Statistics 495, Applied Statistics for Industry I
Exam 2, Fall 2000

Name:____________________________
Site: ____________________________

INSTRUCTIONS: You will have 1 hour and 30 minutes to complete the exam. There are 8 questions worth a total of 100 points. Not all questions have the same point value so gauge your time appropriately. Read the questions carefully and completely. Answer each question and show work in the space provided on the exam. Turn in the **entire** exam when you are done or when time is up. For essay questions, think before you write.

1. [**10 pts**] An electrical device goes through 100% inspection. Each hour's production is tested to see if it works or is defective. Because of variability in the speed of the production line, the number of devices produced varies. The data on the number of devices produced and the number defective is given below.

Hour	Number Produced	Number Defective	Hour	Number Produced	Number Defective
1	223	4	11	233	24
2	209	9	12	274	30
3	209	3	13	262	77
4	175	2	14	221	5
5	208	1	15	175	20
6	216	1	16	263	27
7	286	5	17	237	5
8	256	5	18	295	23
9	255	14	19	259	32
10	187	1	20	278	8
	2224	45		2497	251

(a) [**2**] What is the average fraction defective for these 20 days?

(b) [**4**] Is hour number 12 in or out of control? Justify your answer statistically.

(c) [**4**] Is hour number 15 in or out of control? Justify your answer statistically.

2. **[10 pts]** The two basic principles of statistical thinking are:

   - Variability always is and always will be present.
   - Iterative nature of learning.

   Briefly explain how each of these principles is incorporated into the construction and use of control charts.

3. **[10 pts]** For each of the following briefly explain whether the control charts are being used for analytic of enumerative purposes.

   (a) **[5]** Each month a quality control engineer accesses data that are automatically collected and stored by a data acquisition computer. The engineer produces control charts that are displayed on a bulletin board.

   (b) **[5]** Control charts with limits computed based on past data are placed in easy access of a machine operator. Periodically the operator selects a subgroup of items produced by the machine. Subgroup statistics are plotted on the control charts. If points fall outside the control limits the operator stops the machine and looks for a possible special cause.

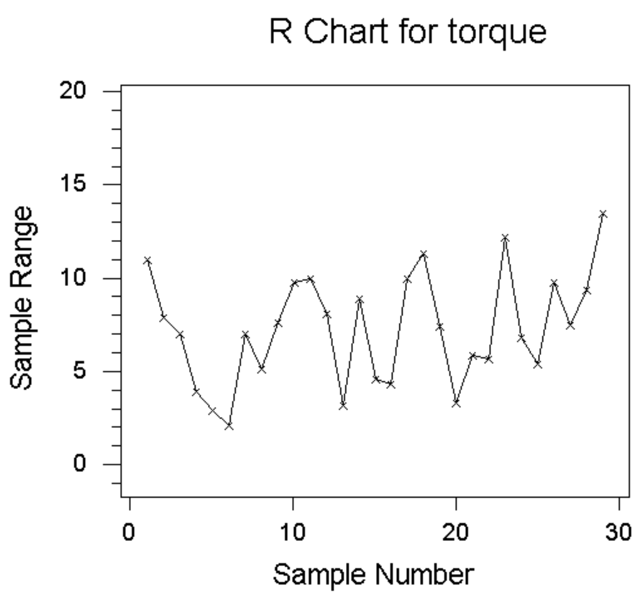
4. **[20 pts]** In a study performed by Shelly Kepczynski of General Motors, the torque (in Newton*meters) on power steering pump bolts was measured using a GSE Transducerized Static Torque Wrench. Data on 29 subgroups, each of size n=5, are summarized below.

Subgroup	$\overline{X}$	R	Subgroup	$\overline{X}$	R	Subgroup	$\overline{X}$	R
1	37.64	11.0	11	37.04	10.0	21	38.68	5.9
2	39.00	7.9	12	38.34	8.1	22	36.82	5.7
3	39.76	7.0	13	40.58	3.2	23	38.62	12.2
4	33.58	3.9	14	39.14	8.9	24	38.20	6.8
5	40.78	2.9	15	36.78	4.6	25	39.56	5.4
6	39.36	2.1	16	39.32	4.3	27	38.10	9.8
7	39.38	7.0	17	37.20	10.0	27	38.10	7.5
8	41.14	5.1	18	34.76	11.3	28	37.52	9.4
9	39.22	7.6	19	36.82	7.4	29	34.80	13.5
10	38.10	9.8	20	38.88	3.3			

$$\overline{\overline{X}} = 38.18 \qquad \overline{R} = 7.297$$

(a) **[4]** Calculate the upper and lower control limits for an R chart for these data.

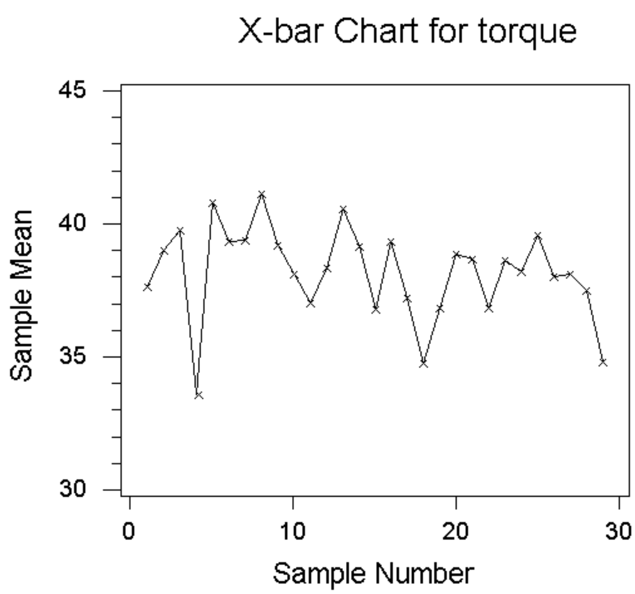
(b) **[2]** Plot the control limits and a center line on the run chart below.



(c) **[4]** Using the one point outside control limits as our operational definition of instability, what does this R chart tell you about the stability of the process? Be specific.

(d) **[4]** Calculate the upper and lower control limits for an $\overline{X}$ chart.

(e) **[2]** Plot the control limits and a centerline on the run chart below.



(f) **[4]** Using the one point outside control limits as our operational definition of instability, what does this $\overline{X}$ chart tell you about the stability of the process? Be specific.

5. **[10 pts]** In a traffic study vehicles going through a particular intersection are monitored between 8 am and 9 am each day. For each of the following scenarios indicate what type of control chart (or charts) you would construct. Briefly explain your choice.

   (a) **[5]** Each day the number of vehicles going through the intersection is counted. You have data for 30 consecutive days.

   (b) **[5]** For each vehicle going through the intersection, whether or not the driver of the vehicle is wearing a seat belt is recorded. Again you have data for 30 consecutive days.

6. **[10 pts]** A paint manufacturer mixes large batches of paint. Each batch is used to fill several thousand cans. For each of the following situations indicate what kind of control chart(s) you would use to monitor the quality characteristic and why.

   (a) **[5]** For each batch, a sample of the paint is sent to a lab for analysis. One quality characteristic measured is the density of the paint for each batch.

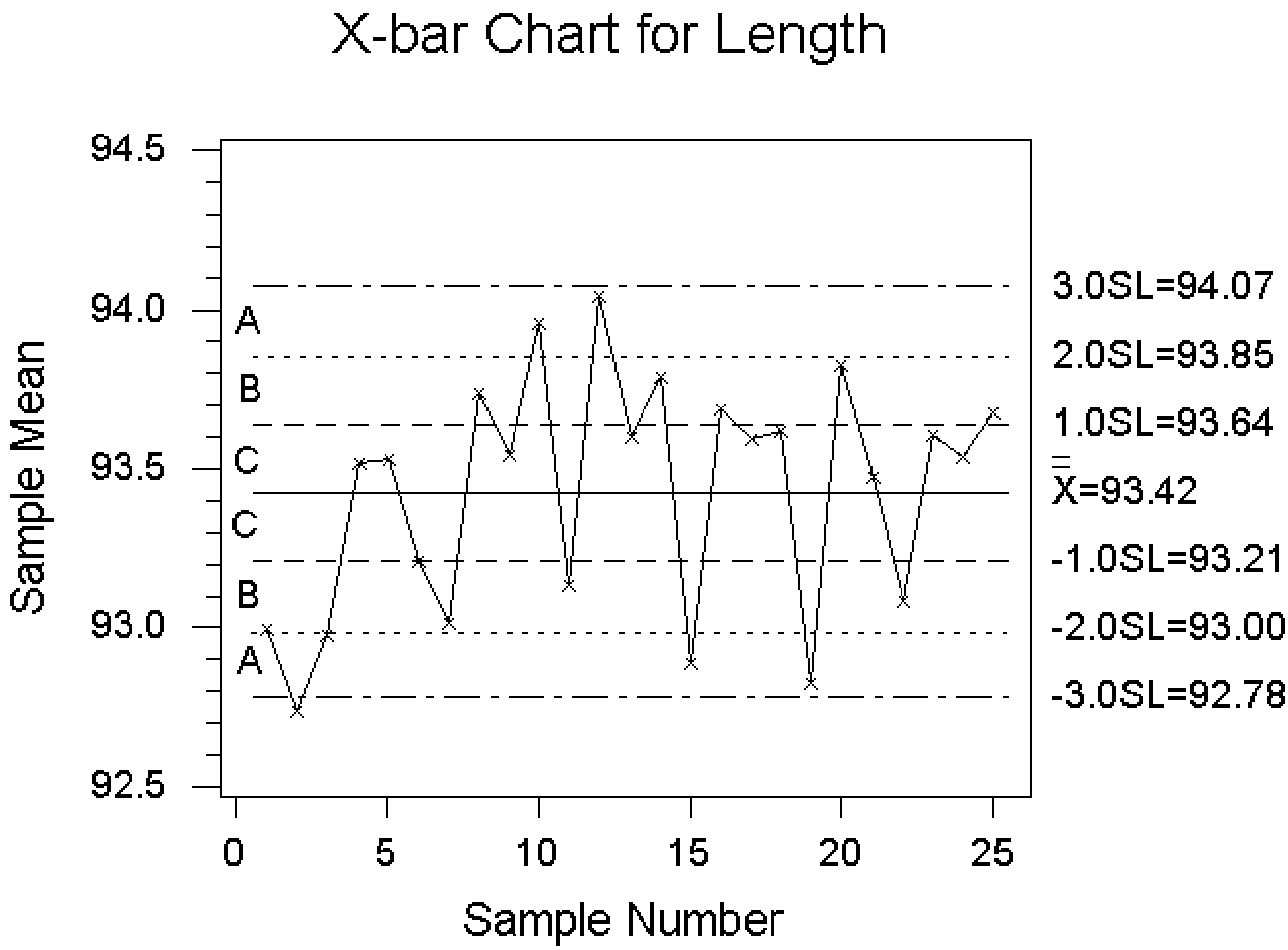
   (b) **[5]** Periodically 50 cans of paint are pulled off the production line. A colorimeter is used to measure the color of the paint in each can. The number of cans that are out of color specifications are counted.

7. **[15 pts]** In a study performed by Ron Beals of General Motors, the amount of chrome plating on intake valves was measured. One measure was the length (in millimeters) of chrome plating on the valve stem. Subgroup means for 25 subgroups, each of size n=4 are plotted on the $\overline{X}$ chart given on the next page.

   (a) **[5]** $\overline{s}$ is used to establish the limits for the $\overline{X}$ chart on the next page. What are the value of $\overline{s}$ and the estimate of the process standard deviation based on $\overline{s}$?

   (b) **[10]** The $\overline{X}$ chart on the next page has the center lines and 1, 2 and 3 "sigma" limits. For each of Nelson's 8 rules (listed below) indicate whether or not there are alarms. If there are alarms, indicate at which subgroups the alarms sound.

Alarm rule: Test for special cause	Alarm?	Where?
1. One point beyond zone A (on one side of the center line)		
2. 9 points in a row in Zone C or beyond (on one side of the center line)		
3. 6 points in a row steadily increasing or decreasing		
4. 14 points in a row alternating up and down		
5. 2 of 3 points in a row in Zone A or beyond (on one side of the center line)		
6. 4 of 5 points in a row in Zone B or beyond (on one side of the center line)		
7. 15 points in a row in Zone C (above and below the center line)		
8. 8 points in a row with none in Zone C (above and below the center line)		



Test continues on the next page

8. **[15 pts]** We have seen that the test that sounds an alarm when a single point plots outside 3 "sigma" limits has an $ARL = \frac{1}{r}$ where

$$r = Pr(\overline{X} > \mu + 3\frac{\sigma}{\sqrt{n}}) + Pr(\overline{X} < \mu - 3\frac{\sigma}{\sqrt{n}})$$

It can be shown that an alternative test that sounds an alarm when the **second** point plots outside m "sigma" limits has an $ARL = \frac{2}{q}$ where

$$q = Pr(\overline{X} > \mu + m\frac{\sigma}{\sqrt{n}}) + Pr(\overline{X} < \mu - m\frac{\sigma}{\sqrt{n}})$$

(a) **[5]** Using this alternative test with $m = 2$, what is the ARL for a process that is normally distributed with center at μ and spread σ (*i.e.* an in control on target process)?

(b) **[5]** What would m have to be in order for this alternative test to have an ARL of 385 when the process is in control and on target?

(c) **[5]** Using subgroups of size n=4 and the alternative test with $m = 2$, what is the ARL for a process that is normally distributed but has shifted 1σ from the center μ?