5.7 Problems

5.1. The following output was obtained from a computer program that performed a two-factor ANOVA on a factorial experiment.

Two-way ANOVA: y versus, A, B

Source	DF	SS	MS	F	P
A	1	0.322			
B	—	80.554	40.2771	4.59	———
Interaction					———
Error	12	105.327	8.7773	———	———
Total	17	231.551			

(a) Fill in the blanks in the ANOVA table. You can use bounds on the P-values.

(b) How many levels were used for factor B?

(c) How many replicates of the experiment were performed?

(d) What conclusions would you draw about this experiment?

5.2. The following output was obtained from a computer program that performed a two-factor ANOVA on a factorial experiment.

Two-way ANOVA: y versus A, B

Source	DF	SS	MS	F	P
A	1		0.0002	———	———
B		180.378		———	———
Interaction	3	8.479	———	———	0.932
Error	8	158.797	———		
Total	15	347.653	———		

(a) Fill in the blanks in the ANOVA table. You can use bounds on the P-values.

(b) How many levels were used for factor B?

(c) How many replicates of the experiment were performed?

(d) What conclusions would you draw about this experiment?

5.3. The yield of a chemical process is being studied. The two most important variables are thought to be the pressure and the temperature. Three levels of each factor are selected, and a factorial experiment with two replicates is performed. The yield data are as follows:

Temperature (°C)	Pressure (psig) 200	215	230
	90.4	90.7	90.2
	90.2	90.6	90.4
	90.1	90.5	89.9
	90.3	90.6	90.1
	90.5	90.8	90.4
	90.7	90.9	90.1

(a) Analyze the data and draw conclusions. Use $\alpha = 0.05$.

(b) Prepare appropriate residual plots and comment on the model's adequacy.

(c) Under what conditions would you operate this process?

5.4. An engineer suspects that the surface finish of a metal part is influenced by the feed rate and the depth of cut. He selects three feed rates and four depths of cut. He then conducts a factorial experiment and obtains the following data:

Feed Rate (in/min)	Depth of Cut (in) 0.15	0.18	0.20	0.25
0.20	74	79	82	99
	64	68	88	104
0.25	60	73	92	96
	92	98	99	104
	86	104	108	110
0.30	88	88	95	99
	99	104	108	114
	98	99	110	111
	102	95	99	107

(a) Analyze the data and draw conclusions. Use $\alpha = 0.05$.

(b) Prepare appropriate residual plots and comment on the model's adequacy.

(c) Obtain point estimates of the mean surface finish at each feed rate.

(d) Find the P-values for the tests in part (a).

5.5. For the data in Problem 5.4, compute a 95 percent confidence interval estimate of the mean difference in response for feed rates of 0.20 and 0.25 in/min.

5.6. An article in *Industrial Quality Control* (1956, pp. 5–8) describes an experiment to investigate the effect of the type of glass and the type of phosphor on the brightness of a television tube. The response variable is the current necessary (in microamps) to obtain a specified brightness level. The data are as follows:

Glass Type	Phosphor Type 1	2	3
1	280	300	290
	290	310	285
	285	295	290
2	230	260	220
	235	240	225
	240	235	230

(a) Is there any indication that either factor influences brightness? Use $\alpha = 0.05$.

(b) Do the two factors interact? Use $\alpha = 0.05$.

(c) Analyze the residuals from this experiment.

5.7. Johnson and Leone (*Statistics and Experimental Design in Engineering and the Physical Sciences*, Wiley, 1977) describe an experiment to investigate warping of copper plates. The two factors studied were the temperature and the copper content of the plates. The response variable was a measure of the amount of warping. The data were as follows:

	Copper Content (%)			
Temperature (°C)	40	60	80	100
50	17, 20	16, 21	24, 22	28, 27
75	12, 9	18, 13	17, 12	27, 31
100	16, 12	18, 21	25, 23	30, 23
125	21, 17	23, 21	23, 22	29, 31

(a) Is there any indication that either factor affects the amount of warping? Is there any interaction between the factors? Use $\alpha = 0.05$.

(b) Analyze the residuals from this experiment.

(c) Plot the average warping at each level of copper content and compare them to an appropriately scaled t distribution. Describe the differences in the effects of the different levels of copper content on warping. If low warping is desirable, what level of copper content would you specify?

(d) Suppose that temperature cannot be easily controlled in the environment in which the copper plates are to be used. Does this change your answer for part (c)?

5.8. The factors that influence the breaking strength of a synthetic fiber are being studied. Four production machines and three operators are chosen and a factorial experiment is run using fiber from the same production batch. The results are as follows:

	Machine			
Operator	1	2	3	4
1	109	110	108	110
	110	115	109	108
2	110	110	111	114
	112	111	109	112
3	116	112	114	120
	114	115	119	117

(a) Analyze the data and draw conclusions. Use $\alpha = 0.05$.

(b) Prepare appropriate residual plots and comment on the model's adequacy.

5.9. A mechanical engineer is studying the thrust force developed by a drill press. He suspects that the drilling speed and the feed rate of the material are the most important factors. He selects four feed rates and uses a high and low drill speed chosen to represent the extreme operating conditions. He obtains the following results. Analyze the data and draw conclusions. Use $\alpha = 0.05$.

	Feed Rate			
Drill Speed	0.015	0.030	0.045	0.060
125	2.70	2.45	2.60	2.75
	2.78	2.49	2.72	2.86
200	2.83	2.85	2.86	2.94
	2.86	2.80	2.87	2.88

5.10. An experiment is conducted to study the influence of operating temperature and three types of faceplate glass in the light output of an oscilloscope tube. The following data are collected:

	Temperature		
Glass Type	100	125	150
	580	1090	1392
1	568	1087	1380
	570	1085	1386
	550	1070	1328
2	530	1035	1312
	579	1000	1299
	546	1045	867
3	575	1053	904
	599	1066	889

(a) Use $\alpha = 0.05$ in the analysis. Is there a significant interaction effect? Does glass type or temperature affect the response? What conclusions can you draw?

(b) Fit an appropriate model relating light output to glass type and temperature.

(c) Analyze the residuals from this experiment. Comment on the adequacy of the models you have considered.

5.11. Consider the experiment in Problem 5.3. Fit an appropriate model to the response data. Use this model to provide guidance concerning operating conditions for the process.

5.12. Use Tukey's test to determine which levels of the pressure factor are significantly different for the data in Problem 5.3.