MASTER'S DIAGNOSTIC EXAMINATION - January 2013

Student's Name ____

INSTRUCTIONS FOR STUDENTS:

1. The exam has an Instruction page, 8 pages of questions, and 21 pages of SAS code and output.
2. DO NOT put your NAME on the exam. Place the NUMBER assigned to you on the

   UPPER RIGHT HAND CORNER of EACH PAGE of your solutions.
3. Please start your answer to EACH QUESTION on a SEPARATE sheet of paper.
4. Use only one side of each sheet of paper.
5. You must answer all four questions: Questions I, II, III and IV.
6. Be sure to attempt all parts of the four questions. It may be possible to answer a later part of a question without having solved the earlier parts.
7. Be sure to hand in all of your exam. No additional material will be accepted once the exam has ended and you have left the exam room.
8. You may use the following:
   - Calculator which does not have capability to phone, text, or access the Web
   - Pencil or pen
   - Blank paper for your solutions to the questions on this examination
   - No other materials are allowed

- I attest that I spent no more than 4 hours to complete the exam,
- I used only the materials described above, and
- I did not receive assistance from anyone during the taking of this exam.

Student's Signature__________________________________

INSTRUCTIONS FOR PROCTOR:

Immediately after the student completes the exam, **fax** the student's solutions to **979-845-6060** or **scan** the solutions into a pdf file and **email to longneck@stat.tamu.edu**.

DO NOT send the exam booklet or SAS output, just send the student's solutions.

1. I certify that the time at which the student started the exam was ______________________

   and the time at which the student completed the exam was ______________________
2. I certify that the student has followed all the **INSTRUCTIONS FOR STUDENTS** listed above.
3. I certify that the student's solutions were faxed to **979-845-6060** or

   emailed to **longneck@stat.tamu.edu**.

Proctor's Signature__________________________________

QUESTION I.

You are the consulting statistician on a study of the genetic components of exercise. The PI plans to raise 30 mice in which a particular gene suspected to be involved in regulating exercise has been knocked out (you can think of it like turning off this gene), as well as 30 wild-type mice (mice in which the gene has not been knocked out). Each mouse will then be observed over a two week period, and the average number of minutes mouse i spends running on the exercise wheel per day, y_i, will be recorded. The variables in the study are

- the 60 response values $y_1, y_2, \ldots, y_{60}$
- a variable indicating comparison group ($x_i = 1$ if knockout, $x_i = 0$ if wild-type, $i = 1, 2, \ldots, 60$)
- gender ($g_i = 1$ if female, $g_i = 0$ if male, $i = 1, 2, \ldots, 60$)
- average daily food consumption (f_i, a continuous number, standardized so that a value of 0 indicates average consumption, negative values indicate less than average, positive values indicate greater than average, $i = 1, 2, \ldots, 60$).

Based on your exploratory analysis of preliminary data, you and the PI agree that a sensible model is

$$y_i = \beta_0 + \beta_1 x_i + \beta_2 g_i + \beta_3 f_i + \beta_4 (x_i \times g_i) + \epsilon_i,$$

where the ϵ_i are i.i.d. with mean 0 and s.d. σ.

1.) Interpret each of the coefficients in the above model.

2.) Using the following `R` output construct an approximate 95% confidence interval for $\beta_1 - \beta_4$?

Based on the interval you report, comment on your conclusions regarding whether there is a genotype effect.

`Hint:` If $\boldsymbol{v}$ is a column vector of length 5, then the standard error of $\boldsymbol{v}'\hat{\boldsymbol{\beta}}$ is equal to the square root of $\hat{\sigma}^2 \boldsymbol{v}'(\boldsymbol{X}'\boldsymbol{X})^{-1}\boldsymbol{v}$, where $\hat{\sigma}$ is the estimated residual s.d., and $\boldsymbol{X}$ is the model matrix. In our example, $\hat{\sigma} = 1.716$ and

$$(\boldsymbol{X}'\boldsymbol{X})^{-1} = \begin{pmatrix} 0.07 & -0.07 & -0.07 & -0.01 & 0.07 \\ -0.07 & 0.14 & 0.07 & 0.01 & -0.13 \\ -0.07 & 0.07 & 0.13 & 0.00 & -0.13 \\ -0.01 & 0.01 & 0.00 & 0.05 & 0.00 \\ 0.07 & -0.13 & -0.13 & 0.00 & 0.27 \end{pmatrix}$$

Here's the `R` output from fitting the above model:

```
Call:
lm(formula = y ~ 1 + x + g + f + x * g)

Residuals:
    Min      1Q  Median      3Q     Max
-4.3862 -1.0618 -0.0837  1.1362  4.2091

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  10.6375     0.4463  23.835  < 2e-16 ***
x             0.8728     0.6325   1.380  0.17319
g            -0.9642     0.6265  -1.539  0.12955
f             1.1632     0.3880   2.998  0.00407 **
x:g           0.0586     0.8867   0.066  0.94755
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Residual standard error: 1.716 on 55 degrees of freedom
Multiple R-squared: 0.221,Adjusted R-squared: 0.1643
F-statistic:   3.9 on 4 and 55 DF,  p-value: 0.007369
```

3.) An F-test of the null hypothesis that $\beta_1 = \beta_4 = 0$ returned a p-value of 0.15. Meanwhile, stepwise model selection tells you that the best-fitting model is the one without the treatment-by-gender interaction, with abbreviated `R` output:

```
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  10.6230     0.3853  27.573  < 2e-16 ***
x             0.9018     0.4404   2.048  0.04535 *
g            -0.9349     0.4392  -2.128  0.03771 *
f             1.1622     0.3843   3.025  0.00375 **
```

The PI is primarily interested in whether there is sufficient evidence of an effect of treatment, the knockout variable, on time spent exercising in mice. Based on the F-test and stepwise regression results, how would you advise the PI? Provide a detail explanation of your advice.

QUESTION II.

The Storm Prediction Center (an agency of NOAA) tracks the number and characteristics of tornadoes. In this problem we will consider the variable **Killer_tornadoes**, which is the number of tornadoes in a given year which resulted in one or more deaths. The summary statistics for the variable **Killer_tornadoes** over 48 years of data were found using the SAS function `proc means`:

```
                         The MEANS Procedure

              Analysis Variable : Killer_tornadoes

   N           Mean         Std Dev         Minimum         Maximum

  48      2.0416667       2.9532408               0      13.0000000
```

Use the above information, the SAS output, and the tables on page 5 to answer the following questions.

1.) Explain why $\bar{X} \pm Z_{\alpha/2}\sqrt{\bar{X}/n}$ is a reasonable $1-\alpha$ confidence set for λ, the mean of a Poisson distribution. Then assuming that the variable `Killer_tornadoes` has a Poisson distribution, obtain a 95% confidence interval for the mean number of killer tornadoes.

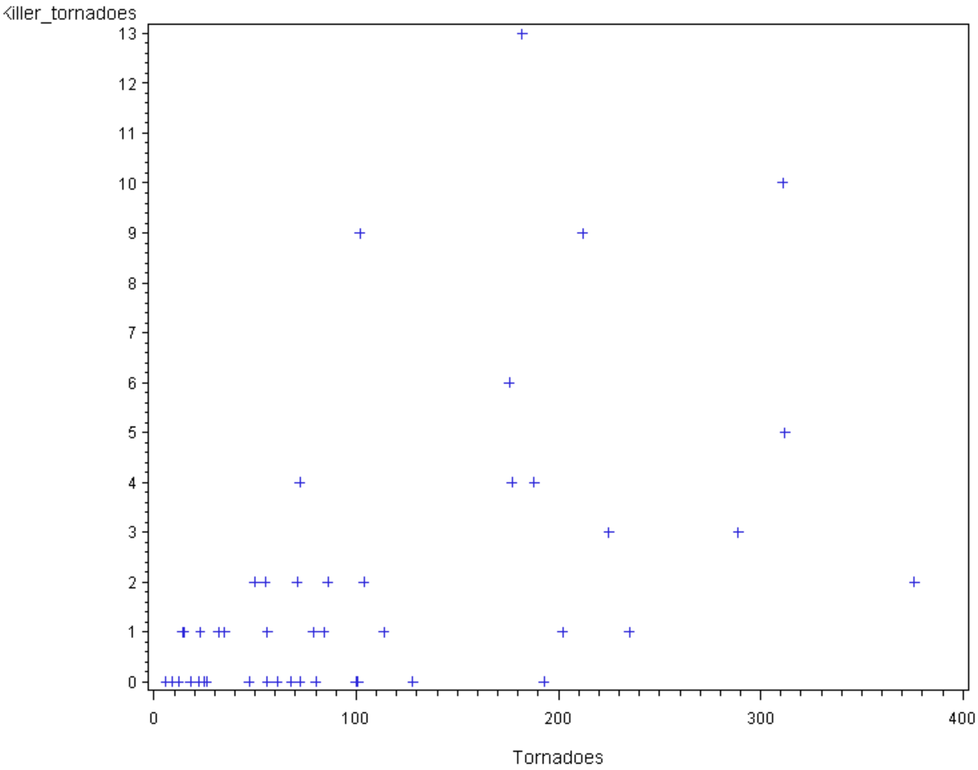
2.) Is the assumption of a Poisson distribution reasonable for the variable `Killer_tornadoes`? Explain why or why not based only on the summary statistics above.

3.) A chi-squared goodness-of-fit test was carried out by using the Poisson distribution with the estimated mean $\hat{\mu} = 2.042$ to specify the cell probabilities for $x = 0, 1, 2, 3, \geq 4$. The chi-squared test statistic was computed to be $\chi^2 = 32.35$. What does this tell you about the assumption of the Poisson distribution for the variable `Killer_tornadoes`? Explain your reasoning.

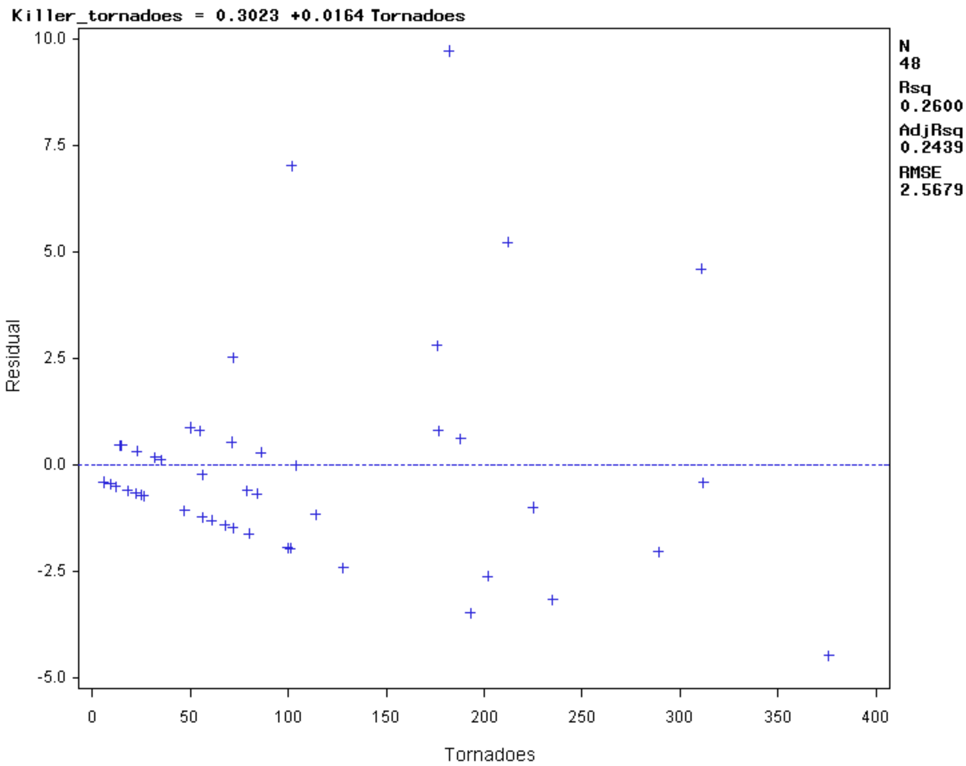
4.) Suppose that the researcher decides to predict the number of killer tornadoes using `Tornadoes`, the number of tornadoes in a year, as a predictor.

Using the 48 years of data on the pair (`Tornadoes`, `Killer_tornadoes`), a simple linear regression model was fit with `Killer_tornadoes` as the response and `Tornadoes` as the predictor. Some SAS output is given below. A scatter plot of the data and a plot of residuals versus the predictor are on the next page. Discuss the appropriateness of using this prediction model for the number of killer tornadoes.

```
                             Analysis of Variance

                                    Sum of           Mean
Source                   DF        Squares         Square    F Value    Pr > F

Model                     1      106.59133      106.59133      16.16    0.0002
Error                    46      303.32533        6.59403
Corrected Total          47      409.91667


             Root MSE              2.56788    R-Square     0.2600
             Dependent Mean        2.04167    Adj R-Sq     0.2439
             Coeff Var           125.77392


                             Parameter Estimates

                             Parameter       Standard
 Variable          DF         Estimate          Error    t Value    Pr > |t|

 Intercept          1          0.30234        0.56967       0.53      0.5982
 Tornadoes          1          0.01641        0.00408       4.02      0.0002
```



Killer_tornadoes
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
100
200
300
400
Tornadoes



Killer_tornadoes = 0.3023 +0.0164 Tornadoes
N
48
Rsq
0.2600
AdjRsq
0.2439
RMSE
2.5679
Residual
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
0
50
100
150
200
250
300
350
400
Tornadoes

Some Chi-Squared Percentiles

	Right-Tail Probability			
df	0.100	0.050	0.025	0.010
1	2.71	3.84	5.02	6.63
2	4.61	5.99	7.38	9.21
3	6.25	7.81	9.35	11.34
4	7.78	9.49	11.14	13.28
5	9.24	11.07	12.83	15.09
6	10.64	12.59	14.45	16.81
7	12.02	14.07	16.01	18.48
8	13.36	15.51	17.53	20.09
9	14.68	16.92	19.02	21.67
10	15.99	18.31	20.48	23.21

Some Normal Percentiles

Right-Tail Probability			
0.100	0.050	0.025	0.010
1.282	1.645	1.960	2.326

Some t-Distribution Percentiles

	Right-Tail Probability			
df	0.100	0.050	0.025	0.010
1	3.078	6.314	12.706	31.821
2	1.886	2.920	4.303	6.965
3	1.638	2.353	3.182	4.541
4	1.533	2.132	2.776	3.747
6	1.440	1.943	2.447	3.143
8	1.397	1.860	2.306	2.896
12	1.356	1.782	2.179	2.681
27	1.314	1.703	2.052	2.473
53	1.298	1.674	2.006	2.399
54	1.297	1.674	2.005	2.397
∞	1.282	1.645	1.960	2.326

QUESTION III.

Consider a regression model for an experiment with a continuous response Y and two factors, A and B, each with two levels, *High* and *Low*. Consider the two models:

- **Dummy Variable Model :** $E(Y) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2$

  where

$$x_1 = \begin{cases} 1 & \text{if} \quad A = \textit{High} \\ 0 & \text{if} \quad A = \textit{Low} \end{cases} \qquad x_2 = \begin{cases} 1 & \text{if} \quad B = \textit{High} \\ 0 & \text{if} \quad B = \textit{Low} \end{cases}$$

- **Design Effects Model :** $E(Y) = \alpha^* + \beta_1^* x_1^* + \beta_2^* x_2^* + \beta_3^* x_1^* x_2^*$,

  where

$$x_1^* = \begin{cases} 1 & \text{if} \quad A = \textit{High} \\ -1 & \text{if} \quad A = \textit{Low} \end{cases} \qquad x_2^* = \begin{cases} 1 & \text{if} \quad B = \textit{High} \\ -1 & \text{if} \quad B = \textit{Low} \end{cases}$$

1.) Express the following null hypotheses in term of the coefficients for the Dummy Variable Model :

   a.) No interaction between A and B

   b.) No effect due to A

   c.) No effect due to B

2.) By considering the mean response for the four treatments (combinations of A and B), determine the relationship between $\alpha, \beta_1, \beta_2, \beta_3$ and $\alpha^*, \beta_1^*, \beta_2^*, \beta_3^*$.

3.) Using the Dummy Variable Model, obtain expressions for the difference in mean response between

   a.) $A_{high}B_{high}$ and $A_{low}B_{low}$

   b.) $A_{high}B_{high}$ and $A_{high}B_{low}$

   c.) $A_{low}B_{high}$ and $A_{low}B_{low}$.

4.) Using the Design Effects Model, obtain expressions for the difference in mean response between

   a.) $A_{high}B_{high}$ and $A_{low}B_{low}$

   b.) $A_{high}B_{high}$ and $A_{high}B_{low}$

   c.) $A_{low}B_{high}$ and $A_{low}B_{low}$.

5.) Suppose that there is also a third factor C with two levels, *High* and *Low*. Describe how to form a Dummy Variable Model for the mean response in each of the following cases:

   a.) Main effects only for A, B, and C.

   b.) Main effects and all two-way interactions for A, B, and C.

   c.) Main effects and all possible interactions for A, B, and C.

6.) Consider now the Dummy Variable Model for the logarithm of the mean response:

- **Dummy Variable Model :** $\log(E(Y)) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1 x_2$,

  where

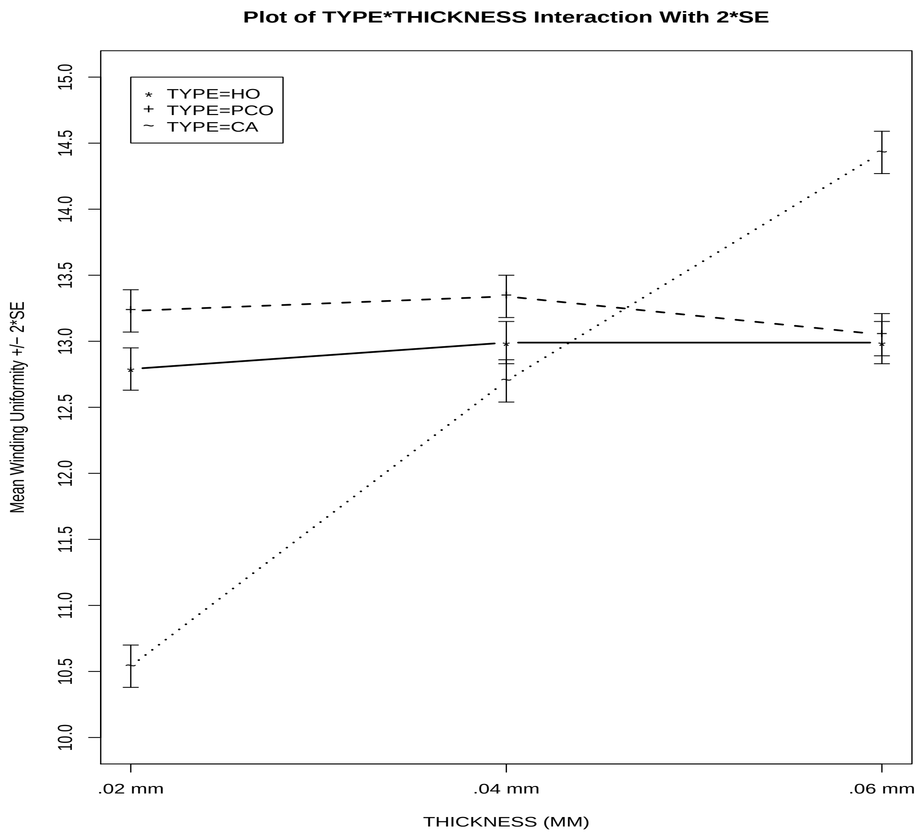
$$x_1 = \begin{cases} 1 & \text{if} \quad A = \textit{High} \\ 0 & \text{if} \quad A = \textit{Low} \end{cases} \qquad x_2 = \begin{cases} 1 & \text{if} \quad B = \textit{High} \\ 0 & \text{if} \quad B = \textit{Low} \end{cases}$$

Explain what the coefficients $\alpha, \beta_1, \beta_2, \beta_3$ represent in terms of the mean response $E(Y)$.

QUESTION IV.

A company is interested in the ability of a machine to consistently place electrical wire on a coil. There are three types of machines available: hand operated(HO), partially computer operated(PCO), and completely automated(CA). Three machines of each type are randomly selected from their suppliers for use in the study. The wire placed on the coils comes in one of three thicknesses: .02mm, .04mm, or .06mm. Each of the machines assembles two coils of each of the three wire thicknesses. Each wound coil is then measured for the uniformity of windings at a middle position on the coil. These measurements are given in the following table.

		TYPE OF MACHINE								
		HO			PCO			CA		
MACHINE ID		1	2	3	1	2	3	1	2	3
	.02mm	12.30	13.46	12.35	13.01	13.46	13.15	10.47	10.75	10.24
		12.59	14.00	12.06	12.63	13.92	13.20	10.96	19.68	10.15
THICKNESS	.04mm	13.15	13.29	12.50	12.74	13.84	13.46	12.73	12.60	12.92
		13.00	13.62	12.39	12.68	13.75	13.57	12.64	12.65	12.64
	.06mm	12.87	13.46	12.73	12.47	13.62	13.36	14.01	14.80	14.19
		12.92	13.82	12.15	12.15	13.28	13.42	14.62	14.71	14.23



Use the above plot, data, the attached SAS output, and the tables on page 5 to answer the following questions.

1.) Do the necessary conditions for testing hypotheses and constructing confidence intervals appear to be satisfied? Justify your answers.

C_1 - Normality:

C_2 - Equal Variance:

C_3 - Independence:

2.) Write a model for $y_{ijk\ell}$, the uniformity of windings on the ℓth Coil wound by the kth Machine of Type i using Wire Thickness j.

- Make sure to include all necessary conditions on parameters and random variables in your model.

3.) At the $\alpha = .05$ level, which main effects and interactions are significant? Justify your answer by including the relevant p-values along with their pair of degrees of freedom $(df_{NUM.}, df_{DEN.})$.

4.) The researchers were interested in estimating the difference in the mean uniformity in the windings between wires of thickness .02 mm and .06 mm wound using a Type CA machine: $\mu_{31} - \mu_{33}$

Determine the variance of the estimated mean difference: $\text{Var}(\hat{\mu}_{31} - \hat{\mu}_{33})$, in terms of the variance components from your model.

Using the estimated variance components from the SAS output, compute the estimated standard error of the estimated mean difference: $\widehat{SE}(\hat{\mu}_{31} - \hat{\mu}_{33})$.

- Provide supporting details for your expressions.

5.) Place the three types of machines into groups such that the machines within a group are not significantly different from any machine in the same group with respect to their mean uniformity of windings. Use an experimentwise error rate of $\alpha = .05$.

6.) Provide a 95% confidence on the mean uniformity of windings of a wire of thickness .04 mm wound with a CA machine.

7.) The wire regulatory agency reviewed the study and were concerned that the rigidity of the different wire samples was not included in the study. Suggest a method by which the rigidity measurements of the 54 wire samples could be used in the analysis.

The following SAS program was used to analyze the data. The output is contained in the following pages.

```
ods html;ods graphics on;
OPTIONS LS=90 PS=55 nocenter nodate;
TITLE 'SAS OUTPUT FOR PROBLEM IV';
DATA MANU;
INPUT TYPE $ MACH $ THICK  $ Y @@;
TRT=COMPRESS (TYPE) || COMPRESS (THICK);
CARDS;

HO M1 .02 12.30  HO M2 .02 13.46  HO M3 .02  12.35
HO M1 .02 12.59  HO M2 .02 14.00  HO M3 .02  12.06
HO M1 .04 13.15  HO M2 .04 13.29  HO M3 .04  12.50
HO M1 .04 13.00  HO M2 .04 13.62  HO M3 .04  12.39
HO M1 .06 12.87  HO M2 .06 13.46  HO M3 .06  12.73
HO M1 .06 12.92  HO M2 .06 13.82  HO M3 .06  12.15

PCO M1 .02 13.01  PCO M2 .02 13.46  PCO M3 .02  13.15
PCO M1 .02 12.63  PCO M2 .02 13.92  PCO M3 .02  13.20
PCO M1 .04 12.74  PCO M2 .04 13.84  PCO M3 .04  13.46
PCO M1 .04 12.68  PCO M2 .04 13.75  PCO M3 .04  13.57
PCO M1 .06 12.47  PCO M2 .06 13.62  PCO M3 .06  13.36
PCO M1 .06 12.15  PCO M2 .06 13.28  PCO M3 .06  13.42

CA M1 .02 10.47  CA M2 .02 10.75  CA M3 .02  10.24
CA M1 .02 10.96  CA M2 .02 10.68  CA M3 .02  10.15
CA M1 .04 12.73  CA M2 .04 12.60  CA M3 .04  12.92
CA M1 .04 12.64  CA M2 .04 12.65  CA M3 .04  12.64
CA M1 .06 14.01  CA M2 .06 14.80  CA M3 .06  14.19
CA M1 .06 14.62  CA M2 .06 14.71  CA M3 .06  14.23

RUN;


PROC GLM ORDER=DATA;
CLASS TYPE MACH THICK;
MODEL  Y = TYPE THICK TYPE*THICK MACH(TYPE) THICK*MACH(TYPE);
RANDOM MACH(TYPE) THICK*MACH(TYPE)/TEST;
LSMEANS TYPE THICK THICK*TYPE/STDERR PDIFF ADJUST=TUKEY;
RUN;



PROC MIXED CL ALPHA=.05 COVTEST;
CLASS TYPE MACH THICK;
MODEL  Y = TYPE THICK TYPE*THICK;
RANDOM MACH(TYPE) THICK*MACH(TYPE);
LSMEANS TYPE THICK TYPE*THICK/ ADJUST=TUKEY;
RUN;



PROC GLM;
CLASS TRT;
MODEL  Y = TRT;
MEANS TRT/HOVTEST=BF;
OUTPUT OUT=ASSUMP R=RESID P=MEANS;
PROC GPLOT; PLOT RESID*MEANS/VREF=0;
PROC UNIVARIATE DEF=5 PLOT NORMAL;
VAR RESID;
RUN;
ods graphics off;ods html close;
```

SAS OUTPUT FOR PROBLEM IV

The GLM Procedure

Class Level Information		
Class	Levels	Values
TYPE	3	HO PCO CA
MACH	3	M1 M2 M3
THICK	3	.02 .04 .06

Number of Observations Read	54
Number of Observations Used	54

SAS OUTPUT FOR PROBLEM IV

The GLM Procedure

Dependent Variable: Y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	59.31313333	2.28127436	51.34	<.0001
Error	27	1.19980000	0.04443704		
Corrected Total	53	60.51293333			

R-Square	Coeff Var	Root MSE	Y Mean
0.980173	1.634679	0.210801	12.89556

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TYPE	2	3.83981111	1.91990556	43.21	<.0001
THICK	2	15.59923333	7.79961667	175.52	<.0001
TYPE*THICK	4	30.27515556	7.56878889	170.33	<.0001
MACH(TYPE)	6	8.46555556	1.41092593	31.75	<.0001
MACH*THICK(TYPE)	12	1.13337778	0.09444815	2.13	0.0507

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TYPE	2	3.83981111	1.91990556	43.21	<.0001
THICK	2	15.59923333	7.79961667	175.52	<.0001
TYPE*THICK	4	30.27515556	7.56878889	170.33	<.0001
MACH(TYPE)	6	8.46555556	1.41092593	31.75	<.0001
MACH*THICK(TYPE)	12	1.13337778	0.09444815	2.13	0.0507

SAS OUTPUT FOR PROBLEM IV

The GLM Procedure

Source	Type III Expected Mean Square
TYPE	Var(Error) + 2 Var(MACH*THICK(TYPE)) + 6 Var(MACH(TYPE)) + Q(TYPE,TYPE*THICK)
THICK	Var(Error) + 2 Var(MACH*THICK(TYPE)) + Q(THICK,TYPE*THICK)
TYPE*THICK	Var(Error) + 2 Var(MACH*THICK(TYPE)) + Q(TYPE*THICK)
MACH(TYPE)	Var(Error) + 2 Var(MACH*THICK(TYPE)) + 6 Var(MACH(TYPE))
MACH*THICK(TYPE)	Var(Error) + 2 Var(MACH*THICK(TYPE))

SAS OUTPUT FOR PROBLEM IV

The GLM Procedure
Tests of Hypotheses for Mixed Model Analysis of Variance

Dependent Variable: Y

	Source	DF	Type III SS	Mean Square	F Value	Pr > F
*	TYPE	2	3.839811	1.919906	1.36	0.3256
	Error	6	8.465556	1.410926		
Error: MS(MACH(TYPE))						
* This test assumes one or more other fixed effects are zero.						

	Source	DF	Type III SS	Mean Square	F Value	Pr > F
*	THICK	2	15.599233	7.799617	82.58	<.0001
	TYPE*THICK	4	30.275156	7.568789	80.14	<.0001
	MACH(TYPE)	6	8.465556	1.410926	14.94	<.0001
	Error	12	1.133378	0.094448		
Error: MS(MACH*THICK(TYPE))						
* This test assumes one or more other fixed effects are zero.						

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MACH*THICK(TYPE)	12	1.133378	0.094448	2.13	0.0507
Error: MS(Error)	27	1.199800	0.044437		

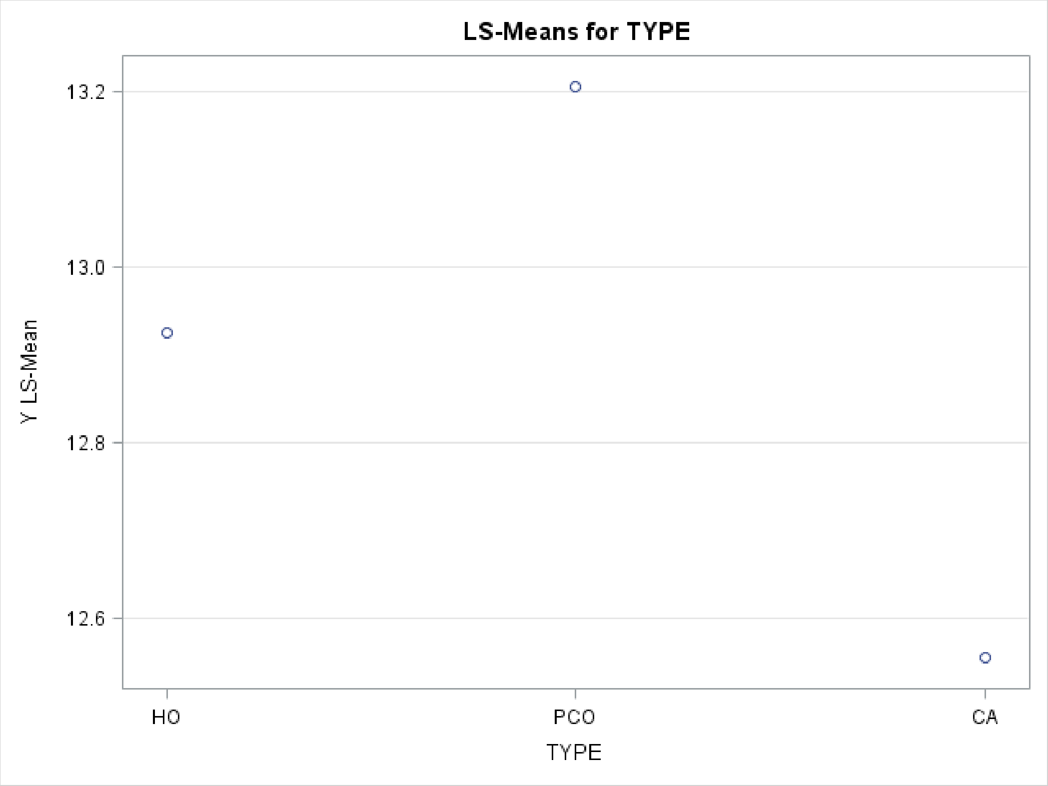
SAS OUTPUT FOR PROBLEM IV

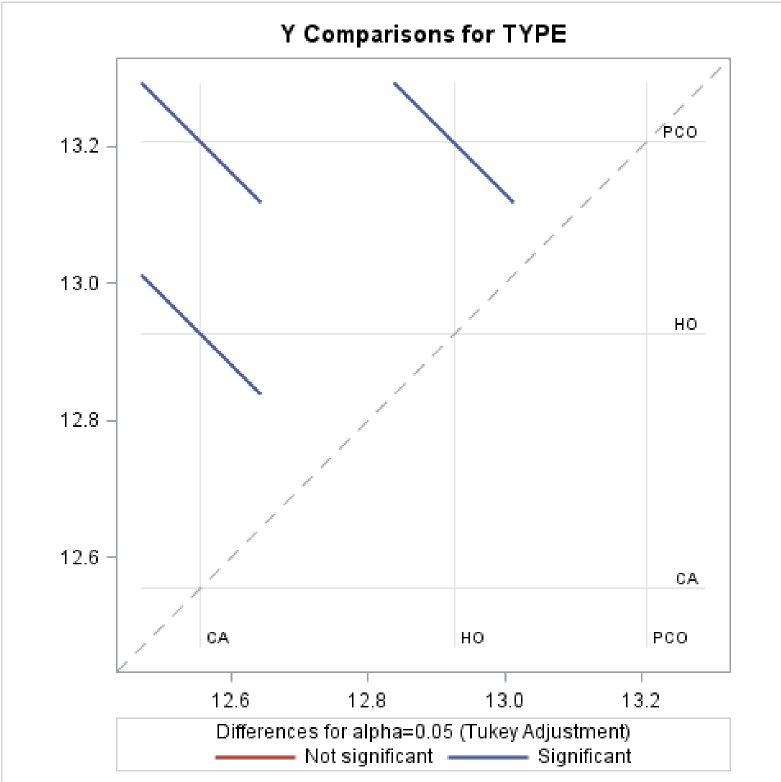
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

TYPE	Y LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
HO	12.9255556	0.0496863	<.0001	1
PCO	13.2061111	0.0496863	<.0001	2
CA	12.5550000	0.0496863	<.0001	3

Least Squares Means for effect TYPE
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Y

i/j	1	2	3
1		0.0013	<.0001
2	0.0013		<.0001
3	<.0001	<.0001	



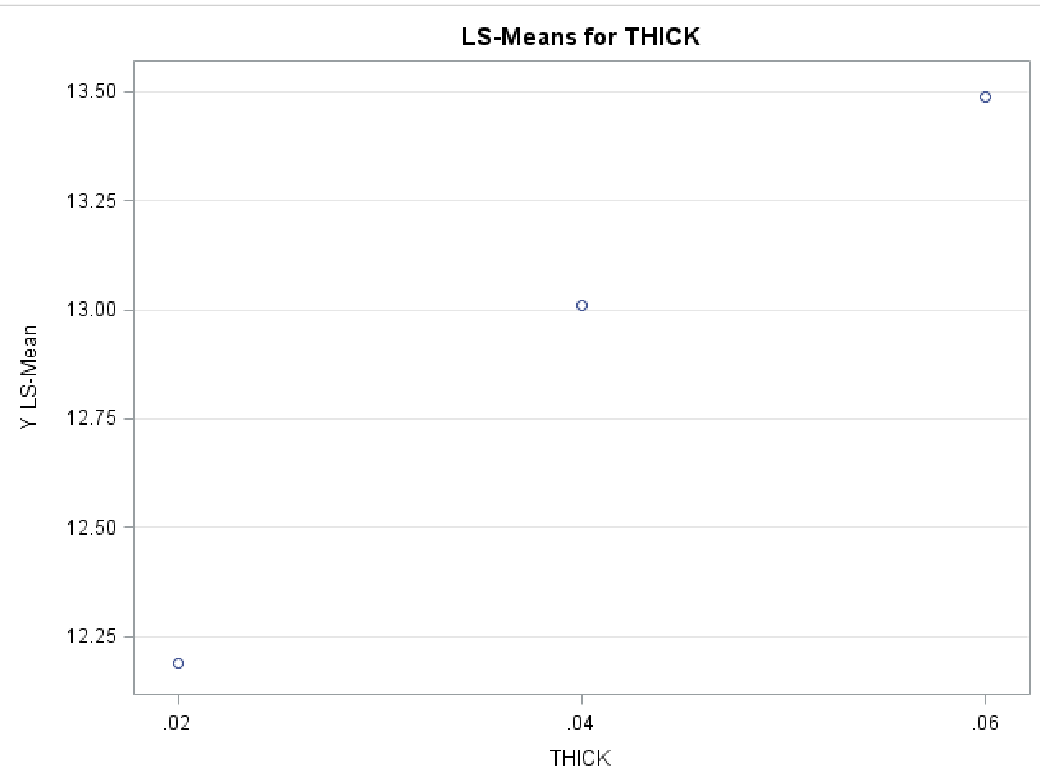

Y Comparisons for TYPE
13.2
13.0
12.8
12.6
PCO
HO
CA
CA
HO
PCO
12.6
12.8
13.0
13.2
Differences for alpha=0.05 (Tukey Adjustment)
Not significant
Significant

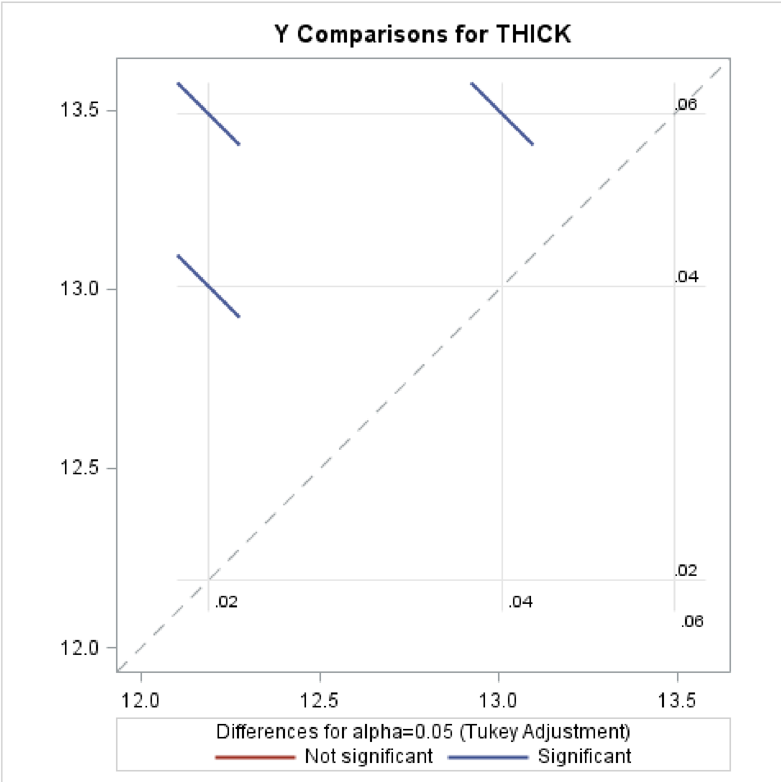
SAS OUTPUT FOR PROBLEM IV

Least Squares Means
Adjustment for Multiple Comparisons: Tukey

THICK	Y LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
.02	12.1877778	0.0496863	<.0001	1
.04	13.0094444	0.0496863	<.0001	2
.06	13.4894444	0.0496863	<.0001	3

Least Squares Means for effect THICK Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: Y			
i/j	1	2	3
1		<.0001	<.0001
2	<.0001		<.0001
3	<.0001	<.0001	




Y Comparisons for THICK
13.5
13.0
12.5
12.0
12.0
12.5
13.0
13.5
.06
.04
.02
.02
.04
.06
Differences for alpha=0.05 (Tukey Adjustment)
Not significant
Significant

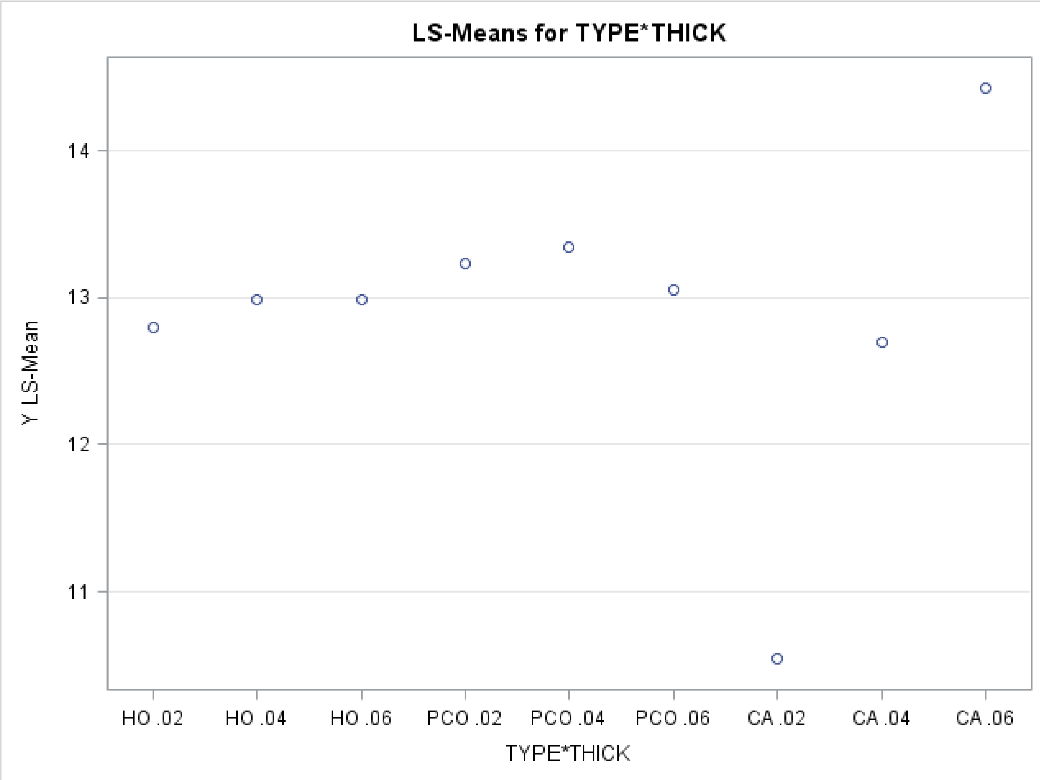
SAS OUTPUT FOR PROBLEM IV

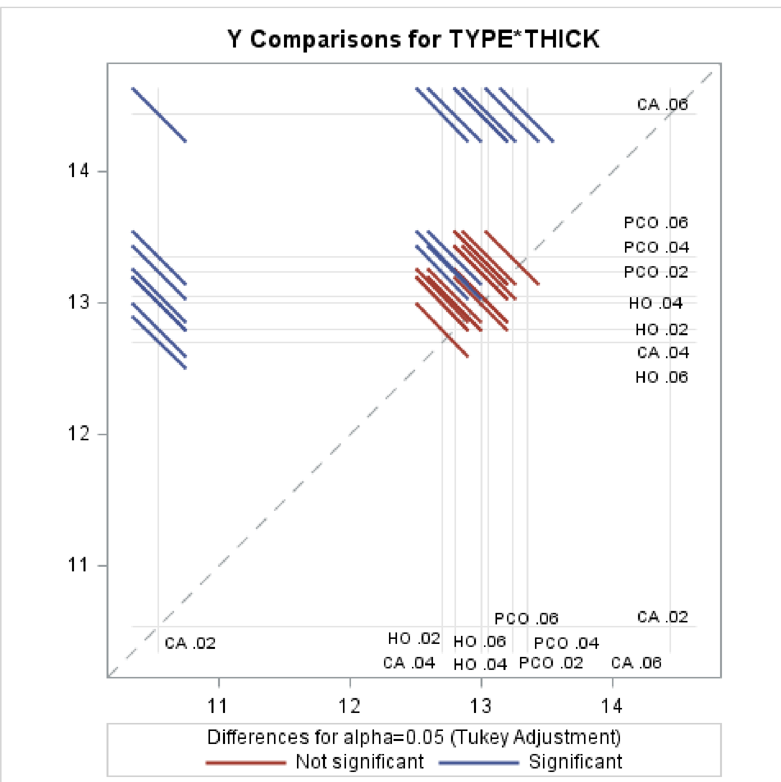
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

TYPE	THICK	Y LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
HO	.02	12.7933333	0.0860591	<.0001	1
HO	.04	12.9916667	0.0860591	<.0001	2
HO	.06	12.9916667	0.0860591	<.0001	3
PCO	.02	13.2283333	0.0860591	<.0001	4
PCO	.04	13.3400000	0.0860591	<.0001	5
PCO	.06	13.0500000	0.0860591	<.0001	6
CA	.02	10.5416667	0.0860591	<.0001	7
CA	.04	12.6966667	0.0860591	<.0001	8
CA	.06	14.4266667	0.0860591	<.0001	9

Least Squares Means for effect TYPE*THICK
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: Y

i/j	1	2	3	4	5	6	7	8	9
1		0.7808	0.7808	0.0310	0.0033	0.4882	<.0001	0.9961	<.0001
2	0.7808		1.0000	0.5913	0.1434	0.9999	<.0001	0.3117	<.0001
3	0.7808	1.0000		0.5913	0.1434	0.9999	<.0001	0.3117	<.0001
4	0.0310	0.5913	0.5913		0.9899	0.8614	<.0001	0.0045	<.0001
5	0.0033	0.1434	0.1434	0.9899		0.3323	<.0001	0.0004	<.0001
6	0.4882	0.9999	0.9999	0.8614	0.3323		<.0001	0.1324	<.0001
7	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001	<.0001
8	0.9961	0.3117	0.3117	0.0045	0.0004	0.1324	<.0001		<.0001
9	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	


LS-Means for TYPE*THICK
Y LS-Mean
14
13
12
11
HO .02
HO .04
HO .06
PCO .02
PCO .04
PCO .06
CA .02
CA .04
CA .06
TYPE*THICK


Y Comparisons for TYPE*THICK
CA .06
PCO .06
PCO .04
PCO .02
HO .04
HO .02
CA .04
HO .06
14
13
12
11
PCO .06
CA .02
CA .02
HO .02
HO .06
PCO .04
CA .04
HO .04
PCO .02
CA .06
11
12
13
14
Differences for alpha=0.05 (Tukey Adjustment)
Not significant
Significant

SAS OUTPUT FOR PROBLEM IV

The Mixed Procedure

Model Information	
Data Set	WORK.MANU
Dependent Variable	Y
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	Levels	Values
TYPE	3	CA HO PCO
MACH	3	M1 M2 M3
THICK	3	.02 .04 .06

Dimensions	
Covariance Parameters	3
Columns in X	16
Columns in Z	36
Subjects	1
Max Obs Per Subject	54

Number of Observations	
Number of Observations Read	54
Number of Observations Used	54
Number of Observations Not Used	0

Iteration History			
Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	79.60478912	
1	1	33.50991503	0.00000000

Convergence criteria met.

Covariance Parameter Estimates							
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z	Alpha	Lower	Upper
MACH(TYPE)	0.2194	0.1359	1.61	0.0532	0.05	0.08676	1.2528
MACH*THICK(TYPE)	0.02501	0.02021	1.24	0.1079	0.05	0.008092	0.3330
Residual	0.04444	0.01209	3.67	0.0001	0.05	0.02778	0.08233

Fit Statistics	
-2 Res Log Likelihood	33.5

AIC (smaller is better)	39.5
AICC (smaller is better)	40.1
BIC (smaller is better)	40.1

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
TYPE	2	6	1.36	0.3256
THICK	2	12	82.58	<.0001
TYPE*THICK	4	12	80.14	<.0001

Least Squares Means							
Effect	TYPE	THICK	Estimate	Standard Error	DF	t Value	Pr > |t|
TYPE	CA		12.5550	0.2800	6	44.84	<.0001
TYPE	HO		12.9256	0.2800	6	46.17	<.0001
TYPE	PCO		13.2061	0.2800	6	47.17	<.0001
THICK		.02	12.1878	0.1721	12	70.81	<.0001
THICK		.04	13.0094	0.1721	12	75.58	<.0001
THICK		.06	13.4894	0.1721	12	78.37	<.0001
TYPE*THICK	CA	.02	10.5417	0.2981	12	35.36	<.0001
TYPE*THICK	CA	.04	12.6967	0.2981	12	42.59	<.0001
TYPE*THICK	CA	.06	14.4267	0.2981	12	48.39	<.0001
TYPE*THICK	HO	.02	12.7933	0.2981	12	42.91	<.0001
TYPE*THICK	HO	.04	12.9917	0.2981	12	43.58	<.0001
TYPE*THICK	HO	.06	12.9917	0.2981	12	43.58	<.0001
TYPE*THICK	PCO	.02	13.2283	0.2981	12	44.37	<.0001
TYPE*THICK	PCO	.04	13.3400	0.2981	12	44.75	<.0001
TYPE*THICK	PCO	.06	13.0500	0.2981	12	43.77	<.0001

Differences of Least Squares Means											
Effect	TYPE	THICK	_TYPE	_THICK	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
TYPE	CA		HO		-0.3706	0.3959	6	-0.94	0.3855	Tukey	0.6396
TYPE	CA		PCO		-0.6511	0.3959	6	-1.64	0.1512	Tukey	0.2996
TYPE	HO		PCO		-0.2806	0.3959	6	-0.71	0.5052	Tukey	0.7676
THICK		.02		.04	-0.8217	0.1024	12	-8.02	<.0001	Tukey-Kramer	<.0001
THICK		.02		.06	-1.3017	0.1024	12	-12.71	<.0001	Tukey-Kramer	<.0001
THICK		.04		.06	-0.4800	0.1024	12	-4.69	0.0005	Tukey-Kramer	0.0014
TYPE*THICK	CA	.02	CA	.04	-2.1550	0.1774	12	-12.15	<.0001	Tukey-Kramer	<.0001
TYPE*THICK	CA	.02	CA	.06	-3.8850	0.1774	12	-21.90	<.0001	Tukey-Kramer	<.0001
TYPE*THICK	CA	.02	HO	.02	-2.2517	0.4216	12	-5.34	0.0002	Tukey-Kramer	0.0037
TYPE*THICK	CA	.02	HO	.04	-2.4500	0.4216	12	-5.81	<.0001	Tukey-Kramer	0.0018
TYPE*THICK	CA	.02	HO	.06	-2.4500	0.4216	12	-5.81	<.0001	Tukey-Kramer	0.0018
TYPE*THICK	CA	.02	PCO	.02	-2.6867	0.4216	12	-6.37	<.0001	Tukey-Kramer	0.0008
TYPE*THICK	CA	.02	PCO	.04	-2.7983	0.4216	12	-6.64	<.0001	Tukey-Kramer	0.0005
TYPE*THICK	CA	.02	PCO	.06	-2.5083	0.4216	12	-5.95	<.0001	Tukey-Kramer	0.0015

TYPE*THICK	CA	.04	CA	.06	-1.7300	0.1774	12	-9.75	<.0001	Tukey-Kramer	<.0001
TYPE*THICK	CA	.04	HO	.02	-0.09667	0.4216	12	-0.23	0.8225	Tukey-Kramer	1.0000
TYPE*THICK	CA	.04	HO	.04	-0.2950	0.4216	12	-0.70	0.4975	Tukey-Kramer	0.9978
TYPE*THICK	CA	.04	HO	.06	-0.2950	0.4216	12	-0.70	0.4975	Tukey-Kramer	0.9978
TYPE*THICK	CA	.04	PCO	.02	-0.5317	0.4216	12	-1.26	0.2313	Tukey-Kramer	0.9252
TYPE*THICK	CA	.04	PCO	.04	-0.6433	0.4216	12	-1.53	0.1530	Tukey-Kramer	0.8245
TYPE*THICK	CA	.04	PCO	.06	-0.3533	0.4216	12	-0.84	0.4184	Tukey-Kramer	0.9927
TYPE*THICK	CA	.06	HO	.02	1.6333	0.4216	12	3.87	0.0022	Tukey-Kramer	0.0391
TYPE*THICK	CA	.06	HO	.04	1.4350	0.4216	12	3.40	0.0052	Tukey-Kramer	0.0835
TYPE*THICK	CA	.06	HO	.06	1.4350	0.4216	12	3.40	0.0052	Tukey-Kramer	0.0835
TYPE*THICK	CA	.06	PCO	.02	1.1983	0.4216	12	2.84	0.0148	Tukey-Kramer	0.1974
TYPE*THICK	CA	.06	PCO	.04	1.0867	0.4216	12	2.58	0.0242	Tukey-Kramer	0.2867
TYPE*THICK	CA	.06	PCO	.06	1.3767	0.4216	12	3.27	0.0068	Tukey-Kramer	0.1039
TYPE*THICK	HO	.02	HO	.04	-0.1983	0.1774	12	-1.12	0.2855	Tukey-Kramer	0.9599
TYPE*THICK	HO	.02	HO	.06	-0.1983	0.1774	12	-1.12	0.2855	Tukey-Kramer	0.9599
TYPE*THICK	HO	.02	PCO	.02	-0.4350	0.4216	12	-1.03	0.3225	Tukey-Kramer	0.9743
TYPE*THICK	HO	.02	PCO	.04	-0.5467	0.4216	12	-1.30	0.2191	Tukey-Kramer	0.9144
TYPE*THICK	HO	.02	PCO	.06	-0.2567	0.4216	12	-0.61	0.5540	Tukey-Kramer	0.9992
TYPE*THICK	HO	.04	HO	.06	-866E-17	0.1774	12	-0.00	1.0000	Tukey-Kramer	1.0000
TYPE*THICK	HO	.04	PCO	.02	-0.2367	0.4216	12	-0.56	0.5849	Tukey-Kramer	0.9995
TYPE*THICK	HO	.04	PCO	.04	-0.3483	0.4216	12	-0.83	0.4248	Tukey-Kramer	0.9934
TYPE*THICK	HO	.04	PCO	.06	-0.05833	0.4216	12	-0.14	0.8923	Tukey-Kramer	1.0000
TYPE*THICK	HO	.06	PCO	.02	-0.2367	0.4216	12	-0.56	0.5849	Tukey-Kramer	0.9995
TYPE*THICK	HO	.06	PCO	.04	-0.3483	0.4216	12	-0.83	0.4248	Tukey-Kramer	0.9934
TYPE*THICK	HO	.06	PCO	.06	-0.05833	0.4216	12	-0.14	0.8923	Tukey-Kramer	1.0000
TYPE*THICK	PCO	.02	PCO	.04	-0.1117	0.1774	12	-0.63	0.5409	Tukey-Kramer	0.9989
TYPE*THICK	PCO	.02	PCO	.06	0.1783	0.1774	12	1.01	0.3347	Tukey-Kramer	0.9779
TYPE*THICK	PCO	.04	PCO	.06	0.2900	0.1774	12	1.63	0.1281	Tukey-Kramer	0.7715

SAS OUTPUT FOR PROBLEM IV

The GLM Procedure

Class Level Information		
Class	Levels	Values
TRT	9	CA.02 CA.04 CA.06 HO.02 HO.04 HO.06 PCO.02 PCO.04 PCO.06

Number of Observations Read	54
Number of Observations Used	54

SAS OUTPUT FOR PROBLEM IV

The GLM Procedure

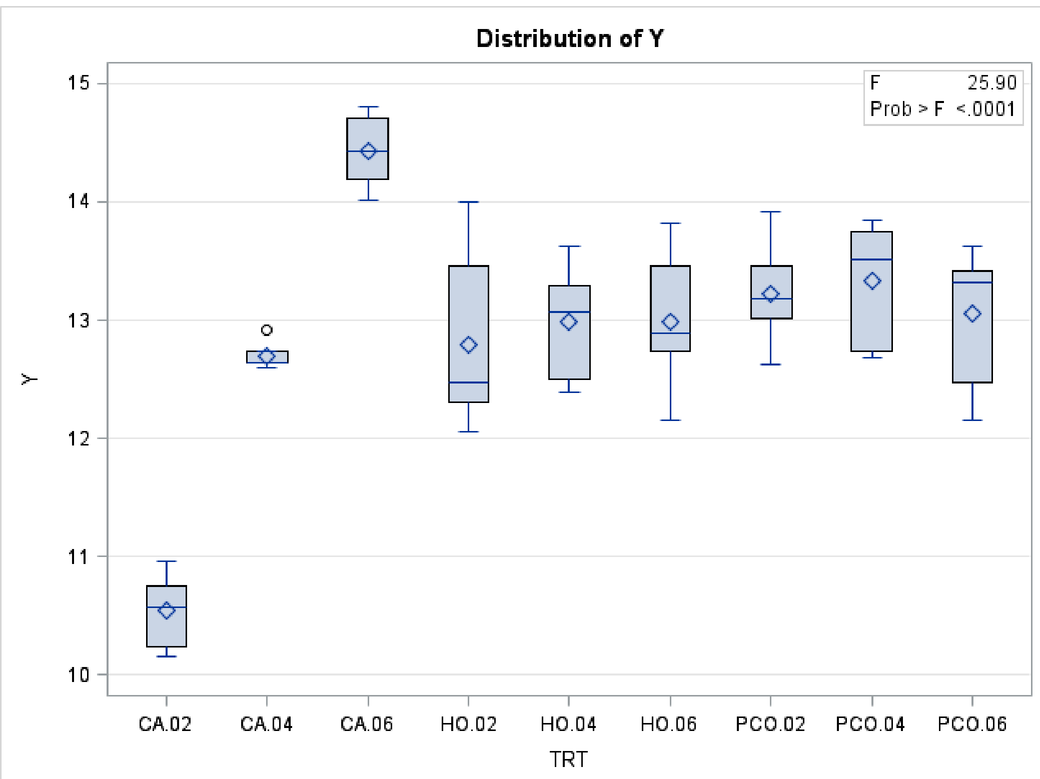
Dependent Variable: Y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	49.71420000	6.21427500	25.90	<.0001
Error	45	10.79873333	0.23997185		
Corrected Total	53	60.51293333			

R-Square	Coeff Var	Root MSE	Y Mean
0.821547	3.798745	0.489869	12.89556

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	8	49.71420000	6.21427500	25.90	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRT	8	49.71420000	6.21427500	25.90	<.0001



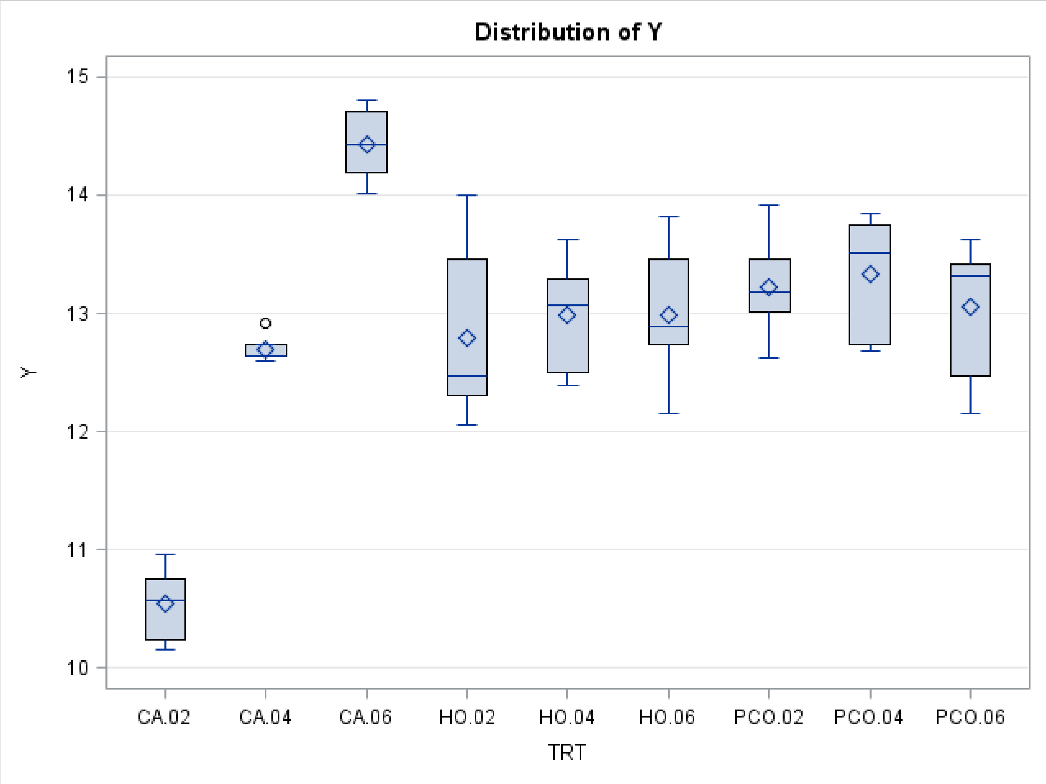
SAS OUTPUT FOR PROBLEM IV

The GLM Procedure

Brown and Forsythe's Test for Homogeneity of Y Variance ANOVA of Absolute Deviations from Group Medians					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
TRT	8	0.8672	0.1084	0.94	0.4948
Error	45	5.1969	0.1155		

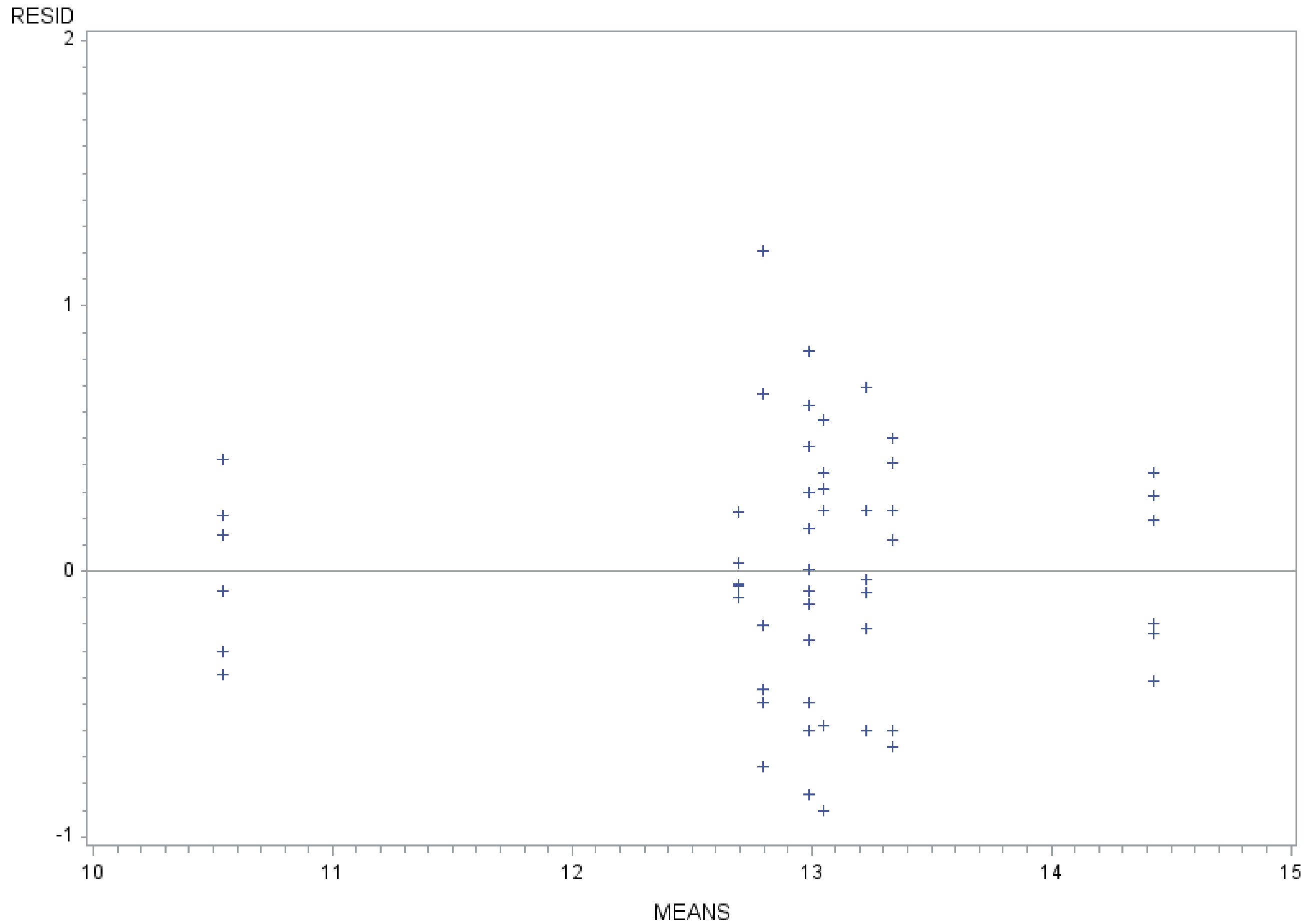
SAS OUTPUT FOR PROBLEM IV

The GLM Procedure



Level of TRT	N	Y Mean	Y Std Dev
CA.02	6	10.5416667	0.31211643
CA.04	6	12.6966667	0.11741664
CA.06	6	14.4266667	0.32413989
HO.02	6	12.7933333	0.76413786
HO.04	6	12.9916667	0.47173792
HO.06	6	12.9916667	0.58348665
PCO.02	6	13.2283333	0.43466846
PCO.04	6	13.3400000	0.50616203
PCO.06	6	13.0500000	0.59282375

SAS OUTPUT FOR PROBLEM IV



SAS OUTPUT FOR PROBLEM IV

The UNIVARIATE Procedure
Variable: RESID

Moments			
N	54	Sum Weights	54
Mean	0	Sum Observations	0
Std Deviation	0.4513864	Variance	0.20374969
Skewness	0.13033828	Kurtosis	-0.1764522
Uncorrected SS	10.7987333	Corrected SS	10.7987333
Coeff Variation	.	Std Error Mean	0.06142591

Basic Statistical Measures			
Location		Variability	
Mean	0.00000	Std Deviation	0.45139
Median	-0.03750	Variance	0.20375
Mode	-0.05667	Range	2.10667
		Interquartile Range	0.60000

Note: The mode displayed is the smallest of 2 modes with a count of 2.

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	0	Pr > |t|	1.0000
Sign	M	-1	Pr >= |M|	0.8919
Signed Rank	S	-4.5	Pr >= |S|	0.9695

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.98865	Pr < W	0.8877
Kolmogorov-Smirnov	D	0.054676	Pr > D	>0.1500
Cramer-von Mises	W-Sq	0.028584	Pr > W-Sq	>0.2500
Anderson-Darling	A-Sq	0.190357	Pr > A-Sq	>0.2500

Quantiles (Definition 5)	
Quantile	Estimate
100% Max	1.206667
99%	1.206667
95%	0.691667
90%	0.570000
75% Q3	0.298333
50% Median	-0.037500
25% Q1	-0.301667
10%	-0.600000

5%	-0.733333
1%	-0.900000
0% Min	-0.900000

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
-0.900000	34	0.628333	11
-0.841667	18	0.666667	2
-0.733333	6	0.691667	23
-0.660000	28	0.828333	17
-0.601667	12	1.206667	5