ANOVA Practice Problems

1. Suppose that a random sample of $n = 5$ was selected from the vineyard properties for sale in Sonoma County, California, in each of three years. The following data are consistent with summary information on price per acre for disease-resistant grape vineyards in Sonoma County. Carry out an ANOVA to determine whether there is evidence to support the claim that the mean price per acre for vineyard land in Sonoma County was not the same for each of the three years considered. Test at the 0.05 level and at the 0.01 level.

1996:	30000	34000	36000	38000	40000
1997:	30000	35000	37000	38000	40000
1998:	40000	41000	43000	44000	50000

2. The following data on calcium content of wheat are consistent with summary quantities that appeared in the article "Mineral Contents of Cereal Grains as Affected by Storage and Insect Infestation" (*Journal of Stored Products Research* [1992]). Four different storage times were considered. Is there sufficient evidence to conclude that the mean calcium content is not the same for the four different storage times? Test the appropriate hypotheses at the 0.05 level.

Storage Time	**Observations**					
0 months	58.75	57.94	58.91	56.85	55.21	57.30
1 month	58.87	56.43	56.51	57.67	59.75	58.48
2 months	59.13	60.38	58.01	59.95	59.51	60.34
3 months	62.32	58.76	60.03	59.36	59.61	61.95

3. Use the data below, showing a summary of highway gas mileage for several observations, to decide if the average highway gas mileage is the same for midsize cars, SUV's, and pickup trucks. Test the appropriate hypotheses at the $\alpha = 0.01$ level.

	n	***Mean***	***Std. Dev.***
Midsize	31	25.8	2.56
SUV's	31	22.68	3.67
Pickups	14	21.29	2.76

4. To examine the effects of pets and friends in stressful situations, researchers recruited 45 people to participate in an experiment. Fifteen of the subjects were randomly assigned to each of three groups to perform a stressful task alone (control group), with a good friend present, or with their dog present. Each subject's mean heart rate during the task was recorded. Test the appropriate hypotheses at the $\alpha = 0.05$ level to decide if the mean heart rate differs between the groups.

	n	***Mean***	***Std. Dev.***
Control	15	82.52	9.24
Pets	15	73.48	9.97
Friends	15	91.325	8.34

5. An investigation carried out to study the toxic effects of mercury was described in the article "Comparative Responses of the Action of Different Mercury Compounds on Barley" (*International Journal of Environmental Studies* [1983]). Ten different concentrations of mercury were compared with respect to their effects on average dry weight (per 100 seven-day-old seedlings). The basic experiment was replicated 4 times for a total of 40 observations. The article reported an ANOVA F statistic of 1.895. Using a significance level of 0.05, test the hypothesis that the true mean dry weight is the same for all 10 concentration levels.

6. High productivity and carbohydrate storage ability of the Jerusalem artichoke make it a promising agricultural crop. The article "Leaf Gas Exchange and Tuber Yield in Jerusalem Artichoke Cultivars" (*Field Crops Research* [1991]) reported on various plant characteristics. Consider the following data on chlorophyll concentration (in grams per square meter) for four varieties of Jerusalem artichoke:

	n	***Mean***	***Std. Dev.***
Variety 1	5	0.3	0.12
Variety 2	5	0.24	0.089
Variety 3	4	0.41	0.1
Variety 4	6	0.33	0.054

Do the data suggest that true average chlorophyll concentration depends on the variety? State and test the appropriate hypotheses at a level of 0.05.

Solutions

1. ANOVA Test

H_0:	$\mu_{1996} = \mu_{1997} = \mu_{1998}$
H_a:	H_0 is not true
Test Stat:	ANOVA: $F = 6.834$
P-Value:	0.01044
Conclude:	At the 0.01 level, there is not enough evidence to reject the null hypothesis. We cannot conclude that the mean price per acre was different in these years.
	At the 0.05 level, we do reject the null hypothesis and say that the mean price per acre was not the same in each year.
Validity:	Normal populations with ≈ equal variances must be assumed.

2. ANOVA Test

H_0:	$\mu_0 = \mu_1 = \mu_2 = \mu_3$
H_a:	H_0 is not true
Test Stat:	ANOVA: $F = 6.512$
P-Value:	0.003
Conclude:	We reject the null hypothesis. We conclude that the mean calcium content is not the same for the four different storage times.
Validity:	Normal populations with ≈ equal variances must be assumed.

3. ANOVA Program

H_0:	$\mu_M = \mu_S = \mu_P$
H_a:	H_0 is not true
Test Stat:	ANOVA: $F = 13.055$
P-Value:	0.0000142
Conclude:	We reject the null hypothesis. We conclude that the mean highway gas mileage is not the same for the three types of vehicles.
Validity:	Normal populations with ≈ equal variances must be assumed.

4. ANOVA Program

H_0:	$\mu_C = \mu_P = \mu_F$
H_a:	H_0 is not true
Test Stat:	ANOVA: $F = 14.08$
P-Value:	0.000021
Conclude:	We reject the null hypothesis. We conclude that the mean heart rate is not the same for each of the three groups.
Validity:	Normal populations with ≈ equal variances must be assumed.

5. First of all note that $df_1 = 10 - 1 = 9$ and $df_2 = 40 - 10 = 30$. So we can find the P-value for this scenario by calculating $Fcdf(1.895, 1e99, 9, 30) = 0.0916$. So the hypothesis test would look as follows:

H_0:	$\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = \mu_8 = \mu_9 = \mu_{10}$
H_a:	H_0 is not true
Test Stat:	ANOVA: $F = 1.895$
P-Value:	0.0916
Conclude:	There is not enough evidence to reject the null hypothesis. We cannot conclude that the mean dry weight is not the same for each of the concentration levels.
Validity:	Normal populations with ≈ equal variances must be assumed.

6. ANOVA Program

H_0:	$\mu_1 = \mu_2 = \mu_3 = \mu_4$
H_a:	H_0 is not true
Test Stat:	ANOVA: $F = 2.6566$
P-Value:	0.0836
Conclude:	There is not enough evidence to reject the null hypothesis. We cannot conclude that the mean chlorophyll concentration depends on the variety.
Validity:	Normal populations with ≈ equal variances must be assumed.