Response Surface Methodology, Stat 579 — Homework 03 — Name:__________________
Fall 2014 — Prof. Erik B. Erhardt

Part I. (125 points) I recommend reading through all the parts of the HW (with my adjustments) before starting; this may save you some work.
MMA-RSM Chapter 3: 3.1, 3.6, 3.7, 3.11, 3.12, 3.20, 3.26.

- For 3.11 replace part (b) with (d).
- For 3.20 (c), one of the alternative observations for Rep IV is wrong. Indicate what it should be, then answer the question.
- Where applicable, use the calibrated Lenth procedure to assess significance with SMOE to pool errors.

General: Try to do all calculations in R. All R code for the assignment should be included with the part of the problem it addresses (for code and output use a fixed-width font, such as Courier). Code is used to calculate result; text is used to report and interpret results – do not report or interpret results in the code.

(20$^{\text{pts}}$) **1. 3.1** A router is used to cut registration notches on a printed circuit board. The vibration at the surface of the board as it is cut is considered to be a major source of dimensional variation in the notches. Two factors are thought to influence vibration: bit size (A) and cutting speed (B). Two bit sizes (1/16 and 1/8 inch) and two speeds (40 and 90 rpm) are selected, and four boards are cut at each set of conditions as shown in Table E3.1. The response variable is vibration measured as the resultant vector of three accelerometers (x, y, and z) on each test circuit board.

(a) (5 pts) Analyze the data from this experiment.

(b) (5 pts) Construct a normal probability plot of the residuals and a plot of the residuals versus the predicted vibration level. Interpret these plots.

(c) (5 pts) Draw the AB interaction plot. Interpret this plot. What levels of bit size and speed would you recommend for routine operation?

(d) (5 pts) Construct a contour plot of vibration as a function of speed and bit size.

(20$^{\text{pts}}$) **2. 3.6** An experiment was performed to improve the yield of a chemical process. Four factors were selected, and one replicate of a completely randomized experiment was run. The results are shown in Table E3.4.

(a) (5 pts) Estimate the factor effects. Construct a normal probability plot of these effects. Which effects appear large?
To assess significance use the calibrated Lenth procedure with SMOE to pool errors.

(b) (5 pts) Prepare an analysis of variance table using the information obtained in part (a).

(c) (5 pts) Plot the residuals versus the predicted yield and on normal probability paper. Does the residual analysis appear satisfactory?

(d) (5 pts) Construct a contour plot of yield as a function of the important process variables.

(10$^{\text{pts}}$) **3. 3.7** Consider the design of Exercise 3.6. Suppose that four additional runs were made at the center of the region of experimentation. The response values at these center points were 94, 90, 99, and 87. Use this additional information to test for curvature in the response function. What are your conclusions?

(25$^{\text{pts}}$) **4. 3.11** An article in Solid State Technology ("Orthogonal Design for Process Optimization and its Application in Plasma Etching," May 1987, pp. 127–132) describes the application of factorial designs in developing a nitride etch process on a single-wafer plasma etcher. The process uses C_2F_6 as the reactant gas. Four factors are of interest: anode-cathode gap (A), pressure in the reactor chamber (B) C_2F_6 gas flow (C), and power applied to the cathode (D). The response variable of interest is the etch rate for silicon nitride. A single replicate of a 2^4 design is run, and the resulting data are in Table E3.7.

(a) (5 pts) Estimate the factor effects. Construct a normal probability plot of the factor effects. Which effects appear large?
Use the calibrated Lenth procedure to assess significance with SMOE to pool errors.

(b) (5 pts) Conduct an analysis of variance to confirm your findings for part (a).

(c) (5 pts) Analyze the residuals from this experiment. Comment on the model's adequacy.

(d) (0 pts) If not all the factors are important, project the 2^4 design into a 2^k design with $k < 4$ and conduct the analysis of variance.
See part (b).

(e) (5 pts) Draw graphs to interpret any significant interactions.

(f) (5 pts) Plot the residuals versus the actual run order. What problems might be revealed by this plot?

(10^{pts}) **5. 3.12** Consider the single replicate of the 2^4 design in Example 3.11. Suppose we had arbitrarily decided to analyze the data assuming that all three- and four-factor interactions were negligible. Conduct this analysis and compare your results with those obtained in the example. Do you think that it is a good idea to arbitrarily assume interactions to be negligible even if they are relatively high-order ones?

(15^{pts}) **6. 3.20** Consider the experiment described in Exercise 3.1. Suppose that only one replicate (four runs) could be obtained in a single 4-hr time period, and the experimenters were concerned about unknown factors that could vary from one time period to another.

(a) (5 pts) Set up a design in four blocks that will minimize the time effects.

(b) (5 pts) Analyze the data assuming that the design had been run as in part (a). Compare the results of your analysis with the original analysis in Exercise 3.1.

(c) (5 pts) Suppose that the experimenter's concerns were realized and that as a result of the time effect, the observations in replicate IV were $(1) = 34.4$, $a = 44.5$, $b = 34.2$, and $ab = 59.9$ instead of the values shown in Exercise 3.1. Reanalyze these new data, assuming that the blocked design from part (a) had been used. How has the time effect influenced your conclusions?
For 3.20 (c), one of the alternative observations for Rep IV is wrong. Indicate what it should be, then answer the question.

(25^{pts}) **7. 3.26** Consider the situation described in Exercise 3.13. Set up a design in two blocks for 16 observations each of this problem. Analyze the data that result.