1. The data shown in Table 6E.1 are $\overline{x}$ and R values for 24 samples of size $n = 5$ taken from a process producing bearings. The measurements are made on the inside diameter of the bearing, with only the last three decimals recorded (i.e., 34.5 should be 0.50345).
   (a) Set up $\overline{x}$ and R charts on this process. Does the process seem to be in statistical control? If necessary, revise the trial control limits.
   (b) If specifications on this diameter are 0.5030 ± 0.0010, find the percentage of nonconforming bearings produced by this process. Assume that diameter is normally distributed.
2. A high-voltage power supply should have a nominal output voltage of 350 V. A sample of four units is selected each day and tested for process-control purposes. The data shown in Table 6E.2 give the difference between the observed reading on each unit and the nominal voltage times ten; that is,
   $x_i =$ (observed voltage on unit i - 350)10
   (a) Set up $\overline{x}$ and R charts on this process. Is the process in statistical control?
   (b) If specifications are at $350\text{ V} \pm 5\text{ V}$, what can you say about process capability?
   (c) Is there evidence to support the claim that voltage is normally distributed?
3. The data shown in Table 6E.3 are the deviations from nominal diameter for holes drilled in a carbon-fiber composite material used in aerospace manufacturing.

TABLE 6E.1
Bearing Diameter Data

Sample Number	$\overline{x}$	R	Sample Number	$\overline{x}$	R
1	34.5	3	13	35.4	8
2	34.2	4	14	34.0	6
3	31.6	4	15	37.1	5
4	31.5	4	16	34.9	7
5	35.0	5	17	33.5	4
6	34.1	6	18	31.7	3
7	32.6	4	19	34.0	8
8	33.8	3	20	35.1	4
9	34.8	7	21	33.7	2
10	33.6	8	22	32.8	1
11	31.9	3	23	33.5	3
12	38.6	9	24	34.2	2

TABLE 6E.2
Voltage Data for Exercise 6.2.

Sample Number	x_1	x_2	x_3	x_4
1	6	9	10	15
2	10	4	6	11
3	7	8	10	5
4	8	9	6	13
5	9	10	7	13
6	12	11	10	10
7	16	10	8	9
8	7	5	10	4
9	9	7	8	12
10	15	16	10	13
11	8	12	14	16
12	6	13	9	11
13	16	9	13	15
14	7	13	10	12
15	11	7	10	16
16	15	10	11	14
17	9	8	12	10
18	15	7	10	11
19	8	6	9	12
20	13	14	11	15

■ TABLE E.3

Hole Diameter Data for Exercise 3

Sample Number	x_1	x_2	x_3	x_4	x_5
1	−30	+50	−20	+10	+30
2	0	+50	−60	−20	+30
3	−50	+10	+20	+30	+20
4	−10	−10	+30	−20	+50
5	+20	−40	+50	+20	+10
6	0	0	+40	−40	+20
7	0	0	+20	−20	−10
8	+70	−30	+30	−10	0
9	0	0	+20	−20	+10
10	+10	+20	+30	+10	+50
11	+40	0	+20	0	+20
12	+30	+20	+30	+10	+40
13	+30	−30	0	+10	+10
14	+30	−10	+50	−10	−30
15	+10	−10	+50	+40	0
16	0	0	+30	−10	0
17	+20	+20	+30	+30	−20
18	+10	−20	+50	+30	+10
19	+50	−10	+40	+20	0
20	+50	0	0	+30	+10

The values reported are deviations from nominal in ten-thousandths of an inch.

(a) Set up $\bar{x}$ and R charts on the process. Is the process in statistical control?

(b) Estimate the process standard deviation using the range method.

(c) If specifications are at nominal ±100, what can you say about the capability of this process? Calculate the PCR C_p.

Ex 4 Rework Ex 2 using the s Chart

Ex5 Rework Ex 3 using the s Chart

Ex6

Control charts on $\bar{x}$ and s are to be maintained on the torque readings of a bearing used in a wingflap actuator assembly. Samples of size $n = 10$ are to be used, and we know from past experience that when the process is in control, bearing torque has a normal distribution with mean $\mu = 80$ inch-pounds and standard deviation $\sigma = 10$ inch-pounds. Find the center line and control limits for these control charts.

Ex7

Samples of $n = 6$ items each are taken from a manufacturing process at regular intervals. A quality characteristic is measured, and $\bar{x}$ and R values are calculated for each sample. After 50 samples, we have

$$\sum_{i=1}^{50} \bar{x}_i = 2000 \quad \text{and} \quad \sum_{i=1}^{50} R_i = 200$$

Assume that the quality characteristic is normally distributed.

(a) Compute control limits for the $\bar{x}$ and R control charts.

(b) All points on both control charts fall between the control limits computed in part (a). What are the natural tolerance limits of the process?

(c) If the specification limits are 41 ± 5.0, what are your conclusions regarding the ability of the process to produce items within these specifications?

(d) Assuming that if an item exceeds the upper specification limit it can be reworked, and if it is below the lower specification limit it must be scrapped, what percent scrap and rework is the process producing?

(e) Make suggestions as to how the process performance could be improved.

Ex8

Consider the $\bar{x}$ and R charts you established in Exercise 1 using $n = 5$.

(a) Suppose that you wished to continue charting this quality characteristic using $\bar{x}$ and R charts based on a sample size of $n = 3$. What limits would be used on the $\bar{x}$ and R charts?

(b) What would be the impact of the decision you made in part (a) on the ability of the $\bar{x}$ chart to detect a 2σ shift in the mean?

(c) Suppose you wished to continue charting this quality characteristic using $\bar{x}$ and R charts based on a sample size of $n = 8$. What limits would be used on the $\bar{x}$ and R charts?

(d) What is the impact of using $n = 8$ on the ability of the $\bar{x}$ chart to detect a 2σ shift in the mean?