**STATISTICS 642 - ASSIGNMENT 10**

**DUE DATE: 8 am Central, Monday, May 2, 2022**

Name (**Typed**) ______________________________

Email Address (**Typed**) ______________________________

- **Due 8 am Central, Monday, May 2, 2022**
- Read Handouts 11 & 12
- Supplemental Reading: Chapters 9, 10, 11, 12, 19 in Design & ANOVA book.
- Hand in the solutions to the following problems.

• SAS programs for Problems I, III, IV, V, VI are in the HomeworkAssignment folder in Canvas

**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 |

1. Display the AOV table
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.
3. Identify all significant main effects and interactions (use $\alpha = .05$).
4. Compute the relative efficiency of the blocking factor.
5. If the conditions of normality and/or equal variance appear to be violated, suggest an alternative analysis.

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

**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.
2. Test for a difference in the mean time to break across the seven voltages.
3. Compare the "raw" treatment means to the Least Squares Means. Explain any differences.
4. Is there a decreasing trend in the mean time to breakdown with increasing voltage? Justify your answer.

**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 $P_2O_5$ 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 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
2. Test for interactions and main effects. Interpret the results.

**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/$m^3$) 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 $CO_2$ produced above atmospheric levels. The $CO_2$ 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 |

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

**Problem VI. (10 points)** An experiment was conducted on the shear strength of spot welds for three types of steel alloy, A1, A2, A3. Six welds were made on each of the three alloys and the force required to shear the weld was measured. The diameter of the weld was measured because it was believed that the strength of the was affected by its diameter. The data are shown in the table with Weld Strength = WS, Diameter = D.

| 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 significance of the covariate and adjusted treatment effects.
2. Compare the "raw" treatment means to the adjusted treatment means. Also, compute the standard errors of the adjusted treatment means and their differences.
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 that Alloys within a group are not significantly different.