CHAPTER 12 FORM A

Name_____Course Number:_____ Section Number:_____

Directions: Answer the questions and solve the problems in the spaces provided, or attach paper. Circle the correct choice for each response set. Where appropriate, use computer assistance.

Provide an appropriate response.

1) Describe the null and alternative hypotheses for one–way ANOVA. Give an example.

2) When using statistical software packages, the critical value is typically not given. What method is used to determine whether you reject or fail to reject the null hypothesis?

3) Why do researchers concentrate on explaining an interaction in a two–way ANOVA rather then the effects of each factor separately?

4) What is a Tukey Honestly Significant Difference test? Why is it used?

Given below are the analysis of variance results from a Minitab display. Assume that you want to use a 0.05 significance level in testing the null hypothesis that the different samples come from populations with the same mean.

5) Identify the value of the test statistic.

Source	DF	SS	MS	F	p
Factor	3	13.500	4.500	5.17	0.011
Error	16	13.925	0.870		
Total	19	27.425			

A) 0.011 B) 13.500 C) 5.17 D) 4.500

6) What can you conclude about the equality of the population means?

Source	DF	SS	MS	F	p
Factor	3	30	10.00	1.6	0.264
Error	8	50	6.25		
Total	11	80			

A) Reject the null hypothesis since the p–value is greater than the significance level.

B) Accept the null hypothesis since the p–value is greater than the significance level.

C) Accept the null hypothesis since the p–value is less than the significance level.

D) Reject the null hypothesis since the p–value is less than the significance level.

Test the claim that the samples come from populations with the same mean. Assume that the populations are normally distributed with the same variance.

7) The data below represent the weight losses for people on three different exercise programs.

Exercise A	Exercise B	Exercise C
2.5	5.8	4.3
8.8	4.9	6.2
7.3	1.1	5.8
9.8	7.8	8.1
5.1	1.2	7.9

At the 1% significance level, does it appear that a difference exists in the true mean weight loss produced by the three exercise programs?

8) At the 0.025 significance level, test the claim that the three brands have the same mean if the following sample results have been obtained.

Brand A	Brand B	Brand C
32	27	22
34	24	25
37	33	32
33	30	22
36		21
39		

Provide an appropriate response.

9) At the same time each day, a researcher records the temperature in each of three greenhouses. The table shows the temperatures in degrees Fahrenheit recorded for one week.

Greenhouse #1	Greenhouse #2	Greenhouse #3
73	71	67
72	69	63
73	72	62
66	72	61
68	65	60
71	73	62
72	71	59

i) Use a 0.05 significance level to test the claim that the average temperature is the same in each greenhouse.
ii) How are the analysis of variance results affected if the same constant is added to every one of the original sample values?

Use the Minitab display to test the indicated claim.

10) A manager records the production output of three employees who each work on three different machines for three different days. The sample results are given below and the Minitab results follow.

		Employee		
		A	B	C
Machine	I	23, 27, 29	30, 27, 25	18, 20, 22
	II	25, 26, 24	24, 29, 26	19, 16, 14
	III	28, 25, 26	25, 27, 23	15, 11, 17

ANALYSIS OF VARIANCE ITEMS

SOURCE	DF	SS	MS
MACHINE	2	34.67	17.33
EMPLOYEE	2	504.67	252.33
INTERACTION	4	26.67	6.67
ERROR	18	98.00	5.44
TOTAL	26	664.00	

Assume that the number of items produced is not affected by an interaction between employee and machine. Using a 0.05 significance level, test the claim that the choice of employee has no effect on the number of items produced.

11) A manager records the production output of three employees who each work on three different machines for three different days. The sample results are given below and the Minitab results follow.

		Employee		
		A	B	C
	I	16, 18, 19	15, 17, 20	14, 18, 16
Machine	II	20, 27, 29	25, 28, 27	29, 28, 26
	III	15, 18, 17	16, 16, 19	13, 17, 16

ANALYSIS OF VARIANCE ITEMS

SOURCE	DF	SS	MS
MACHINE	2	588.74	294.37
EMPLOYEE	2	2.07	1.04
INTERACTION	4	15.48	3.87
ERROR	18	98.67	5.48
TOTAL	26	704.96	

Assume that the number of items produced is not affected by an interaction between employee and machine. Using a 0.05 significance level, test the claim that the machine has no effect on the number of items produced.

12) A manager records the production output of three employees who each work on three different machines for three different days. The sample results are given below and the Minitab results follow.

		Employee		
		A	B	C
	I	31, 34, 32	29, 23, 22	21, 20, 24
Machine	II	19, 26, 22	35, 33, 30	25, 19, 23
	III	21, 18, 26	20, 23, 24	36, 37, 31

ANALYSIS OF VARIANCE ITEMS

SOURCE	DF	SS	MS
MACHINE	2	1.19	.59
EMPLOYEE	2	5.85	2.93
INTERACTION	4	710.81	177.70
ERROR	18	160.00	8.89
TOTAL	26	877.85	

Using a 0.05 significance level, test the claim that the interaction between employee and machine has no effect on the number of items produced.

Use the data in the given table and the corresponding Minitab display to test the hypothesis.

13) The following table entries are the times in seconds for three different drivers racing on four different tracks. Assuming no effect from the interaction between driver and track, test the claim that the three drivers have the same mean time. Use a 0.05 significance level.

	Track 1	Track 2	Track 3	Track 4
Driver 1	72	70	68	71
Driver 2	74	71	66	72
Driver 3	76	69	64	70

Source	DF	SS	MS	F	p
Driver	2	2	1	0.33	0.729
Track	3	98.25	32.75	10.92	0.00763
Error	6	18	3		
Total	11	118.25			

14) The following table entries are test scores for males and females at different times of day. Assuming no effect from the interaction between gender and test time, test the claim that time of day does not affect test scores. Use a 0.05 significance level.

	6 a.m. – 9 a.m.	9 a.m. – 12 p.m.	12 p.m. – 3 p.m.	3 p.m. – 6 p.m.
Male	87	89	92	85
Female	72	84	94	89

Source	DF	SS	MS	F	p
Gender	1	24.5	24.5	0.6652	0.4745
Time	3	183	61	1.6561	0.3444
Error	3	110.5	36.83		
Total	7	318			

Provide an appropriate response.

15) The following results are from a statistics software package in which all of the F values and P–values are given. Is there a significant effect from the interaction? Should you test to see if there is a significant effect due to either A or B? If the answer is yes, is there a significant effect due to either A or B?

ANOVA Table

Source	DF	Sum squares	Mean square	F test	P–value
A	2	164.020	82.010	25.010	<.0001
B	4	230.786	57.697	18.002	<.0001
Interaction	8	80.879	10.110	3.154	.0031
Error	101	323.708	3.205		
Total	115	799.393			

16) The following data shows the yield, in bushels per acre, categorized according to three varieties of corn and three different soil conditions. Assume that yields are not affected by an interaction between variety and soil conditions, and test the null hypothesis that soil conditions have no effect on yield. Use a 0.05 significance level.

	Plot 1	Plot 2	Plot 3
Variety 1	156, 167, 170, 162	162, 160, 169, 168	145, 151, 148, 155
Variety 2	172, 176, 166, 179	179, 186, 160, 176	161, 162, 165, 170
Variety 3	175, 157, 179, 178	178, 170, 172, 174	169, 165, 170, 169

17) The following data contains task completion times, in minutes, categorized according to the gender of the machine operator and the machine used.

	Male	Female
Machine 1	15, 17	16, 17
Machine 2	14, 13	15, 13
Machine 3	16, 18	17, 19

The ANOVA results lead us to conclude that the completion times are not affected by an interaction between machine and gender, and the times are not affected by gender, but they are affected by the machine. Change the table entries so that there is an effect from the interaction between machine and gender.

18) The following data contains task completion times, in minutes, categorized according to the gender of the machine operator and the machine used.

	Male	Female
Machine 1	15, 17	16, 17
Machine 2	14, 13	15, 13
Machine 3	16, 18	17, 19

Assume that two–way ANOVA is used to analyze the data. How are the ANOVA results affected if the first sample value in the first cell is changed to 30 minutes?

19) **Provide an appropriate response.**
What advantage do boxplots offer to one–way ANOVA?

20) **Provide an appropriate response.**
Compare and contrast range tests and multiple comparison tests.

1) The null hypothesis for one–way ANOVA is that three or more population means are equal. The alternative hypothesis is that the population means are not all equal. Examples will vary. Possible example: Null hypothesis: mean mpg of three different car engines are the same; Alternative hypothesis: means are not all the same.
2) The decision to reject or fail to reject is based on P–values. If the P–value is less than or equal to the significance level, you reject the null hypothesis. Otherwise you fail to reject.
3) When an interaction occurs, the effect of one of the factors changes for the different categories of the other factor. Consequently, it makes sense to address how the two factors interact.
4) The Tukey Honestly Significant Difference test is one of several multiple comparison procedures designed to determine which mean or means are different from the others in ANOVA. It is used to find the source of a significant F test statistic.
5) C
6) B
7) Test statistic: F = 1.491. Critical value: F = 6.9266. P-value: p = 0.264.
   Fail to reject the claim of equal means. The data do not provide sufficient evidence to conclude that there is a difference in the true mean weight loss produced by the three exercise programs.
8) H_0 : $\mu 1 = \mu 2 = \mu 3$. H_1 : The means are not all equal. P-value: p = 0.00132.
   Test statistic: F = 12.1230. Critical value: F = 5.0959.
   Reject the null hypothesis. There is sufficient evidence to warrant rejection of the claim that the three brands have the same mean.
9) i) Reject the claim that the average temperature is the same in each greenhouse since $F = 24.2899 > F_{0.05}(2, 18) = 3.5546$.
   ii) The analysis of variance results are not affected.
10) H_0: There is no employee effect.
    H_1: There is an employee effect.
    Test statistic: F = 46.3842. Critical value: F = 3.5546.
    Reject the null hypothesis. The employee does appear to have an effect on the number of items produced.
11) H_0: There is no machine effect.
    H_1: There is a machine effect.
    Test statistic: F = 53.7172. Critical value: F = 3.5546.
    Reject the null hypothesis. There does appear to be a machine effect.
12) H_0: There is no interaction effect.
    H_1: There is an interaction effect.
    Test statistic: F = 19.9888. Critical value: F = 2.9277.
    Reject the null hypothesis. There does appear to be an interaction effect.
13) H_0: There is no driver effect. H_1: There is a driver effect. The P–value is 0.729, which is greater than 0.05. We fail to reject the null hypothesis; it appears that the driver does not affect the racing times.
14) H_0: There is no effect due to the time of day. H_1: There is an effect due to the time of day. The P–value is 0.3444, which is greater than 0.05. We fail to reject the null hypothesis; it appears that the scores are not affected by time of day.
15) Since P = 0.0031 for the interaction, you reject the null hypothesis that there is no effect due to the interaction. No, it is not appropriate to see if there is a significant effect due to either A or B. Do not consider the effects of either factor without considering the effects of the other.

16) H_0: Soil conditions have no effect on yield. H_1: Soil conditions have an effect on yield. The test statistic is F = 9.232917, and the corresponding P–value is 0.00088. Because the P–value is less than 0.05, we reject the null hypothesis that soil condition has no effect on yield. It appears that the soil condition does affect the yield.
17) The following table is one example of entries that produce an effect from the interaction between machine and gender.

	Male	Female
Machine 1	15, 17	16, 17
Machine 2	14, 13	12, 10
Machine 3	12, 10	17, 19

18) If the first sample value is changed to 30 minutes, the ANOVA results are changed. The null hypothesis of no interaction between machine and gender is still not rejected. The null hypothesis of no effect from gender is still not rejected. However, the null hypothesis of no effect from machine is now accepted instead of rejected.
19) Boxplots offer an informal method to observe which data sets are different from the others, after a significant F test. A boxplot substantially to the left or right of the others suggests that the mean of its data set could be different from the means of the other data sets.
20) Range tests and multiple comparison tests are both used as formal methods to determine which mean or means of data sets are different from the others, after a significant F test. Range tests work with subsets of means to identify those that are not significantly different from each other. Multiple comparison tests work with pairs of means to tease out differences, while controlling for the rising significance level of the pair–wise tests.