

Please put your name on the back of your answer book.

Do NOT put it on the front. Thanks.

- The exam is closed book, closed notes. Use only the formula sheet and tables I provide today. You may use a calculator.
- Write your answers in your blue book. Ask if you need a second (or third) blue book.
- You have 2 hours (120 minutes) to complete the exam.  
**Stop working when the end of the exam is announced.**
- Points are indicated for each question. There are 120 total points.
- Important reminders:
  - budget your time. Some parts of each question should be easy; others may be hard. Make sure you do all parts you can.
  - notice that some parts do not require any computations.
  - show your work neatly so you can receive partial credit.
- Good luck!

1. 10 pts. This problem is based on a study of nurses salaries in for-profit and non-profit hospitals. The investigators are interested in the evenness of salaries; that is whether all nurses receive similar salaries or whether salaries are very different. The Gini coefficient was used as the measure of salary evenness. The details of the computation are irrelevant, but it may help to know that a Gini coefficient of 0 indicates all salaries are identical (maximum possible evenness) and a coefficient of 1 indicates the minimum possible evenness.

The investigators randomly sampled 20 for-profit hospitals and 20 non-profit hospitals in the United States and computed the Gini coefficient for each group. Here is what they found:

Group	$n_i$	Gini coefficient	s.e.
for-profit	20	0.672	0.120
non-profit	20	0.457	0.105
difference		0.215	0.159

The investigators computed a randomization distribution with 99 values. Here are the 10 smallest and 10 largest values in the randomization distribution:

-0.456 -0.356 -0.273 -0.257 -0.231 -0.210 -0.198 -0.157 -0.152 -0.143 ... 0.171 0.172 0.181 0.218  
0.239 0.248 0.263 0.357 0.440 0.601

They also computed a bootstrap distribution with 100 values. Here are the 10 smallest and 10 largest values in that distribution.

-0.173 -0.171 -0.168 -0.150 -0.143 -0.141 -0.135 -0.130 -0.127 -0.113 ... 0.554 0.555 0.568 0.599  
0.608 0.642 0.717 0.745 0.786 0.800

a) 5 pts. Calculate an appropriate design-based 90% confidence interval for the difference between the Gini coefficients between for-profit and non-profit hospitals in the United States. If you need additional information, indicate what is needed.

b) 5 pts. Is it reasonable to extrapolate from the 40 hospitals in the study to all for-profit and all non-profit hospitals in the United States? Briefly explain why or why not.

2. 32 pts (4pts each part). A randomized experiment was set up to compare 3 treatments (labelled A, B, and C). Each treatment was randomly applied to 8 e.u's, so the total sample size,  $N$ , is 24. The sample means, variances, and pooled error variance are:

$\bar{Y}_A.$	$\bar{Y}_B.$	$\bar{Y}_C.$	$s_A^2$	$s_B^2$	$s_C^2$	$s_p^2$
3.10	2.00	2.00	1.2	1.2	0.6	1.0

The investigators are especially interested in the difference between treatments A and B. They test  $H_0: \mu_A - \mu_B = 0$  using a linear contrast, the pooled error variance, and a T distribution. The p-value is 0.039.

Each item in the following list identifies one change in the experimental design or data. Each item on the list may affect the p-value for the test of  $H_0: \mu_A - \mu_B = 0$ . Tell me whether the **p-value** will INCREASE (become less significant), DECREASE (become more significant), NOT CHANGE, or you CAN'T TELL. You **DO NOT** need to calculate or report the new p-value(s). No explanation needed.

- (a) Decrease the number of replicates (e.g. from 8 to 4 e.u.s per treatment)
- (b) Increase the sample variance ( $s_p^2$ )
- (c) Decrease the sample average for treatment A from 3.10 to 2.90
- (d) Increase the number of treatments (e.g. from 3 to 5). The number of replicates per e.u. is not changed.

The following are changes to the test. Tell me whether the **p-value** for the new test will INCREASE (become less significant), DECREASE (become more significant), NOT CHANGE, or you CAN'T TELL, compared to the original test. Again, you **DO NOT** need to report the new p-value(s).

- (e) Test  $H_0: \mu_A - \mu_B = 1$ .
- (f) Test  $H_0: \mu_A - (\mu_B + \mu_C)/2 = 0$
- (g) Test  $H_0: \mu_A - \mu_B = 0$  using a Tukey multiple comparisons adjustment.
- (h) Test  $H_0: \mu_A - \mu_B = 0$  using an unequal variance (Welch) t-test.

3. 30 pts. The following problem is based on a study to compare the economic value of two types of information about Genetical Modified Organisms (GMO). Participants in the study read one page of information about GMO foods then participated in an experimental auction. Their bids during the auction provide information about the dollar value of the information. Participants are randomly assigned to read either a pro-GMO page of information produced by a major biotech company or an anti-GMO page of information produced by a major environmental organization. The response, measured on each participant, is the dollar value of the information they read. Fourty (40) participants started the study. Three refused to bid and are omitted from the data summary.

Group	$n_i$	average	s.d.
pro-GMO	19	0.80	0.284
anti-GMO	18	1.23	0.310

- (a) 3 pts. Is this a random sample, an observational study, an experimental study, or a randomized experiment?
- (b) 2 pts. Calculate the pooled estimate of the standard deviation.

For the next two parts, assume that errors have equal variances and are normally distributed.

- (c) 5 pts. Calculate a 95% confidence interval for the difference in means (as pro-GMO - anti-GMO).
- (d) 5 pts. The investigators will be repeating this study in another city. They expect that the error variance will be the same as in this study. They would like a more precise estimate of the difference between the means, specifically the width of the 95% confidence interval to be 0.25. You may assume equal sample sizes for each group. What total number of participants should be in the study?
- (e) 5 pts. Below are a residual plot and a normal quantile-quantile plot of the pooled residuals. Use these to evaluate the assumptions of equal variance and normality.

- (f) 5 pts. Determine the Box-Cox transformation that equalizes the variances. What practical transformation would you recommend?
- (g) 5 pts. Based on the information you just collected, what method would you use to test whether the two groups have the same mean dollow value? Explain your choice. You **DO NOT** need to perform your chosen test.

4. 48 pts. The following problem is based on ISU research to understand biological mechanisms for the beneficial effects of *Echinacea*, a herbal medicine. A graduate student is looking at anti-inflammatory activity, using an assay of PGE-2 activity. Lower values are a good thing; they correspond to less inflammation after an injury. There are many different species of *Echinacea* and each species grows in many different locations. Different species and different locations are suspected of having different anti-inflammatory activity. In this particular experiment, the student is comparing seven treatments, including two different species each from three locations, and a control treatment. The control is not expected to have any effect. 35 “cell cultures” were prepared; treatments were randomly assigned these cell cultures, with 5 cell cultures per treatment. There are 35 lines of data in the data file. SAS code and output follow.

Treatment #	species	location	average	s.d.
1	control		91.8	1.4
2	<i>E. angustifolia</i>	A	79.2	2.8
3	<i>E. angustifolia</i>	B	74.4	3.8
4	<i>E. angustifolia</i>	C	79.4	3.3
5	<i>E. purpurea</i>	D	29.8	9.1
6	<i>E. purpurea</i>	E	23.8	4.6
7	<i>E. purpurea</i>	F	28.4	4.7

- (a) 10 pts. Complete the ANOVA table

Source	d.f.	SS	MS
Treatments			
Error			17.77
Total		25271.9	

- (b) 5 pts. Test  $H_0$ : all treatments have the same mean. Report your test statistic and an approximate p-value. Provide an appropriate one sentence conclusion.
- (c) 8 pts. What is the observational unit in this study? What is the experimental unit?

The investigators chose the treatments because they are interested in three questions:

- a) What is the difference between the control and the average of the 6 *Echinacea* treatments?
- b) What is the difference between the two *Echinacea* species, averaged over locations?
- c) Are there differences between locations within species?
- (d) 6 pts. Estimate the difference between the two *Echinaceae* species averaged over locations. Estimate the s.e. of this difference. What d.f. is associated with this s.e.?
- (e) 4 pts. Both questions a) and b) above can be answered by linear contrasts. Are those contrasts orthogonal? Explain why or why not.
- (f) 5 pts. The investigator’s question c, “Are there differences between locations within species?” is a comparison between locations A, B, and C, and between locations D, E, and F. Use the available information to provide the most appropriate answer. Report your test statistic (or statistics) and p-value(s). If there is insufficient information, indicate what additional information you need.
- (g) 5 pts. Is the assumption of independence appropriate here? Explain why or why not.
- (h) 5 pts. A residual plot for these data is shown at the end of the SAS outout. Is it appropriate to log transform the data? Explain why or why not.

```

data pge;
  infile ...;
  input trt pge2;
proc glm;
  class trt;
  model pge2 = trt;
  lsmeans trt / stderr pdiff adjust=tukey;
  estimate '1 vs ave. of rest' trt 6 -1 -1 -1 -1 -1 -1 / divisor=6;
  contrast '1 vs ave. of rest' trt 6 -1 -1 -1 -1 -1 -1;
  contrast 'ave. of 2,3,4 - ave. of 5,6,7' trt 0 1 1 1 -1 -1 -1;
  contrast '2 - 3' trt 0 1 -1 0 0 0 0;
  contrast '2 - 4' trt 0 1 0 -1 0 0 0;
  contrast '3 - 4' trt 0 0 1 -1 0 0 0;
  contrast '5 - 6' trt 0 0 0 0 1 -1 0;
  contrast '5 - 7' trt 0 0 0 0 1 0 -1;
  contrast '6 - 7' trt 0 0 0 0 0 1 -1;
  title 'Echinaceae PGE2 assay';
run;

```

Echinaceae PGE2 assay  
Class Level Information

Class	Levels	Values
trt	7	1 2 3 4 5 6 7
Number of Observations Read		35
Number of Observations Used		35

Part of the output deleted

Least Squares Means  
Adjustment for Multiple Comparisons: Tukey

trt	pge2 LSMEAN	Standard Error	Pr >  t
1	91.8000000	1.8852813	<.0001
2	79.2000000	1.8852813	<.0001
3	74.4000000	1.8852813	<.0001
4	74.0000000	1.8852813	<.0001
5	29.8000000	1.8852813	<.0001
6	23.8000000	1.8852813	<.0001
7	28.4000000	1.8852813	<.0001

Least Squares Means for effect trt  
 Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: pge2

i/j	1	2	3	4	5	6	7
1		0.0010	<.0001	<.0001	<.0001	<.0001	<.0001
2	0.0010		0.5587	0.4662	<.0001	<.0001	<.0001
3	<.0001	0.5587		1.0000	<.0001	<.0001	<.0001
4	<.0001	0.4662	1.0000		<.0001	<.0001	<.0001
5	<.0001	<.0001	<.0001	<.0001		0.3023	0.9982
6	<.0001	<.0001	<.0001	<.0001	0.3023		0.6058
7	<.0001	<.0001	<.0001	<.0001	0.9982	0.6058	

Contrast	DF	Contrast SS	MS	F Value	Pr > F
1 vs ave. of rest	1	6925.88	6925.88	389.72	<.0001
ave. 2,3,4 - ave. 5,6,7	1	17666.13	17666.13	994.08	<.0001
2 - 3	1	57.60	57.60	3.24	0.0826
2 - 4	1	67.60	67.60	3.80	0.0612
3 - 4	1	0.40	0.40	0.02	0.8818
5 - 6	1	90.00	90.00	5.06	0.0325
5 - 7	1	4.90	4.90	0.28	0.6037
6 - 7	1	52.90	52.90	2.98	0.0955

Parameter	Estimate	Standard Error	t Value	Pr >  t
1 vs ave. of rest	40.20	2.04	19.74	<.0001