ANOVA HW SOLUTION

Commonly used z values: 95% =1.96, 90% =1.645, 99% = 2.576

Q1. At what age do babies learn to crawl? Does it depend on the time of the year that babies are born? Data were collected from parents who brought their babies into the University of Denver's Infant Study Center to participate in one of a number of experiments between 1988 and 1991. Parents reported the birth month and the age in which their child was first able to creep or crawl a distance of four feet within one minute. The resulting data were grouped by month of birth: January, May, and September.

Birth month	**Mean**	**Std. dev.**	***n***
January	29.84	7.08	32
May	28.58	8.07	27
September	33.83	6.93	38

Crawling age is given in weeks. Assume that the data can be considered as three independent random samples, one from each of the populations comprised of babies born in that particular month, and that the populations of crawling ages have normal distributions.

Test the hypothesis of no difference among the months. Show all of your work.

ANOVA

Source	df	Sums of squares	Mean square	*F*-ratio	*P*
Group	2	505.26	252.63	4.73	.01-.025
Error	94	5024.3	53.45		
Total					

Q2. Changes in serum cholesterol (mg/100 ml) following treatments with 1 of 3 pharmaceuticals were measured in 15 rabbits

1	2	3
15	16	17
22	20	13
17	19	16
16	22	18
16	25	12

Are the products equal in mean effects?

SSy 171.6 SSt 68.8 SSe 102.8
MSt 68.8/2=34.4 mse 102.8/12=8.567
F = 34.4/8.567 = 4.015 >f.05,2,12 =3.89

Q3. Four levels of planting density were studied: 12,000, 16,000, 20,000, and 24,000 plants per acre to determine their effects on crop yield. The experimenters had 12 acres available for the study, and three acres were assigned at random to each of the planting densities. The data follow.

Plants (per acre)	**Yield (bushels per acre)**
12,000	150.1 113.0 118.4
16,000	166.9 120.7 135.2
20,000	165.3 130.1 139.6
24,000	134.7 138.4 156.1

Assume the data are four independent SRSs, one from each of the four populations of planting densities, and that the distribution of the yields is normal.
Is the planting density different? Test the hypothesis and show all the results with p value.

ANOVA

Source	DF	SS	MS	F	P
Density	3	589	196.3	0.55	.05
Error	8	2848	356		
Total					

Q4. In a study of lettuce growth, 36 seedlings were randomly allocated to receive either high or low light and to be grown in either a standard nutrient solution or one containing extra nitrogen. After 16 days of growth, the lettuce plants were harvested the dry weight of the leaves were determined for each plant. The accompanying table shows mean leaf dry weigh (g) of the nine plants in each treatment group.

	Nutrient Solution	
	Standard	*Extra Nitrogen*
Low Light	2.16	3.09
High Light	3.26	4.48

For these data, SS (nutrient solution) = 10.4006, SS (light) = 13.9502, SS (interaction) = 0.1892, and SS (within) = 11.1392.

a) Construct the ANOVA table.
b) Carry out an F test for, light and interaction; use $\alpha = .05$
c) Test the null hypothesis that nutrient solution has no effect on weight. Use $\alpha = .01$

ANOVA

Source	DF	SS	MS	F	P
Light	1	13.95	13.95	39.86	
Solution	1	10.4	10.4	29.8	
Interaction	1	0.19	0.19	0.54	
Error	32	11.14	0.35		
Total	35				

Q5. The following ANOVA table is partially completed

Source	df	SS	MS
Between groups	3		45
Within groups	12	337	
Total		472	

a) complete the table
b) How many groups were there in the study
c) How many total observations were there in the study

A. We find SS(between) by subtraction: SS(between) = 472 - 337 = 135.
We find df(total) by adding df(between) and df(within): df(total) = 3 + 12 = 15.
We find MS(within) by division: MS(within) = SS(within)/df(within) = 337/12 = 28.08.

The completed table is

Source	df	SS	MS
Between groups	3	135	45
Within groups	12	337	28.08
Total	15	472	

(b) We have df(between) = 3 = I - 1, so I = 4.

(c) We have df(total) = 15 = n* - 1, so n* = 16.

Q6. An experiment was conducted to determine the effects of sex and stage of gestation on the activity of fructose-1-phosphate aldolase (n-moles substrate metabolized/min/mg protein) in the upper third of the intestinal mucosa of calves taken by Cesarean section from 18 Holstein heifers undergoing first gestations. The data are given below:

Sex (A)	90 d	Stage of 180 d	Gestation 270 d	(B) Total
Males	22.2	35.1	84.6	
	25.4	47.6	108.4	
	38.5	84.9	134.6	
subtotal	86.1	167.6	327.6	581.3
Females	40.5	44.2	81.5	
	76.2	58.8	81.9	
	104.6	125.0	110.7	
subtotal	221.3	228.0	274.1	723.4
Total	307.4	395.6	601.7	1304.7

Construct the ANOVA table.
Test hypothesis for sex, gestation and interaction at $\alpha = 0.05$

ANOVA

Source	DF	SS	MS	F	P
Sex	1	1122	1122	1.48	
Gestation	2	7604	3802	5.03	
Interaction	2	3010	1505	1.99	
Error	12	9075	756.3		
Total	17	20810			

Q7. The following data is from a study of mutual effects of the air pollutants ozone and sulfur dioxide on Blue Lake snap beans:

SS (ozone), present or absent = 0.696
SS (sulfur), present or absent = 0.492
SS (interaction) = 0.166
SS (within) = 0.275
Number of obs. = 12

a) Construct the ANOVA table.
b) Carry out an F test for interaction; use $\alpha = .05$.
c) Test the null hypothesis that ozone has no effect on yield; use $\alpha = .05$

A.

Source	df	SS	MS
Between ozone levels	1	0.696	0.696
Between sulfur levels	1	0.492	0.492
Interaction	1	0.166	0.166
Within groups	8	0.275	0.034
Total	11	1.629	

(b) $F_I = .166/.034 = 4.88$. With df = 1 and 8, Table 10 gives $F_{.10} = 3.46$ and $F_{.05} = 5.32$. Thus, $.05 < P < .10$ and we do not reject H_0. There is insufficient evidence ($.05 < P < .10$) to conclude that there is an interaction present.

(c) $F_S = .696/.034 = 20.47$. With df = 1 and 8, Table 10 gives $F_{.01} = 11.26$ and $F_{.001} = 25.41$. Thus, $.001 < P < .01$, so we reject H_0. There is strong evidence ($.001 < P < .01$) to conclude that ozone affects yield.