Statistics 496, Applied Statistics for Industry II Name:_____
Exam 1, Spring 2001 Site: _____

INSTRUCTIONS: You will have 1 hour and 30 minutes to complete the exam. There are 6 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. **[8 pts]** Engineers monitor the outside diameter of a motor shaft that is machined on a CNC turning center. Subgroups of 5 consecutive parts are selected approximately every half hour. There are a total of 35 such subgroups. Subgroup statistics, such as the mean, range and standard deviation are calculated.

   (a) **[4]** Using the average range, $\overline{R}$=16.97 and the average standard deviation, $\overline{s}$=6.85 calculate **two** separate estimates of the process standard deviation, σ.

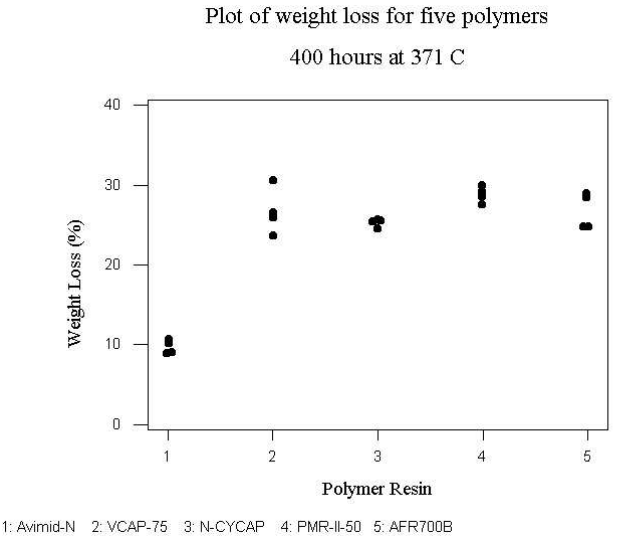
   (b) **[4]** If the standard deviation of all 175 individual measurements is s=10.32, what does this tell you about the stability of the process?

2. **[22 pts]** In a 1995 article in *Journal of Applied Polymer Science* the authors (Sutter, Jobe and Crane) reported on polymer resin weight loss at high temperatures. The larger the weight loss in a polymer resin at a particular time/temperature combination the more unstable, and thus less desirable, the polymer resin. Specimens of five polymer resins (Avimid-N, VCAP-75, N-CYCAP, PRMR-II-50 and AFR700B) are to be exposed for 400 hours to 371 ^{o}C.

   (a) **[3]** We wish to be able to detect a difference as small as 2 standard deviations with a 10% chance of missing a real difference of that size and a 5% chance of falsely detecting a difference. How many specimens of each polymer would we need?

   (b) **[3]** Our budget allows for 4 specimens of each of the five polymers. Give a combination of ALPHA, BETA and Δ/σ that will fit our budget.

(c) [**4**] The data are plotted below. Comment on the differences (level and spread) among the resins in terms of weight loss.



(d) [**4**] Below are the data and the associated ANOVA table. Compute the LSD (use t=2).

	Avimid-N	VCAP-75	N-CYCAP	PMR-II-50	AFR700B
	10.66	25.88	25.23	27.52	28.43
	9.10	23.59	25.37	29.14	28.95
	9.09	26.51	24.59	29.89	24.79
	10.23	30.54	25.57	28.57	24.83
Mean	9.77	26.63	25.19	28.78	26.75

Source	df	Sum of Squares	Mean Square
Polymer	4	958.31	239.58
Error	15	45.75	3.05
Total	19	1004.06	

(e) [**5**] Using the LSD calculated in (d), which of the resins show statistically significant differences in mean weight loss?

(f) **[3]** Which polymer, if any, would you recommend? Explain briefly your choice.

3. **[12 pts]** The three fundamental principles of a designed experiment are: control of outside variables, randomization and replication. Does the following scenario adhere to the three principles? If so, describe how. If not, indicate how you would change the design to incorporate the missing principle(s). Be specific and be sure to comment on each principle.

   An experiment is to be performed on the effect of drill speed on the size of drilled holes. A single 0.25 inch drill bit in a vertical head milling machine will be used for the experiment. All drilling will be done by the same operator. A single bar of 6061 Aluminum will be used. Four speeds will be investigated: 100, 150, 200 and 250 rpms. The operator will pick a speed at random from the four and will drill 20 holes. The process will be repeated, picking a speed at random from those remaining and drilling 20 holes until all 4 speeds have been used. Each of the holes will be measured using a special caliper. The order of measurement will be random.

4. **[16 pts]** An independent research firm wishes to study the effects of the speed of an automobile and emission levels. The experiment will be run on a dynamometer rather than on a test track so that factors such as wind, road conditions and driver will not affect the results. Ideally nine speeds (miles per hour) will be used: 40, 45, 50, 55, 60, 65, 70, 75, 80.

   (a) **[3]** The firm wishes to be able to detect a difference of 2 standard deviations. It can accept a 10% chance of missing such a difference when one exists, but wants only a 5% chance of declaring a difference significant when there is no difference. What is the **total** number of experimental units necessary for the experiment?

   (b) **[3]** When the experiment is proposed there are enough resources for 7 experimental units for each of the nine speeds. Can one design an experiment that is able to detect a 2 standard deviation difference? If so, what compromises must be made? Be specific.

   (c) **[4]** Budget cuts at the firm limit the total number of experimental units to 45. Can an experiment be conducted that meets the requirements in (a)? Explain briefly. **Hint: It is okay to reduce the scope of the experiment.**

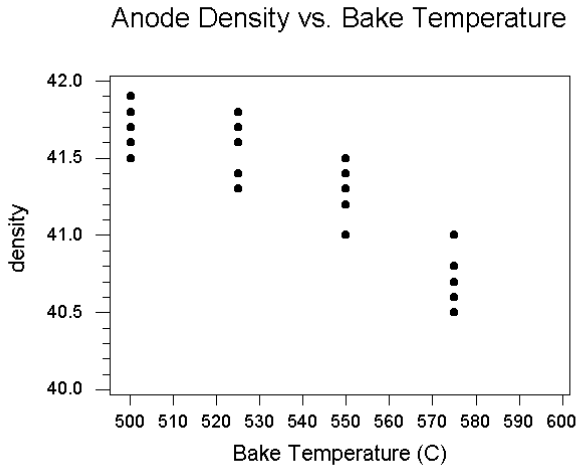
   (d) **[6]** The firm has to decide whether to use one car, repeating the measurement process 45 times, or 45 cars, same make, model, engine capacity, equipment, *etc.*, in the experiment. Comment on each of these choices. Which do you think is better? Why?

5. **[27 pts]** An aluminum smelting operation makes its own carbon anodes for use in their aluminum smelting pots. The baked density of the anode is an important quality characteristic because it affects the usable life of the anode. An experiment is conducted to see the effect of bake temperature on anode density. Twenty anodes are made using the same raw materials, methods and people. Anodes are assigned at random to one of four temperatures, 500, 525, 550 and 575 ^oC. The temperatures are run in a random order and the density measurements for all 20 anodes are done at random.

   (a) **[6]** Discuss how the three fundamental principles of experimentation are incorporated into this experiment.

The data on anode density after baking are summarized and plotted below.

Temperature	Number	Mean, $\overline{Y}_i$	Variance, s_i^2
500	5	41.70	0.025
525	5	41.56	0.043
550	5	41.28	0.037
575	5	40.72	0.037
		Average Variance = 0.03555	



   (b) **[3]** Describe the relationship between bake temperature and density of the anodes.

(c) **[8]** Give the simple linear regression equation of density on temperature. Hint: It will be easiest to use a coded temperature, C_1, to find the regression of density on C_1 and then convert.

(d) **[5]** Is the linear relationship statistically significant? How do you know?

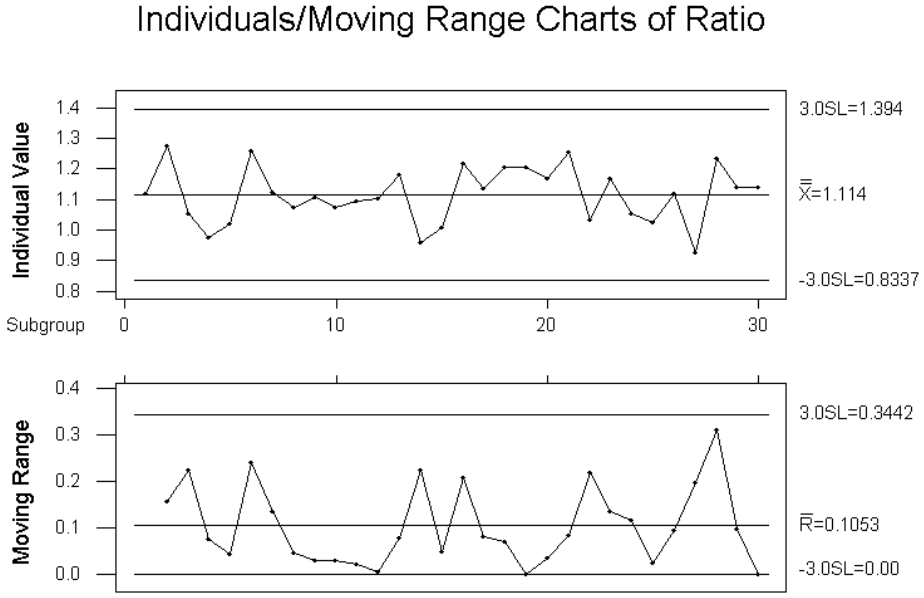
(e) **[2]** Use the linear regression equation to predict the density of anodes baked at 510^oC.

(f) **[3]** The slope coefficient for the quadratic term is $\hat{m}_2 = -0.105$ and its associated sum of squares is 0.2205. Is the quadratic term statistically significant? How do you know?

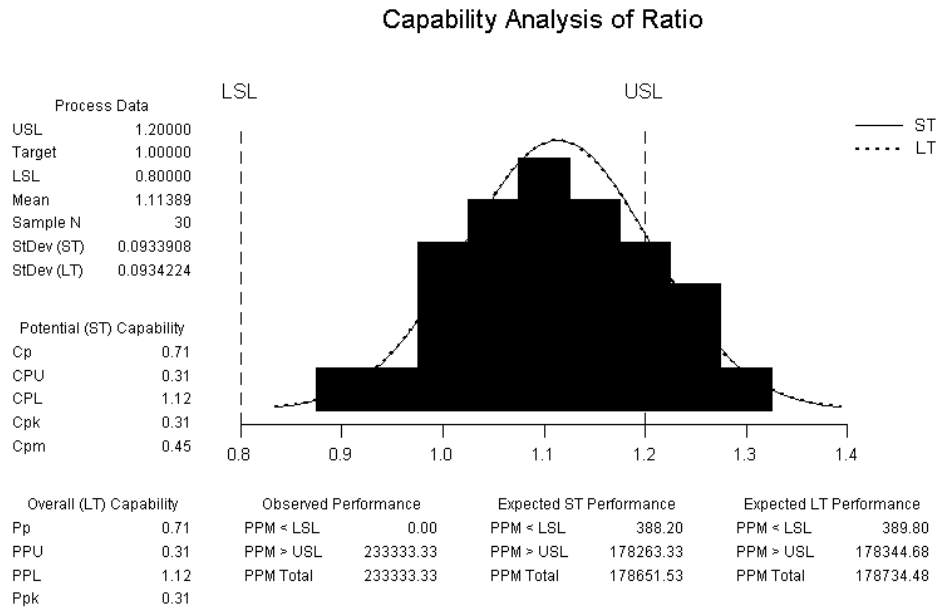
6. **[15 pts]** Delivering a product on time is an important quality characteristic. For a project in Stat 495 one student examined the ratio of the time it took to produce a software product relative to the quoted time. A ratio of 1.00 indicates that the actual production time matched the quoted time. A ratio greater than 1.00 indicates that it took longer to produce the software than was originally quoted.

   (a) **[4]** Briefly explain why a process must be in a state of statistical control before the capability of the process can be assessed.

   (b) **[3]** Below are Individuals/Moving Range charts for the ratio of actual time to quoted time for 30 software production jobs. Using the one point outside of control limits as the only alarm rule, comment on the stability of the process.



(c) [**8**] Ideally, each job should take the quoted time. The company has specifications that says that the actual time should not deviate by more than 20% of the quoted time (Ratio: 1.00 ± 0.20) Below is a capability analysis for the 30 production jobs given above. Comment on the capability of the process. Be sure to include values and interpretations of capability indices as well as observed and expected numbers of jobs outside of specs.



Process Data	
USL	1.20000
Target	1.00000
LSL	0.80000
Mean	1.11389
Sample N	30
StDev (ST)	0.0933908
StDev (LT)	0.0934224

Potential (ST) Capability	
Cp	0.71
CPU	0.31
CPL	1.12
Cpk	0.31
Cpm	0.45

Overall (LT) Capability	
Pp	0.71
PPU	0.31
PPL	1.12
Ppk	0.31

Observed Performance	
PPM < LSL	0.00
PPM > USL	233333.33
PPM Total	233333.33

Expected ST Performance	
PPM < LSL	388.20
PPM > USL	178263.33
PPM Total	178651.53

Expected LT Performance	
PPM < LSL	389.80
PPM > USL	178344.68
PPM Total	178734.48