STAT 5200 Spring 2015 Final Exam

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: Solutions

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.

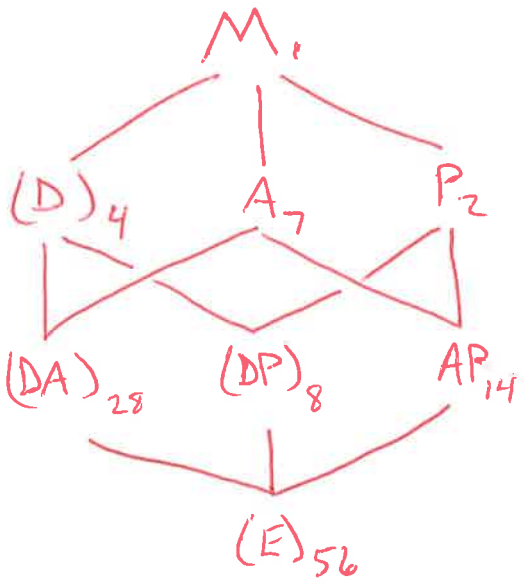
Statistical Significance: For all significance tests on this exam, use significance level $\alpha = 0.05$. You may assume that relevant model assumptions are satisfied whenever a significance test is used on this exam.

(any order okay)

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

(a) (2 points) This is a(n) 8 by 3 by 5 factorial design with 1 replicate(s) per factor level combination. (Fill in the blanks. The order of factors doesn't matter here.) (+0.5 for each blank)

(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.



- -1 for each missing or extraneous piece, including term, df, line, parentheses, or subscript.
- -3 if D(A) or D(P)
- -5 if D(AP)
- order of terms in each row doesn't matter

(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.

$$F_P = \frac{MS_P}{MS_{DP}} \sim F_{2,8}$$

[Full points based on part (b)]

(d) (3 points) Which (if any) of the tests in the analysis of this study will require approximate F-tests? How can you tell? [Full points based on part (b)]

+1 { D

+2 { ↳ has no unique next random term below [in Hasse diagram]

(e) (2 points) In the statistical model for Study 1, what [omitted] interaction term does the error term correspond to?

DAP [any order in 3-way interaction; full points based on part (b)]

-5 if focus on significance of interaction, or on how the interaction is "driven" by the A_1/P_3 combination

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?

[There are several ways to answer this, but should include the following main point:]

+8 { The effect of P is different for A level 1 than for other A levels
(may specify how A level is different at P level 3)

(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	A
22.6803	7	A B
19.7071	3	A B
19.6631	1	A B
19.5437	8	A B
19.4575	2	A B
19.0056	4	B
18.3866	5	B

- -0.5 for each extraneous or missing letter
- Exact letters don't matter

(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
+5 ✓ 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.

+2 { $R^2 = \frac{7845.185}{7956.385} \approx .986$

+4 { About 98.6% of variation in FAN can be explained by this model.

(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?

+2 { No

+3 { Need to check model assumptions

[-4 for unrelated response]

(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 = Days and T = 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.

+8 (interpret) {

$H_0: \frac{\mu_{23}+\mu_{24}}{2} = \frac{\mu_{33}+\mu_{34}}{2}$

$H_0: \mu_{23}+\mu_{24}-\mu_{33}-\mu_{34} = 0$

[• -5 if "−" instead of "+" in numerators
• -10 if $H_0: \mu_{21} = \mu_{31}$ or $H_0: DT_{21} = DT_{31}$]

+5 (effects parameterization) {

$H_0: (\mu + D_2 + T_3 + DT_{23}) + (\mu + D_2 + T_4 + DT_{24})$
$-(\mu + D_3 + T_3 + DT_{33}) - (\mu + D_3 + T_4 + DT_{34}) = 0$

+3 (simplify and identify ψ) {

$H_0: \underbrace{2D_2 - 2D_3 + DT_{23} + DT_{24} - DT_{33} - DT_{34}}_{\psi} = 0$

[okay if have $k \cdot \psi$ for some $k \neq 0$]

[+5 for any linear combination of parameters where coeffs. sum to zero]

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

+4 (circle)

+4 (explain) Two treatment factors (M & S), one blocking factor (P), and one nested randomization (S) ← (key)

+4 (table) [Several ways this design could be sketched, like these two (okay if not "randomized"):

P	1	2	3	4	5	6	7	8
M	1	4	1	3	2	3	4	2
S	b	c	b	b	c	b	c	c
	c	b	c	c	b	c	b	b

M:	1		2		3		4	
P:	1	2	3	4	5	6	7	8
S order:	bc	cb	bc	bc	cb	bc	cb	cb

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.

either → Panels are experimental units, while individuals are measurement units

-or-

→ This proposed strategy would lead to over-stated significance

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

+4 (circle) vi.

+4 (explain)

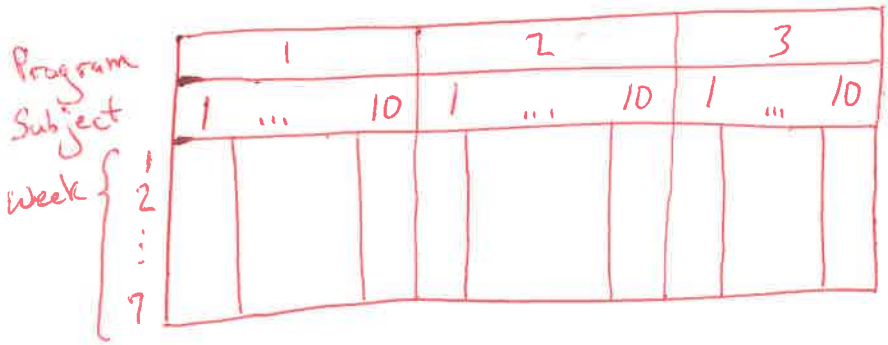
Repeated measurements at same time points on subjects nested within treatments [Program]

-or-

Two treatment factors (Program & Week), one blocking factor (Subject), with "time" factor (Week) not randomized, and multiple observations on each experimental unit (Subject) at the same time points

+4 (table)

Several ways this design could be sketched, like this one (okay if not "randomized")



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

(Anything)