Using Graphing Calculators for Math 11

Graphing calculators are not required for Math 11, but they are likely to be helpful, primarily because they enable you to avoid the use of tables in some problems. The TI-83 graphing calculator is the best option for statistics and therefore is recommended. However, all graphing calculators will be permitted on homework and exams. TI-85 and TI-86 calculators and some older TI-89 calculators do not have statistics capabilities. On homework assignments, you may also use MINITAB, Excel, or other software if you would like. However, this is recommended only for checking your work or possibly as preparation for Math 11L assignments because computers will not be permitted on exams. To ensure that students without graphing calculators are not at a serious disadvantage on exams, tables will be provided. Also, students will be expected to show work when performing integration or calculating test statistics.

Instructions for how to use the TI-83 and TI-89 calculators are given in the textbook. However, we provide below instructions for the procedures that are most likely to be useful for Math 11 because there are a few procedures that are not explained well in the book. Because there are many different graphing calculators and these instructions were tested only on a few of them, it is possible that these instructions will not be as exact as those for the computer labs, but hopefully they should be mostly reliable.

Getting Started with the TI-89

On the TI-83, you can follow the instructions below as soon as you turn on your calculator. On the TI-89, you first have to press APPS, then select FlashApps, then scroll to Stats/List Editor, then press Enter twice. At this point, you should see options at the top of the page ranging from F1-Tools to F7-Ints, and you are ready to follow the instructions below. On some older TI-89 calulators, these options are not available. Such calculators will not be helpful in Math 11, although it is possible to download the necessary package from the web site http://education.ti.com and transfer it to your calculator using a cable. To do this, go to Downloads, then Apps and Software, then Math Apps (under TI-89), and select Statistics with List Editor.

Calculating Means and Standard Deviations

You may find it useful to manually enter a short list of numbers into your calculator so that your calculator can compute the mean and standard deviation. For example, to find the mean and standard deviation of the numbers 23, 9, 13, 12, you can use the following procedure:

TI-83: Press STAT, then select 1:Edit so that you can type numbers into lists. With the cursor under the first list L1, type 23, Enter, 9, Enter, 13, Enter, 12, Enter. Now L1 contains the data. Then press STAT, select CALC, then 1:1-Var Stats. Then press the L1 key (2nd followed by the 1 button), and press enter. The mean is $\bar{x}$ and the standard deviation is s_x. You should get a mean of 14.25 and a standard deviation of 6.076.

TI-89: Using the arrows if necessary, scroll over to list1. Press the down arrow so that the row of dashes is highlighted. Then type 23, Enter, 9, Enter, 13, Enter, 12, Enter. Now list1 contains the data. Press F4, then select 1:1-Var Stats. Type "list1" into the box that says "List" (you will need to use the "alpha" key to type the "l", "i", and "s") and then press Enter. The mean is $\bar{x}$ and the standard deviation is s_x. You should get a mean of 14.25 and a standard deviation of 6.076.

Calculating Normal Distribution Probabilities

When solving probability problems, especially those involving the Central Limit Theorem, or when trying to obtain p-values from test statistics in hypothesis testing, it will often be necessary to calculate probabilities of the form $P(Z \leq z)$, $P(Z \geq z)$, or $P(a \leq Z \leq b)$, where Z has a normal distribution with mean zero and variance one. Using a graphing calculator (but not using tables), it is possible to calculate probabilities for normally distributed random variables with different means and standard deviations by changing the inputs, but on homework and exams you will be expected to show how you can reduce computations to those involving a standard normal distribution.

Tables: There is a table of normal distribution probabilities, listed as Table Z, in Appendix D of the textbook. The table gives probabilities of the form $P(Z \leq z)$. To find, for example, $P(Z \leq 1.26)$, look up the row labeled 1.2 and the column labeled 0.06. The number in this cell, which is .8962, is $P(Z \leq 1.26)$. To find other probabilities, it is necessary to convert them into the form $P(Z \leq z)$. For example, to find $P(Z \geq -0.37)$, observe that this is $1 - P(Z \leq -0.37)$, which from the table is $1 - .3557 = .6443$. To find $P(-0.37 \leq Z \leq 1.26)$, we can calculate $P(Z \leq 1.26) - P(Z \leq -0.37) \approx .8962 - .3557 = .5405$.

TI-83: Press DISTR (that is, 2nd and VARS), and choose 2:normalcdf. To calculate $P(-0.37 \leq Z \leq 1.26)$, type "-0.37, 1.26, 0, 1)" to finish the command, then press ENTER. The numbers 0 and 1 that are entered correspond to the mean and standard deviation of Z respectively. You should obtain an answer of .540. The TI-83 only calculates probabilities of the form $P(a \leq Z \leq b)$ and not of the form $P(Z \leq z)$ or $P(Z \geq z)$. However, to find $P(Z \leq 1.26)$, you can type a number such as -100 for the lower endpoint, so the full command becomes normcdf(-100, 1.26, 0, 1) and the answer should be .896. To find $P(Z \geq -0.37)$, use 100 for the upper endpoint to get the answer of .644.

TI-89: Press F5, then scroll down to 4:normal Cdf. Then input the four numbers requested, moving from each number to the next one using the down arrow. To calculate $P(-0.37 \leq Z \leq 1.26)$, enter -0.37 for the Lower Value, 1.26 for the Upper Value, 0 for the mean μ, and 1 for the standard deviation σ. To find $P(Z \leq 1.26)$, use a number such as -100 for the Lower Value and 1.26 for the Upper Value to get an answer of .896. To find $P(Z \geq -0.37)$, use -0.37 for the Lower Value and 100 for the Upper Value to get the answer of .644.

Especially when finding critical values for confidence intervals or for inference, it may be necessary, for a given value y, to find the value of z such that $P(Z \leq z) = y$, or $P(Z \geq z) = y$, or $P(-z \leq Z \leq z) = y$. We will show below how to do this with $y = .95$. One might also need $y = .90$ or $y = .99$ at times.

Tables: To find the value of z such that $P(Z \leq z) = .95$, look for the value of .95 in the table. One does not find .95 exactly, but instead .9495 and .9505. We see that $P(Z \leq 1.64) = .9495$ and $P(Z \leq 1.65) = .9505$. Therefore, we can say that $P(Z \leq 1.645) \approx .95$. (It would also be acceptable just to use either 1.64 or 1.65.) That is, 95 percent of the area under the normal curve is to the left of 1.645. By the symmetry of the normal distribution, we have $P(Z \geq -1.645) \approx .95$, so 95 percent of the area under the normal curve is to the right of -1.645. To find the middle 95 percent of the area under the normal curve, use the above procedure but with .975 in place of

.95, because we do not want an area of .05 in the right tail but rather just half the area, which is .025. The number .9750 appears in the table, so we see from the table that $P(Z \leq 1.96) \approx .975$, and therefore that $P(-1.96 \leq Z \leq 1.96) \approx .95$.

TI-83: Press DISTR (that is, 2nd and VARS), and choose 3:invnorm. The command "invNorm(" should appear. To finish the command, type ".95, 0, 1)" to get the answer of 1.645. This means that $P(Z \leq 1.645) \approx .95$. That is, 95 percent of the area under the normal curve is to the left of 1.645. By the symmetry of the normal distribution, we have $P(Z \geq -1.645) \approx .95$, so 95 percent of the area under the normal curve is to the right of -1.645. To find the middle 95 percent of the area under the normal curve, use the above command but with .975 in place of .95, because we do not want an area of .05 in the right tail but rather just half the area, which is .025. This should give the answer of 1.960, which means that $P(Z \leq 1.960) \approx .975$ and therefore that $P(-1.960 \leq Z \leq 1.960) \approx .95$.

TI-89: Press F5, then scroll down to 2:Inverse, then select 1:Inverse Normal. Type .95 for Area, 0 for μ, and 1 for σ to get the answer of 1.645. This means that $P(Z \leq 1.645) \approx .95$. That is, 95 percent of the area under the normal curve is to the left of 1.645. By the symmetry of the normal distribution, we have $P(Z \geq -1.645) \approx .95$, so 95 percent of the area under the normal curve is to the right of -1.645. To find the middle 95 percent of the area under the normal curve, use the above command but use .975 for the area instead of .95, because we do not want an area of .05 in the right tail but rather just half the area, which is .025. This should give the answer of 1.960, which means that $P(Z \leq 1.960) \approx .975$ and therefore that $P(-1.960 \leq Z \leq 1.960) \approx .95$.

Calculating t-distribution Probabilities

When conducting t-tests, it will be necessary to convert your test statistic, which has a t-distribution under the null hypothesis, into a p-value. This is more easily done on a calculator than with tables, as with tables it is only possible to calculate an interval that contains the p-value. Depending on whether the test is one-sided or two-sided, it will be necessary to compute a probability of the form $P(T \leq t)$, $P(T \geq t)$, or $P(-t \leq T \leq t)$, where T has a t-distribution with a given number of degrees of freedom.

Tables: There is a table of critical values for the t-distribution, listed as Table T, in Appendix D of the textbook. Suppose T has a t-distribution with 57 degrees of freedom. Unfortunately, probabilities for this distribution can not be found as precisely with tables as they can with calculators; we can only find intervals containing the probabilities. The number of degrees of freedom is on the left-hand side of the table. Not all values are present, so to be conservative, we round down to the smallest number in the table. In this case, 57 is between 50 and 60, so we use the row in the table with 50 degrees of freedom. The five numbers in this row are 1.299, 1.676, 2.009, 2.403, and 2.678. The two-tailed probabilities and one-tailed probabilites to which these numbers correspond are at the top of the table. Therefore, we can say that if $0 \leq t \leq 1.299$, then $P(|T| > t)$ is at least .20. If $1.299 \leq t \leq 1.676$, then $P(|T| > t)$ is between .10 and .20. If $1.676 \leq t \leq 2.009$, then $P(|T| > t)$ is between .05 and .10. If $2.009 \leq t \leq 2.403$, then $P(|T| > t)$ is between .02 and .05. If $2.403 \leq t \leq 2.678$, then $P(|T| > t)$ is between .01 and .02. Finally, if $t \geq 2.678$, then $P(|T| > t)$ is at most .01. If instead you want to find a probability of the form $P(T > t)$, then use the one-tailed probabilities at the top of the table. For example, if $2.009 \leq t \leq 2.403$, then $P(T > t)$ is between .01 and .025. To find a probability of the form

$P(T < -t)$, use the symmetry of the t-distribution and find $P(T > t)$ instead. For example, $P(T < -2.2)$ is between .01 and .025 because 2.2 is between 2.009 and 2.403.

TI-83: Suppose T has a t-distribution with 57 degrees of freedom, and we want to compute $P(-1.45 \leq T \leq 1.45)$. Press DISTR (that is, 2nd and VARS), and choose 5:tcdf. The command "tcdf(" should appear. To finish the command, type "-1.45, 1.45, 57", with the first number being the lower limit, the second being the upper limit, and the third being the degrees of freedom. You should compute an answer of .847. To find $P(T \leq 1.45)$, use something like -100 for the lower limit instead of -1.45 to get the answer of .924. To get $P(T \geq -1.45)$, use something like 100 for the upper limit instead of 1.45. The answer again is .924.

TI-89: Suppose T has a t-distribution with 57 degrees of freedom, and we want to compute $P(-1.45 \leq T \leq 1.45)$. Press F5, then select 6:t CDF. Type in -1.45 for the Lower Value, then (after using the down arrow), type 1.45 for the Upper Value, and type in 57 for Deg of Freedom. Press Enter twice to get the answer of .847. To find $P(T \leq 1.45)$, use something like -100 for the Lower Value instead of -1.45 to get the answer of .924. To get $P(T \geq -1.45)$, use something like 100 for the Upper Value instead of 1.45. The answer again is .924.

When finding critical values for confidence intervals or for inference, it may be necessary, for a given value y, to find the value of z such that $P(T \leq z) = y$, or $P(T \geq z) = y$, or $P(-z \leq T \leq z) = y$, where T has a t-distribution with a given number of degrees of freedom. We will show below how to do this with $y = .95$ and 57 degrees of freedom. One might also need $y = .90$ or $y = .99$ at times.

Tables: There is no row for 57 degrees of freedom in the table, so we conservatively round down to 50 degrees of freedom. For a one-tailed probability of .05 (the second column in the table), we have a value of 1.676. This means that $P(T \geq 1.676) \approx .05$. The t-distribution is symmetric, so this result also implies $P(T \leq -1.676) \approx .05$. To find the middle 95 percent of the t-distribution, we look at the two-tailed probabilities. Here the value for .05 is in the third column, which is 2.009. This means that $P(|T| \geq 2.009) \approx .05$.

TI-83: There is no inverse t-distribution function on the TI-83, so if you have a TI-83, it is best to find critical values using tables or computer software.

TI-89: Press F5, then scroll down to 2:Inverse, then select 2: Inverse t. Type .95 for Area and 57 Deg of Freedom to get an answer of 1.672. This means that $P(T \leq 1.672) \approx .95$. The t-distribution is symmetric, so this calculation also implies $P(T \geq -1.672) \approx .95$. To find the middle 95 percent of the t-distribution, use the above command but use .975 for Area instead of .95, because we do not want an area of .05 in the right tail but rather just half of that number, which is .025. You should get an answer of 2.002, which means $P(T \leq 2.002) \approx .975$ and therefore $P(-2.002 \leq T \leq 2.002) \approx .95$.

Calculating Chi-square Probabilities

When converting chi-square test statistics into p-values, it will be necessary to make some probability computations involving the chi-square distribution. Because chi-square tests are always one-sided, p-values for the chi-square test always take the form $P(X \geq x)$, where X is a random variable having the chi-square distribution with a given number of degrees of freedom.

Tables: There is a table of critical values for the chi-square distribution, listed as Table X, in Appendix D of the textbook. Suppose X has a chi-square distribution with 3 degrees of freedom. Consider the row of the table corresponding to 3 degrees of freedom. Only intervals containing probabilities can be computed from the table. If $x \leq 6.251$, then $P(X \geq x) \geq .10$. If $6.251 \leq x \leq 7.815$, then $.05 \leq P(X \geq x) \leq .10$. If $7.815 \leq x \leq 9.348$, then $.025 \leq P(X \geq x) \leq .05$. If $9.348 \leq x \leq 11.345$, then $.01 \leq P(X \geq x) \leq .025$. If $11.345 \leq x \leq 12.838$, then $.005 \leq P(X \geq x) \leq .01$. Finally, if $x \geq 12.838$, then $P(X \geq x) \leq .005$.

TI-83: We show how to compute $P(X \geq 12.43)$, where X has a chi-square distribution with 3 degrees of freedom. Press DISTR (that is, 2nd and VARS), and choose 7:χ^2cdf. The command "χ^2cdf(" should appear. To finish the command, type "12.43, 10000, 3)" to get the answer of .00605. Here 12.43 is the lower endpoint, 10000 is used to approximate the upper endpoint (which really is infinite), and 3 is the number of degrees of freedom. As an alternative to typing 10,000 for the upper endpoint, you can type "0, 12.43, 3", which computes $P(X \leq 12.43)$ because chi-square random variables are always nonnegative. The answer is .99395, and you can then obtain $P(X \geq 12.43)$ by calculating $1 - .99395 = .00605$.

TI-89: We show how to compute $P(X \geq 12.43)$, where X has a chi-square distribution with 3 degrees of freedom. Press F5, then scroll down to 8:Chi-square CDF. Enter 12.43 for the Lower Value, enter 10,000 to approximate the Upper Value (which really is infinite), and enter 3 for the degrees of freedom to get the answer of .00605. As an alternative to entering 10,000 for the Upper Value, you can enter 0 for the Lower Value and 12.43 for the Upper Value. The calculator will compute $P(X \leq 12.43)$ because chi-square random variables are always nonnegative. The answer is .99395, and you can then obtain $P(X \geq 12.43)$ by calculating $1 - .99395 = .00605$.

Confidence Intervals and Hypothesis Testing

It is possible to use graphing calculators to find confidence intervals and conduct hypothesis tests. On the TI-83, one can press STAT, then scroll over to TESTS, and choose the appropriate option. On the TI-89, one can press F6 (that is, 2nd followed by the F1 button) for hypothesis tests or F7 for confidence intervals. More detailed instructions are given in the textbook for each particular interval or test. Because these instructions seem to be quite adequate, we do not give further instructions here.

Keep in mind that although it may be useful to check your answers using a graphing calculator (or MINITAB), it is not sufficient on homework or exams just to provide an answer that you get with your graphing calculator. You will need to show how you computed the test statistic, to demonstrate that you understand where it comes from and how this is connected to what we did in the probability portion of the course. Once you have computed a test statistic, you do not need to show your work for how you get from the test statistic to the p-value, because the only way to do this is to read the answer off a calculator, computer, or table.