

Read Carefully. Give an answer in the form of a number or numeric expression where possible. Use a value of 0.05 for  $\alpha$  if not specified. t-tables are NOT provided, if you need a t-value use "2".

1) 2 points each – Circle T for a true statement below or F for a false statement.

- T  F a) Tests of mean difference using Tukey's adjustment are more powerful than Fisher's protected LSD.
- T  F b) Tests of mean difference using Scheffé's adjustment are more powerful than Tukey's.
- T F c) The F test of treatments in the usual Analysis of Variance is a one tailed test.
- T F d) Tests of mean difference using Fishers LSD are the most likely to make a TYPE I error.
- T F e) Tests of mean difference using Scheffé's adjustment are the most likely to make a TYPE II error.
- T F f) Tests of mean difference using Fisher's Protected LSD have an " $\alpha$ " probability of error on every single test.
- T  F g) Tests of mean difference using Dunnett's adjustment are suitable for data dredging.
- T  F h) Tests of mean difference between a control and the other treatment levels is best done with a Bonferroni adjustment.
- T  F i) The assumption of normality is no longer needed if PROC MIXED is used instead of PROC GLM.
- T  F j) Welch's test is one of the tests of homogeneity of variance provided by PROC GLM.
- T F k) All analysis of variance experiments will have at least one random variance component.
- T  F l) If subjects are randomly chosen from a population of males and randomly chosen from a population of females then "GENDER" is a random treatment effect.
- T  F m) Getting an analysis of variance with more replicates (i.e. larger n) is an important step to reducing the TYPE I ( $\alpha$ ) error rate.
- T F n) The Satterthwaite approximation can be used to estimate the degrees of freedom when variances are not equal in the two sample t-test and in analysis of variance.

2) 3 points – Which of the tests of homogeneity below are based on the comparison of a full model to a reduced model, where the reduced model is some subset or restriction of the full model?

- a) Levene's test
- b) O'Brien's test
- c) Brown and Forsythe's
- d) Bartlett's test

- 3) 3 points – Techniques for the analysis of differences among more than 3 means and other modern statistical techniques were developed by which of the following?
- Carlo Emilio Bonferroni
  - Ronald Aylmer Fisher
  - Barack Obama
  - James P Geaghan
- 4) 3 points – One test of homogeneity of variance can be done in SAS as either “Absolute values” or as “Squared values”. Which test below has these characteristics?
- Levene’s test
  - O’Brien’s test
  - Brown and Forsythe’s
  - Bartlett’s test
- 5) 3 points – Post hoc test like Tukey’s and Scheffé’s are used instead of the LSD for which of the following reasons?
- they reduce Type I ( $\alpha$ ) error rate inflation
  - they reduce Type II ( $\beta$ ) error rate inflation
  - they increase power
  - they are easier to interpret
- 6) 3 points – Both Tukey’s and Scheffé’s adjustments are said to have which of the following?
- comparisonwise error rate
  - familywise error rate
  - experimentwise error rate
  - samplewise error rate
- 7) 3 points each – An instructor teaching a high school class wants to know if the students are all understanding the material equally. In particular, he wants to know if the males and females are scoring equally in his exams and he wants to know if the upper classmen are scoring higher than the lower level classes. He has both boys and girls from the senior and junior classes, but only girls from the sophomore class. Write three contrasts below; (1) one contrast comparing the mean of all boys to all girls, (2) one contrast comparing the mean of all seniors to all juniors and (3) one contrast comparing the mean of the sophomore girls versus the mean of the junior and senior girls combined.

Treatments →	Senior Boys	Senior Girls	Junior Boys	Junior Girls	Sophomore Girls
<b>a) All Boys versus all Girls</b>	<u>-3</u>	<u>2</u>	<u>-3</u>	<u>2</u>	<u>2</u>
<b>b) All Seniors versus all Juniors</b>	<u>-1</u>	<u>-1</u>	<u>1</u>	<u>1</u>	<u>0</u>
<b>c) Sophomore girls versus all other girls</b>	<u>0</u>	<u>1</u>	<u>0</u>	<u>1</u>	<u>-2</u>

8) 3 points – Contrasts are said to be orthogonal if which of the following is true?

- a) all of the contrasts sum to zero
- b) the cross product between each pair of contrasts sums to zero**
- c) all values in the contrast are integers (not fractions)
- d) the sum of the sum of squares of the contrasts is equal to the sum of squares of the treatment

9) For each experiment described below name the most appropriate type of analysis and any additional questions where applicable.

a) 3 points each – A Veterinary Medicine student saw an advertisement for a dog food called “Kibbles and Bits” claiming that “Bits” make the difference in the desirability of dog food (to dogs). He decides to test this hypothesis. He has 30 dogs of similar size currently housed in the facility where he works. He prepares 3 diets; (1) Kibbles & Bits, (2) Kibbles **without** Bits and he uses (3) Purina Dog Chow as a control, He randomly assigns 10 dogs to each diet and measures the mean weight of food consumed in 30 minutes. What type of analysis should he use to see if mean consumption differs among the 3 diets?

- a) Type of analysis (circle one)      **a) CRD**      b) RBD
- b) What is the treatment variable (circle one) **a) Diets** b) Dogs c) Consumed d) 30 minutes
- c) How many degrees of freedom would the treatment mean square have?    d.f. = 2

The student decided to try some contrasts among the diet means. Fill in the appropriate contrast indicated below.

Contrast (3 points each)	A) Kibbles with Bits	B) Kibbles without Bits	C) Purina Dog Chow
d) “Kibbles with Bits versus Kibbles without Bits” Means compared: A versus B with C excluded	<u>-1</u>	<u>1</u>	<u>0</u>
e) “Anything with Kibbles versus Purina Dog Chow” Means compared: A and B versus C	<u>-1</u>	<u>-1</u>	<u>2</u>

10) 3 points – A librarian is studying the book usage by college professors. The variable of interest is the mean number of books check out by male and female faculty during the fall semester. He also wants to compare the usage by Assistant Professors, Associate Professors and Full Professors. What type of analysis would be used for this experiment?

Answer: CRD factorial (2 x 3)

Do not write in this space

11) The questions below refer to SAS output. The program is given above and the output is provided separately. Be sure to turn in your output with your exam!

Three separate analyses have been provided: (1) PROC MIXED with heterogeneous variance, (2) PROC MIXED with homogeneous variance and (3) GLM which can only be done with homogenous variance but HOV tests are provided.

Choose the best and most appropriate of the 3 models to answer the questions pertaining to the SAS output. Also note that the investigators have calculated all pairwise tests AND a number of contrasts.

Decide which post-ANOVA technique is appropriate for this situation and use it wherever possible.

Note that computations have been requested for 3 different adjustments (Tukey, Scheffé and Bonferroni) and, of course, PROC MIXED automatically provides LSD tests for pairwise differences.

a) 3 points – Do there appear to be significant differences among the levels of the treatment(s).

Circle one:  YES  NO P value (4 decimals) = 0.0237

b) 3 points – There are several contrasts included with the analysis (see computer program). One or more of these contrasts test pairwise differences in treatment level means? Circle all letters below that correspond to contrasts that do pairwise tests of treatment means.

Circle all that apply:      A              B              C               D              E

c) 3 points – In addition to the contrasts, there are several range tests provided. If the investigators are interested in all pairwise comparisons among means and **also** interested in the contrasts, which would be the best choice of the multiple range tests provided?

Circle one:              LSD              Tukey's               Scheffé's              Bonferroni's

d) 4 points – Give a confidence interval for the mean of treatment number A3.

P( 64.2989  $\leq \mu \leq$  69.3411 ) = 0.95

e) 3 points – Give a linear model for this analysis?

$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$

f) 4 points – If the investigators said that their **only** interest was in “all pairwise tests”, would they conclude that treatment level “A4” significantly different from level “A6”?

Circle one:  YES  NO P value required here (4 decimals) = 0.0446

g) 3 points – How many replicates are there for each treatment? 10

h) 4 points – Does the assumption of homogeneity of variance appear to have been met? Use the “best” available statistic to determine this.

Circle one:  YES  NO P value (4 decimals) = 0.5467 or 0.5767