**1-Way ANOVA Problems**

Q.1. An experiment was conducted with four treatment groups. The table below gives the number of observations for each treatment and the treatment means. A partial ANOVA table is also furnished. Use this information to answer the questions.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | A | B | C | D |
| Sa. Size | 5 | 4 | 3 | 4 |
| Mean | 56.900 | 55.775 | 53.233 | 51.125 |

Source DF Mean Sq.

Treatment \_\_\_\_\_\_ 28.559

Error \_\_\_\_\_\_ 7.880

Total \_\_\_\_\_\_

1. Complete the ANOVA table by providing the correct values for the degrees of freedom.

b) Is there significant evidence the population means for the four treatments are not all equal based on =0.05 significance level?

Test Statistic \_\_\_\_\_\_\_\_\_\_\_\_

Rejection Region \_\_\_\_\_\_\_\_\_\_\_\_

Conclusion: i) Fail to conclude means differ

ii) Conclude Means differ

**Q.2. A study is conducted to compare golf ball distances among 4 brands of golf balls. A mechanical driver is set up and hits 12 balls of each brand, and the distance travelled (meters) is measured. The F-test determines that there are differences among the brands. A follow-up comparison based on Tukey’s method yields the following table:**

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**Clearly state what can be said of all pairs of brands at the 0.05 experimentwise error rate.**

**Brands:**

**1 vs 2: 1 vs 3: 1 vs 4:**

1. **vs 3: 2 vs 4: 3 vs 4:**

Q.3. A comparison of 3 drugs was conducted to test whether there are any differences among their effects of relieving pain. The mean relief ratings and standard deviations are given below. Each drug was assigned at random to 10 subjects in a completely randomized design (n1=n2=n3=10).

|  |  |  |
| --- | --- | --- |
| **Drug** | **Mean** | **SD** |
| **1** | **8** | **1** |
| **2** | **10** | **2** |
| **3** | **12** | **2** |

H0: Not all i are equal

* + Between Drug Sum of Squares and degrees of freedom:
  + Within Drug Sum of Squares and degrees of freedom:
  + F-Statistic \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Reject H0 (at =0.05 level) if F-statistic is **Above / Below \_\_\_\_\_\_\_\_\_\_\_\_**

**Q.4. Ford wants to compare mean assembly times for Explorer’s at their 3 assembly plants. They observe random samples of 10 cars at each plant, and obtain the following summary statistics on assembly times (in minutes):**

|  |  |  |
| --- | --- | --- |
| **Plant** | **Mean** | **Std. Dev.** |
| **Atlanta** | **180** | **12** |
| **Chicago** | **185** | **10** |
| **Detroit** | **175** | **9** |

1. **Compute the between plant (Treatment) sum of squares and its degrees of freedom**
2. **Compute the within plant (Error) sum of squares and its degrees of freedom**
3. **Compute the test statistic**
4. **Conclude that the population means differ ( if the test statistic is \_\_\_\_\_\_\_\_\_\_**

Q.5. A study compared the deuterium/hydrogen (D/H) ratio at methyl for 5 variety of wines grown in north Xinjiang in 2009. There were samples of 4 wines from each variety. The means and standard deviations for the D/H ratios are given below. Complete the Analysis of Variance Table, and test for difference among Variety population means. 





Q.6. A study was conducted, comparing 5 treatments of khat, given to female rats for sexual motivation. There were n=6 rats per treatment, and MSE = s2 = 6.0 for the response: time spent in the incentive zone. Use Tukey’s HSD and Bonferroni’s method to compare all pairs of treatment means. State which pairs of treatment have significantly different means.



Tukey’s W: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Bonferroni’s B: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Q.7. Random samples of n1 = n2 =n3 = 12 players each from 3 men’s professional leagues were selected. The leagues were: 1=English Football (EPL), 2=North American Hockey (NHL), 3=American Basketball (NBA). Body Mass Indices were obtained for all N = 36 players sampled. Use the Kruskal-Wallis test to determine whether population medians differ among the leagues. H0: All population medians are equal.



Test Statistic: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Rejection Region: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Reject H0? **Yes No**

Q.8. For a given set of data for the Completely Randomized Design, which statement best describes the relation between Tukey’s *W* and Bonferroni’s *B*:

i) *W* will always be larger than *B* ii) *W* will always be smaller than *B* iii) It depends on the dataset.

Q.9. An automobile rental company is interested in comparing the mean highway mileages among 3 models of cars. They sample 10 cars of each model, and measure the mileage on each car (Y, in miles per gallon), based on a highway drive of a fixed distance. The results (mean and standard deviation) are given below. Complete the Analysis of Variance table.





Q.10. A 1-Way ANOVA model is fit comparing the weights of 4 natural fiber fabrics of common dimensions. There were 15 replicates for each of the 4 fibers (cotton, linen, silk, and wool). The sample means and error sum of squares are given below. Compute Tukey’s Honest Significant Difference (*W*), and identify which fibers differ significantly.



**Q.11.:**  An experimenter is interested in comparing the mean potencies among 3 formulations of insecticides. She sets up 18 containers, each with 100 specimens. He then randomly assigns the insecticides to the containers, so that each insecticide is used in 6 containers. He measures the numbers of specimens dying for each container. The results are given below.



p.11.a. Compute the treatment (formulation) sum of squares and degrees of freedom.

p.11.b. Compute the error sum of squares and degrees of freedom.

p.11.c. Use Bonferroni’s method to obtain simultaneous 95% Confidence Intervals for differences between population means among the 3 formulations.

*B*ij =

p.11.d. Show your results by drawing lines that join means that are not significantly different. **1 2 3**

**Q.12.** A study compared life-spans among 3 species of plants in lab settings. The researchers determined that the life-spans followed distributions that were clearly not normal. They planted 10 plants from each variety, and measured the time until the plants demonstrated a particular amount of wilting. The life-spans and their ranks are given below. (Conduct the test described below at  = 0.05 significance level)



p.12.a. Compute the Kruskal-Wallis statistic for testing H0: Species median life-spans are equal.

p.12.b. **Reject** / **Do not Reject**  H0 because Test statistic is **Larger** / **Smaller** than \_\_\_\_\_\_\_\_\_\_\_\_\_\_

Q.13. A researcher wants to compare the effects of 3 advertisements on consumers’ attitude toward a new consumer product. He obtains 60 consumers, and randomly assigns 20 to each of the advertisements (each consumer is only exposed to one of the ads). After viewing the advertisement, each person is asked to rate his/her feelings toward the product on a visual analogue scale, where higher scores are more favorable. The results (means, standard deviations, and sample sizes) are given below.



p.13.a. Compute the Between treatment sum of squares and its corresponding degrees of freedom

Between Treatment Sum of Squares \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Degrees of Freedom \_\_\_\_\_\_\_\_\_\_\_\_

p.13.b. Compute the Within treatment sum of squares and its corresponding degrees of freedom

Within Treatment Sum of Squares \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Degrees of Freedom \_\_\_\_\_\_\_\_\_\_\_\_

p.13.c. Test H0: No differences among the true ad means () versus:

vs HA: Differences exist among true ad means (Not all i are equal) (significance level)

p.13.c.i. Test Statistic:

p.13.c.ii. Clearly state Rejection Region: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Q.14. A scientist is interested in comparing the duration of lifetimes of insects exposed to 4 varieties of pesticides. He runs a Completely Randomized Design with 10 insects per variety of pesticide (thus, a total of N=40). Due to some outliers, he decides to use the Kruskal-Wallis test. You are given the following partial results (Hint: 1+2+…+n = n(n+1)/2).

p.15.a. Compute T4

p.7.a. Compute T4 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



p.14.b. Test H0: No differences among the 4 varieties’ medians versus HA: Differences exist at  = 0.05 significance level.

p.14.b.i. Compute the test statistic (there were no “ties” among the data)

Test Statistic = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

p.14.b.ii. Clearly state the rejection region \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

p.14.b.iii. The P-value will be (circle one) **> 0.05 < 0.05 Need More Information**

Q.15. Researchers wished to compare the yields (in pounds) of 3 varieties of 4-year old orange trees in an orchard. They obtain random samples of 10 trees of each variety from the orchard and obtain the following results. Due to the skew of the distributions, they choose to use the appropriate non-parametric test.



* Give the test statistic for testing H0: Variety Medians all equal versus HA: Variety Means not all equal
* We reject H0 at the =0.05 significance level if it falls in what range \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* The P-value for this test is **greater than / less than**  0.05 (circle correct answer).

Q.16. A study is conducted to compare 2 methods of teaching foreign language to children (independent samples). One analyst uses a 2-sided test of H0:  = 0 versus HA:  ≠ 0 based on the independent sample t-test, assuming equal variances. The other analyst uses a 1-Way Analysis of Variance F-test to test H0:  versus HA: ≠. They use the same computing software, so there are no issues due to rounding. Choose the correct answer:

* The p-value from the t-test will always be higher than the p-value from the F-test
* The p-value from the t-test will always be lower than the p-value from the F-test
* The p-value from the t-test will always be the same as the p-value from the F-test
* None of the above

Q.17. A scientist wants to compare the effects of 3 treatments on behavior in mice. The treatments are:

1) Placebo, 2) Drug A, 3) Drug B. The experiment is balanced. The researcher is interested in 2 specific contrasts: Contrast 1: Placebo (1) versus Average of Drug A (2) and Drug B (3), Contrast 2: Drug A versus B. Give the two contrasts (note there are many ways of writing these, but they share a specific pattern):



Q.18. For a balanced 1-Way ANOVA, with t > 2 groups, when making all pairwise comparisons, Tukey’s W will always be smaller than Bonferroni’s B.

**TRUE** or **FALSE**

Q.19. A 1-Way ANOVA is conducted, comparing clarity of t = 3 methods if meniscal repair. A sample of N=18 subjects was obtained and assigned at random such that n1 = 6 received method 1, n2 = 6 received method 2, and n3 = 6 received method 3. The response was Y = Displacement (mm). Complete the following table to test:





Do we reject the null hypothesis? **Yes** or **No** Is the P-value **< 0.05** or **> 0.05**

Q.20. An experiment was conducted to compare wine color intensity (Y) among t = 6 types of wine barrels. There 9 replicates for each of the wine barrel types. The Mean Square Error (MSW) was 1.04.

p.20.a. Compute Tukey’s Honest Significant Difference for Comparing all pairs of wine barrel types

Conclude 

p.20.b. Compute Bonferroni’s Minimum Significant Difference for Comparing all pairs of wine barrel types

Conclude 

Q.21. A scientist wants to compare the effects of 3 treatments on behavior in mice. The treatments are:

1) Placebo, 2) Drug A, 3) Drug B. The experiment is balanced. The researcher is interested in 2 specific contrasts: Contrast 1: Placebo (1) versus Average of Drug A (2) and Drug B (3), Contrast 2: Drug A versus B. Give the two contrasts (note there are many ways of writing these, but they share a specific pattern):



Q.22. A study is conducted to compare 2 methods of teaching foreign language to children (independent samples). One analyst uses a 2-sided test of H0:  = 0 versus HA:  ≠ 0 based on the independent sample t-test, assuming equal variances. The other analyst uses a 1-Way Analysis of Variance F-test to test H0:  versus HA: ≠. They use the same computing software, so there are no issues due to rounding. Choose the correct answer:

* The p-value from the t-test will always be higher than the p-value from the F-test
* The p-value from the t-test will always be lower than the p-value from the F-test
* The p-value from the t-test will always be the same as the p-value from the F-test
* None of the above

Q.23. For a balanced 1-Way ANOVA, with t > 2 groups, when making all pairwise comparisons, Tukey’s W will always be smaller than Bonferroni’s B.

**TRUE** or **FALSE**

Q.24. A 1-Way ANOVA is conducted, comparing clarity of t = 3 methods if meniscal repair. A sample of N=18 subjects was obtained and assigned at random such that n1 = 6 received method 1, n2 = 6 received method 2, and n3 = 6 received method 3. The response was Y = Displacement (mm). Complete the following table to test:





Do we reject the null hypothesis? **Yes** or **No** Is the P-value **< 0.05** or **> 0.05**

Q.25. An experiment was conducted to compare wine color intensity (Y) among t = 6 types of wine barrels. There 9 replicates for each of the wine barrel types. The Mean Square Error (MSW) was 1.04.

p.25.a. Compute Tukey’s Honest Significant Difference for Comparing all pairs of wine barrel types

Conclude 

p.25.b. Compute Bonferroni’s Minimum Significant Difference for Comparing all pairs of wine barrel types

Conclude 