

and one approach was used for each group. The dollar amounts of the resulting contributions are shown in the following table.

Approach	Contributions (in \$)							
1	1000	1500	1200	1800	1600	1100	1000	1250
2	1500	1800	2000	1200	2000	1700	1800	1900
3	900	1000	1200	1500	1200	1550	1000	1100

- (a) Do the data indicate that there is a difference in results obtained from the three different approaches? Use $\alpha = 0.05$.
- (b) Analyze the residuals from this experiment and comment on model adequacy.

3.20 An experiment was run to determine whether four specific firing temperatures affect the density of a certain type of brick. A completely randomized experiment led to the following data:

Temperature	Density				
100	21.8	21.9	21.7	21.6	21.7
125	21.7	21.4	21.5	21.4	
150	21.9	21.8	21.8	21.6	21.5
175	21.9	21.7	21.8	21.4	

- (a) Does the firing temperature affect the density of the bricks? Use $\alpha = 0.05$.
- (b) Is it appropriate to compare the means using the Fisher LSD method (for example) in this experiment?
- (c) Analyze the residuals from this experiment. Are the analysis of variance assumptions satisfied?
- (d) Construct a graphical display of the treatment as described in Section 3.5.3. Does this graph adequately summarize the results of the analysis of variance in part (a)?

3.21 Rework part (d) of Problem 3.20 using the Tukey method. What conclusions can you draw? Explain carefully how you modified the technique to account for unequal sample sizes.



3.22 A manufacturer of television sets is interested in the effect on tube conductivity of four different types of coating for color picture tubes. A completely randomized

experiment is conducted and the following conductivity data are obtained:

Coating Type	Conductivity			
1	143	141	150	146
2	152	149	137	143
3	134	136	132	127
4	129	127	132	129

- (a) Is there a difference in conductivity due to coating type? Use $\alpha = 0.05$.
- (b) Estimate the overall mean and the treatment effects.
- (c) Compute a 95 percent confidence interval estimate of the mean of coating type 4. Compute a 99 percent confidence interval estimate of the mean difference between coating types 1 and 4.
- (d) Test all pairs of means using the Fisher LSD method with $\alpha = 0.05$.
- (e) Use the graphical method discussed in Section 3.5.3 to compare the means. Which coating type produces the highest conductivity?
- (f) Assuming that coating type 4 is currently in use, what are your recommendations to the manufacturer? We wish to minimize conductivity.

3.23 Reconsider the experiment from Problem 3.22. Analyze the residuals and draw conclusions about model adequacy.

3.24 An article in the *ACI Materials Journal* (Vol. 84, 1987, pp. 213–216) describes several experiments investigating the rodding of concrete to remove entrapped air. A 3-inch \times 6-inch cylinder was used, and the number of times this rod was used is the design variable. The resulting compressive strength of the concrete specimen is the response. The data are shown in the following table:

Rodding Level	Compressive Strength		
10	1530	1530	1440
15	1610	1650	1500
20	1560	1730	1530
25	1500	1490	1510

- (a) Is there any difference in compressive strength due to the rodding level? Use $\alpha = 0.05$.
- (b) Find the P -value for the F -statistic in part (a).

- (c) Analyze the residuals from this experiment. What conclusions can you draw about the underlying model assumptions?
- (d) Construct a graphical display to compare the treatment means as described in Section 3.5.3.



3.25 An article in *Environment International* (Vol. 18, No. 4, 1992) describes an experiment in which the amount of radon released in showers was investigated. Radon-enriched water was used in the experiment, and six different orifice diameters were tested in shower heads. The data from the experiment are shown in the following table:

Orifice Diameter	Radon Released (%)			
0.37	80	83	83	85
0.51	75	75	79	79
0.71	74	73	76	77
1.02	67	72	74	74
1.40	62	62	67	69
1.99	60	61	64	66

- (a) Does the size of the orifice affect the mean percentage of radon released? Use $\alpha = 0.05$.
- (b) Find the P -value for the F -statistic in part (a).
- (c) Analyze the residuals from this experiment.
- (d) Find a 95 percent confidence interval on the mean percent of radon released when the orifice diameter is 1.40.
- (e) Construct a graphical display to compare the treatment means as described in Section 3.5.3. What conclusions can you draw?

3.26 The response time in milliseconds was determined for three different types of circuits that could be used in an automatic valve shutoff mechanism. The results from a completely randomized experiment are shown in the following table:

Circuit Type	Response Time				
1	9	12	10	8	15
2	20	21	23	17	30
3	6	5	8	16	7

- (a) Test the hypothesis that the three circuit types have the same response time. Use $\alpha = 0.01$.
- (b) Use Tukey's test to compare pairs of treatment means. Use $\alpha = 0.01$.

- (c) Use the graphical procedure in Section 3.5.3 to compare the treatment means. What conclusions can you draw? How do they compare with the conclusions from part (b)?
- (d) Construct a set of orthogonal contrasts, assuming that at the outset of the experiment you suspected the response time of circuit type 2 to be different from the other two.
- (e) If you were the design engineer and you wished to minimize the response time, which circuit type would you select?
- (f) Analyze the residuals from this experiment. Are the basic analysis of variance assumptions satisfied?

3.27 The effective life of insulating fluids at an accelerated load of 35 kV is being studied. Test data have been obtained for four types of fluids. The results from a completely randomized experiment are as follows:



Fluid Type	Life (in h) at 35 kV Load					
1	17.6	18.9	16.3	17.4	20.1	21.6
2	16.9	15.3	18.6	17.1	19.5	20.3
3	21.4	23.6	19.4	18.5	20.5	22.3
4	19.3	21.1	16.9	17.5	18.3	19.8

- (a) Is there any indication that the fluids differ? Use $\alpha = 0.05$.
- (b) Which fluid would you select, given that the objective is long life?
- (c) Analyze the residuals from this experiment. Are the basic analysis of variance assumptions satisfied?

3.28 Four different designs for a digital computer circuit are being studied to compare the amount of noise present. The following data have been obtained:

Circuit Design	Noise Observed				
1	19	20	19	30	8
2	80	61	73	56	80
3	47	26	25	35	50
4	95	46	83	78	97

- (a) Is the same amount of noise present for all four designs? Use $\alpha = 0.05$.
- (b) Analyze the residuals from this experiment. Are the analysis of variance assumptions satisfied?
- (c) Which circuit design would you select for use? Low noise is best.