Exercises for Chapter 9

9.1 You studied the effects of three factors of interest on the yield of a chemical reaction using a full (2-level) factorial design plus 3 center points. You found that curvature was important (as well as all three factors), and want to augment the design with "star" points and 3 more center points to make it a full central composite design. List the additional runs that are needed in the table below, in both coded and uncoded form. Note: $\alpha = 1.68$ for this design.

Variable Coding	**Low (-1)**	**Mid (0)**	**High (+1)**
X_1 (Temperature)	130	150	170
X_2 (Pressure)	800	1000	1200
X_3 (Catalyst)	30	40	50

9.2 You have the same system described in Problem 9.1, but you have severe budget constraints. Therefore, you are thinking about running a "Small Composite Design" with the three factors.

(a) Write out the whole central composite design in three factors, using coded factors. Then put a check in front of each run that would still be required for the "Small Composite Design" and put an X in front of each run that would not be required. How many runs would be saved?

(b) Under what conditions is the "Small Composite Design" justified?

(c) If you use the "Small Composite Design", how many degrees of freedom are available to estimate error once you fit the full quadratic equation?

9.3 You studied a process to manufacture electrical tape, and you found (via a screening design) that only three factors significantly impacted the response: the percent elongation of the tape (which is how much it stretches before it breaks). The three factors and limits are given below:

Factor	Description	Low Value	Mid Value	High Value
X_1	% Plasticizer in Formulation	-1 = 10%	0 = 25%	1 = 40%
X_2	Temperature of Compounding	-1 = 200 F	0 = 275 F	1 = 350 F
X_3	Extruder Speed	-1 = 300 rpm	0 = 450 rpm	1 = 600 rpm

(a) Write out the next set of experiments, in both coded and uncoded form, if a central composite design is to be used. Be sure to include the run order.

(b) Write out the next set of experiments, in both coded and uncoded form, if a Box-Behnken design is to be used. Be sure to include the run order.

9.4 Please answer the following questions about RSM designs in outline form.

(a) What is the main drawback of using 3^k designs for Response Surface designs when $k > 2$?

(b) What are the advantages of a Box-Behnken design over a Central-Composite design?

(c) Are there any disadvantages of a Box-Behnken design versus a Central-Composite design?

9.5 Make a "Family of Curves" plot, similar to Figure 9.15, for the Polypropylene Pyrolysis example, but change the X-Axis for the plot to Temperature (X_1), and make a curve for X_2 = -1.5, -1.0, -0.5, 0.0, 0.5, 1.0, and 1.5. Put all seven curves on one graph. The final equation for the example is given at the bottom of Figure 9.13. Are the conclusions from the graph (the prediction of the optimum conditions) consistent with Figure 9.15?