

STAT 5309 – SPRING 2020

Midterm Exam

***Direction:** (a) Answer **all question parts**, enumerated and separated by blank spaces or lines (b) Answers(remarks, numerical answers) must be put in boxes, or highlighted, and supported by tests/plots. Plot sizes are reduced.

Points will possibly be decimated if answers are not supported. Present work in a readable form of a scientific report.

***Due: Mon, MAR 16**

1. Problem 3.12[5 points]

- 3-12. Four different designs for a digital computer circuit are being studied to compare the amount of noise present. The following data have been obtained:

Circuit Design		Noise Observed			
1	19	20	19	30	8
2	80	61	73	56	80
3	47	26	25	35	50
4	95	46	83	78	97

- (a) Is the amount of noise present the same for all four designs? Use $\alpha = 0.05$.
- (b) Analyze the residuals from this experiment. Are the analysis of variance assumptions satisfied?
- (c) Which circuit design would you select for use? Low noise is best.

Set up a data frame, named “circuits”.

2. Problem 3.14(10 points)

- 3-14. Three brands of batteries are under study. It is suspected that the lives (in weeks) of the three brands are different. Five batteries of each brand are tested with the following results:

Weeks of Life		
Brand 1	Brand 2	Brand 3
100	76	108
96	80	100
92	75	96
96	84	98
92	82	100

- (a) Are the lives of these brands of batteries different?
- (b) Analyze the residuals from this experiment.
- (c) Construct a 95 percent confidence interval estimate on the mean life of battery brand 2. Construct a 99 percent confidence interval estimate on the mean difference between the lives of battery brands 2 and 3.

Set up the data frame, named “batteries” . More on (c)

- (c) Perform a boxplot and a stripchart.

Construct a 99% -CI for the mean life of brand 2. Using Fisher LSD.
Construct 99%-CI for mean difference between the lives of brand 2 and 3, using Fisher LSD.

- (d) Calculate the number of replicates for a power of .90

3. Problem 5.5[10 points]

Johnson and Leone (*Statistics and Experimental Design in Engineering and the Physical Sciences*, Wiley, 1977) describe an experiment to investigate warping of copper plates. The two factors studied were the temperature and the copper content of the plates. The response variable was a measure of the amount of warping. The data were as follows:

Temperature (°C)	Copper Content (%)			
	40	60	80	100
50	17, 20	16, 21	24, 22	28, 27
75	12, 9	18, 13	17, 12	27, 31
100	16, 12	18, 21	25, 23	30, 23
125	21, 17	23, 21	23, 22	29, 31

Set up a data frame, named “plates”

- Build a linear model using aov(). Is there any indication that either factor affects the amount of warping? Is there any interaction between the factors . Use $\alpha = 0.05$
- Do a Box plot on Temperature, on Content and on Temperature*Content
Which level combination give the lowest warpage.
- Suppose Temperature cannot be controlled in where the copper plate are used, which Content gives the smallest warpage?
- Perform a 3-part residuals assumption check of the aov model.
- Build a RSM (Response Surface model). Locate the maximum, minimum or saddle point.

4. Problem 5.8 [10 points]

- 5-8. An experiment is conducted to study the influence of operating temperature and three types of face-plate glass in the light output of an oscilloscope tube. The following data are collected:

Glass Type	Temperature		
	100	125	150
1	580	1090	1392
	568	1087	1380
	570	1085	1386
2	550	1070	1328
	530	1035	1312
	579	1000	1299
3	546	1045	867
	575	1053	904
	599	1066	889

- Use $\alpha = 0.05$ in the analysis. Is there a significant interaction effect? Does glass type or temperature affect the response? What conclusions can you draw?
- Fit an appropriate model relating light output to glass type and temperature.
- Analyze the residuals from this experiment. Comment on the adequacy of the models you have considered.

Create a data frame, named “tubes”. More on (b)

(b) Any interaction between Glass type and Temperature? Build a reduced model if interaction is not significant.

5. Problem[10 points]

Data: Salinity. Temperature, Salinity, and Density affect growth and survival of Shrimps. 3 factors: “Temperature” (25 degree, 35 degree), “Salinity” (10%,25%, 40%), “Density” (80 shrimp/40 liters, 160/40 liters).

Temp	Density	Salinity	Weight Gain
25	80	10%	86, 52, 73,
		25%	544, 371, 482
		40%	390, 290, 397
	160	10%	53, 73, 86
		25%	393, 398, 208,
		40%	249, 265, 243
35	80	10%	439, 436, 349
		25%	249, 245, 330
		40%	247, 277, 205
	160	10%	324, 305, 364
		25%	352, 267, 316
		40%	188, 223, 281

Enter the data. Set up a data frame, named “shrimp”.

- Check interaction of factors by plots.
- Build a full linear model with interactions (including 2-way and 3-way interactions). Which factors (main and interactions) are significant.
- Build a reduced model.
- Find the combination of Temp, Density, Salinity which produces the shrimp largest weight gain
- Perform residual check.

6. Problem 5.17

- 5-17. The quality control department of a fabric finishing plant is studying the effect of several factors on the dyeing of cotton–synthetic cloth used to manufacture men’s shirts. Three operators, three cycle times, and two temperatures were selected, and three small specimens of cloth were dyed under each set of conditions. The finished cloth was compared to a standard, and a numerical score was assigned. The results follow. Analyze the data and draw conclusions. Comment on the model’s adequacy.

Cycle Time	Temperature					
	300°			350°		
	Operator			Operator		
	1	2	3	1	2	3
40	23	27	31	24	38	34
	24	28	32	23	36	36
	25	26	29	28	35	39
50	36	34	33	37	34	34
	35	38	34	39	38	36
	36	39	35	35	36	31
60	28	35	26	26	36	28
	24	35	27	29	37	26
	27	34	25	25	34	24

Create a data frame, named “fabrics” with 3 factors.

- Build a linear model. Any interaction among factors?
- Can we use any factor as Blocking factor? Is the Blocking factor effective?
- Consider any reduced model?
- Do a complete 3-part residual assumption check.

7. Problem 5.16 [10 points]

- 5-16. The percentage of hardwood concentration in raw pulp, the vat pressure, and the cooking time of the pulp are being investigated for their effects on the strength of paper. Three levels of hardwood concentration, three levels of pressure, and two cooking times are selected. A factorial experiment with two replicates is conducted, and the following data are obtained:

Percentage of Hardwood Concentration	Cooking Time 3.0 Hours			Cooking Time 4.0 Hours		
	Pressure			Pressure		
	400	500	650	400	500	650
2	196.6	197.7	199.8	198.4	199.6	200.6
	196.0	196.0	199.4	198.6	200.4	200.9
4	198.5	196.0	198.4	197.5	198.7	199.6
	197.2	196.9	197.6	198.1	198.0	199.0
8	197.5	195.6	197.4	197.6	197.0	198.5
	196.6	196.2	198.1	198.4	197.8	199.8

- Analyze the data and draw conclusions. Use $\alpha = 0.05$.
- Prepare appropriate residual plots and comment on the model’s adequacy.
- Under what set of conditions would you operate this process? Why?

8. Problem [10 points]

	Oil	Truck	Fuel Consumption
1	1	1	0.5
2	1	2	0.634
3	1	3	0.487
4	1	4	0.329
5	1	5	0.512
6	2	1	0.535
	2	2	0.675
8	2	3	0.52
9	2	4	0.435
10	2	5	0.54
11	3	1	0.513
12	3	2	0.595
13	3	3	0.488
14	3	4	0.4
15	3	5	0.51

Enter data, create a data frame, named “fuel”.

- Build a linear model. Is there any significant difference of means about the oil types. Which oil type gives the lowest fuel consumption.
- Use Truck as a Blocking factor. Is the **Blocking factor effective**?
- Do a complete residual assumption check.

9. Problem 4.5(10 points)

4-5. An article in the *Fire Safety Journal* (“The Effect of Nozzle Design on the Stability and Performance of Turbulent Water Jets,” Vol. 4, August 1981) describes an experiment in which a shape factor was determined for several different nozzle designs at six levels of

jet efflux velocity. Interest focused on potential differences between nozzle designs, with velocity considered as a nuisance variable. The data are shown below:

Nozzle Design	Jet Efflux Velocity (m/s)					
	11.73	14.37	16.59	20.43	23.46	28.74
1	0.78	0.80	0.81	0.75	0.77	0.78
2	0.85	0.85	0.92	0.86	0.81	0.83
3	0.93	0.92	0.95	0.89	0.89	0.83
4	1.14	0.97	0.98	0.88	0.86	0.83
5	0.97	0.86	0.78	0.76	0.76	0.75

Create a data frame named “nozzles”

- Build a linear model, nozzle as a blocking factor. Does the nozzle design affect the shape factor? Use $\alpha = .05$.
- Which nozzle designs are different with respect to the shape factor? [Hint: use Tukey HSD]
- Is the velocity effect significant?
- If nozzle is used as a Blocking factor, check if nozzle is effective?.

10. Problem 5.19 [10 points]

5-19. The yield of a chemical process is being studied. The two factors of interest are temperature and pressure. Three levels of each factor are selected; however, only nine runs can

be made in one day. The experimenter runs a complete replicate of the design on each day. The data are shown in the following table. Analyze the data, assuming that the days are blocks.

Temperature	Day 1 Pressure			Day 2 Pressure		
	250	260	270	250	260	270
Low	86.3	84.0	85.8	86.1	85.2	87.3
Medium	88.5	87.3	89.0	89.4	89.9	90.3
High	89.1	90.2	91.3	91.7	93.2	93.7

11. Problem (5-by-5 Latin Square) [5 points]

The effect of five different ingredients (A, B, C, D, E) on the reaction time of a chemical process is being studied. Each batch of new material is only large enough to permit five runs to be made. Furthermore, each run requires approximately $1\frac{1}{2}$ hours, so only five runs can be made in one day. The experimenter decides to run the experiment as a Latin square so that day and batch effects may be systematically controlled. She obtains the data that follow. Analyze the data from this experiment (use $\alpha = 0.05$) and draw conclusions.

Batch	Day				
	1	2	3	4	5
1	$A = 8$	$B = 7$	$D = 1$	$C = 7$	$E = 3$
2	$C = 11$	$E = 2$	$A = 7$	$D = 3$	$B = 8$
3	$B = 4$	$A = 9$	$C = 10$	$E = 1$	$D = 5$
4	$D = 6$	$C = 8$	$E = 6$	$B = 6$	$A = 10$
5	$E = 4$	$D = 2$	$B = 3$	$A = 8$	$C = 8$

Set up a data frame. “chemical”. Use Day and Batch as row and column Blocking factors
In a 5-by-5 Latin square design. Ingredient as Treatment factor.

- Build a linear model, using `aov()`. Do the ingredients affect the reaction time?
- Are Day, Batch effective Blocking factors?
Check interaction between Day and Batch.
- Find the lowest reaction time.