MTH 324, Lab #9, Fall 2022          Name ________________________________________

**Instructions**: Follow along with the tutorial portion of the lab. Replicate the code examples in R on your own, along with the demonstration. Then use those examples as a model to answer the questions/perform the tasks that follow. Copy and paste the results of your code to answer questions where directed. Submit your response file and the code used (both for the tutorial and part two). Your code file and your lab response file should each include your name inside.

**Non-parametric tests**

In this lab, we are going to review how to conduct non-parametric tests that we are coving in class. In some cases, we'll be looking ahead to topics will be covering in the next week due to the Thanksgiving holiday. We'll use the examples I'll discuss in class.

Let's start with the Wilcoxon signed rank test.  This is a one-sample test that compares the data to given mean or median.

```
x<-c(494.6, 510.8, 487.5, 493.2, 502.6, 485.0, 495.9, 498.2, 501.6, 497.3, 492.0,
     504.3, 499.2, 493.5, 505.8)
wilcox.test(x, mu=500)
```

First, enter your data in vector form (or pull it out of a column of a dataframe). The function wilcox.test() defaults to compare to 0, or set mu equal to the value in your null hypothesis.

The output of the test prints in text.

```
        Wilcoxon signed rank exact test

data:  x
V = 35, p-value = 0.1688
alternative hypothesis: true location is not equal to 500
```

If we want to do a two-sample Wilcoxon rank-sum test, we use the same function, but put the data in two separate vectors. Likewise, you can specify the null mean if it's not zero, and indicate whether the test is meant to be paired or not.

```
x<-c(8.2, 9.4, 9.6, 9.7, 10.0, 14.5, 15.2, 16.1, 17.6, 21.5)
y<-c(4.2, 5.2, 5.8, 6.4, 7.0, 7.3, 10.1, 11.2, 11.3, 11.5)

wilcox.test(x,y,paired=FALSE)
```

The output prints the results of the test.

```
        Wilcoxon rank sum exact test

data:  x and y
W = 80, p-value = 0.02323
alternative hypothesis: true location shift is not equal to 0
```

The non-parametric equivalent of an ANOVA test is Kruskal-Wallis. We'll test the mtcars data as we did when we discussed ANOVA originally.

```
data(mtcars)
mtcars$cyl<-factor(mtcars$cyl)
kruskal.test(mpg ~ cyl, data = mtcars)
```

The syntax for the kruskal.test() is exactly the same as the aov() test. The numerical measurement comes first and the factor variable comes second.

```
        Kruskal-Wallis rank sum test

data:  mpg by cyl
Kruskal-Wallis chi-squared = 25.746, df = 2, p-value = 2.566e-06
```

The test produces the p-value, which is what we need to interpret it. But we don't have a traditional ANOVA table since the procedure for calculating it is significantly different (we'll discuss in an upcoming lecture).

As with traditional ANOVA, once we reject the null hypothesis that all means are the same, we want to look deeper into the variables to determine which levels produce differences. To accomplish this with non-parametric tests, we conduct pairwise Wilcoxon tests.

```
pairwise.wilcox.test(mtcars$mpg, mtcars$cyl, p.adjust.method = "BH")
```

When we conduct multiple tests, we have more opportunity to make a Type I error, so to reduce that risk, we can adjust the P-value we use in various ways to account for multiple tests. Check the documentation for the test for the different kinds of methods used here.

```
        Pairwise comparisons using Wilcoxon rank sum test with continuity correction

data:  mtcars$mpg and mtcars$cyl

  4       6
6 0.001   -
8 8.3e-05 0.001

P value adjustment method: BH
```

This test produces a table of p-values for each of the paired tests. This result concurs with our previous analysis that all the means are different.

There is an alternative to the Kruskal-Wallis test, and that is Friedman's ANOVA. This is also a non-parametric test, but it is used in a more limited context. It's designed for a repeated measures analysis (like a paired t-test, but more than two conditions).

The data is submitted in a dataframe.

```r
data <- data.frame(person = rep(1:5, each=4),
                   drug = rep(c(1, 2, 3, 4), times=5),
                   score = c(30, 28, 16, 34, 14, 18, 10, 22, 24, 20,
                             18, 30, 38, 34, 20, 44, 26, 28, 14, 30))
friedman.test(y=data$score, groups=data$drug, blocks=data$person)
```

Each person (5 of them) is each receiving 4 drugs, and the final column are the measurements of the response variable.

```
        Friedman rank sum test

data:  data$score, data$drug and data$person
Friedman chi-squared = 13.56, df = 3, p-value = 0.00357
```

Recall that when we first looked at two-way ANOVA, we had problems that modeled this design with one observation per condition.

**Tasks**

1. Both a gravimetric and a spectrophotometric method are under consideration for determining phosphate content of a particular material. Twelve samples of the material are obtained, each is split in half, and a determination is made on each half using one of the two methods, resulting in the following data:

| **Sample** | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Gravimetric** | 54.7 | 58.5 | 66.8 | 46.1 |
| **Spectrophotometric** | 55.0 | 55.7 | 62.9 | 45.5 |
| **Sample** | 5 | 6 | 7 | 8 |
| **Gravimetric** | 52.3 | 74.3 | 92.5 | 40.2 |
| **Spectrophotometric** | 51.1 | 75.4 | 89.6 | 38.4 |
| **Sample** | 9 | 10 | 11 | 12 |
| **Gravimetric** | 87.3 | 74.8 | 63.2 | 68.5 |
| **Spectrophotometric** | 86.8 | 72.5 | 62.3 | 66.0 |

Use the Wilcoxon test to decide whether one technique gives on average a different value than the other technique for this type of material. Check your assumptions for the test. Paste your results below and interpret them in context. Be sure to state your null and alternative hypotheses.

2. An article reports the following data on burn time (hours) for samples of oak and pine. Test at level .05 to see whether there is any difference in true average burn time for the two types of wood. Check your assumptions. Be sure to state your null and alternative hypotheses. Paste your results below and clearly state your conclusion in the context of the problem.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Oak** | 1.72 | .67 | 1.55 | 1.56 | 1.42 | 1.23 | 1.77 | .48 |
| **Pine** | .98 | 1.40 | 1.33 | 1.52 | .73 | 1.20 | | |

3. The accompanying data on cortisol level was reported in a research article. Experimental subjects were pregnant women whose babies were delivered between 38 and 42 weeks gestation. Group 1 individuals elected to deliver by Caesarean section before labor onset, group 2 delivered by emergency Caesarean during induced labor, and group 3 individuals experienced spontaneous labor. Use the Kruskal-Wallis test at level .05 to test for equality of the three population means. Check your assumptions. Be sure to state your null and alternative hypotheses. Paste your results below and clearly state your conclusion in the context of the problem.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Group 1** | 262 | 307 | 211 | 323 | 454 | 339 |
| | 304 | 154 | 287 | 356 | | |
| **Group 2** | 465 | 501 | 455 | 355 | 468 | 362 |
| **Group 3** | 343 | 772 | 207 | 1048 | 838 | 687 |

4. In an experiment to study the way in which different anesthetics affect plasma epinephrine concentration, ten dogs were selected and concentration was measured while they were under the influence of the anesthetics isoflurane, halothane, and cyclopropane. Test at level .05 to see whether there is an anesthetic effect on concentration. Use Friedman's ANOVA to conduct the analysis. How does the result differ (if at all) from using Kruskal-Wallis? Check your assumptions. Be sure to state your null and alternative hypotheses. Paste your results below and clearly state your conclusion in the context of the problem.

| | | | Dog | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| **Isoflurane** | .28 | .51 | 1.00 | .39 | .29 |
| **Halothane** | .30 | .39 | .63 | .38 | .21 |
| **Cyclopropane** | 1.07 | 1.35 | .69 | .28 | 1.24 |
| | **6** | **7** | **8** | **9** | **10** |
| **Isoflurane** | .36 | .32 | .69 | .17 | .33 |
| **Halothane** | .88 | .39 | .51 | .32 | .42 |
| **Cyclopropane** | 1.53 | .49 | .56 | 1.02 | .30 |

References:


1. Discovering Statistics Using R. Andy Field, Jeremy Miles, Zoe Field. (2012)
2. https://book.stat420.org/applied_statistics.pdf
3. https://scholarworks.montana.edu/xmlui/handle/1/2999
4. https://www.rstudio.com/resources/cheatsheets/
5. http://www.r-tutor.com/elementary-statistics/non-parametric-methods/wilcoxon-signed-rank-test