

Do not open the exam until you are instructed to do so.

Directions: You have 110 minutes (11:30-1:20) to complete the exam. You may use your calculator and two pages (both sides) of notes, but no laptops or wireless-capable devices are allowed. Be concise with all your responses (no more than 1-2 sentences are needed for each question). You may use 3 decimal places in any calculations. The point-worth of each question is given, and the total points sum to 100.

Student Name: _____

Separate Handout: Four studies (clearly numbered 1-4) are described in a separate handout for this exam. Variable names in resulting data sets are **bolded** in the handout. Total sample sizes reported in the handout refer to numbers of rows in the resulting data sets. For some of these studies, partial output using SAS procedures is provided in the handout. Each question on the exam clearly refers to a specific study by number.

Statistical Significance: For all significance tests on this exam, use significance level $\alpha = 0.05$. You may assume that relevant model assumptions are satisfied whenever a significance test is used on this exam.

Question 1: Refer to the description of Study 1 (dental fillings) in the handout.

- (a) (2 points) This is a(n) _____ by _____ by _____ factorial design with _____ replicate(s) per factor level combination. (Fill in the blanks. The order of factors doesn't matter here.)
- (b) (11 points) Draw a Hasse diagram for this design. Be sure to include all necessary lines, indications of random effects, and subscripts to denote corresponding degrees of freedom.
- (c) (3 points) What is the test statistic for the effect of preparation method (P), in terms of the mean squares (MS symbolically)? Also report the sampling distribution.
- (d) (3 points) Which (if any) of the tests in the analysis of this study will require approximate F-tests? How can you tell?
- (e) (2 points) In the statistical model for Study 1, what [omitted] interaction term does the error term correspond to?

Question 2: Refer to Study 1 (dental fillings) in the handout.

(a) (8 points) How does the specific non-parallel pattern in the interaction plot (in the handout) communicate the correct interpretation of the A*P interaction term?

(b) (8 points) The following line of SAS code (in PROC GLIMMIX) creates a table seen in the handout.

```
lsmeans A / pdiff adjust=tukey;
```

Using the appropriate portion of this output, add a column of letter groupings to the table below so that “LS-means with the same letter are not significantly different” while controlling a meaningful family-wise error rate at 0.05.

LSMEAN	A
23.7144	6
22.6803	7
19.7071	3
19.6631	1
19.5437	8
19.4575	2
19.0056	4
18.3866	5

(c) (5 points) The researchers also recorded the number of uniform-power hammer-strikes it took to crack each filling. This response variable **Strikes** had a Poisson distribution, and the resulting residuals could not be made normal. Circle the topic below from this class that would be most applicable here.

- i. Power / Sample Size Calculation
- ii. R-square and Design Matrix in Mixed Model
- iii. Generalized Linear Mixed Models
- iv. Analysis of Covariance
- v. Fractional Factorial Design
- vi. Balanced Incomplete Block Design

Question 3: (16 points) Refer to Study 2 (germination rate) in the handout, where an appropriate model was fit using the given SAS code. Partial SAS output is in the handout.

(a) (6 points) Report and interpret this model's R-square value.

(b) (5 points) Does the high value in part (a) demonstrate that the results of this statistical model can be trusted? If so, why? If not, what else would you want to look at?

(c) (16 points) Based on the resulting plot in the handout, someone comments on how it appears that, averaging across Temp levels 3 and 4, the mean FAN level at Days level 2 may be different than at Days level 3. Using effects model notation $D = \text{Days}$ and $T = \text{Temp}$, construct a contrast ψ (as a linear combination of parameters μ , D_i , T_j , and DT_{ij} ; do not include any parameters with zero coefficients) such that " $H_0: \psi=0$ " addresses this question.

Question 4: (12 points) Refer to Study 3 (pianos) in the handout. Circle which of the following “named designs” below best describes this study, and briefly explain which features of the study lead you to this decision. Sketch out a table or diagram below [with sample randomization(s); not a Hasse diagram] to help explain your decision.

- i. Randomized Complete Block Design
- ii. Latin Square Design
- iii. Split Plot Design
- iv. Split Split Plot Design
- v. Strip Plot Design
- vi. Repeated Measures Design

Question 5: (6 points) Refer to Study 3 (pianos) in the handout. Someone proposes to analyze data from this study using individual panelists’ ratings, in the same statistical model as in Question 4 (but with total sample size of 80 rather than 16). Explain clearly why this is inappropriate, referring to principles discussed in this course.

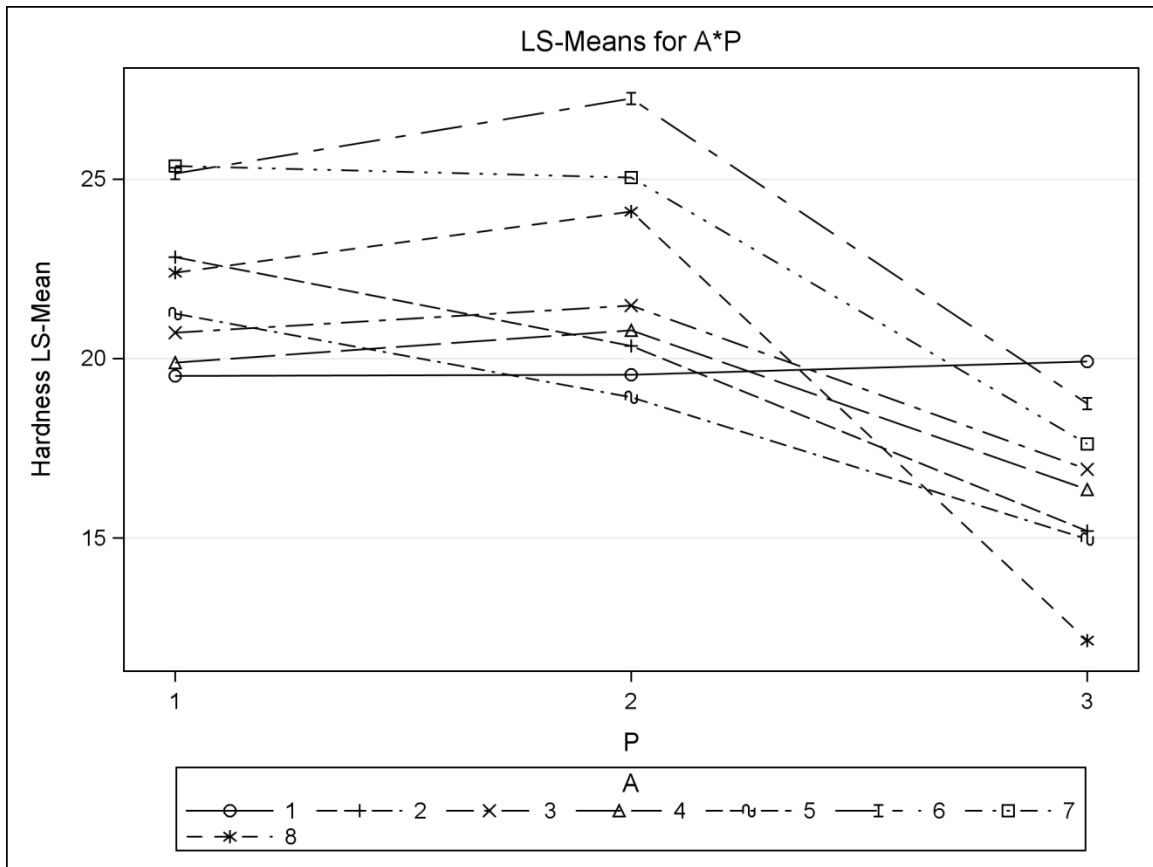
Question 6: (12 points) Refer to Study 4 (exercise) in the handout. Circle which of the following “named designs” below best describes this study, and briefly explain which features of the study lead you to this decision. Sketch out a table or diagram below [with sample randomization(s); not a Hasse diagram] to help explain your decision.

- i. Randomized Complete Block Design
- ii. Latin Square Design
- iii. Split Plot Design
- iv. Split Split Plot Design
- v. Strip Plot Design
- vi. Repeated Measures Design

Question 7: (1 point) What topic(s) did you study most that did not appear on this exam?

Handout for STAT 5200 Spring 2015 Final Exam

Study 1: A study is carried out to evaluate the effects of two factors on the “hardness” of dental fillings. One factor is the alloy (**A**) used to make the filling. There are eight alloys of interest (coded 1,...,8). The other factor is preparation method (**P**). There are three preparation methods of interest (coded 1, 2, 3). The study is carried out as follows. Five dentists (**D**, coded 1,...,5) participate (they are a representative sample of all possible dentists). Each dentist makes one filling with each combination of alloy and preparation method in a completely random order (and a different random order for each dentist), and a single measurement of the **Hardness** of each filling is made (using a surface-scratching device), for a total sample size of 120.



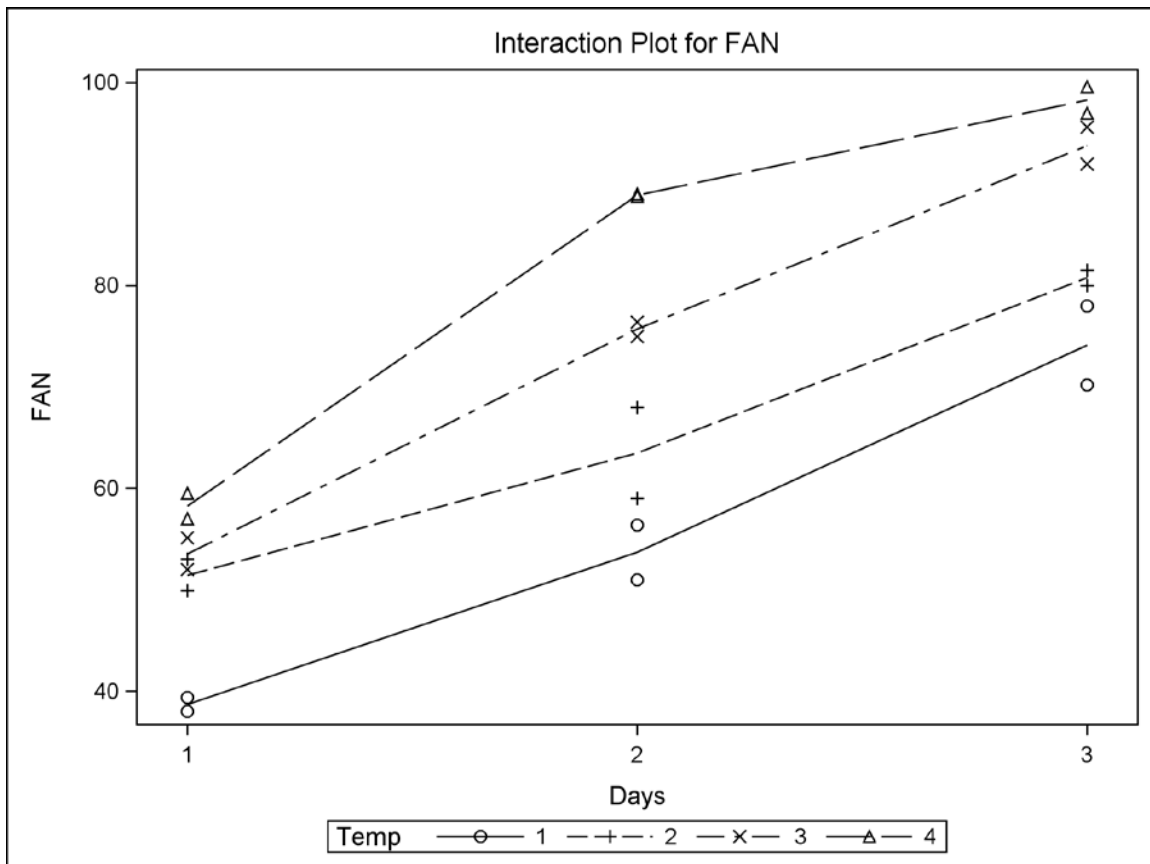
Differences of A Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

A	_A	Estimate	Standard Error	DF	t Value	Pr > t	Adj P
1	2	0.2056	1.3542	28	0.15	0.8804	1.0000
1	3	-0.04400	1.3542	28	-0.03	0.9743	1.0000
1	4	0.6575	1.3542	28	0.49	0.6311	0.9996
1	5	1.2765	1.3542	28	0.94	0.3540	0.9788
1	6	-4.0513	1.3542	28	-2.99	0.0057	0.0917
1	7	-3.0172	1.3542	28	-2.23	0.0341	0.3663
1	8	0.1194	1.3542	28	0.09	0.9304	1.0000
2	3	-0.2496	1.3542	28	-0.18	0.8551	1.0000
2	4	0.4519	1.3542	28	0.33	0.7411	1.0000
2	5	1.0709	1.3542	28	0.79	0.4357	0.9923
2	6	-4.2569	1.3542	28	-3.14	0.0039	0.0662
2	7	-3.2228	1.3542	28	-2.38	0.0244	0.2893
2	8	-0.08621	1.3542	28	-0.06	0.9497	1.0000
3	4	0.7015	1.3542	28	0.52	0.6085	0.9995
3	5	1.3205	1.3542	28	0.98	0.3379	0.9744
3	6	-4.0073	1.3542	28	-2.96	0.0062	0.0981
3	7	-2.9732	1.3542	28	-2.20	0.0366	0.3841
3	8	0.1634	1.3542	28	0.12	0.9048	1.0000
4	5	0.6190	1.3542	28	0.46	0.6512	0.9998
4	6	-4.7089	1.3542	28	-3.48	0.0017	0.0311
4	7	-3.6748	1.3542	28	-2.71	0.0113	0.1601
4	8	-0.5381	1.3542	28	-0.40	0.6941	0.9999
5	6	-5.3278	1.3542	28	-3.93	0.0005	0.0103
5	7	-4.2937	1.3542	28	-3.17	0.0037	0.0624
5	8	-1.1571	1.3542	28	-0.85	0.4001	0.9878
6	7	1.0341	1.3542	28	0.76	0.4515	0.9937
6	8	4.1707	1.3542	28	3.08	0.0046	0.0760
7	8	3.1366	1.3542	28	2.32	0.0281	0.3203

Study 2: Researchers seek to determine the effect of germination time (**Days**, coded 1,2,3) and temperature (**Temp**, coded 1,2,3,4) on the free alpha amino nitrogen content (**FAN**) of rice malt. There were two replicates at each treatment level combination, for a total sample size of 24.

```
proc glm data=GermRate;
  class Days Temp;
  model FAN = Days|Temp;
run;
```

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	7845.185000	713.198636	76.96	<.0001
Error	12	111.200000	9.266667		
Corrected Total	23	7956.385000			



Study 3: A study is carried out to evaluate the effect of the manufacturer and size of a piano on perceived sound quality. There are four manufacturers of interest (**M**, coded 1,...,4). Eight separate panels (**P**, coded 1,...,8) of music students are created (with five students on each panel). The levels of manufacturer are randomly assigned to panels (so that there are two panels for each manufacturer). There are two sizes of pianos (**S**, coded 'b' for baby grand and 'c' for concert grand) from each manufacturer (so there are eight pianos total). Each panel is seated and blindfolded for a two-part listening session in a small sound studio, where two pianos (one baby grand and one concert grand from the panel's randomly-assigned manufacturer) are on stage. A well-known piece is played on one of the pianos (chosen at random from the two on stage). Then the panelists are individually asked to rate the sound on a scale of 1-100. The same piece is played on the other piano, and again the panelists rate the sound. Thus for each panel's listening session, the two piano sizes are randomly assigned to the first and second parts. Throughout this study, the same well-known piece of music is used. The average rating (**AveSound**) of each panel in each listening session part is used as the response variable, for a total sample size of 16.

Study 4: A study is carried out to compare three exercise programs (**Program**, coded 1,2,3) – each one involving a different emphasis. Of interest is how these programs may differently affect blood pressure over time. Ten subjects (**Subject**, coded 1,...,10) were randomly assigned to each of the 3 programs (for a total of 30 subjects), and each subject exercised (using their assigned program only) each Tuesday and Thursday for seven weeks. Blood pressure measurements (**BP**) were made on each subject on the Friday at the end of each week (**Week**, coded 1,...,7), for a total sample size of 210.