Problem I. (24 points) A field experiment was conducted to evaluate the effects of the time at which a nitrogen application is applied to the soil (early, optimum, late) and two levels of a nitrification inhibitor (none or .5 lb/acre). The inhibitor delays conversion of ammonium forms of nitrogen into a more mobile nitrate form to reduce leaching losses of fertilizer derived nitrates. Three fields were divided into 6 plots. The plots were randomly assigned to the 6 combinations of Nitrogen Inhibitor and Application Date. The data given below are the percent of Nitrogen taken up be sweet corn plants grown on the 18 plots.

	Nitrogen Inhibitor Levels					
	None			.5 lb/acre		
Field	Early	Optimum	Late	Early	Optimum	Late
1	21.4	50.8	53.2	54.8	56.9	57.7
2	11.3	42.7	44.8	47.9	46.8	54.0
3	34.9	61.8	57.8	40.1	57.9	62.0

NOTES: H.O. 11

- For RCBD example, general procedure and general ANOVA table setup see pgs 4,7,9,11

Questions for Office Hours:

(1) What is the difference between the two chunks of code given, specifically,

(i) the difference between using Method = TYPE3 in the first chunk and not specifying a method in the second chunk

(ii) Does it have to do with H.O. 11 pg 15

(2) What do the things like Q(NI,NI*D) represent again?

(3) Do we need to include the Type 3 Tests of Fixed Effects with the ANOVA table, or just the Type 3 Anova table (as I have it rn)?

(4) Why don't we get an AOV table with the second chunk of code when we run essentially the same code on pg 17 and the output includes and AOV table?

1.) Display the AOV table

Type 3 Analysis of Variance								
Source	DF	Sum of Squares	Mean Square	Expected Mean Square	Error Term	Error DF	F Value	Pr > F
NI	1	548.908889	548.908889	Var(Residual) + Q(NI,NI*D)	MS(Residual)	10	14.77	0.0032
D	2	1426.990000	713.495000	Var(Residual) + Q(D,NI*D)	MS(Residual)	10	19.20	0.0004
NI*D	2	453.614444	226.807222	Var(Residual) + Q(NI*D)	MS(Residual)	10	6.10	0.0185
F	2	395.243333	197.621667	Var(Residual) + 6 Var(F)	MS(Residual)	10	5.32	0.0267
Residual	10	371.523333	37.152333	Var(Residual)	.	.	.	.

Problem I. (Continued)

2.) Compute the standard error estimates for the LSE of the marginal means of Nitrogen Inhibitor and Timing of Nitrogen Application and the Cell means of the six Treatments.

NOTES: H.O. 11

- For Calculation of SEs see pg 12

Questions for Office Hours

(1) What is meant by marginal means… If I use the formula given on pg 12, I get what I would consider to be the $\widehat{SE}(\mu_{ij})$ not $\widehat{SE}(\mu_{i.})$ which I guess makes sense because on pg 12 we only have 1 factor and in our problem we have two factors.

---

* I'm guessing that what is wanted here is what is shown below, where the marginal means are the first 5 rows and the cell means are the last 6 rows. When I use the formula on pg 12, I get the SE for the cell means, but I'm unsure how to get the SE for the marginal means.

Least Squares Means

Effect	NI	D	Estimate	Standard Error	DF	t Value	Pr > |t|
NI	N		42.0778	3.6115	10	11.65	<.0001
NI	.5		53.1222	3.6115	10	14.71	<.0001
D		E	35.0667	3.8868	10	9.02	<.0001
D		O	52.8167	3.8868	10	13.59	<.0001
D		L	54.9167	3.8868	10	14.13	<.0001
NI*D	N	E	22.5333	4.6151	10	4.88	0.0006
NI*D	N	O	51.7667	4.6151	10	11.22	<.0001
NI*D	N	L	51.9333	4.6151	10	11.25	<.0001
NI*D	.5	E	47.6000	4.6151	10	10.31	<.0001
NI*D	.5	O	53.8667	4.6151	10	11.67	<.0001
NI*D	.5	L	57.9000	4.6151	10	12.55	<.0001

Problem I. (Continued)

3.) Identify all significant main effects and interactions (use α = .05).

Questions for Office Hours

(1) See question posted by Michael in the discussion

(2) Does the procedure for our analysis change whether or not the blocking factor is significant?

(3) Did I get the α_{pc} correct?

(4) Instead of grouping both ways, could we say because the groups are not the same for the two levels of NI that NI also has a significant effect?

(5) Does it matter which one of the Differences in LS means tables we use?

(6) If NI*D wasn't Significant we could just

* I am going to proceed as we have before when the interaction is significant and group the means for one of the factors at each level of another factor to see if the main effects of each of the factors are significant

----

We can see in the AOV table above that the interaction between Nitrogen Inhibitor (NI) and the time of the nitrogen application (D) is significant, thus in order to determine if we have significant main effects for each factor we must look at the differences between the levels of one of our factors at fixed levels of the other factor.

Group the 3 Times separately for each of the 2 Levels of NI with $\alpha_{pc} = \frac{0.05}{6} = 0.008\overline{3}$ because there are $2 * \binom{3}{2} = 6$ pairs of treatment means being compared.

- NI = C: $G_1 = \{E\}, G_2 = \{O, L\}$
- NI = 0.5: $G_1 = \{E, O, L\}$

Thus, we have significant evidence at the $\alpha_f = 0.05$ level that Time (D) is a significant factor

Group the 2 levels of NI separately for each of the 3 levels of Time (D) with $\alpha_{pc} = \frac{0.05}{3} = 0.0167$ because there are $3 * \binom{2}{2} = 3$ pairs of treatment means being compared.

- D = E: $G_1 = \{C\}, G_2 = \{0.5\}$
- D = O: $G_1 = \{C, 0.5\}$
- D = L: $G_1 = \{C, 0.5\}$

Thus, we have significant evidence at the $\alpha_f = 0.05$ level that the main effect of Nitrogen Inhibitor (NI) is significant

For grouping the times we look at the p-values marked in

For grouping the levels of the nitrogen inhibitor we look at the p-values marked in

Differences of Least Squares Means									
Effect	TRT	_TRT	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
TRT	CE	CO	-29.2333	4.9768	10	-5.87	0.0002	Tukey-Kramer	0.0016
TRT	CE	CL	-29.4000	4.9768	10	-5.91	0.0001	Tukey-Kramer	0.0015
TRT	CE	E	-25.0667	4.9768	10	-5.04	0.0005	Tukey-Kramer	0.0049
TRT	CE	O	-31.3333	4.9768	10	-6.30	<.0001	Tukey-Kramer	0.0009
TRT	CE	L	-35.3667	4.9768	10	-7.11	<.0001	Tukey-Kramer	0.0003
TRT	CO	CL	-0.1667	4.9768	10	-0.03	0.9739	Tukey-Kramer	1.0000
TRT	CO	E	4.1667	4.9768	10	0.84	0.4220	Tukey-Kramer	0.9533
TRT	CO	O	-2.1000	4.9768	10	-0.42	0.6820	Tukey-Kramer	0.9977
TRT	CO	L	-6.1333	4.9768	10	-1.23	0.2460	Tukey-Kramer	0.8124
TRT	CL	E	4.3333	4.9768	10	0.87	0.4043	Tukey-Kramer	0.9454
TRT	CL	O	-1.9333	4.9768	10	-0.39	0.7058	Tukey-Kramer	0.9985
TRT	CL	L	-5.9667	4.9768	10	-1.20	0.2582	Tukey-Kramer	0.8281
TRT	E	O	-6.2667	4.9768	10	-1.26	0.2366	Tukey-Kramer	0.7995
TRT	E	L	-10.3000	4.9768	10	-2.07	0.0653	Tukey-Kramer	0.3717
TRT	O	L	-4.0333	4.9768	10	-0.81	0.4366	Tukey-Kramer	0.9590

Alternatively, we could've looked at the following table and achieved the same results. Again:

For grouping the times we look at the p-values marked in

For grouping the levels of the nitrogen inhibitor we look at the p-values marked in

Differences of Least Squares Means

Effect	NI	D	_NI	_D	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
NI	N		.5		-11.0444	2.8733	10	-3.84	0.0032	Tukey-Kramer	0.0032
D		E		O	-17.7500	3.5191	10	-5.04	0.0005	Tukey-Kramer	0.0013
D		E		L	-19.8500	3.5191	10	-5.64	0.0002	Tukey-Kramer	0.0006
D		O		L	-2.1000	3.5191	10	-0.60	0.5639	Tukey-Kramer	0.8250
NI*D	N	E	N	O	-29.2333	4.9768	10	-5.87	0.0002	Tukey-Kramer	0.0016
NI*D	N	E	N	L	-29.4000	4.9768	10	-5.91	0.0001	Tukey-Kramer	0.0015
NI*D	N	E	.5	E	-25.0667	4.9768	10	-5.04	0.0005	Tukey-Kramer	0.0049
NI*D	N	E	.5	O	-31.3333	4.9768	10	-6.30	<.0001	Tukey-Kramer	0.0009
NI*D	N	E	.5	L	-35.3667	4.9768	10	-7.11	<.0001	Tukey-Kramer	0.0003
NI*D	N	O	N	L	-0.1667	4.9768	10	-0.03	0.9739	Tukey-Kramer	1.0000
NI*D	N	O	.5	E	4.1667	4.9768	10	0.84	0.4220	Tukey-Kramer	0.9533
NI*D	N	O	.5	O	-2.1000	4.9768	10	-0.42	0.6820	Tukey-Kramer	0.9977
NI*D	N	O	.5	L	-6.1333	4.9768	10	-1.23	0.2460	Tukey-Kramer	0.8124
NI*D	N	L	.5	E	4.3333	4.9768	10	0.87	0.4043	Tukey-Kramer	0.9454
NI*D	N	L	.5	O	-1.9333	4.9768	10	-0.39	0.7058	Tukey-Kramer	0.9985
NI*D	N	L	.5	L	-5.9667	4.9768	10	-1.20	0.2582	Tukey-Kramer	0.8281
NI*D	.5	E	.5	O	-6.2667	4.9768	10	-1.26	0.2366	Tukey-Kramer	0.7995
NI*D	.5	E	.5	L	-10.3000	4.9768	10	-2.07	0.0653	Tukey-Kramer	0.3717
NI*D	.5	O	.5	L	-4.0333	4.9768	10	-0.81	0.4366	Tukey-Kramer	0.9590

Problem I. (Continued)

4.) Compute the relative efficiency of the blocking factor

NOTES: H.O.11

- For calculation of Relative Efficiency of Blocking see pg 14

We know from our notes that:

$$\widehat{RE} = \frac{SS_B + r(t-1) * MSE}{(rt-1) * MSE}$$

In our problem $SS_B = 395.24\overline{33}$, r = 3, t = 6 and $MSE = 37.152\overline{33}$ thus

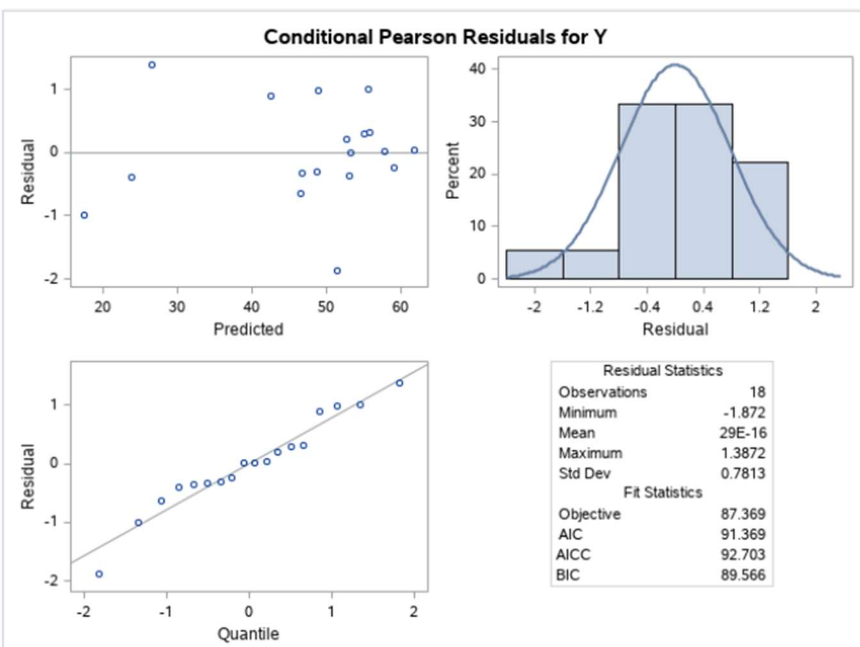
$$\widehat{RE} = \frac{395.24\overline{33} + 3(6-1) * 37.152\overline{33}}{((3)(6)-1) * 37.152\overline{33}} = \mathbf{1.508144265}$$

5.) If the conditions of normality and/or equal variance appear to be violated, suggest an alternative analysis.

Questions for Office Hours:

(1) Did we ever talk about what to do if the assumptions mentioned above were violated?

Looking at the figure below we can see that the assumption of normality doesn't seem to be violated. However, it seems as though the assumption of constant variance may be violated, though it is hard to tell. If we determined that the assumptions were violated, we could use Friedmans test.



Problem II. (12 points) A study is proposed to determine the amount of contamination of stream water by human activity in a national forest. Four streams are located, each of which has a small permanent community located near the stream. Each of the communities have waste disposal plants in the watershed of their stream. Also, each stream has a large recreational camp site located five to ten miles downstream from the community. A water sample will be taken at each of four locations on each stream: L1 - A sample upstream from each community; L2 - A sample one mile below each community; L3 - A sample 100 yards upstream from each recreational camp; L4 - A sample 100 yards below each recreational camp. Because of major activity differences per day of the week, it will be necessary to sample each of the four locations on the stream on each of the following days: Sunday, Monday, Wednesday, and Friday. The budget for the study provides only enough resources to take a total of 16 samples for the entire study.

1.) Design the study to acquire the 16 water samples with "Stream Location" as the treatment factor and "Day of Week" as an extraneous factor. Provide the AOV table for your design with Source of Variation and the associated Degrees of Freedom.

NOTES:

- From discussion board: "For each day and stream, you have one sample for sample location so you control the extraneous factors to detect differences in sample locations. Second part, you have two samples instead of one and again, you control the extraneous factors to detect differences in sample locations"
- See notes on Latin Square design pg 5, 30, 32, 33, 34, 43, 45, 46
- For part two, see Case 1 on pg 43

Questions for Office Hours:

(1) Are we ignoring 3 of the streams in part 1? (i.e. just randomly select 1 of the streams to study)
(2) Are streams random?
(3) Do you want us to include Expected Mean Squares in the AOV tables below?
(4) Is the df correct on pg 44? Should that 3 be in there or is that a typo, should it be r?
(5) Are BIBD related to fractional factorial studies and will we have to consider which effects we're confounding in order to maximize the resolution of our study? *(not really related to this question but still a good question to ask)

***** I am going to proceed as if I can use a Latin Square design with Location as my treatment and Stream and DOW as my blocking factors

	STREAM			
Day of The Week	S_1	S_2	S_3	S_4
Sunday	L_1	L_2	L_3	L_4
Monday	L_3	L_3	L_4	L_1
Wednesday	L_3	L_4	L_1	L_2
Friday	L_4	L_1	L_2	L_3

Problem II. (12 points)

1.) (continued)

Source of Variation	Degrees of Freedom
Stream	(4-1) = 3
Day of the Week	(4-1) = 3
Stream Location	(4-1) = 3
Error	(15-9) = 6
Total	(16-1) = 15

2.) Suppose that two samples are taken each time you sample the stream. Answer the questions from part 1 for this modification to the original design.

We now have a Latin Square Design with 2 replications

Square 1					**Square 2**				
	STREAM					**STREAM**			
Day of The Week	S_1	S_2	S_3	S_4	**Day of The Week**	S_1	S_2	S_3	S_4
Sunday	L_1	L_2	L_3	L_4	Sunday	L_1	L_4	L_3	L_2
Monday	L_3	L_3	L_4	L_1	Monday	L_2	L_1	L_4	L_3
Wednesday	L_3	L_4	L_1	L_2	Wednesday	L_3	L_2	L_1	L_4
Friday	L_4	L_1	L_2	L_3	Friday	L_4	L_3	L_2	L_1

Source of Variation	Degrees of Freedom
Stream	(4-1) = 3
Day of the Week	(4-1) = 3
Squares	(2-1) = 1
Stream Location	(4-1) = 3
Error	(t-1)[r(t+1)-3] = (3)[2(5)-3]=21
Total	(32-1) = 31

Problem III. (15 points) The research division of a company has developed a new type of insulation for electrical devices. An accelerated life testing process is conducted to access the length of time it takes for the insulation to breakdown after being subjected to elevated voltages. The researcher was interested in evaluating the insulation at seven voltages but was able to implement only four of the seven voltages on a given day. The minutes to insulation breakdown were recorded in the following table.

	Voltage (kv)						
Day	24	28	32	36	40	44	48
1			38.19		5.44	1.96	0.55
2	220.22			7.66		2.54	0.67
3	270.85	200.67			6.24		0.76
4	360.14	170.52	45.43			3.22	
5		220.12	56.74	9.32			0.61
6	300.66		55.34	10.41	7.19		
7		190.78		8.74	6.92	2.21	

1.) Is the design for this problem a BIBD? Justify your answer.

NOTES:

- See Handout 11, pg 47 to get the following: A BIBD has the following
  - t = number of treatments (factor level combinations)
  - b = number of blocks
  - r = number of blocks in which each treatment appears
  - k = number of EU's per block
  - λ = number of blocks in which each pair of treatments appear together
  - n = number of EU's in the experiment
- With Restrictions:
  - n = tr = bk
  - $\lambda = \frac{r(k-1)}{t-1}$
  - $b \geq t$
  - $\lambda < r < b$

In our problem:

- b = 7
- t = 7
- r = 4
- k = 4
- n = bk = tr = 28
- λ = 4(4-1)/(7-1) = 2

All the restrictions on a BIBD seem to be satisfied, thus the design for this problem is a BIBD.

2.) Test for a difference in the mean time to break across the seven voltages.

Type 3 Analysis of Variance								
Source	DF	Sum of Squares	Mean Square	Expected Mean Square	Error Term	Error DF	F Value	Pr > F
VOLT	6	103.969425	17.328237	Var(Residual) + Q(VOLT)	MS(Residual)	15	1107.52	<.0001
BLOCK	6	0.318313	0.053052	Var(Residual) + 3.5 Var(BLOCK)	MS(Residual)	15	3.39	0.0256
Residual	15	0.234690	0.015646	Var(Residual)	.	.	.	.

We can see in the above table that we have significant evidence of differences in the mean time to break across the seven voltages. Looking at the p-value associated with the F statistic for Volt, we see that (Pr>F) < 0.0001, thus the treatment is significant.

3.) Compare the "raw" treatment means to the Least Squares Means. Explain any differences.

Voltage	"Raw" Treatment Mean	Least Squares Treatment Mean
24	287.9675	275.393229
28	195.5225	188.4626794
32	48.925	47.65082768
36	9.0325	8.831280314
40	6.4475	6.495437452
44	2.4825	2.546449408
48	0.6475	0.6663101674

The reason for the differences is the Least Squares means are adjusted using the formula:

$$\hat{\mu}_i^{adj} = \bar{y}_{i..} + \omega[(t-k)(\bar{y}_{i..} - \bar{y}_{...}) - \frac{t-1}{r}(B_i - \bar{B}_.)]$$

where $\omega = \frac{(b-1)(MS_B^{adj} - MSE)}{(t-k)(b-t)MSE + t(k-1)(b-1)MS_B^{adj}}$; $\bar{B}_. = \frac{1}{t}\sum_{i=1}^{t} B_i$

4.) Is there a decreasing trend in the mean time to breakdown with increasing voltage? Justify your answer.

Contrasts				
Label	Num DF	Den DF	F Value	Pr > F
LINEAR	1	15	6819.97	<.0001

Estimates					
Label	Estimate	Standard Error	DF	t Value	Pr > |t|
LINEAR	-28.6736	0.3472	15	-82.58	<.0001

Yes, looking at the above outputs, there does seem to be a decreasing trend in the mean time to breakdown with increasing voltage.

Problem IV. (24 points) An experiment was designed to evaluate the effects of Nitrogen, Water, and Phosphorus rates on the water use efficiency in a commercial sweet corn farm using drip irrigation. Two large fields were randomly selected for the field experiment. Each field was divided into halves with one half randomly assigned to a phosphorus rate of 245 lb P2O5 per acre and the other half receiving 0 lb per acres. Each half of a field was then divided into nine equally sized regions with one region randomly assigned to each of the nine combinations of three levels of Nitrogen (0, 130, 260 lbs per acre) and three levels of Water (16, 22, and 28 inches). The water efficiency was computed for each of the 36 regions and are displayed in the following table.

		Field 1		Field 2	
Water	Nitrogen	P_1	P_2	P_1	P_2
16	0	8.1	9.7	8.6	15.5
	130	36.0	34.2	34.5	33.1
	260	34.6	34.0	40.7	39.3
22	0	10.0	6.2	5.1	10.9
	130	21.5	19.7	19.9	21.9
	260	30.7	28.9	26.4	25.7
28	0	10.6	6.3	4.5	10.4
	130	19.4	19.7	21.7	19.9
	260	23.2	23.0	19.4	23.2

Use the above data to answer the following questions:

1.) Compute the estimated standard errors for the estimated difference between the following treatments:

a.) The means of the two Phosphorus Rates

b.) The means of the 16 Water Level with 130 Nitrogen Rate and the 28 Water Level with the 260 Nitrogen Rate

Differences of Least Squares Means								
Effect	PHOSPHORUS	NITROGEN	WATER	PHOSPHORUS	NITROGEN	WATER	Estimate	Standard Error
P	P1			P2			-0.3722	1.7500
N*W		130	16		260	28	12.2500	1.7777

2.) Test for interactions and main effects. Interpret the results

Type 3 Analysis of Variance								
Source	DF	Sum of Squares	Mean Square	Expected Mean Square	Error Term	Error DF	F Value	Pr > F
P	1	1.246944	1.246944	Var(Residual) + 9 Var(P*F) + Q(P,P*W,P*N,P*N*W)	MS(P*F)	1	0.05	0.8666
W	2	751.842222	375.921111	Var(Residual) + Q(W,N*W,P*W,P*N*W)	MS(Residual)	16	59.48	<.0001
N	2	2768.648889	1384.324444	Var(Residual) + Q(N,N*W,P*N,P*N*W)	MS(Residual)	16	219.03	<.0001
N*W	4	242.079444	60.519861	Var(Residual) + Q(N*W,P*N*W)	MS(Residual)	16	9.58	0.0004
P*W	2	0.808889	0.404444	Var(Residual) + Q(P*W,P*N*W)	MS(Residual)	16	0.06	0.9383
P*N	2	12.708889	6.354444	Var(Residual) + Q(P*N,P*N*W)	MS(Residual)	16	1.01	0.3879
P*N*W	4	13.872778	3.468194	Var(Residual) + Q(P*N*W)	MS(Residual)	16	0.55	0.7026
F	1	0.666944	0.666944	Var(Residual) + 9 Var(P*F) + 18 Var(F)	MS(P*F)	1	0.02	0.9018
P*F	1	27.562500	27.562500	Var(Residual) + 9 Var(P*F)	MS(Residual)	16	4.36	0.0531
Residual	16	101.125556	6.320347	Var(Residual)	.	.	.	.

We can see in the above table that we find the following to be significant:

- The interaction between Nitrogen and Water (N*W) with p-value = 0.0004
- The main effect of Nitrogen (N) with p-value < 0.0001
- The main effect of Water (W) with p-value < 0.0001

Problem V. (15 points) An agronomist wants to evaluate the effects of soil compaction and soil moisture on the activity of soil microbes. This is important in that low levels of soil microbe activity will result in reduced nitrification in the soils. One factor which affects soil microbe activity is low soil aeration levels resulting from highly saturated or compacted soils. The agronomist designed the following experiment. Soil samples were randomly subjected to a combination of one of three levels of soil compaction (bulk density = mg soil/m3) and one of three soil moisture levels (kg water/kg soil). Two soil samples were randomly assigned to each of the nine treatments. The 18 treated soil samples were placed in airtight containers and incubated under conditions conducive to increased microbial activity. The microbe activity level in each soil sample was measured as the percent increase in CO2 produced above atmospheric levels. The CO2 evolution/kg soil was recorded on three successive days yielding the following data.

			Day		
Density	Moisture	Container	1	2	3
1.1	0.10	1	2.70	0.34	0.11
		2	2.90	1.57	1.25
	0.20	3	5.20	5.04	3.70
		4	3.60	3.92	2.69
	0.24	5	4.00	3.47	3.47
		6	4.10	3.47	2.46
1.4	0.10	7	2.60	1.12	0.90
		8	2.20	0.78	0.34
	0.20	9	4.30	3.36	3.02
		10	3.90	2.91	2.35
	0.24	11	1.90	3.02	2.58
		12	3.00	3.81	2.69
1.6	0.10	13	2.00	0.67	0.22
		14	3.00	0.78	0.22
	0.20	15	3.80	2.80	2.02
		16	2.60	3.14	2.46
	0.24	17	1.30	2.69	2.46
		18	0.50	0.34	0.00

Problem V (Continued)

1.) Conduct a repeated measures analysis with an AR(1) covariance structure across the Day variable.

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
DEN	2	9	6.29	0.0196
MO	2	9	16.31	0.0010
DEN*MO	4	9	1.37	0.3179
DAY	2	18	28.30	<.0001
DEN*DAY	4	18	0.59	0.6722
MO*DAY	4	18	13.80	<.0001
DEN*MO*DAY	8	18	2.22	0.0761

Looking at the above table we can see that Density, Monisture, Day and the Moisture*Day interaction are significant.

2.) Conduct a separate analysis with the response being first the linear contrast across day and then the quadratic contrast across day. What interactions and main effects are significant? Do your conclusions differ from the results obtained in part 1?

Looking at the tables to the right we see that we have significant evidence of a linear tread in the day variable at the alpha = 0.05 level. However, we don't have significant evidence of a quadratic trend in the day variable. To the contrary of the question, our conclusions here support the results obtained in part 1.

DAY_N represents the nth degree polynomial contrast for DAY

Contrast Variable: DAY_1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	11.85654444	11.85654444	42.74	0.0001
DEN	2	0.46888889	0.23444444	0.85	0.4610
MO	2	5.25468889	2.62734444	9.47	0.0061
DEN*MO	4	0.97727778	0.24431944	0.88	0.5125
Error	9	2.49690000	0.27743333		

Contrast Variable: DAY_2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	0.00005926	0.00005926	0.00	0.9769
DEN	2	0.01187407	0.00593704	0.09	0.9158
MO	2	2.67871852	1.33935926	20.04	0.0005
DEN*MO	4	1.16644815	0.29161204	4.36	0.0310
Error	9	0.60160000	0.06684444		

Problem VI … r three
types of stee … e required
to shear the … ved that the
strength of t … th = WS,
Diameter = …

Alloy	WS	D	Alloy	WS	D	Alloy	WS	D
A1	37.5	12.5	A2	57.5	16.5	A3	38.0	15.5
A1	40.5	14.0	A2	69.5	17.5	A3	44.5	16.0
A1	49.0	16.0	A2	87.0	19.0	A3	53.0	19.0
A1	51.0	15.0	A2	92.0	19.5	A3	55.0	18.0
A1	61.5	18.0	A2	107.0	24.0	A3	58.5	19.0
A1	63.0	19.5	A2	119.5	22.5	A3	60.0	20.5

1.) Test for the sig…

Source	DF	Type III SS	Mean Square	F Value	Pr > F
A	2	122.257995	61.128997	1.60	0.2417
D	1	2213.861330	2213.861330	58.02	<.0001
D*A	2	258.264925	129.132462	3.38	0.0683

We can see in th … ent (Alloy) and
the interaction b … action is not
significant, we s … vs for different
intercepts but th … nt (Alloy) and
the covariate (D…

Source	DF	Type III SS	Mean Square	F Value	Pr > F
A	2	2005.972170	1002.986085	19.61	<.0001
D	1	2838.919336	2838.919336	55.50	<.0001

2.) Compare the "raw" treatment means to the adjusted treatment means. Also, compute the standard errors of the adjusted treatment means and their differences.

Alloy	Raw Treatment Mean	Adjusted Treatment Mean
A1	50.4167	61.7331949
A2	88.75	78.0451760
A3	51.5	50.8882958

Problem VI. (10 points)
2.) (Continued)

Standard errors of the adju

A	Y LSMEAN	Standard Error
1	61.7331949	3.2914051
2	78.0451760	3.2543235
3	50.8882958	2.9210451

Standard Errors of the differences of the adjusted treatment means:

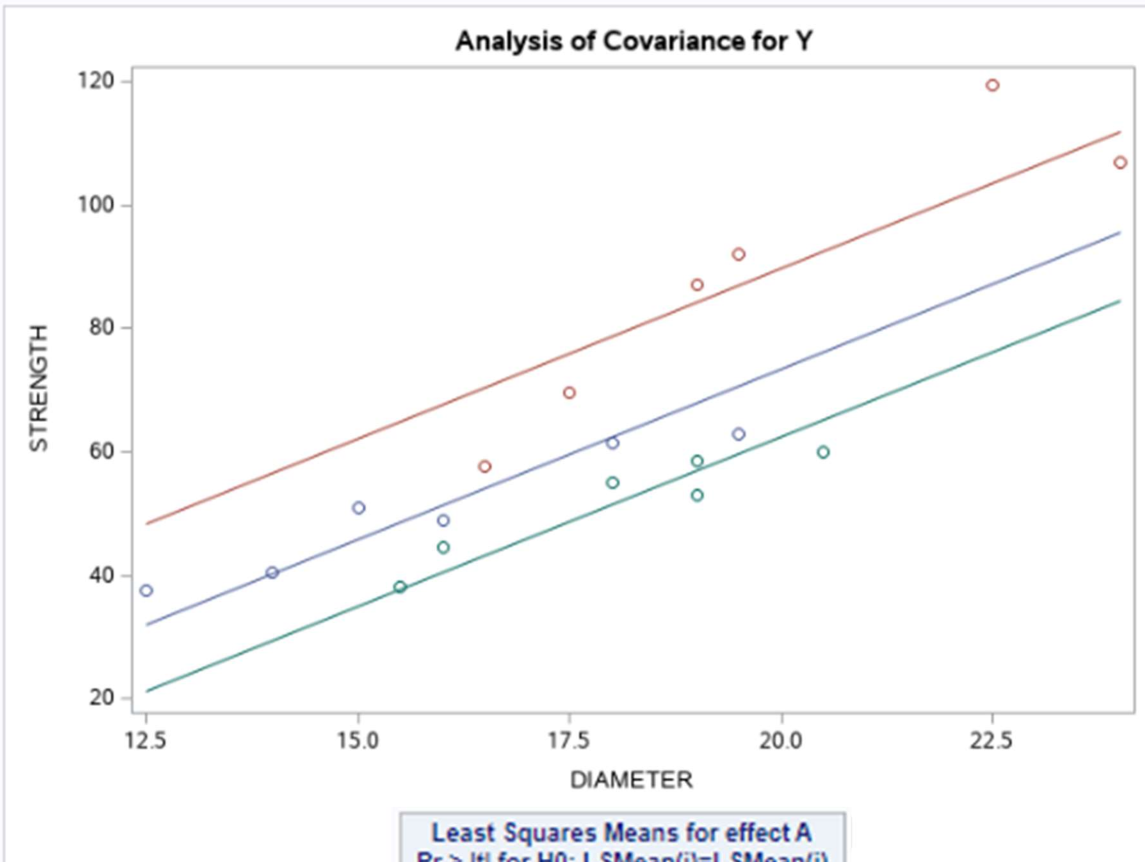
$$\widehat{SE}\left(\mu_i^{ADJ} - \mu_{i'}^{ADJ}\right) = \sqrt{MSE\left(\frac{1}{r_i} + \frac{1}{r_{i'}} + \frac{(\bar{X}_{i.} - \bar{X}_{i'.})^2}{\sum_{k=1}^{t}\sum_{j=1}^{r_k}(X_{kj} - \bar{X}_{k.})^2}\right)}$$

In our case:

- $MSE = 51.154571$
- $r_i = r = 6$
- $\bar{X}_{1.} = 15.8333;\ \bar{X}_{2.} = 19.8333;\ \bar{X}_{3.} = 18$

- $\widehat{SE}\left(\mu_1^{ADJ} - \mu_2^{ADJ}\right) = 5.078353$
- $\widehat{SE}\left(\mu_1^{ADJ} - \mu_3^{ADJ}\right) = 4.428919$
- $\widehat{SE}\left(\mu_2^{ADJ} - \mu_3^{ADJ}\right) = 4.345934$

3.) Provide a scatter plot of Weld Strength vs Diameter. Display the slope of the linear relationship between the Weld Strength and Diameter



4.) Group the three Alloys such th cantly different.

Least Squares Means for effect A
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Y

i/j	1	2	3
1		0.0162	0.0681
2	0.0162		<.0001
3	0.0681	<.0001	

Using $\alpha_{pc} = \frac{0.05}{3} = 0.0167$ we get the following groupings:

- $G_1 = \{A1, A3\}$
- $G_2 = \{A2\}$