Response Surface Methodology, Stat 579 | Homework 04 | Name: ____________
Fall 2014 | Prof. Erik B. Erhardt

**Part I.** (130 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 4: 4.1, 4.4, 4.5, 4.7, 4.11, 4.20, 4.23.

- Whenever appropriate, use Table 4.11, p. 156, and take the main fraction when designing a $2(k-p)$.
- For 4.1, we want a one-half fraction of the $2^4$ design (not $2^3$).
- For 4.4, (i) show that in order to use the data from Table 4.5, p. 144, your design must at best alias some main effects, (ii) choose the design with second generator $I = ABD$ to analyze.
- For 4.23, the original design in Table 4.13 is a $2^{7-4}_{\text{III}}$, not a $2^{7-3}_{\text{III}}$, and the resulting design is a $2^{7-3}_{\text{IV}}$, not a $2^{8-4}_{\text{IV}}$.

**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.

(30pts) **1. 4.1** Suppose that in the chemical process development experiment described in Exercise 3.6, it was only possible to run a one-half fraction of the $2^3$ design. Construct the design and perform the statistical analysis by selecting the relevant runs.
For 4.1, we want a one-half fraction of the $2^4$ design (not $2^3$).

(30pts) **2. 4.4** Example 4.2 describes a process improvement study in the manufacture of an integrated circuit. Suppose that only eight runs could be made in this process. Set up an appropriate $2^{5-2}$ design and find the alias structure. Use the data from Example 4.2 as the observations in this design, and estimate the factor effects. What conclusions can you draw?
For 4.4, (i) show that in order to use the data from Table 4.5, p. 144, your design must at best alias some main effects, (ii) choose the design with second generator $I = ABD$ to analyze.

(10pts) **3. 4.5** Continuation of Exercise 4.4. Suppose you have made the eight runs in the $2^{5-2}$ design in Exercise 4.4. What additional runs would be required to identify the factor effects that are of interest? What are the alias relationships in the combined design?

(25pts) **4. 4.7** An article in the Journal of Quality Technology (Vol. 17, 1985, pp. 198–206) describes the use of a replicated fractional factorial to investigate the effect of five factors on the free height of leaf springs used in a automotive application. The factors are $A$ = furnace temperature, $B$ = heating time, $C$ = transfer time, $D$ = hold-down time, and $E$ = quench oil temperature. The data are shown in Table E4.1

(a) (5 pts) Write out the alias structure for this design. What is the resolution of this design?
(b) (5 pts) Analyze the data. What factors influence the mean free height?
(c) (5 pts) Calculate the range and standard deviation of the free height for each run. Is there any indication that any of these factors affects variability in the free height?
(d) (5 pts) Analyze the residuals from this experiment, and comment on your findings.
(e) (5 pts) Is this the best possible design for five factors in 16 runs? Specifically, can you find a fractional design for five factors in 16 runs with a higher resolution than this one?

(15pts) **5. 4.11** An industrial engineer is conducting an experiment using a Monte Carlo simulation model of an inventory system. The independent variables in her model are the order quantity ($A$), the reorder point ($B$), the setup cost ($C$), the backorder cost ($D$), and the carrying cost rate ($E$). The response variable is average annual cost. To conserve computer time, she decides to investigate these factors using a $2^{5-2}_{\text{III}}$ design with $I = ABD$ and $I = BCE$. The results she obtains are $de = 95$, $ae = 134$, $b = 158$, $abd = 190$, $cd = 92$, $ac = 187$, $bce = 155$, and $abcde = 185$.

(a) (5 pts) Verify that the treatment combinations given are correct. Estimate the effects, assuming three-factor and higher interaction are negligible.

(b) (5 pts) Suppose that a second fraction is added to the first. The runs in this new design are $ade = 136$, $e = 93$, $ab = 187$, $bd = 153$, $acd = 139$, $c = 99$, $abce = 191$, and $bcde = 150$. How was this second fraction obtained? Add these runs to the original fraction, and estimate the effects.

(c) (5 pts) Suppose that the fraction $abc = 189$, $ce = 96$, $bed = 154$, $acde = 135$, $abe = 193$, $bde = 152$, $ad = 137$, and $(1) = 98$ was run. How was this fraction obtained? Add these data to the original fraction, and estimate the effects.

(10pts) **6. 4.20** Project the $2_{\text{IV}}^{4-1}$ design in Example 4.1 into two replicates of a $2^2$ design in the factors $A$ and $B$. Analyze the data and draw conclusions.

(10pts) **7. 4.23** Fold over the $2_{\text{III}}^{7-3}$ design in Table 4.13. Verify that the resulting design is a $2_{\text{IV}}^{8-4}$ design. Is this a minimal design?
For 4.23, the original design in Table 4.13 is a $2_{\text{III}}^{7-4}$, not a $2_{\text{III}}^{7-3}$, and the resulting design is a $2_{\text{IV}}^{7-3}$, not a $2_{\text{IV}}^{8-4}$.