

■ **TABLE P8.1**
Leaf Spring Experiment

<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	Free Height		
–	–	–	–	–	7.78	7.78	7.81
+	–	–	+	–	8.15	8.18	7.88
–	+	–	+	–	7.50	7.56	7.50
+	+	–	–	–	7.59	7.56	7.75
–	–	+	+	–	7.54	8.00	7.88
+	–	+	–	–	7.69	8.09	8.06
–	+	+	–	–	7.56	7.52	7.44
+	+	+	+	–	7.56	7.81	7.69
–	–	–	–	+	7.50	7.25	7.12
+	–	–	+	+	7.88	7.88	7.44
–	+	–	+	+	7.50	7.56	7.50
+	+	–	–	+	7.63	7.75	7.56
–	–	+	+	+	7.32	7.44	7.44
+	–	+	–	+	7.56	7.69	7.62
–	+	+	–	+	7.18	7.18	7.25
+	+	+	+	+	7.81	7.50	7.59

- (a) Write out the alias structure for this design. What is the resolution of this design?
- (b) Analyze the data. What factors influence the mean free height?
- (c) Calculate the range and standard deviation of the free height for each run. Is there any indication that any of these factors affects variability in the free height?
- (d) Analyze the residuals from this experiment, and comment on your findings.
- (e) Is this the best possible design for five factors in 16 runs? Specifically, can you find a fractional design for five factors in 16 runs with a higher resolution than this one?
- ~~8.11.~~ An article in *Industrial and Engineering Chemistry* ("More on Planning Experiments to Increase Research Efficiency," 1970, pp. 60–65) uses a 2^{5-2} design to investigate the effect of A = condensation temperature, B = amount of material 1, C = solvent volume, D = condensation time, and E = amount of material 2 on yield. The results obtained are as follows:

$$e = 23.2 \quad ad = 16.9 \quad cd = 23.8 \quad bde = 16.8 \\ ab = 15.5 \quad bc = 16.2 \quad ace = 23.4 \quad abcde = 18.1$$

- (a) Verify that the design generators used were $I = ACE$ and $I = BDE$.
- (b) Write down the complete defining relation and the aliases for this design.
- (c) Estimate the main effects.
- (d) Prepare an analysis of variance table. Verify that the AB and AD interactions are available to use as error.
- (e) Plot the residuals versus the fitted values. Also construct a normal probability plot of the residuals. Comment on the results.

8.12. Consider the leaf spring experiment in Problem 8.7. Suppose that factor E (quench oil temperature) is very difficult to control during manufacturing. Where would you set factors A , B , C , and D to reduce variability in the free height as much as possible regardless of the quench oil temperature used?

~~8.13.~~ Construct a 2^{7-2} design by choosing two four-factor interactions as the independent generators. Write down the complete alias structure for this design. Outline the analysis of variance table. What is the resolution of this design?

8.14. Consider the 2^5 design in Problem 6.24. Suppose that only a one-half fraction could be run. Furthermore, two days were required to take the 16 observations, and it was necessary to confound the 2^{5-1} design in two blocks. Construct the design and analyze the data.

8.15. Analyze the data in Problem 6.26 as if it came from a 2_{IV}^{4-1} design with $I = ABCD$. Project the design into a full factorial in the subset of the original four factors that appear to be significant.

8.16. Repeat Problem 8.15 using $I = -ABCD$. Does the use of the alternate fraction change your interpretation of the data?

8.17. Project the 2_{IV}^{4-1} design in Example 8.1 into two replicates of a 2^2 design in the factors A and B . Analyze the data and draw conclusions.

~~8.18.~~ Construct a 2_{III}^{5-2} design. Determine the effects that may be estimated if a full fold over of this design is performed.

~~8.19.~~ Construct a 2_{III}^{6-3} design. Determine the effects that may be estimated if a full fold over of this design is performed.

~~8.20.~~ Consider the 2_{III}^{6-3} design in Problem 8.18. Determine the effects that may be estimated if a single factor fold over of this design is run with the signs for factor A reversed.

~~8.21.~~ Fold over the 2_{III}^{7-4} design in Table 8.19 to produce an eight-factor design. Verify that the resulting design is a 2_{IV}^{8-4} design. Is this a minimal design?

~~8.22.~~ Fold over a 2_{III}^{5-2} design to produce a six-factor design. Verify that the resulting design is a 2_{IV}^{6-2} design. Compare this design to the 2_{IV}^{6-2} design in Table 8.10.

~~8.23.~~ An industrial engineer is conducting an experiment using a Monte Carlo simulation model of an inventory system. The independent variables in her model are the order quantity (A), the reorder point (B), the setup cost (C), the backorder cost (D), and the carrying cost rate (E). The response variable is average annual cost. To conserve computer time, she decides to investigate these factors using a 2_{III}^{5-2} design with $I = ABD$ and $I = BCE$. The results she obtains are $de = 95$, $ae = 134$, $b = 158$, $abd = 190$, $cd = 92$, $ac = 187$, $bce = 155$, and $abcde = 185$.

- (a) Verify that the treatment combinations given are correct. Estimate the effects, assuming three-factor and higher interactions are negligible.
- (b) Suppose that a second fraction is added to the first, for example, $ade = 136$, $e = 93$, $ab = 187$, $bd = 153$,