# Design and Analysis of Experiments/Försöksplanering

## (KBT120, KKR031)

## Thursday 25/10 2012,   8:30-13:30

**Claes Niklasson will be available at ext 3027 (0731-574690) and will visit the examination room ca 10:30.**

**The examination results will be available for review 9/11**
**12:45 – 13:15 KRT sem. room.**

**Time for examination = 5 h**

**Examination aids:**

**Textbook (Douglas C. Montgomery: Design and Analysis of Experiments) with notes. No calculation examples (in book or on paper) are allowed as aid.**

**All type of calculators are allowed.**

**Standard Math. Tables, TEFYMA table, Beta Mathematics Handbook or Handbook of Chemistry and Physics and Language dictionaries are accepted.**

## Problem 1 (10 credits)

A pharmaceutical manufacturer wants to investigate the bioactivity of a new drug. A completely randomized experiment was conducted with three dosage levels, and the following results were obtained.

| Dosage (g) | Observations | | | |
|---|---|---|---|---|
| 20 | 24 | 28 | 37 | 30 |
| 30 | 37 | 44 | 31 | 35 |
| 40 | 42 | 47 | 52 | 38 |

**A: Is there evidence to indicate that dosage level affects bioactivity?**

**B: Make comparisons between the pairs of means. What conclusions can you draw?**

**C: Analyze the residuals from this experiment and comment on model adequacy.**

**Use $\alpha = 0.05$**

## Problem 2 (8 credits)

Three different washing solutions are being compared to study their effectiveness in retarding bacteria growth in milk containers. The analysis is done in a laboratory, and only three trials can be run on any day. Because days could represent a potential source of variability, the experimenter decides to use a randomized block design. Observations are taken for four days, and the data are shown here.

| Solution | Days | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| I | 13 | 22 | 18 | 39 |
| II | 16 | 24 | 17 | 44 |
| III | 5 | 4 | 1 | 22 |

**A: Analyze the data and draw appropriate conclusions.**

**B: Estimate the parameters in the effect model assuming that solutions and days are fixed.**

**Use the significance level: $\alpha = 0.05$**

## Problem 3 ( 12 credits)

The following data have been obtained from a $2^3$ factorial design with centre points.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | 10 | 12 | 4 | 4 | 9 | 10 | 5 | 4 | 6 | 7 | 8 | 7 |
| $x_1$ | -1 | 1 | -1 | 1 | -1 | 1 | -1 | 1 | 0 | 0 | 0 | 0 |
| $x_2$ | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 | 0 | 0 | 0 | 0 |
| $x_3$ | -1 | -1 | -1 | -1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

**A: Fit a first-order model with interaction to the data and examine parameter significance.**

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \varepsilon$$

**B: Test for lack of fit.**

**C: Estimate the sum of regression coefficients for the pure quadratic terms and check for significant quadratic curvature.**

**D: How should you add further runs for properly fitting a second-order model?**

**Use $\alpha = 0.05$**

## Problem 4 (8 credits)

The yield (y) of a process depends on three variables (**x**) and has been examined according to the following design:

| $x_1$ | $x_2$ | $x_3$ | y |
|---|---|---|---|
| 0 | $\sqrt{2}$ | -1 | 18.5 |
| $-\sqrt{2}$ | 0 | 1 | 19.8 |
| 0 | $-\sqrt{2}$ | -1 | 17.4 |
| $\sqrt{2}$ | 0 | 1 | 22.5 |

**A: Prove that the design is a simplex.**

**B: Fit a linear first-order model to the data.**

**C: Find the path of steepest ascent and draw it with $x_3 = 1$. Starting point = $(x_1,x_2) = (0,0)$**

## Problem 5 (12 credits)

A $2^{3-1}$ fractional factorial design was used to develop a nitride etch process on a single-wafer plasma etching tool. The design factors are the gap between the electrodes (A), the gas flow (B) ($C_2F_6$ is used as the reactant gas), and the RF power applied to the cathode (C). Each factor is run at two levels, and the design is replicated twice. The response variable is the etch rate for silicon nitride (Å/m). The etch rate data are shown in the table below.

| **Treatment combin.** | **c** | **a** | **b** | **abc** |
|---|---|---|---|---|
| **Response Replicate 1** | **1037** | **669** | **633** | **729** |
| **Response Replicate 2** | **1052** | **650** | **601** | **860** |

| **Factor** | **A (cm)** | **B ($cm^3$/min)** | **C (W)** |
|---|---|---|---|
| **Level -1** | **0.80** | **125** | **200** |
| **Level +1** | **1.20** | **200** | **325** |

**A: Identify the defining relation and show the alias structures.**

**B: Calculate the factor effects and examine their significance ($\alpha$=0.05).**

**C: Decide if the model is significant.**

**D: Express the final model in terms of natural variables**

## Problem 6 (10 credits)

A student from a Technical University close to the lake Mälaren has read something about experimental design in a black book and is thinking on how to perform a $2^{5-1}$ reduced exp. design. This student thinks, after talking to one local engineer, that the effect C is large (A=Temp, B= Pressure, C =Time, D= Stirrer rate and E = Catalyst) which means that the student decides to confound variable E with the effect ABD.

**A: Describe the Alias structure for this design and the experiments to be executed.**

**B: What are possible advantages and disadvantages with this Experimental design compared with the most common confounding structure ($2^{5-1}$) ?**

**C: Assume A and D are large effects. Describe how further experiments can separate second order effects involving these two large effects?**

**D: In what University should this student study to do a better job in the future?**