hardness for the oil quenching process. Use $\alpha = 0.05$ and assume equal variances.

(b) Assuming that the variances σ_1^2 and σ_2^2 are equal, construct a 95% confidence interval on the difference in mean hardness.

(c) Construct a 95% confidence interval on the ratio σ_1^2/σ_2^2. Does the assumption made earlier of equal variances seem reasonable?

(d) Does the assumption of normality seem appropriate for these data?

4.20. A random sample of 200 printed circuit boards contains 18 defective or nonconforming units. Estimate the process fraction nonconforming.

(a) Test the hypothesis that the true fraction nonconforming in this process is 0.10. Use $\alpha = 0.05$. Find the *P*-value.

(b) Construct a 90% two-sided confidence interval on the true fraction nonconforming in the production process.

4.21. A random sample of 500 connecting rod pins contains 65 nonconforming units. Estimate the process fraction nonconforming.

(a) Test the hypothesis that the true fraction defective in this process is 0.08. Use $\alpha = 0.05$.

(b) Find the *P*-value for this test.

(c) Construct a 95% upper confidence interval on the true process fraction nonconforming.

4.22. Two processes are used to produce forgings used in an aircraft wing assembly. Of 200 forgings selected from process 1, 10 do not conform to the strength specifications, whereas of 300 forgings selected from process 2, 20 are nonconforming.

(a) Estimate the fraction nonconforming for each process.

(b) Test the hypothesis that the two processes have identical fractions nonconforming. Use $\alpha = 0.05$.

(c) Construct a 90% confidence interval on the difference in fraction nonconforming between the two processes.

4.23. A new purification unit is installed in a chemical process. Before its installation, a random sample yielded the following data about the percentage of impurity: $\bar{x}_1 = 9.85$, $s_1^2 = 6.79$, and $n_1 = 10$. After installation, a random sample resulted in $\bar{x}_2 = 8.08$, $s_2^2 = 6.18$, and $n_2 = 8$.

(a) Can you conclude that the two variances are equal? Use $\alpha = 0.05$.

(b) Can you conclude that the new purification device has reduced the mean percentage of impurity? Use $\alpha = 0.05$.

4.24. Two different types of glass bottles are suitable for use by a soft-drink beverage bottler. The internal pressure

■ **TABLE 4E.3**
Measurements Made by the Inspectors for Exercise 4.25

Inspector	Micrometer Caliper	Vernier Caliper
1	0.150	0.151
2	0.151	0.150
3	0.151	0.151
4	0.152	0.150
5	0.151	0.151
6	0.150	0.151
7	0.151	0.153
8	0.153	0.155
9	0.152	0.154
10	0.151	0.151
11	0.151	0.150
12	0.151	0.152

strength of the bottle is an important quality characteristic. It is known that $\sigma_1 = \sigma_2 = 3.0$ psi. From a random sample of $n_1 = n_2 = 16$ bottles, the mean pressure strengths are observed to be $\bar{x}_1 = 175.8$ psi and $\bar{x}_2 = 181.3$ psi. The company will not use bottle design 2 unless its pressure strength exceeds that of bottle design 1 by at least 5 psi. Based on the sample data, should they use bottle design 2 if we use $\alpha = 0.05$? What is the *P*-value for this test?

4.25. The diameter of a metal rod is measured by 12 inspectors, each using both a micrometer caliper and a vernier caliper. The results are shown in Table 4E.3. Is there a difference between the mean measurements produced by the two types of caliper? Use $\alpha = 0.01$.

4.26. The cooling system in a nuclear submarine consists of an assembly pipe through which a coolant is circulated. Specifications require that weld strength must meet or exceed 150 psi.

(a) Suppose the designers decide to test the hypothesis H_0: $\mu = 150$ versus H_1: $\mu > 150$. Explain why this choice of alternative is preferable to H_1: $\mu < 150$.

(b) A random sample of 20 welds results in $\bar{x} = 153.7$ psi and $s = 11.5$ psi. What conclusions can you draw about the hypothesis in part (a)? Use $\alpha = 0.05$.

4.27. An experiment was conducted to investigate the filling capability of packaging equipment at a winery in Newberg, Oregon. Twenty bottles of Pinot Gris were randomly selected and the fill volume (in ml) measured. Assume that fill volume has a normal distribution. The data are as follows: 753, 751, 752, 753, 753, 753, 752, 753, 754, 754, 752, 751, 752, 750, 753, 755, 753, 756, 751, and 750.

(a) Do the data support the claim that the standard deviation of fill volume is less than 1 ml? Use $\alpha = 0.05$.

(b) Find a 95% two-sided confidence interval on the standard deviation of fill volume.

(c) Does it seem reasonable to assume that fill volume has a normal distribution?

4.28. Suppose we wish to test the hypotheses

$$H_0\colon\ \mu = 15$$
$$H_1\colon\ \mu \neq 15$$

where we know that $\sigma^2 = 9.0$. If the true mean is really 20, what sample size must be used to ensure that the probability of type II error is no greater than 0.10? Assume that $\alpha = 0.05$.

4.29. Consider the hypotheses

$$H_0\colon\ \mu = \mu_0$$
$$H_1\colon\ \mu \neq \mu_0$$

where σ^2 is known. Derive a general expression for determining the sample size for detecting a true mean of $\mu_1 \neq \mu_0$ with probability $1 - \beta$ if the type I error is α.

4.30. **Sample size allocation.** Suppose we are testing the hypotheses

$$H_0\colon \mu_1 = \mu_2$$
$$H_1\colon \mu_1 \neq \mu_2$$

where σ_1^2 and σ_2^2 are known. Resources are limited, and consequently the total sample size $n_1 + n_2 = N$. How should we allocate the N observations between the two populations to obtain the most powerful test?

4.31. Develop a test for the hypotheses

$$H_0\colon\ \mu_1 = \mu_2$$
$$H_1\colon\ \mu_1 \neq \mu_2$$

where σ_1^2 and σ_2^2 are known.

4.32. Nonconformities occur in glass bottles according to a Poisson distribution. A random sample of 100 bottles contains a total of 11 nonconformities.

(a) Develop a procedure for testing the hypothesis that the mean of a Poisson distribution λ equals a specified value λ_0. Hint: Use the normal approximation to the Poisson.

(b) Use the results of part (a) to test the hypothesis that the mean occurrence rate of nonconformities is $\lambda = 0.15$. Use $\alpha = 0.01$.

4.33. An inspector counts the surface-finish defects in dishwashers. A random sample of five dishwashers contains three such defects. Is there reason to conclude that the mean occurrence rate of surface-finish defects per dishwasher exceeds 0.5? Use the results of part (a) of Exercise 4.32 and assume that $\alpha = 0.05$.

4.34. An in-line tester is used to evaluate the electrical function of printed circuit boards. This machine counts the number of defects observed on each board. A random sample of 1,000 boards contains a total of 688 defects. Is it reasonable to conclude that the mean occurrence rate of defects is $\lambda = 1$? Use the results of part (a) of Exercise 4.26 and assume that $\alpha = 0.05$.

■ **TABLE 4E.4**
Uniformity Data for Exercise 4.35

C_2F_6 Flow (SCCM)	Observations 1	2	3	4	5	6
125	2.7	2.6	4.6	3.2	3.0	3.8
160	4.6	4.9	5.0	4.2	3.6	4.2
200	4.6	2.9	3.4	3.5	4.1	5.1

4.35. An article in *Solid State Technology* (May 1987) describes an experiment to determine the effect of C_2F_6 flow rate on etch uniformity on a silicon wafer used in integrated-circuit manufacturing. Three flow rates are tested, and the resulting uniformity (in percent) is observed for six test units at each flow rate. The data are shown in Table 4E.4.

(a) Does C_2F_6 flow rate affect etch uniformity? Answer this question by using an analysis of variance with $\alpha = 0.05$.

(b) Construct a box plot of the etch uniformity data. Use this plot, together with the analysis of variance results, to determine which gas flow rate would be best in terms of etch uniformity (a small percentage is best).

(c) Plot the residuals versus predicted C_2F_6 flow. Interpret this plot.

(d) Does the normality assumption seem reasonable in this problem?

4.36. Compare the mean etch uniformity values at each of the C_2F_6 flow rates from Exercise 4.33 with a scaled *t* distribution. Does this analysis indicate that there are differences in mean etch uniformity at the different flow rates? Which flows produce different results?

4.37. An article in the *ACI Materials Journal* (Vol. 84, 1987, pp. 213–216) describes several experiments investigating the rodding of concrete to remove entrapped air. A 3-in.-diameter cylinder was used, and the number of times this rod was used is the design variable. The resulting compressive strength of the concrete specimen is the response. The data are shown in Table 4E.5.