

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

Directions: You have 120 minutes to complete the exam. You may use your calculator and two pages (both sides) of notes, but no laptops, cell phones, or other 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: Seven studies (clearly numbered 1-7) are described in a separate handout for this exam. 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 $\alpha = 0.05$. Where multiple hypotheses have been or are to be tested, control the strong family-wise error rate at $\alpha = 0.05$.

Question 1: Refer to Study 1 (knee braces) in the handout.

(a) (4 points) Is this study an experiment? Answer yes or no, and explain briefly.

No - subjects not assigned to trt. groups
 +2 +2 (or not controlled)

(b) (4 points) Is this study design balanced? Answer yes or no, and explain briefly.

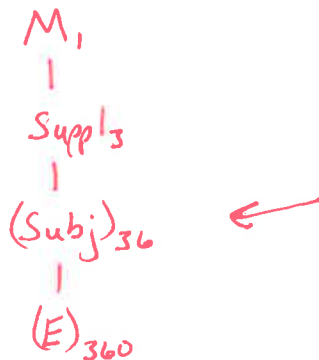
Yes - same # subjects in each group
 +2 +2

Question 2: (10 points) Refer to Study 2 (diet supplements) in the handout. Among the team of researchers, there is some disagreement about how to best analyze the data. Anvar argues the response variable should be the mean nail strength for each subject, saying that “We need to get at the central effect for each subject, and we should treat experimental units appropriately.” Ray argues the response variable should be the strength of each nail clipping, saying “Good data should never be discarded, and the mean basically boils ten measurements down to just one. If we use the mean for each subject, we’re reducing our sample size dramatically.” Based on principles discussed in this course, give a single, valid statistical model to simultaneously satisfy the concerns of both Anvar and Ray. (You may write out an effects parameterization model or sketch a Hasse diagram; clearly define your notation.)

Key: subject nested in supplement

$$Y_{ijk} = \mu + \text{Suppl}_i + \text{Sub}_{j(i)} + \epsilon_{ijk}$$

- or -



- Max. +5/10 for (i), if treat individual cloth sample as exp. unit for both W & D
- Max. +7/10 for (iii), if treat individual cloth sample as exp. unit for D, and

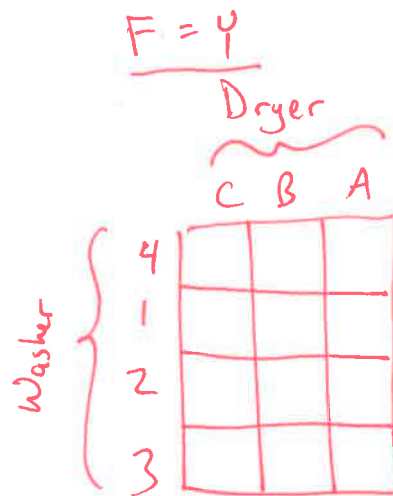
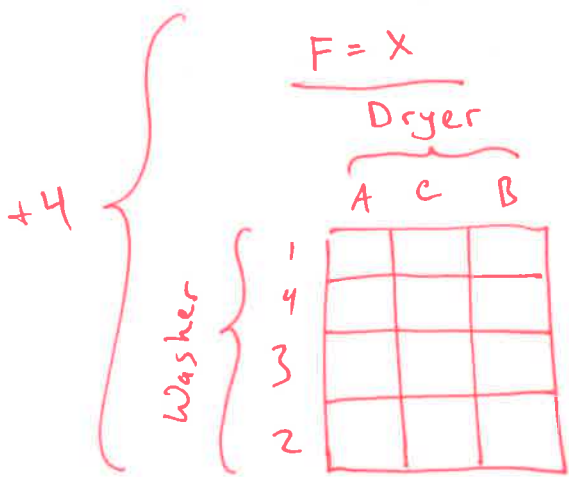
Question 3: (10 points) Refer to Study 3 (appliances) in the handout. Circle which of the following "named designs" best describes this experiment, and briefly explain what features of the experiment lead you to this decision. Sketch out a table or diagram below [with sample randomization(s)] to help explain your decision.

mis-read as D having a nested randomization within W level

- i. Randomized Complete Block Design
- ii. Latin Square Design
- iii. Split-Plot Design
- iv. Split-Split-Plot Design
- +4 v. Strip-Plot Design
- vi. Repeated Measures Design

Key: exp. unit for D is a group of 4 cloth samples, and for W is a batch of 3 cloth samples

+2 { F is blocking factor
 W is trt. factor, randomized to batch of 3 cloth samples
 D is trt. factor, randomized to batch of 4 cloth samples
 No nested randomization



Question 4: Refer to Study 4 (blood) in the handout. In your responses to the following prompts, use 'C' for factor Chemical, 'T' for factor Treatment, and 'S' for factor Subject.

(a) (3 points) Which factors, if any, are crossed?

C & T (may also say S & C)

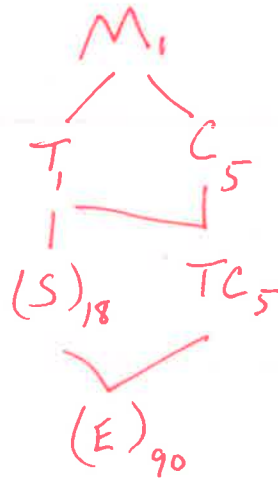
(b) (3 points) Which factors, if any, are nested?

S [nested in T]

(c) (6 points) Which factors, if any, are random? Explain clearly why.

+3 { S
 +3 { these subjects are representative of all possible subjects

(d) (8 points) Construct the appropriate 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, or parentheses
 Full points based on (a)-(c)

(e) (3 points) In terms of the mean squares (symbolically), what is the test statistic for testing the overall Treatment effect? Also specify its sampling distribution.

$$\frac{MST}{MSE} \sim F_{1,18}$$

[Full points based on (d)]

(f) (3 points) What [omitted] interaction term does the error term correspond to in the appropriate model for this design?

C x S or e x S(T)

• Max +6/10 for (vi), if focus on "time" aspect at the expense of (i.e., while ignoring) this key

Question 5: (10 points) Refer to Study 5 (milk yield) in the handout. Circle which of the following "named designs" best describes this experiment, and briefly explain what features of the experiment lead you to this decision. Sketch out a table or diagram below [with sample randomization(s)] to help explain your decision.

- i. Randomized Complete Block Design
- +4 ii. Latin Square Design
- iii. Split-Plot Design
- iv. Split-Split-Plot Design
- v. Strip-Plot Design
- vi. Repeated Measures Design

Key: there are only 3 cows, each diet is used only once per time period, and each cow eventually receives all three diets (no nesting)

+2 { Cow & Period are blocking factors
Diet is t.t. factor, randomized such that every Diet "sees" every cow and every Period once.
All factors have same # levels.

+4 {

		Period		
		7-12	1-6	13-18
Cow	III	F	R	P
	I	P	F	R
	II	R	P	F

Question 6: Refer to Study 6 (barley) in the handout. The SAS code given there generates the partial output; you may assume model assumptions are met.

- (a) (5 points) What can you conclude, in context, from the P-value for Week*Water? (Not just "significant" or not, but what can be concluded?)

There is insufficient evidence to say that [any of the following:]

- the effect of Week (on sqrt-seed) depends on Water
- the effect of Water (on sqrt-seed) depends on Week
- there is an interaction involving Week & Water

- (b) (4 points) Looking at the posthoc comparisons table (Least Squares Means P-values), an observer concludes that Week level 5 gives significantly different results than any of the other Week levels. Do you agree? Why or why not?

+2 ~~⊗~~ } No.

+2 ~~⊗~~ } These p-values have not been adjusted for multiple comparisons. (Tukey, for example) or Bonferroni

- (c) (4 points) What percentage of the variation in sqrt_seeds can be explained by the combined effects of Week and Water levels?

$$R^2 = \frac{46.04}{46.04 + 18.43} = .71, \text{ or about } 71\%$$

Question 7: (14 points) Refer to Study 7 (FAN) in the handout. A two-way ANOVA model is fit (with interaction). Based on the interaction plot in the output, someone comments on how it appears that the average FAN across temp levels 1 and 2 at days level 1 is different than the average FAN across temp levels 1 and 2 at days level 2. 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.

+6 correct understanding
+7 correct substitution of effects model

$$H_0: \frac{\mu_{11} + \mu_{12}}{2} = \frac{\mu_{21} + \mu_{22}}{2}$$

← max +7/13 if use DT_{ij} here

$$\begin{aligned} \psi &= \mu_{11} + \mu_{12} - \mu_{21} - \mu_{22} \\ &= (\mu + D_1 + T_1 + DT_{11}) + (\mu + D_1 + T_2 + DT_{12}) \\ &\quad - (\mu + D_2 + T_1 + DT_{21}) - (\mu + D_2 + T_2 + DT_{22}) \\ &= 2D_1 - 2D_2 + DT_{11} + DT_{12} - DT_{21} - DT_{22} \end{aligned}$$

$$\psi = 2D_1 - 2D_2 + DT_{11} + DT_{12} - DT_{21} - DT_{22}$$

okay if multiplied by any nonzero constant

min +5/14 for any linear comb. of parameters where coeffs. sum to zero

Question 8: (7 points. This question does not refer to any experiment in particular.) In your own words, how would you explain the difference between fixed and random effects in a designed experiment?

+4 { Fixed: levels only ones of interest
(or want to test differences in means)

+3 { Random: levels representative of all possible levels
(or want to test variation)

Question 9: (2 points) What topic(s) did you study most that did not appear on this exam?

(anything)

