Problems

The OM Explorer and POM for Windows software is available to all students using the 10th edition of this textbook. Go to **www.pearsonhighered.com/krajewski** to download these computer packages. If you purchased MyOMLab, you also have access to Active Models software and significant help in doing the following problems. Check with your instructor on how best to use these resources. In many cases, the instructor wants you to understand how to do the calculations by hand. At the least, the software provides a check on your calculations. When calculations are particularly complex and the goal is interpreting the results in making decisions, the software replaces entirely the manual calculations. The software also can be a valuable resource well after your course is completed.

1. At Quickie Car Wash, the wash process is advertised to take less than 7 minutes. Consequently, management has set a target average of 390 seconds for the wash process. Suppose the average range for a sample of 9 cars is 10 seconds. Use Table 5.1 to establish control limits for sample means and ranges for the car wash process.

2. At Isogen Pharmaceuticals, the filling process for its asthma inhaler is set to dispense 150 milliliters (ml) of steroid solution per container. The average range for a sample of 4 containers is 3 ml. Use Table 5.1 to establish control limits for sample means and ranges for the filling process.

3. Garcia's Garage desires to create some colorful charts and graphs to illustrate how reliably its mechanics "get under the hood and fix the problem." The historic average for the proportion of customers that return for the same repair within the 30-day warranty period is 0.10. Each month, Garcia tracks 100 customers to see whether they return for warranty repairs. The results are plotted as a proportion to report progress toward the goal. If the control limits are to be set at two standard deviations on either side of the goal, determine the control limits for this chart. In March, 8 of the 100 customers in the sample group returned for warranty repairs. Is the repair process in control?

4. The Canine Gourmet Company produces delicious dog treats for canines with discriminating tastes. Management wants the box-filling line to be set so that the process average weight per packet is 45 grams. To make sure that the process is in control, an inspector at the end of the filling line periodically selects a random box of 10 packets and weighs each packet. When the process is in control, the range in the weight of each sample has averaged 6 grams.

   a. Design an R- and an $\bar{x}$-chart for this process.

   b. The results from the last 5 samples of 10 packets are

Sample	$\bar{x}$	R
1	44	9
2	40	2
3	46	5
4	39	8
5	48	3

   Is the process in control? Explain.

5. Aspen Plastics produces plastic bottles to customer order. The quality inspector randomly selects four bottles from the bottle machine and measures the outside diameter of the bottle neck, a critical quality dimension that determines whether the bottle cap will fit properly. The dimensions (in.) from the last six samples are

	BOTTLE			
Sample	**1**	**2**	**3**	**4**
1	0.594	0.622	0.598	0.590
2	0.587	0.611	0.597	0.613
3	0.571	0.580	0.595	0.602
4	0.610	0.615	0.585	0.578
5	0.580	0.624	0.618	0.614
6	0.585	0.593	0.607	0.569

   a. Assume that only these six samples are sufficient, and use the data to determine control limits for an R- and an $\bar{x}$-chart.

   b. Suppose that the specification for the bottle neck diameter is 0.600 ± 0.050 and the population standard deviation is 0.013 in. What is the Process Capability Index? The Process Capability Ratio?

   c. If the firm is seeking four-sigma performance, is the process capable of producing the bottle?

6. In an attempt to judge and monitor the quality of instruction, the administration of Mega-Byte Academy devised an examination to test students on the basic concepts that all should have learned. Each year, a random sample of 10 graduating students is selected for the test. The average score is used to track the quality of the educational process. Test results for the past 10 years are shown in Table 5.2.

   Use these data to estimate the center and standard deviation for this distribution. Then, calculate the two-sigma control limits for the process average. What comments would you make to the administration of the Mega-Byte Academy?

7. As a hospital administrator of a large hospital, you are concerned with the absenteeism among nurses' aides. The issue has been raised by registered nurses, who feel they often have to perform work normally done by their aides. To get the facts, absenteeism data were gathered for the last 3 weeks, which is considered a representative period for future conditions. After taking random samples of 64 personnel files each day, the following data were produced:

TABLE 5.2 | TEST SCORES ON EXIT EXAM

	STUDENT										
Year	1	2	3	4	5	6	7	8	9	10	Average
1	63	57	92	87	70	61	75	58	63	71	69.7
2	90	77	59	88	48	83	63	94	72	70	74.4
3	67	81	93	55	71	71	86	98	60	90	77.2
4	62	67	78	61	89	93	71	59	93	84	75.7
5	85	88	77	69	58	90	97	72	64	60	76.0
6	60	57	79	83	64	94	86	64	92	74	75.3
7	94	85	56	77	89	72	71	61	92	97	79.4
8	97	86	83	88	65	87	76	84	81	71	81.8
9	94	90	76	88	65	93	86	87	94	63	83.6
10	88	91	71	89	97	79	93	87	69	85	84.9

Day	Aides Absent	Day	Aides Absent
1	4	9	7
2	3	10	2
3	2	11	3
4	4	12	2
5	2	13	1
6	5	14	3
7	3	15	4
8	4		

Because your assessment of absenteeism is likely to come under careful scrutiny, you would like a type I error of only 1 percent. You want to be sure to identify any instances of unusual absences. If some are present, you will have to explore them on behalf of the registered nurses.

a. Design a p-chart.

b. Based on your p-chart and the data from the last 3 weeks, what can you conclude about the absenteeism of nurses' aides?

8. A textile manufacturer wants to set up a control chart for irregularities (e.g., oil stains, shop soil, loose threads, and tears) per 100 square yards of carpet. The following data were collected from a sample of twenty 100-square-yard pieces of carpet:

Sample	1	2	3	4	5	6	7	8	9	10
Irregularities	11	8	9	12	4	16	5	8	17	10
Sample	11	12	13	14	15	16	17	18	19	20
Irregularities	11	5	7	12	13	8	19	11	9	10

a. Using these data, set up a c-chart with $z = 3$.

b. Suppose that the next five samples had 15, 18, 12, 22, and 21 irregularities. What do you conclude?

9. The IRS is concerned with improving the accuracy of tax information given by its representatives over the telephone. Previous studies involved asking a set of 25 questions of a large number of IRS telephone representatives to determine the proportion of correct responses. Historically, the average proportion of correct responses has been 72 percent. Recently, IRS representatives have been receiving more training. On April 26, the set of 25 tax questions were again asked of 20 randomly selected IRS telephone representatives. The numbers of correct answers were 18, 16, 19, 21, 20, 16, 21, 16, 17, 10, 25, 18, 25, 16, 20, 15, 23, 19, 21, and 19.

a. What are the upper and lower control limits for the appropriate p-chart for the IRS? Use $z = 3$.

b. Is the tax information process in statistical control?

10. A travel agency is concerned with the accuracy and appearance of itineraries prepared for its clients. Defects can include errors in times, airlines, flight numbers, prices, car rental information, lodging, charge card numbers, and reservation numbers, as well as typographical errors. As the possible number of errors is nearly infinite, the agency measures the number of errors that do occur. The current process results in an average of three errors per itinerary.

a. What are the two-sigma control limits for these defects?

b. A client scheduled a trip to Dallas. Her itinerary contained six errors. Interpret this information.

11. Jim's Outfitters, Inc., makes custom fancy shirts for cowboys. The shirts could be flawed in various ways, including flaws in the weave or color of the fabric, loose buttons or decorations, wrong dimensions, and uneven

stitches. Jim randomly examined 10 shirts, with the following results:

Shirt	Defects
1	8
2	0
3	7
4	12
5	5
6	10
7	2
8	4
9	6
10	6

a. Assuming that 10 observations are adequate for these purposes, determine the three-sigma control limits for defects per shirt.

b. Suppose that the next shirt has 13 flaws. What can you say about the process now?

12. The Big Black Bird Company produces fiberglass camper tops. The process for producing the tops must be controlled so as to keep the number of dimples low. When the process was in control, the following defects were found in 10 randomly selected camper tops over an extended period of time:

Top	Dimples
1	7
2	9
3	14
4	11
5	3
6	12
7	8
8	4
9	7
10	6

a. Assuming 10 observations are adequate for this purpose, determine the three-sigma control limits for dimples per camper top.

b. Suppose that the next camper top has 15 dimples. What can you say about the process now?

13. The production manager at Sunny Soda, Inc., is interested in tracking the quality of the company's 12-ounce bottle filling line. The bottles must be filled within the tolerances set for this product because the dietary information on the label shows 12 ounces as the serving size. The design standard for the product calls for a fill level of 12.00 $\pm$ 0.10 ounces. The manager collected the following sample data (in fluid ounces per bottle) on the production process:

	OBSERVATION			
Sample	1	2	3	4
1	12.00	11.97	12.10	12.08
2	11.91	11.94	12.10	11.96
3	11.89	12.02	11.97	11.99
4	12.10	12.09	12.05	11.95
5	12.08	11.92	12.12	12.05
6	11.94	11.98	12.06	12.08
7	12.09	12.00	12.00	12.03
8	12.01	12.04	11.99	11.95
9	12.00	11.96	11.97	12.03
10	11.92	11.94	12.09	12.00
11	11.91	11.99	12.05	12.10
12	12.01	12.00	12.06	11.97
13	11.98	11.99	12.06	12.03
14	12.02	12.00	12.05	11.95
15	12.00	12.05	12.01	11.97

a. Are the process average and range in statistical control?

b. Is the process capable of meeting the design standard at four-sigma quality? Explain.

14. The Money Pit Mortgage Company is interested in monitoring the performance of the mortgage process. Fifteen samples of 5 completed mortgage transactions each were taken during a period when the process was believed to be in control. The times to complete the transactions were measured. The means and ranges of the mortgage process transaction times, measured in days, are as follows:

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	17	14	8	17	12	13	15	16	13	14	16	9	11	9	12
Range	6	11	4	8	9	14	12	15	10	10	11	6	9	11	13

Subsequently, samples of size 5 were taken from the process every week for the next 10 weeks. The times were measured and the following results obtained:

Sample	16	17	18	19	20	21	22	23	24	25
Mean	11	14	9	15	17	19	13	22	20	18
Range	7	11	6	4	12	14	11	10	8	6

a. Construct the control charts for the mean and the range, using the original 15 samples.

b. On the control charts developed in part (a), plot the values from samples 16 through 25 and comment on whether the process is in control.

c. In part (b), if you concluded that the process was out of control, would you attribute it to a drift in the mean, or an increase in the variability, or both? Explain your answer.

15. The Money Pit Mortgage Company of Problem 14 made some changes to the process and undertook a process capability study. The following data were obtained for 15 samples of size 5. Based on the individual observations, management estimated the process standard deviation to be 4.21 (days) for use in the process capability analysis. The lower and upper specification limits (in days) for the mortgage process times were 5 and 25.

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Mean	11	12	8	16	13	12	17	16	13	14	17	9	15	14	9
Range	9	13	4	11	10	9	8	15	14	11	6	6	12	10	11

a. Calculate the process capability index and the process capability ratio values.

b. Suppose management would be happy with three-sigma performance. What conclusions is management likely to draw from the capability analysis? Can valid conclusions about the process be drawn from the analysis?

c. What remedial actions, if any, do you suggest that management take?

16. Webster Chemical Company produces mastics and caulking for the construction industry. The product is blended in large mixers and then pumped into tubes and capped. Management is concerned about whether the filling process for tubes of caulking is in statistical control. The process should be centered on 8 ounces per tube. Several samples of eight tubes were taken, each tube was weighed, and the weights in Table 5.3 were obtained.

a. Assume that only six samples are sufficient and develop the control charts for the mean and the range.

b. Plot the observations on the control chart and comment on your findings.

•17. Management at Webster, in Problem 16, is now concerned as to whether caulking tubes are being properly capped. If a significant proportion of the tubes are not being sealed, Webster is placing its customers in a messy situation. Tubes are packaged in large boxes of 144. Several boxes are inspected, and the following numbers of leaking tubes are found:

Sample	Tubes	Sample	Tubes	Sample	Tubes
1	3	8	6	15	5
2	5	9	4	16	0
3	3	10	9	17	2
4	4	11	2	18	6
5	2	12	6	19	2
6	4	13	5	20	1
7	2	14	1	Total	72

Calculate *p*-chart three-sigma control limits to assess whether the capping process is in statistical control.

18. At Webster Chemical Company, lumps in the caulking compound could cause difficulties in dispensing a smooth bead from the tube. Even when the process is in control, an average of four lumps per tube of caulk will remain. Testing for the presence of lumps destroys the product, so an analyst takes random samples. The following results are obtained:

Tube No.	Lumps	Tube No.	Lumps	Tube No.	Lumps
1	6	5	6	9	5
2	5	6	4	10	0
3	0	7	1	11	9
4	4	8	6	12	2

Determine the *c*-chart two-sigma upper and lower control limits for this process. Is the process in statistical control?

TABLE 5.3 | OUNCES OF CAULKING PER TUBE

	TUBE NUMBER							
Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	7.98	8.34	8.02	7.94	8.44	7.68	7.81	8.11
2	8.33	8.22	8.08	8.51	8.41	8.28	8.09	8.16
3	7.89	7.77	7.91	8.04	8.00	7.89	7.93	8.09
4	8.24	8.18	7.83	8.05	7.90	8.16	7.97	8.07
5	7.87	8.13	7.92	7.99	8.10	7.81	8.14	7.88
6	8.13	8.14	8.11	8.13	8.14	8.12	8.13	8.14