Read Carefully. Give an answer in the form of a number or numeric expression where possible. Show all calculations for possible partial credit. Use a value of 0.05 for α if not specified. All multiple choice questions have a single answer unless "circle all that apply" is requested.

1) 30 points – Answer TRUE (T) or FALSE (F) to the following questions.

a) _____ Both the two-sample t-test and Analysis of Variance (ANOVA) require the assumption of normality.

b) _____ Analysis of variance (ANOVA) does not require the assumption of independence when the treatment arrangement is a factorial.

c) _____ The flounder is a flatfish that has eyes on either the right side of the body, or the left side of the body (depending on the species). A student interested in including "right-eyed" and "left-eyed" as the two levels of a treatment in ANOVA should consider this treatment to be random effect.

d) _____ If we are pretty sure that we can assume independence because the sampling has been truly random, then the variance among treatments should be homogeneous.

e) _____ If an investigator feels that it will be necessary to increase the sample size in his CRD experiment, then he is probably trying to decrease his Type I error rate.

f) _____ The MSE (mean squared error) in an Analysis of Variance is an estimate of the variance among, or between, the groups in the experiment (i.e. treatments).

g) _____ Welch's test is not a test of homogeneity of variance.

h) _____ The test of a treatment interaction can also be referred to as a test for additivity.

i) _____ The F tests done for an Analysis of ANOVA are always one tailed tests.

j) _____ Balanced Analyses of Variance are more powerful than unbalanced ANOVAs.

2) 3 points – Which of the expressions below best describes the "P value" listed by SAS for the test of treatments in a CRD (in PROC GLM)?

a) The probability of error in rejecting the null hypothesis

b) The probability of observing a larger value of the test statistic

c) The probability of erroneously failing to reject the null hypothesis

d) The probability that an interval contains the true population parameter

3) 3 points – Which of the expressions below best describes the motive for blocking?

a) Blocking helps with the assumption of normality

b) Blocking adds a test for new sources of variation that is of interest

c) Blocking adds power by increasing the error degrees of freedom

d) Blocking adds power by removing a source of variation from the error term

4) 3 points – According to Geaghan, the test of homogeneity of variance that generally performs best is which of the following?

a) Levin's test

b) O'Brien's test

c) Brown and Forsythe's

d) Bartlett's test

5) 3 points – Which of the following was developed by **R. A. Fisher**?

a) Chi square test of independence

b) Analysis of variance

c) Two sample t-test

d) The atomic bomb

6) 3 points – A potential problem with unbalanced ANOVA and two-sample t-tests is that the degrees of freedom may not be known. Which of the following names is associated with the development of an equation to estimate these degrees of freedom when variances cannot be pooled?

a) Satterthwaite

b) R. A. Fisher

c) Pearson

d) Welch

7) 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?

a) Levin's test

b) O'Brien's test

c) Brown and Forsythe's

d) Bartlett's test

8) 3 points – The expression $\frac{(t_{\alpha/2} + t_{\beta})^2 S^2}{\bar{d}^2}$ calculates the minimum number of ANOVA replicates needed (per treatment) for significance, where the value t_β is used to adjust for a desired level of power. The formula given in some text books omits the term for t_β. If the value for t_β is omitted and all other values are correct, what is the expected power of the resulting sample size.

a) 1.00

b) 0.50

c) <0.0001

d) 0.00

Do not write in this space

9) There are 4 experiments described below. For each experiment give the degrees of freedom (d.f.) for the TREATMENTS and name the most appropriate type of analysis. Where applicable, assume that the variances are homogeneous.

a) **6 points –** A Veterinary Medicine student has been told that "you cannot teach an old dog new tricks". He agrees that this is probably true for old Poodles, but firmly believes that old Beagles and old Fox Terriers can learn new tricks. He gets access to 14 Fox Terriers and 9 Beagles and 11 Poodles (all at least 8 years old in "human" years). He gives each of the dogs equal training in 10 new tricks, and records their success as the number of new tricks learned out of 10 possible (this is the dependent variable Y). What type of analysis should he use for this experiment?

How many total d.f. are there for treatments? (circle one): [1] [2] [3] [4] [5] [6] [7] [8]

Circle one: [CRD & single factor] [CRD & factorial] [RBD & single factor] [RBD & factorial]

b) **6 points –** An entomology graduate student has decided to test the hypothesis that "you can catch more flies with molasses than with vinegar". He locates 20 likely sites near a garbage dump. At each site he places three sheets of flypaper on a table. On one of these pieces of flypaper he places a few drops of molasses, on another piece he places a few drops of vinegar. Since his major professor told him that "all experiments need a control," he leaves the third piece of flypaper untreated. After 8 hours the number of flies on the pieces of flypaper (the variable of interest) are counted for analysis.

How many total d.f. are there for treatments? (circle one): [1] [2] [3] [4] [5] [6] [7] [8]

Circle one: [CRD & single factor] [CRD & factorial] [RBD & single factor] [RBD & factorial]

b) **6 points –** Everyone knows that an apple a day keeps the Doctor away. A nutritionist is interested in specifically which type of apple is the most effective in keeping doctors away. She gets 80 volunteer children and randomly assigns 20 to "Red Delicious" apples, 20 to "Golden Delicious" apples, 20 to "Granny Smith" apples and 20 to "McIntosh" apples. Each child is told to eat an apple a day during one year, and the total number of Doctor visits during the year are recorded for each child. How would we determine if the different types of apples resulted in varying numbers of Doctor visits (the variable of interest) for the three groups?

How many total d.f. are there for treatments? (circle one): [1] [2] [3] [4] [5] [6] [7] [8]

Circle one: [CRD & single factor] [CRD & factorial] [RBD & single factor] [RBD & factorial]

b) **6 points –** A Home Economics major is testing the hypothesis that "a stitch in time saves nine". She purchases 18 skirts. and makes a 5 cm cut on the hem on both the left and right side of each skirt. She randomly chooses the left or right side of each skirt and mends the randomly selected side; these represent the "stitches in time". The skirts are then worn and washed at least 10 times by volunteers during the Fall semester 2003. At the end of the semester the skirts are examined. If the old mend requires additional stitches, these are done and then the total stitches are counted. The unmended cut is also repaired and the total number of stitches counted. The variable of interest is the total number of stitches required to mend the cut that was "stitched in time" and the total number of stitches required for the unrepaired cut. Test the hypothesis that a stitch in time saves nine (ie. the unrepaired cut minus 9 equals the repaired cut or μ_1-9 = μ_2).

How many total d.f. are there for treatments? (circle one): [1] [2] [3] [4] [5] [6] [7] [8]

Circle one: [CRD & single factor] [CRD & factorial] [RBD & single factor] [RBD & factorial]

EXPERIMENTAL STATISTICS 7005 Name ________________________________
April 29, 2004 EXAM 3 All sections : Geaghan

The questions below pertain to SAS computer output attached. For each question provide an answer including a P value where possible. Provide 4 decimal places on all p values. If there are several choices of P values for a given question, use the P value from the best available statistical test to answer the question. Do each requested test independently regardless of the results of other test.

The data is from Samuels (1989) Problem 12.11 (page 407). The analysis deals with the effect of flooding on root metabolism of two species of birch trees. Four seedlings of each species were flooded for a day, and four others that were not flooded were used as a Control.

a) 4 points – What type of analysis is this? Circle the one best answer.

CRD & single factor - CRD & factorial - RBD & single factor - RBD & factorial

b) 4 points – Would you reject or accept the null hypothesis of "additivity" of the treatment effects in this experiment and what is the P value (give 4 decimal places)?

Circle the one best answer. ACCEPT REJECT P value = _0.___ ___ ___ ___

c) 4 points – Would you reject or accept the null hypothesis of homogeneous variance for the two treatments in this experiment (F and C) and what is the P value (give 4 decimal places)?

Circle the one best answer. ACCEPT REJECT P value = _0.___ ___ ___ ___

d) 4 points – Would you reject or accept the null hypothesis of normality in this experiment and what is the P value? (give 4 decimal places)

Circle the one best answer. ACCEPT REJECT P value = _0.___ ___ ___ ___

e) 4 points – Regardless of the outcome of other tests, the investigators were interested in a test of the two species under ordinary, unflooded conditions. Would you reject or accept the null hypothesis that treatment (European control) = treatment (River Birch control) when the test was Tukey adjusted? The hypothesis is H_0: $\mu_{EC} = \mu_{RC}$. What is the P value (give 4 decimal places)?

Circle the one best answer. ACCEPT REJECT P value = _0.___ ___ ___ ___

f) 5 points – Place a 99% two-tailed confidence interval on the estimate of the mean for flooded birches (both species combined)?

$$P(\_\_\_\_\_\_\_\_\_\_\_\_ < \mu_{A1} < \_\_\_\_\_\_\_\_\_\_\_\_) = 0.99$$

```
**************************************************************;
***    Data from Samuels (1989) Problem 12.11 (page 407)     ***;
***    Description: The effect of flooding on root metabolism ***;
***    was studied for two species of trees.  Four seedlings  ***;
***    of each species were flooded for a day, and four other ***;
***    unflooded were used as a Control for comparison.       ***;
**************************************************************;
dm'log;clear;output;clear';
options ps=256 ls=132 nocenter nodate nonumber;

OPTIONS PS=61 LS=78 NOCENTER NODATE NONUMBER;

DATA ONE; TITLE1 'Samuels (1989) Example 6 : Analysis of Variance Chapter';
  INPUT Group $ 1-3 Rep ATP SPECIES $ 1 TREATMENT $ 3;
  LABEL ATP ='Concentration of ATP in plant roots';
  LABEL GROUP ='Species (R-E); flood or control (F-C)';
CARDS; RUN;
;
PROC PRINT DATA=ONE; TITLE2 'LISTING OF DATA'; RUN;

PROC MIXED DATA=ONE; CLASS SPECIES TREATMENT;
   TITLE2 'Analysis of Variance for the ATP levels';
   TITLE3 'Done with PROC MIXED';
   MODEL ATP = SPECIES TREATMENT SPECIES*TREATMENT  / HTYPE=3 outp=NEXT2;
   repeated / group = treatment;
   LSMEANS SPECIES TREATMENT SPECIES*TREATMENT / PDIFF ADJUST=TUKEY;
RUN; QUIT;
```

Samuels (1989) Example 6 : Analysis of Variance Chapter
LISTING OF DATA

Obs	Group	Rep	ATP	SPECIES	TREATMENT
1	R-F	1	1.45	R	F
2	R-F	2	1.19	R	F
3	R-F	3	1.05	R	F
4	R-F	4	1.07	R	F
5	R-C	1	1.70	R	C
6	R-C	2	2.04	R	C
7	R-C	3	1.49	R	C
8	R-C	4	1.91	R	C
9	E-F	1	0.21	E	F
10	E-F	2	0.58	E	F
11	E-F	3	0.11	E	F
12	E-F	4	0.27	E	F
13	E-C	1	1.34	E	C
14	E-C	2	0.99	E	C
15	E-C	3	1.17	E	C
16	E-C	4	1.30	E	C

```
Samuels (1989) Example 6 : Analysis of Variance Chapter
Analysis of Variance for the ATP levels
Done with PROC MIXED

The Mixed Procedure

                  Model Information
Data Set                     WORK.ONE
Dependent Variable           ATP
Covariance Structure         Variance Components
Group Effect                 TREATMENT
Estimation Method            REML
Residual Variance Method     None
Fixed Effects SE Method      Model-Based
Degrees of Freedom Method    Between-Within

               Class Level Information
Class        Levels    Values
SPECIES           2    E R
TREATMENT         2    C F

            Dimensions
Covariance Parameters            2
Columns in X                     9
Columns in Z                     0
Subjects                        16
Max Obs Per Subject              1
Observations Used               16
Observations Not Used            0
Total Observations              16

                     Iteration History
Iteration    Evaluations    -2 Res Log Like       Criterion
        0              1         0.83173687
        1              1         0.81554691      0.00000000

                   Convergence criteria met.

   Covariance Parameter Estimates
Cov Parm     Group          Estimate
Residual     TREATMENT C     0.04158
Residual     TREATMENT F     0.03748

           Fit Statistics
-2 Res Log Likelihood             0.8
AIC (smaller is better)           4.8
AICC (smaller is better)          6.1
BIC (smaller is better)           6.4

  Null Model Likelihood Ratio Test
    DF    Chi-Square      Pr > ChiSq
     1          0.02          0.8988

            Type 3 Tests of Fixed Effects
                      Num     Den
Effect                 DF      DF    F Value    Pr > F

SPECIES                 1      12      55.60    <.0001
TREATMENT               1      12      57.11    <.0001
SPECIES*TREATMENT       1      12       2.47    0.1420
```

Least Squares Means

Effect	SPECIES	TREATMENT	Estimate	Standard Error	DF	t Value	Pr > |t|
SPECIES	E		0.7463	0.07030	12	10.62	<.0001
SPECIES	R		1.4875	0.07030	12	21.16	<.0001
TREATMENT		C	1.4925	0.07210	12	20.70	<.0001
TREATMENT		F	0.7412	0.06845	12	10.83	<.0001
SPECIES*TREATMENT	E	C	1.2000	0.1020	12	11.77	<.0001
SPECIES*TREATMENT	E	F	0.2925	0.09680	12	3.02	0.0106
SPECIES*TREATMENT	R	C	1.7850	0.1020	12	17.51	<.0001
SPECIES*TREATMENT	R	F	1.1900	0.09680	12	12.29	<.0001

Differences of Least Squares Means

Effect	SPECIES	TREATMENT	_SPECIES	_TREATMENT	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
SPECIES	E		R		-0.7412	0.09941	12	-7.46	<.0001	Tukey	<.0001
TREATMENT		C		F	0.7513	0.09941	12	7.56	<.0001	Tukey-Kramer	<.0001
SPECIES*TREATMENT	E	C	E	F	0.9075	0.1406	12	6.45	<.0001	Tukey-Kramer	0.0002
SPECIES*TREATMENT	E	C	R	C	-0.5850	0.1442	12	-4.06	0.0016	Tukey-Kramer	0.0075
SPECIES*TREATMENT	E	C	R	F	0.01000	0.1406	12	0.07	0.9445	Tukey-Kramer	0.9999
SPECIES*TREATMENT	E	F	R	C	-1.4925	0.1406	12	-10.62	<.0001	Tukey-Kramer	<.0001
SPECIES*TREATMENT	E	F	R	F	-0.8975	0.1369	12	-6.56	<.0001	Tukey-Kramer	0.0001
SPECIES*TREATMENT	R	C	R	F	0.5950	0.1406	12	4.23	0.0012	Tukey-Kramer	0.0055

Samuels (1989) Example 6 : Analysis of Variance Chapter
Univariate analysis of RESIDUALS

The UNIVARIATE Procedure
Variable: Resid

Moments

N	16	Sum Weights	16
Mean	0	Sum Observations	0
Std Deviation	0.17783419	Variance	0.031625
Skewness	0.22922652	Kurtosis	-0.9516224
Uncorrected SS	0.474375	Corrected SS	0.474375
Coeff Variation	.	Std Error Mean	0.04445855

Basic Statistical Measures

Location		Variability	
Mean	0.00000	Std Deviation	0.17783
Median	-0.02625	Variance	0.03163
Mode	.	Range	0.58250
		Interquartile Range	0.26250

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	0	Pr > |t|	1.0000
Sign	M	-1	Pr >= |M|	0.8036
Signed Rank	S	-1.5	Pr >= |S|	0.9505

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.954226	Pr < W	0.5594
Kolmogorov-Smirnov	D	0.125	Pr > D	>0.1500
Cramer-von Mises	W-Sq	0.044102	Pr > W-Sq	>0.2500
Anderson-Darling	A-Sq	0.288027	Pr > A-Sq	>0.2500

Quantiles (Definition 5)

Quantile	Estimate
100% Max	0.28750
99%	0.28750
95%	0.28750
90%	0.26000
75% Q3	0.13250
50% Median	-0.02625
25% Q1	-0.13000
10%	-0.21000
5%	-0.29500
1%	-0.29500
0% Min	-0.29500

Extreme Observations

-----Lowest-----		-----Highest----	
Value	Obs	Value	Obs
-0.2950	7	0.1250	8
-0.2100	14	0.1400	13
-0.1825	11	0.2550	6
-0.1400	3	0.2600	1
-0.1200	4	0.2875	10

```
   Stem Leaf                     #  Boxplot                         Normal Probability Plot
      2 669                      3     |        0.25+                                    * +*+++ *
      1 024                      3  +-----+         |                              * *+*+++
      0 0                        1  |  +  |         |                          ++*+++
     -0 8832                     4  *-----*    -0.05+                     +*+** *
     -1 842                      3  +-----+         |                +*+*+*
     -2 1                        1     |            |         * +++*+
     -3 0                        1     |       -0.35+    ++++++
        ----+----+----+----+                         +----+----+----+----+----+----+----+----+----+----+
    Multiply Stem.Leaf by 10**-1                          -2        -1         0        +1        +2
```

t - tables : Probability of a larger absolute value (two tailed test)

d.f.	0.500	0.400	0.300	0.200	0.100	0.050	0.020	0.010	0.002	0.001	d.f.
1	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.656	318.289	636.578	1
2	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.328	31.600	2
3	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.214	12.924	3
4	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610	4
5	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.894	6.869	5
6	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959	6
7	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408	7
8	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041	8
9	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781	9
10	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587	10
11	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437	11
12	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318	12
13	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221	13
14	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140	14
15	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073	15
16	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015	16
17	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965	17
18	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922	18
19	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883	19
20	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850	20
21	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819	21
22	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792	22
23	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768	23
24	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745	24
25	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725	25
26	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707	26
27	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.689	27
28	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674	28
29	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.660	29
30	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646	30
32	0.682	0.853	1.054	1.309	1.694	2.037	2.449	2.738	3.365	3.622	32
34	0.682	0.852	1.052	1.307	1.691	2.032	2.441	2.728	3.348	3.601	34
36	0.681	0.852	1.052	1.306	1.688	2.028	2.434	2.719	3.333	3.582	36
38	0.681	0.851	1.051	1.304	1.686	2.024	2.429	2.712	3.319	3.566	38
40	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551	40
45	0.680	0.850	1.049	1.301	1.679	2.014	2.412	2.690	3.281	3.520	45
50	0.679	0.849	1.047	1.299	1.676	2.009	2.403	2.678	3.261	3.496	50
75	0.678	0.846	1.044	1.293	1.665	1.992	2.377	2.643	3.202	3.425	75
100	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390	100
∞	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.290	∞
d.f.	0.250	0.200	0.150	0.100	0.050	0.025	0.010	0.005	0.001	0.0005	d.f.

t - tables : Probability of a larger value (one tailed test)