Read Carefully. Give an answer in the form of a number or numeric expression where possible. Show all calculations for possible partial credit. Us a value of 0.05 for α if not specified. t-tables, Chi square tables and F tables are provided separately. You may keep these tables.

1) 3 points – The probability of testing an H_0 and correctly concluding that no statistically significant difference exists is called ... (circle the ONE best answer below).

a) Confidence.

b) Power.

c) Type I error (α).

d) Type II error (β).

2) 3 points – The calculation we used to estimate degrees of freedom for a two-sample t-test when variances are not equal is called ... (circle the ONE best answer below).

a) The central limit theorem.

b) Satterthwaite's approximation.

c) Paired t-test correction.

d) F value adjustment.

3) 3 points – For the variance of a linear combination, covariances can be assumed to be zero if ... (circle the ONE best answer below).

a) The central limit applies.

b) the design is balanced.

c) the variances are equal.

d) the variables are independent.

4) 3 points – The hypothesis H_0: $\mu_1 - 0.5\mu_2 = 0$ would be tested with which of the analyses below ... (circle the ONE best answer below).

a) one-sample t-test

b) two-sample t-test

c) F test

d) Chi square test

5) 3 points – Which of the following provides the best test of homogeneity of variance (according to Geaghan)? (circle the ONE best answer below).

a) Bartlett's

b) Levin's

c) Hartley's

d) Brown and Forsythe's

6) 3 points – Which of the tests listed below is the best for all possible pairwise post-hoc or post-ANOVA tests? (circle the ONE best answer below).

a) LSD

b) Tukey

c) Scheffé

d) Bonferroni

7) 3 points – Which of the tests listed below is the most powerful for testing among 5 treatment level means? (circle the ONE best answer below).

a) LSD

b) Tukey

c) Scheffé

d) Bonferroni

8) 3 points – Which of the tests listed below is NOT at test of homogeniety? (circle the ONE best answer below).

a) Bartlett's

b) Levin's

c) Welch's

d) O'Brien's

9) 6 points – For each question below circle the ONE best answer.

a) The expected value for the F distribution is …

0 (zero) 1 (one) γ (d.f.) n (sample size) none of these

b) The expected value for the Chi square distribution is …

0 (zero) 1 (one) γ (d.f.) n (sample size) none of these

10) 15 points – Complete the following questions for the distribution indicated.

a) $P(\chi^2 \geq 4.865)$ = ? **d.f. = 10** **P value =** ____________

b) $P(\chi^2 \leq 26.039)$ = ? **d.f. = 22** **P value =** ____________

c) $P(\chi^2 \leq 1.6465)$ = ? **d.f. = 8** **P value =** ____________

d) $P(\chi^2 \leq \chi^2_0) = 0.95$ **d.f. = 12** χ^2_0 = ____________

e) $P(\chi^2 \geq \chi^2_0) = 0.50$ **d.f. = 5** χ^2_0 = ____________

11) 12 points – Complete the following questions for the distribution indicated.

a) $P(F < 3.708)$ = ? $\gamma_{num}, \gamma_{den}$ **= 3, 10** **P value =** ______________

b) $P(F > 3.701)$ = ? $\gamma_{num}, \gamma_{den}$ **= 30, 12** **P value =** ______________

c) $P(F < F_0) = 0.01$ $\gamma_{num}, \gamma_{den}$ **= 2, 4** F_0=_____________

d) $P(F > F_0) = 0.05$ $\gamma_{num}, \gamma_{den}$ **= 5, 7** F_0= _____________

12) 9 points – Complete the following questions for confidence intervals. All tail probabilities are symmetric

a) $P(Y_1 < \mu < Y_2) = 0.90$ $\bar{Y} = 50, S^2 = 49, n = 25$ Y_1 = ________ , Y_2 = ________

b) $P(Y_1 < \mu_{\bar{Y}} < Y_2) = 0.99$ $\bar{Y} = 20, S^2 = 36, n = 10$ Y_1 = ________ , Y_2 = ________

c) $P(\sigma_1^2 < \sigma^2 < \sigma_2^2) = 0.950$ $\bar{Y} = 12, S^2 = 16, n = 9$ σ_1^2 = ________ , σ_2^2 = ________

13) 9 points – According to a recent documentary, stray domestic dogs that have returned to the wild average about 40 pounds in size. A veterinary student has hypothesized that dogs in northern cities will weight more than in southern cities. A sample of 30 dogs from the New York City area is compared to a sample of 26 dogs from the Miami area. The null hypothesis to be tested is H_0: μ_1-μ_2 = 0. You may assume that all the usual statistical assumptions are met.

a) What would be the best (most powerful) analysis for this experiment? Circle the one best answer.

two-sample t-test paired t-test one-sample t-test Chi square test

CRD (single factor) CRD (factorial)

b) State the alternative hypothesis : H_1: = __________________________

c) State the critical value of the test statistic : __________________________________

d) State the degrees of freedom for the test : __________________________________

14) 9 points – A technician at the Widget Manufacturing Company is told that he must start testing the widgets to make sure that they are uniform in size. The widget is supposed to be 10 inches in diameter with a variance of <u>no more</u> than 0.5 inches squared. He is told to sample 10 widgets each hour and to call for adjustment of the machinery if the <u>variance</u> is significantly greater than this limit. What type of analysis would he use to test this process to determine if it is producing satisfactory uniformity? You may assume that all the usual statistical assumptions are met.

What would be the best (most powerful) analysis for this experiment? Circle the one best answer.

two-sample t-test paired t-test one-sample t-test Chi square test

CRD (single factor) CRD (factorial)

State the alternative hypothesis : H_1: = __________________________

State the critical value of the test statistic : __________________________________

State the degrees of freedom for the test : __________________________________

The questions on the following pages refers to SAS output also given on those pages. The program is given below. The computer output is given separately.

```
*********************************************;
*** Exam 3 Example                        ***;
*********************************************;

OPTIONS PS=256 LS=111 NOCENTER NODATE PAGENO=1;
DATA ONE;  INFILE CARDS MISSOVER;
   INPUT Treatment_A $ Y_Value;
      TITLE1 'Exam 2 Problem';
CARDS;            RUN;
```

```
PROC mixed DATA=ONE cl covtest;  CLASSES Treatment_A;
  MODEL Y_Value = Treatment_A  / Htype = 3 outp=resids;
  LSMEANS Treatment_A  / adjust=TUKEY pdiff;
  repeated / group=Treatment_A;
RUN; QUIT;
PROC UNIVARIATE DATA=resids NORMAL PLOT; VAR resid; RUN;

PROC GLM DATA=ONE; CLASSES Treatment_A;
  MODEL Y_Value = Treatment_A / SS3;
  MEANS Treatment_A / TUKEY;
  MEANS Treatment_A / HOVTEST=BARTLETT HOVTEST=BF HOVTEST=LEVENE(TYPE=ABS)
            HOVTEST=LEVENE(TYPE=SQUARE) HOVTEST=OBRIEN WELCH;
RUN; QUIT;
```

15) 16 points – The questions below pertain to the computer output given separately. 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.

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

CRD (single factor) **CRD (factorial)**

b) Would you reject or accept the null hypothesis of equal treatments in this experiment and what is the P value (give 4 decimal places)?

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

c) Would you reject or accept the null hypothesis of homogeneous variance in this experiment and what is the P value (give 4 decimal places)?

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

d) 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) Would you reject or accept the null hypothesis that treatment 3 = treatment 4 when the test was Tukey adjusted? The hypothesis is H_0: $\mu_3 = \mu_4$. What is the P value (give 4 decimal places)?

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

The Mixed Procedure

Model Information

Data Set	WORK.ONE
Dependent Variable	Y_Value
Covariance Structure	Variance Components
Group Effect	Treatment_A
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
Treatment_A	4	A1 A2 A3 A4

Dimensions

Covariance Parameters	4
Columns in X	5
Columns in Z	0
Subjects	80
Max Obs Per Subject	1
Observations Used	80
Observations Not Used	0
Total Observations	80

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	510.66760298	
1	1	510.51169885	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Group	Estimate	Standard Error	Z Value	Pr Z	Alpha	Lower	Upper
Residual	Treatment_A A1	44.9047	14.5690	3.08	0.0010	0.05	25.9704	95.7938
Residual	Treatment_A A2	41.3009	13.3998	3.08	0.0010	0.05	23.8862	88.1060
Residual	Treatment_A A3	37.5079	12.1692	3.08	0.0010	0.05	21.6925	80.0144
Residual	Treatment_A A4	41.9664	13.6157	3.08	0.0010	0.05	24.2711	89.5257

Fit Statistics

-2 Res Log Likelihood	510.5
AIC (smaller is better)	518.5
AICC (smaller is better)	519.1
BIC (smaller is better)	528.0

Null Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
3	0.16	0.9844

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Treatment_A	3	76	16.23	<.0001

Least Squares Means

Effect	Treatment_ A	Estimate	Standard Error	DF	t Value	Pr > |t|
Treatment_A	A1	91.1950	1.4984	76	60.86	<.0001
Treatment_A	A2	81.7750	1.4370	76	56.91	<.0001
Treatment_A	A3	82.4450	1.3695	76	60.20	<.0001
Treatment_A	A4	76.8700	1.4486	76	53.07	<.0001

Differences of Least Squares Means

Effect	Treatment_ A	_Treatment_ A	Estimate	Standard Error	DF	t Value	Pr > |t|	Adjustment	Adj P
Treatment_A	A1	A2	9.4200	2.0761	76	4.54	<.0001	Tukey-Kramer	0.0001
Treatment_A	A1	A3	8.7500	2.0299	76	4.31	<.0001	Tukey-Kramer	0.0003
Treatment_A	A1	A4	14.3250	2.0841	76	6.87	<.0001	Tukey-Kramer	<.0001
Treatment_A	A2	A3	-0.6700	1.9851	76	-0.34	0.7367	Tukey-Kramer	0.9867
Treatment_A	A2	A4	4.9050	2.0404	76	2.40	0.0187	Tukey-Kramer	0.0849
Treatment_A	A3	A4	5.5750	1.9934	76	2.80	0.0065	Tukey-Kramer	0.0324

EXPERIMENTAL STATISTICS 7005 **Name ______________________________**

April 1, 2004 **Computer output** **Do not remove these pages**

```
Exam 2 Problem                                                                                   2

The UNIVARIATE Procedure
Variable:  Resid

                            Moments
N                            80    Sum Weights                 80
Mean                          0    Sum Observations             0
Std Deviation        6.31245353    Variance            39.8470696
Skewness             0.30654139    Kurtosis            -0.3511039
Uncorrected SS        3147.9185    Corrected SS         3147.9185
Coeff Variation               .    Std Error Mean      0.70575376

              Basic Statistical Measures
    Location                    Variability
Mean     0.000000     Std Deviation            6.31245
Median   0.340000     Variance                39.84707
Mode     0.825000     Range                   27.62500
                      Interquartile Range      8.86250
NOTE: The mode displayed is the smallest of 4 modes with a count of 2.

           Tests for Location: Mu0=0
Test           -Statistic-    -----p Value------
Student's t    t         0    Pr > |t|    1.0000
Sign           M         2    Pr >= |M|   0.7376
Signed Rank    S       -43    Pr >= |S|   0.8381

                   Tests for Normality
Test                  --Statistic---    -----p Value------
Shapiro-Wilk          W     0.982486    Pr < W      0.3433
Kolmogorov-Smirnov    D     0.078557    Pr > D     >0.1500
Cramer-von Mises      W-Sq   0.05851    Pr > W-Sq  >0.2500
Anderson-Darling      A-Sq  0.365888    Pr > A-Sq  >0.2500

Quantiles (Definition 5)
Quantile      Estimate
100% Max       15.2300
99%            15.2300
95%            10.7550
90%             8.9150
75% Q3          4.1300
50% Median      0.3400
25% Q1         -4.7325
10%            -8.0225
5%             -9.5700
1%            -12.3950
0% Min        -12.3950

          Extreme Observations
-----Lowest-----        -----Highest----
  Value      Obs          Value      Obs
-12.395        1         10.605        8
-11.645       59         10.905       15
-10.345       56         14.230       74
 -9.845       42         14.325       31
 -9.295       19         15.230       72

   Stem Leaf                     #  Boxplot                     Normal Probability Plot
     14 232                      3     |         15+                                            * *  +*+
     12                                |           |                                                +++
     10 569                         3     |           |                                         ***++
      8 356                      3     |           |                                      ***+
      6 01882                    5     |           |                                    ***
      4 00231279                 8  +-----+        |                                 ****
      2 44747                    5  |     |        |                              ***
      0 234889233455567         15  *--+--*       1+                          *****
     -0 93212                    5  |     |        |                       +**
     -2 98444065                 8  |     |        |                    +****
     -4 7221876410              10  +-----+        |                 *****
     -6 5864221                  7     |           |              ****
     -8 83316                    5     |           |         *****
    -10 63                       2     |           |      *+*++
    -12 4                        1     |        -13+ * +++
        ----+----+----+----+                    +----+----+----+----+----+----+----+----+----+----+
                                                    -2        -1         0        +1        +2
```

Exam 2 Problem 3

The GLM Procedure

Class Level Information

Class	Levels	Values
Treatment_A	4	A1 A2 A3 A4

Number of observations 80

Dependent Variable: Y_Value

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2130.465375	710.155125	17.15	<.0001
Error	76	3147.918500	41.419980		
Corrected Total	79	5278.383875			

R-Square	Coeff Var	Root MSE	Y_Value Mean
0.403621	7.747368	6.435836	83.07125

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Treatment_A	3	2130.465375	710.155125	17.15	<.0001

Tukey's Studentized Range (HSD) Test for Y_Value

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	76
Error Mean Square	41.41998
Critical Value of Studentized Range	3.71485
Minimum Significant Difference	5.346

Means with the same letter are not significantly different.

Tukey Grouping		Mean	N	Treatment_A
	A	91.195	20	A1
	B	82.445	20	A3
C	B	81.775	20	A2
C		76.870	20	A4

Levene's Test for Homogeneity of Y_Value Variance
ANOVA of Squared Deviations from Group Means

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treatment_A	3	501.1	167.0	0.06	0.9785
Error	76	197239	2595.3		

O'Brien's Test for Homogeneity of Y_Value Variance
ANOVA of O'Brien's Spread Variable, W = 0.5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treatment_A	3	555.2	185.1	0.06	0.9802
Error	76	230858	3037.6		

Brown and Forsythe's Test for Homogeneity of Y_Value Variance
ANOVA of Absolute Deviations from Group Medians

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Treatment_A	3	6.4024	2.1341	0.15	0.9322
Error	76	1114.5	14.6650		

Bartlett's Test for Homogeneity of Y_Value Variance

Source	DF	Chi-Square	Pr > ChiSq
Treatment_A	3	0.1526	0.9849

Welch's ANOVA for Y_Value

Source	DF	F Value	Pr > F
Treatment_A	3.0000	15.74	<.0001
Error	42.2024		

7

Level of Treatment_A	N	Y_Value Mean	Y_Value Std Dev
A1	20	91.1950000	6.70109771
A2	20	81.7750000	6.42657927
A3	20	82.4450000	6.12436678
A4	20	76.8700000	6.47814951

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)

Chi Square Table : Probability of a larger Chi Square value (one tailed test)

d.f.	0.995	0.990	0.9750	0.9500	0.9000	0.7500	0.5000	0.250	0.100	0.050	0.025	0.010	0.005
1	0.0000	0.0002	0.0010	0.0039	0.0158	0.1015	0.4549	1.3233	2.7055	3.8415	5.0239	6.6349	7.8794
2	0.0100	0.0201	0.0506	0.1026	0.2107	0.5754	1.3863	2.7726	4.6052	5.9915	7.3778	9.2104	10.5965
3	0.0717	0.1148	0.2158	0.3518	0.5844	1.2125	2.3660	4.1083	6.2514	7.8147	9.3484	11.3449	12.8381
4	0.2070	0.2971	0.4844	0.7107	1.0636	1.9226	3.3567	5.3853	7.7794	9.4877	11.1433	13.2767	14.8602
5	**0.4118**	**0.5543**	**0.8312**	**1.1455**	**1.6103**	**2.6746**	**4.3515**	**6.6257**	**9.2363**	**11.0705**	**12.8325**	**15.0863**	**16.7496**
6	0.6757	0.8721	1.2373	1.6354	2.2041	3.4546	5.3481	7.8408	10.6446	12.5916	14.4494	16.8119	18.5475
7	0.9893	1.2390	1.6899	2.1673	2.8331	4.2549	6.3458	9.0371	12.0170	14.0671	16.0128	18.4753	20.2777
8	1.3444	1.6465	2.1797	2.7326	3.4895	5.0706	7.3441	10.2189	13.3616	15.5073	17.5345	20.0902	21.9549
9	1.7349	2.0879	2.7004	3.3251	4.1682	5.8988	8.3428	11.3887	14.6837	16.9190	19.0228	21.6660	23.5893
10	**2.156**	**2.558**	**3.247**	**3.940**	**4.865**	**6.737**	**9.342**	**12.549**	**15.987**	**18.307**	**20.483**	**23.209**	**25.188**
11	2.603	3.053	3.816	4.575	5.578	7.584	10.341	13.701	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	8.438	11.340	14.845	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.041	9.299	12.340	15.984	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	10.165	13.339	17.117	21.064	23.685	26.119	29.141	31.319
15	**4.601**	**5.229**	**6.262**	**7.261**	**8.547**	**11.037**	**14.339**	**18.245**	**22.307**	**24.996**	**27.488**	**30.578**	**32.801**
16	5.142	5.812	6.908	7.962	9.312	11.912	15.338	19.369	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	12.792	16.338	20.489	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	13.675	17.338	21.605	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.651	14.562	18.338	22.718	27.204	30.144	32.852	36.191	38.582
20	**7.434**	**8.260**	**9.591**	**10.851**	**12.443**	**15.452**	**19.337**	**23.828**	**28.412**	**31.410**	**34.170**	**37.566**	**39.997**
21	8.034	8.897	10.283	11.591	13.240	16.344	20.337	24.935	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	17.240	21.337	26.039	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	18.137	22.337	27.141	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	19.037	23.337	28.241	33.196	36.415	39.364	42.980	45.558
25	**10.520**	**11.524**	**13.120**	**14.611**	**16.473**	**19.939**	**24.337**	**29.339**	**34.382**	**37.652**	**40.646**	**44.314**	**46.928**
26	11.160	12.198	13.844	15.379	17.292	20.843	25.336	30.435	35.563	38.885	41.923	45.642	48.290
27	11.808	12.878	14.573	16.151	18.114	21.749	26.336	31.528	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	22.657	27.336	32.620	37.916	41.337	44.461	48.278	50.994
29	13.121	14.256	16.047	17.708	19.768	23.567	28.336	33.711	39.087	42.557	45.722	49.588	52.335
30	**13.787**	**14.953**	**16.791**	**18.493**	**20.599**	**24.478**	**29.336**	**34.800**	**40.256**	**43.773**	**46.979**	**50.892**	**53.672**
35	17.192	18.509	20.569	22.465	24.797	29.054	34.336	40.223	46.059	49.802	53.203	57.342	60.275
40	20.707	22.164	24.433	26.509	29.051	33.660	39.335	45.616	51.805	55.758	59.342	63.691	66.766
45	24.311	25.901	28.366	30.612	33.350	38.291	44.335	50.985	57.505	61.656	65.410	69.957	73.166
50	**27.991**	**29.707**	**32.357**	**34.764**	**37.689**	**42.942**	**49.335**	**56.334**	**63.167**	**67.505**	**71.420**	**76.154**	**79.490**
60	35.534	37.485	40.482	43.188	46.459	52.294	59.335	66.981	74.397	79.082	83.298	88.379	91.952
70	43.28	45.44	48.76	51.74	55.33	61.70	69.33	77.58	85.53	90.53	95.02	100.43	104.21
80	51.17	53.54	57.15	60.39	64.28	71.14	79.33	88.13	96.58	101.88	106.63	112.33	116.32
90	59.20	61.75	65.65	69.13	73.29	80.62	89.33	98.65	107.57	113.15	118.14	124.12	128.30
100	**67.33**	**70.06**	**74.22**	**77.93**	**82.36**	**90.13**	**99.33**	**109.14**	**118.50**	**124.34**	**129.56**	**135.81**	**140.17**
200	152.24	156.43	162.73	168.28	174.84	186.17	199.33	213.10	226.02	233.99	241.06	249.45	255.26
500	422.30	429.39	439.94	449.15	459.93	478.32	499.33	520.95	540.93	553.13	563.85	576.49	585.21
d.f.	**0.995**	**0.990**	**0.9750**	**0.9500**	**0.9000**	**0.7500**	**0.5000**	**0.250**	**0.100**	**0.050**	**0.025**	**0.010**	**0.005**

Df	**Prob>F**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**15**	**20**	**30**	**60**	**120**	**240**	∞
1	**0.05**	161	199	216	225	230	234	237	239	241	242	246	248	250	252	253	254	254
	0.025	648	799	864	900	922	937	948	957	963	969	985	993	1001	1010	1014	1016	1018
	0.010	4052	4999	5404	5624	5764	5859	5928	5981	6022	6056	6157	6209	6260	6313	6340	6353	6366
	0.005	16212	19997	21614	22501	23056	23440	23715	23924	24091	24222	24632	24837	25041	25254	25358	25414	25466
2	**0.05**	**18.5**	**19.0**	**19.2**	**19.2**	**19.3**	**19.3**	**19.4**	**19.4**	**19.4**	**19.4**	**19.4**	**19.4**	**19.5**	**19.5**	**19.5**	**19.5**	**19.5**
	0.025	38.5	39.0	39.2	39.2	39.3	39.3	39.4	39.4	39.4	39.4	39.4	39.4	39.5	39.5	39.5	39.5	39.5
	0.010	98.5	99.0	99.2	99.3	99.3	99.3	99.4	99.4	99.4	99.4	99.4	99.4	99.5	99.5	99.5	99.5	99.5
	0.005	198.5	199.0	199.2	199.2	199.3	199.3	199.4	199.4	199.4	199.4	199.4	199.4	199.5	199.5	199.5	199.5	199.5
3	**0.05**	**10.13**	**9.55**	**9.28**	**9.12**	**9.01**	**8.94**	**8.89**	**8.85**	**8.81**	**8.79**	**8.70**	**8.66**	**8.62**	**8.57**	**8.55**	**8.54**	**8.53**
	0.025	17.44	16.04	15.44	15.10	14.88	14.73	14.62	14.54	14.47	14.42	14.25	14.17	14.08	13.99	13.95	13.92	13.90
	0.010	34.12	30.82	29.46	28.71	28.24	27.91	27.67	27.49	27.34	27.23	26.87	26.69	26.50	26.32	26.22	26.17	26.13
	0.005	55.55	49.80	47.47	46.20	45.39	44.84	44.43	44.13	43.88	43.68	43.08	42.78	42.47	42.15	41.99	41.91	41.83
4	**0.05**	**7.71**	**6.94**	**6.59**	**6.39**	**6.26**	**6.16**	**6.09**	**6.04**	**6.00**	**5.96**	**5.86**	**5.80**	**5.75**	**5.69**	**5.66**	**5.64**	**5.63**
	0.025	12.22	10.65	9.98	9.60	9.36	9.20	9.07	8.98	8.90	8.84	8.66	8.56	8.46	8.36	8.31	8.28	8.26
	0.010	21.20	18.00	16.69	15.98	15.52	15.21	14.98	14.80	14.66	14.55	14.20	14.02	13.84	13.65	13.56	13.51	13.46
	0.005	31.33	26.28	24.26	23.15	22.46	21.98	21.62	21.35	21.14	20.97	20.44	20.17	19.89	19.61	19.47	19.40	19.32
5	**0.05**	**6.608**	**5.786**	**5.409**	**5.192**	**5.050**	**4.950**	**4.876**	**4.818**	**4.772**	**4.735**	**4.619**	**4.558**	**4.496**	**4.431**	**4.398**	**4.382**	**4.365**
	0.025	10.007	8.434	7.764	7.388	7.146	6.978	6.853	6.757	6.681	6.619	6.428	6.329	6.227	6.123	6.069	6.042	6.015
	0.010	16.258	13.274	12.060	11.392	10.967	10.672	10.456	10.289	10.158	10.051	9.722	9.553	9.379	9.202	9.112	9.066	9.020
	0.005	22.785	18.314	16.530	15.556	14.939	14.513	14.200	13.961	13.772	13.618	13.146	12.903	12.656	12.402	12.274	12.209	12.144
6	**0.05**	**5.987**	**5.143**	**4.757**	**4.534**	**4.387**	**4.284**	**4.207**	**4.147**	**4.099**	**4.060**	**3.938**	**3.874**	**3.808**	**3.740**	**3.705**	**3.687**	**3.669**
	0.025	8.813	7.260	6.599	6.227	5.988	5.820	5.695	5.600	5.523	5.461	5.269	5.168	5.065	4.959	4.904	4.877	4.849
	0.010	13.745	10.925	9.780	9.148	8.746	8.466	8.260	8.102	7.976	7.874	7.559	7.396	7.229	7.057	6.969	6.925	6.880
	0.005	18.635	14.544	12.917	12.028	11.464	11.073	10.786	10.566	10.391	10.250	9.814	9.589	9.358	9.122	9.001	8.941	8.879
7	**0.05**	**5.591**	**4.737**	**4.347**	**4.120**	**3.972**	**3.866**	**3.787**	**3.726**	**3.677**	**3.637**	**3.511**	**3.445**	**3.376**	**3.304**	**3.267**	**3.249**	**3.230**
	0.025	8.073	6.542	5.890	5.523	5.285	5.119	4.995	4.899	4.823	4.761	4.568	4.467	4.362	4.254	4.199	4.171	4.142
	0.010	12.246	9.547	8.451	7.847	7.460	7.191	6.993	6.840	6.719	6.620	6.314	6.155	5.992	5.824	5.737	5.694	5.650
	0.005	16.235	12.404	10.883	10.050	9.522	9.155	8.885	8.678	8.514	8.380	7.968	7.754	7.534	7.309	7.193	7.135	7.076
8	**0.05**	**5.318**	**4.459**	**4.066**	**3.838**	**3.688**	**3.581**	**3.500**	**3.438**	**3.388**	**3.347**	**3.218**	**3.150**	**3.079**	**3.005**	**2.967**	**2.947**	**2.928**
	0.025	7.571	6.059	5.416	5.053	4.817	4.652	4.529	4.433	4.357	4.295	4.101	3.999	3.894	3.784	3.728	3.699	3.670
	0.010	11.259	8.649	7.591	7.006	6.632	6.371	6.178	6.029	5.911	5.814	5.515	5.359	5.198	5.032	4.946	4.903	4.859
	0.005	14.688	11.043	9.597	8.805	8.302	7.952	7.694	7.496	7.339	7.211	6.814	6.608	6.396	6.177	6.065	6.008	5.951
9	**0.05**	**5.117**	**4.256**	**3.863**	**3.633**	**3.482**	**3.374**	**3.293**	**3.230**	**3.179**	**3.137**	**3.006**	**2.936**	**2.864**	**2.787**	**2.748**	**2.727**	**2.707**
	0.025	7.209	5.715	5.078	4.718	4.484	4.320	4.197	4.102	4.026	3.964	3.769	3.667	3.560	3.449	3.392	3.363	3.333
	0.010	10.562	8.022	6.992	6.422	6.057	5.802	5.613	5.467	5.351	5.257	4.962	4.808	4.649	4.483	4.398	4.354	4.311
	0.005	13.614	10.107	8.717	7.956	7.471	7.134	6.885	6.693	6.541	6.417	6.032	5.832	5.625	5.410	5.300	5.244	5.188
10	**0.05**	**4.965**	**4.103**	**3.708**	**3.478**	**3.326**	**3.217**	**3.135**	**3.072**	**3.020**	**2.978**	**2.845**	**2.774**	**2.700**	**2.621**	**2.580**	**2.559**	**2.538**
	0.025	6.937	5.456	4.826	4.468	4.236	4.072	3.950	3.855	3.779	3.717	3.522	3.419	3.311	3.198	3.140	3.110	3.080
	0.010	10.044	7.559	6.552	5.994	5.636	5.386	5.200	5.057	4.942	4.849	4.558	4.405	4.247	4.082	3.996	3.953	3.909
	0.005	12.827	9.427	8.081	7.343	6.872	6.545	6.303	6.116	5.968	5.847	5.471	5.274	5.071	4.859	4.750	4.695	4.639
11	**0.05**	**4.844**	**3.982**	**3.587**	**3.357**	**3.204**	**3.095**	**3.012**	**2.948**	**2.896**	**2.854**	**2.719**	**2.646**	**2.570**	**2.490**	**2.448**	**2.426**	**2.404**
	0.025	6.724	5.256	4.630	4.275	4.044	3.881	3.759	3.664	3.588	3.526	3.330	3.226	3.118	3.004	2.944	2.914	2.883
	0.010	9.646	7.206	6.217	5.668	5.316	5.069	4.886	4.744	4.632	4.539	4.251	4.099	3.941	3.776	3.690	3.647	3.602
	0.005	12.226	8.912	7.600	6.881	6.422	6.102	5.865	5.682	5.537	5.418	5.049	4.855	4.654	4.445	4.337	4.281	4.226
12	**0.05**	**4.747**	**3.885**	**3.490**	**3.259**	**3.106**	**2.996**	**2.913**	**2.849**	**2.796**	**2.753**	**2.617**	**2.544**	**2.466**	**2.384**	**2.341**	**2.319**	**2.296**
	0.025	6.554	5.096	4.474	4.121	3.891	3.728	3.607	3.512	3.436	3.374	3.177	3.073	2.963	2.848	2.787	2.756	2.725
	0.010	9.330	6.927	5.953	5.412	5.064	4.821	4.640	4.499	4.388	4.296	4.010	3.858	3.701	3.535	3.449	3.405	3.361
	0.005	11.754	8.510	7.226	6.521	6.071	5.757	5.524	5.345	5.202	5.085	4.721	4.530	4.331	4.123	4.015	3.960	3.904

df	Prob>F	1	2	3	4	5	6	7	8	9	10	15	20	30	60	120	240	∞
13	**0.05**	4.667	3.806	3.411	3.179	3.025	2.915	2.832	2.767	2.714	2.671	2.533	2.459	2.380	2.297	2.252	2.230	2.206
	0.025	6.414	4.965	4.347	3.996	3.767	3.604	3.483	3.388	3.312	3.250	3.053	2.948	2.837	2.720	2.659	2.628	2.595
	0.010	9.074	6.701	5.739	5.205	4.862	4.620	4.441	4.302	4.191	4.100	3.815	3.665	3.507	3.341	3.255	3.210	3.165
	0.005	11.374	8.186	6.926	6.233	5.791	5.482	5.253	5.076	4.935	4.820	4.460	4.270	4.073	3.866	3.758	3.703	3.647
14	**0.05**	4.600	3.739	3.344	3.112	2.958	2.848	2.764	2.699	2.646	2.602	2.463	2.388	2.308	2.223	2.178	2.155	2.131
	0.025	6.298	4.857	4.242	3.892	3.663	3.501	3.380	3.285	3.209	3.147	2.949	2.844	2.732	2.614	2.552	2.520	2.487
	0.010	8.862	6.515	5.564	5.035	4.695	4.456	4.278	4.140	4.030	3.939	3.656	3.505	3.348	3.181	3.094	3.050	3.004
	0.005	11.060	7.922	6.680	5.998	5.562	5.257	5.031	4.857	4.717	4.603	4.247	4.059	3.862	3.655	3.547	3.492	3.436
15	**0.05**	4.543	3.682	3.287	3.056	2.901	2.790	2.707	2.641	2.588	2.544	2.403	2.328	2.247	2.160	2.114	2.090	2.066
	0.025	6.200	4.765	4.153	3.804	3.576	3.415	3.293	3.199	3.123	3.060	2.862	2.756	2.644	2.524	2.461	2.429	2.395
	0.010	8.683	6.359	5.417	4.893	4.556	4.318	4.142	4.004	3.895	3.805	3.522	3.372	3.214	3.047	2.959	2.914	2.868
	0.005	10.798	7.701	6.476	5.803	5.372	5.071	4.847	4.674	4.536	4.424	4.070	3.883	3.687	3.480	3.372	3.317	3.260
16	**0.05**	4.494	3.634	3.239	3.007	2.852	2.741	2.657	2.591	2.538	2.494	2.352	2.276	2.194	2.106	2.059	2.035	2.010
	0.025	6.115	4.687	4.077	3.729	3.502	3.341	3.219	3.125	3.049	2.986	2.788	2.681	2.568	2.447	2.383	2.350	2.316
	0.010	8.531	6.226	5.292	4.773	4.437	4.202	4.026	3.890	3.780	3.691	3.409	3.259	3.101	2.933	2.845	2.799	2.753
	0.005	10.576	7.514	6.303	5.638	5.212	4.913	4.692	4.521	4.384	4.272	3.920	3.734	3.539	3.332	3.224	3.168	3.111
17	**0.05**	4.451	3.592	3.197	2.965	2.810	2.699	2.614	2.548	2.494	2.450	2.308	2.230	2.148	2.058	2.011	1.986	1.960
	0.025	6.042	4.619	4.011	3.665	3.438	3.277	3.156	3.061	2.985	2.922	2.723	2.616	2.502	2.380	2.315	2.282	2.247
	0.010	8.400	6.112	5.185	4.669	4.336	4.101	3.927	3.791	3.682	3.593	3.312	3.162	3.003	2.835	2.746	2.700	2.653
	0.005	10.384	7.354	6.156	5.497	5.075	4.779	4.559	4.389	4.254	4.142	3.793	3.607	3.412	3.206	3.097	3.041	2.984
18	**0.05**	4.414	3.555	3.160	2.928	2.773	2.661	2.577	2.510	2.456	2.412	2.269	2.191	2.107	2.017	1.968	1.943	1.917
	0.025	5.978	4.560	3.954	3.608	3.382	3.221	3.100	3.005	2.929	2.866	2.667	2.559	2.445	2.321	2.256	2.222	2.187
	0.010	8.285	6.013	5.092	4.579	4.248	4.015	3.841	3.705	3.597	3.508	3.227	3.077	2.919	2.749	2.660	2.613	2.566
	0.005	10.218	7.215	6.028	5.375	4.956	4.663	4.445	4.276	4.141	4.030	3.683	3.498	3.303	3.096	2.987	2.931	2.873
20	**0.05**	4.351	3.493	3.098	2.866	2.711	2.599	2.514	2.447	2.393	2.348	2.203	2.124	2.039	1.946	1.896	1.870	1.843
	0.025	5.871	4.461	3.859	3.515	3.289	3.128	3.007	2.913	2.837	2.774	2.573	2.464	2.349	2.223	2.156	2.121	2.085
	0.010	8.096	5.849	4.938	4.431	4.103	3.871	3.699	3.564	3.457	3.368	3.088	2.938	2.778	2.608	2.517	2.470	2.421
	0.005	9.944	6.987	5.818	5.174	4.762	4.472	4.257	4.090	3.956	3.847	3.502	3.318	3.123	2.916	2.806	2.749	2.690
25	**0.05**	4.242	3.385	2.991	2.759	2.603	2.490	2.405	2.337	2.282	2.236	2.089	2.007	1.919	1.822	1.768	1.740	1.711
	0.025	5.686	4.291	3.694	3.353	3.129	2.969	2.848	2.753	2.677	2.613	2.411	2.300	2.182	2.052	1.981	1.944	1.906
	0.010	7.770	5.568	4.675	4.177	3.855	3.627	3.457	3.324	3.217	3.129	2.850	2.699	2.538	2.364	2.270	2.220	2.169
	0.005	9.475	6.598	5.462	4.835	4.433	4.150	3.939	3.776	3.645	3.537	3.196	3.013	2.819	2.609	2.496	2.437	2.377
30	**0.05**	4.171	3.316	2.922	2.690	2.534	2.421	2.334	2.266	2.211	2.165	2.015	1.932	1.841	1.740	1.683	1.654	1.622
	0.025	5.568	4.182	3.589	3.250	3.026	2.867	2.746	2.651	2.575	2.511	2.307	2.195	2.074	1.940	1.866	1.827	1.787
	0.010	7.562	5.390	4.510	4.018	3.699	3.473	3.305	3.173	3.067	2.979	2.700	2.549	2.386	2.208	2.111	2.060	2.006
	0.005	9.180	6.355	5.239	4.623	4.228	3.949	3.742	3.580	3.451	3.344	3.006	2.823	2.628	2.415	2.300	2.239	2.176
50	**0.05**	4.034	3.183	2.790	2.557	2.400	2.286	2.199	2.130	2.073	2.026	1.871	1.784	1.687	1.576	1.511	1.476	1.438
	0.025	5.340	3.975	3.390	3.054	2.833	2.674	2.553	2.458	2.381	2.317	2.109	1.993	1.866	1.721	1.639	1.594	1.545
	0.010	7.171	5.057	4.199	3.720	3.408	3.186	3.020	2.890	2.785	2.698	2.419	2.265	2.098	1.909	1.803	1.745	1.683
	0.005	8.626	5.902	4.826	4.232	3.849	3.579	3.376	3.219	3.092	2.988	2.653	2.470	2.272	2.050	1.925	1.858	1.786
100	**0.05**	3.936	3.087	2.696	2.463	2.305	2.191	2.103	2.032	1.975	1.927	1.768	1.676	1.573	1.450	1.376	1.333	1.283
	0.025	5.179	3.828	3.250	2.917	2.696	2.537	2.417	2.321	2.244	2.179	1.968	1.849	1.715	1.558	1.463	1.409	1.347
	0.010	6.895	4.824	3.984	3.513	3.206	2.988	2.823	2.694	2.590	2.503	2.223	2.067	1.893	1.692	1.572	1.504	1.427
	0.005	8.241	5.589	4.542	3.963	3.589	3.325	3.127	2.972	2.847	2.744	2.411	2.227	2.024	1.790	1.652	1.573	1.485
∞	**0.05**	3.841	2.996	2.605	2.372	2.214	2.099	2.010	1.938	1.880	1.831	1.666	1.571	1.459	1.318	1.221	1.155	1
	0.025	5.024	3.689	3.116	2.786	2.567	2.408	2.288	2.192	2.114	2.048	1.833	1.708	1.566	1.388	1.268	1.187	1
	0.010	6.635	4.605	3.782	3.319	3.017	2.802	2.639	2.511	2.407	2.321	2.039	1.878	1.696	1.473	1.325	1.225	1
	0.005	7.879	5.298	4.279	3.715	3.350	3.091	2.897	2.744	2.621	2.519	2.187	2.000	1.789	1.533	1.364	1.251	1