your  $\chi^2$  test - **STAT** **TESTS**  **$\chi^2$ -Test** and calculate. You can draw your shaded distribution as well.



Conclusion: since your  $p$ -value is so small, 2.94%, we can reject the null hypothesis at the 5% level. This means that there is good evidence to suggest that the breakfast eating habits of the 4 classes are different.

**D. 2-SampFTest** - 2 sample F test - not covered in this course.

\* **E. LinRegTTest** - linear regression T test - computes a linear regression on the given data and a  $t$ -test on the slope  $\beta$  and the correlation  $\rho$  for the equation  $y = \beta x + \alpha$ .

- When to use: You have a set of  $(x, y)$  points. You want to test the strength of of the relationship - to find a  $p$  value that will either confirm or reject the null hypothesis that there is no relationship.

Example: 7 students take 2 exams. Their scores are as follows:

Student	1	2	3	4	5	6	7
Test 1	75	82	91	72	80	69	88
Test 2	78	90	90	78	79	74	95

Put the data in L1 and L2. Plot it using a scatterplot. It appears to have a positive slope.

The null hypothesis is:  $H_o$  : The slope  $\beta = 0$  (no slope)

The alternative hypothesis is:  $H_a$  : The slope  $\beta > 0$  (positive slope)

```
LinRegTTest
Xlist:L1
Ylist:L2
Freq:1
 $\beta & \rho \neq 0 < 0$ 
RegEQ:Y1
Calculate
```

```
LinRegTTest
y=a+bx
 $\beta > 0$  and  $\rho > 0$ 
t=4.540858977
p=.003081923
df=5
a=12.94612069
```

```
LinRegTTest
y=a+bx
 $\beta > 0$  and  $\rho > 0$ 
t=4.540858977
p=.003081923
df=5
a=12.94612069
```

Conclusion: since the  $p$ -value is  $<.01$ , we can reject the null hypothesis. We can say that is good evidence that these higher test scores follow the first test score.

F. ANOVA( - one way analysis of variance - not covered in this course.

F. List Features - **2nd** **LIST** **OPS** - only the features relative to STAT are covered

5. Seq( - sequence - allows you to create a sequence of numbers in a list:

- form: seq(expression using X, X, start X, end X)

```
L1 L2 L3 1
-----
L1=seq(X,X,1,8)
```

6. cumSum( - generates the cumulative sum of a list - adding the list elements

- form: cumsum(List)

```
L1 L2 L3 2
-----
L2=cumSum(L1)
```

7.  $\Delta$  List( - generates the difference between a list term and its preceding term

- form:  $\Delta$  List(List)

L1	L2	3
1	10	10
2	15	15
3	20	20
4	25	25
5	30	30
6	35	35
7	40	40
8	45	45

L3 =  $\Delta$ List(L2)

The **2nd** **LIST** **MATH** menu is obvious:

```

NAMES OPS MATH
1:min(
2:max(
3:mean(
4:median(
5:sum(
6:Prod(
7:stdDev(
8:variance(

```

```

NAMES OPS MATH
2↑max(
3:mean(
4:median(
5:sum(
6:Prod(
7:stdDev(
8:variance(

```

- 1) min( - minimum value in a list
- 2) max( - maximum value in a list
- 3) mean( - mean (average) of a list
- 4) median( - median of a list
- 5) sum( - sum all the values in a list
- 6) product( - multiply all the values in a list
- 7) stdDev( - sample standard deviation of a list
- 8) variance( - sample variance of a list