

**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:** \_\_\_\_\_

**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.

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

**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.)

**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.

- 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:** (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
- ii. Latin Square Design
- iii. Split-Plot Design
- iv. Split-Split-Plot Design
- v. Strip-Plot Design
- vi. Repeated Measures Design

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

**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  $\psi$  (as a linear combination of parameters  $\mu$ ,  $D_i$ ,  $T_j$ , and  $DT_{ij}$ ; do not include any parameters with zero coefficients) such that “ $H_0: \psi=0$ ” addresses this question.

$\psi =$

**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?

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

## Handout for STAT 5200 Fall 2017 Final Exam

**Study 1:** Researchers want to compare the effect of two types of knee braces on knee pain of joggers. 100 subjects agree to participate, and after arriving at the testing facility, they are allowed to pick out a knee brace to use. There are fifty of each type of brace, each brace may be used by only one participant, and the two types of braces look and feel the same before being worn. Each brace has a unique identifier (coded 001 through 100) written on it (odd numbers for one type, even numbers for the other type), and they are lined up on a table (in numeric order) ready to be selected. After putting on their chosen brace, each participant reports their initial degree of knee pain using a sliding scale (to allow pain to be effectively a continuous variable) from 1 to 10. Then they run one mile on a treadmill and repeat their assessment of knee pain on the same scale.

**Study 2:** In a study of four diet supplements, researchers are interested in their effect on fingernail strength (among other things). In a Completely Randomized Design (CRD), ten subjects are assigned to each diet supplement (so there are forty subjects total), which they are to take by mouth daily for three months. At the end of the third month, researchers visit each subject and clip their nails [just to get the final clippings; the subjects were allowed to clip their own nails throughout the year]. Each nail clipping is subjected to a certain stress test that measures its strength. With ten clippings from each of forty subjects, this results in 400 strength measurements.

**Study 3:** A major manufacturer of household appliances wants to better understand how different types of washers and dryers contribute to reduce wrinkling of laundry. There are four types of washing machines (factor **W**, coded 1, 2, 3, 4) and three types of dryers (factor **D**, coded A, B, C) of interest. Two separate research facilities (factor **F**, coded X, Y) were available to study this question. In each research facility, four washing machines (one of each type of interest) and three dryers (one of each type of interest) are already present. A batch of three cloth samples is randomly assigned to each washing machine (there are twelve cloth samples in each research facility). The washing machines run their loads simultaneously. After the wash runs are complete, the cloth samples are randomly assigned to the three dryers in such a way that each dryer gets a batch of four cloth samples (one from each washing machine in the same research facility). The dryers then run their loads simultaneously. After the dryer runs are complete, the wrinkling on each cloth sample is measured and recorded.

**Study 4:** There are six different **Chemicals** (coded 1 through 6) known in existence to initiate a particular biological process in a blood sample. Researchers want to know if there is any difference in the activity level of this biological process based on whether or not a person receives a particular treatment 24 hours before giving the blood sample. 10 willing human **Subjects** (coded 1 through 10) are randomly assigned to each of two **Treatment** levels (coded 1,2), so there are twenty subjects total. Each Subject gives six equal-volume blood samples, which are then randomly assigned to the six Chemicals. After the assigned Chemical is applied to the blood sample for two minutes, the activity level of this biological process is recorded. “Activity” is a continuous response variable, and the total sample size in the resulting data set is 120.

**Study 5:** Dairy researchers want to compare effects of three diets (factor **Diet**, coded F = full grain, P = partial grain, and R = roughage) on cows’ milk yield. Three milk-producing cows (factor **Cow**, coded as I, II, and III) are available for a pilot study. When a cow is assigned a diet, it has to remain on the diet for a six-week time period, and its average daily milk yield for the final week is used as the response variable. Three separate time periods are identified to be used (factor **Period**, coded as Week 1-6, Week 7-12, and Week 13-18). A random mechanism is used to assign diets to cows for each time period, with the restriction that each diet is used only once in each time period, and each cow eventually receives all three diet assignments.

**Study 6:** Researchers studying brewer’s malt (which is produced from germinating barley) want to see the effect of weeks after harvest (**Week**, coded 1,2,3,4,5) and the amount of water used in germination (**Water**, coded 1,2) on the number of seeds germinating. They run a 5-by-2 factorial design with three replicates at each factor level combination. The square root of the number of seeds is used as the response variable to assure model assumptions are met.

```
proc glm data=barley;
  class week water;
  model sqrt_seeds = week|water;
  lsmeans week / pdiff;
run;
```

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	46.03630436	5.11514493	5.55	0.0007
Error	20	18.42800148	0.92140007		

(Study 6 output continues)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
week	4	21.89486064	5.47371516	5.94	0.0026
water	1	21.89297812	21.89297812	23.76	<.0001
week*water	4	2.24846560	0.56211640	0.61	0.6601

Least Squares Means for effect week Pr >  t  for H0: LSMean(i)=LSMean(j) Dependent Variable: sqrt_seeds					
i/j	1	2	3	4	5
1		0.7469	0.0666	0.0506	0.0003
2			0.1224	0.0949	0.0007
3				0.8903	0.0269
4					0.0360

Note: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

**Study 7:** 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 of 24 observations.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
days	2	5274.257500	2637.128750	284.58	<.0001
temp	3	2334.748333	778.249444	83.98	<.0001
days*temp	6	236.179167	39.363194	4.25	0.0159

(Study 7 output continues)

