36-220 Lab #6
Control Charts

Please write your name below, tear off this front page and give it to a teaching assistant as you leave the lab. It will be a record of your participation in the lab. Please remember to include whether you are in Section A or B. Keep the rest of your lab write-up as a reference for doing homework and studying for exams.

Name:

Section:

- The symbol ♣ at the beginning of a question means that, after you answer that question, you should raise your hand and have either the TA or lab assistant review your answer. Once they have reviewed your work they will place a check in the appropriate space in the table below. The purpose of this check is to be sure you have answered the question correctly.
- **You should try to complete as much of the lab exercise as possible. We understand that students work at different paces and have tried to structure the exercise so that it can be completed in the allotted time. If you work systematically through the handout and still don't complete every question don't worry. The important thing is that you understand what you are doing. Nonetheless, you are encouraged to complete the lab on your own.**

Check-Problem ♣	Instructor's Initials
Question 3	
Question 6	
Question 9	

36-220 Lab #6
Control Charts

1 $\bar{X}$-charts

Go to `http://www.stat.cmu.u/~cshalizi/36-220/` and save the data files "cap.MTW" and "screws.MTW" to your desktop. (The data files are at the bottom of the page.) In Minitab, select **File** > **Open Worksheet**. In the "Look in:" field, select "Desktop". Highlight "cap.MTW". Click **Open**.

The data set comes from Procter & Gamble, who were studying a process that tightens the caps on containers of a hair conditioner. Cap torque, a measure of how tightly the caps are screwed onto the containers, was recorded for 17 samples (4 observations per sample). Column C1 displays all 68 observations in the order in which they were taken.

To monitor the process mean, we will use an $\bar{X}$-chart. It's important to realize, though, that the calculations involved in the $\bar{X}$-chart assume that the variance is stable. So, in order to make sure that the variability is stable, we will construct an S-chart as well. Since the process mean and standard deviation are not known, we will estimate them using a base period. This base period will be the first 15 samples. The process engineer has specifically paid attention to the process during the base period, so he can vouch for the stability of the process. Given that the engineer was present for the first 15 samples, we will use this knowledge as historical data to provide a representation for μ and σ. For the purposes of this exercise, we will also assess whether or not the process seems to be in control for all 17 samples, although in real life, having vouched for the stability of the first 15 samples, the engineer would be assessing the process for samples 16 and 17 and any samples collected after that.

To construct the two charts, select **Stat** >**Control Charts** > **Xbar-S**. Select C1 as the variable of interest, and indicate that the subgroup size is 4 (remember, there are 4 observations in each sample). Now click on the **Estimate** button. In the "Omit the following samples when estimating parameters" enter "16 17" (since there are only 17 total samples, this tells Minitab to only use the first 15 samples for estimating the mean and standard deviation). Click **OK**. Click **OK**. Both the S-chart and the $\bar{X}$-chart will appear. You may find it useful to enlarge the window to view this graph.

Question #1: Does it appear as if the process variability is in control? Why or why not?

Question #2: It is undesirable to have caps on the hair conditioner that are too tight or too loose. To get an idea of this, we can monitor the mean cap torque for this process. Does this process look as if it

is in control?

♣ **Question #3: What assumptions are you making when you use the control limits calculated for Questions #1 and #2?**

Let s_t represent the standard deviation of the sample taken at time t. To test the assumption of normality of the s_t's, we would like to make a histogram and a normal probability plot of the s_t's.

Before we can do that, we need to calculate the individual s_t's. To calculate the s_t's, we need to do the following: First, select **Calc** → **Make Patterned Data** → **Simple Set of Numbers**. In the "Store patterned data in" field, select "c2". In the "From first value" field, enter "1". In the "To last value" field, enter "4", in the "In steps of" field, enter "1". In the "List the whole sequence" field, enter "17". Click **OK**.

Now, select **Manip** → **Unstack columns**. In the "Unstack the data in" field, enter "C1". In the "Using subscripts in" field, enter "C2". Under "Store Unstacked data", select the "After last column in use" field. Click **OK**.

Now, select **Calc** → **Row Statistics**. Under "Statistic", select "Standard deviation". In the "Input variable range" select C3-C6. In "Store result in" field, enter "C7". Click **OK**. Label column "C7" as "St".

Create a histogram and a normal probability plot for "St".

Question #4: Comment on the histogram. What is the shape of the distribution?

Question #5: Comment on the normal probability plot. Do the data appear to be normally distributed?

♣**Question #6: A lack of normality is always a problem for the S-chart. Given that our subgroup size is only 4, is a lack of normality of the original data a problem for the $\overline{X}$ chart as well? Discuss the conditions under which it might or might not be a problem.**

2 p Charts

Screws are being checked for tolerances. Those not meeting the tolerance specifications are considered to be defective. Fifty screws are gauged for tolerance every hour, and the number of defective screws is recorded. The results for 30 hours of sampling appears in column C1. These 30 hours constitute the base period for this production process.
In order to control the *proportion* of defective items when the sample size is constant, we can use the p-chart. The points on the chart are the proportion of defectives at each time point.
Question #7: If the proportion of defective screws in the process (the population) is p, and the process is in control, what is the exact distribution of the *number* of defective screws in a sample of size 50?

Question #8: Why can the distribution for the *number* of defective screws be approximated by a normal distribution? What are the parameters for the normal distribution? Now consider the *proportion* of defective screws and why it can be approximated by a normal distribution. What are the new parameters? What are the CL, LCL, and UCL for a p-chart?

Select **File** > **Open Worksheet**. In the "Look in:" field, select "Desktop". Highlight "screws.MTW". Click **Open**.
Make an p-chart of this data by selecting **Stat** > **Control Charts** > **P**. Select C1. Indicate that the subgroups size is 50. Click **OK**.

♣ **Question #9: Is the proportion of defective screws in control? Why or why not?**