Chapter 9 Hypothesis Testing

Section 9.1

1. See text for definitions. Essay may include:

   (a) A working hypothesis about the population parameter in question is called the null hypothesis. The value specified in the null hypothesis is often a historical value, a claim, or a production specification.

   (b) Any hypothesis that differs from the null hypothesis is called an alternate hypothesis.

   (c) If we reject the null hypothesis when it is in fact true, we have an error that is called a type I error. On the other hand, if we accept (i.e., fail to reject) the null hypothesis when it is in fact false, we have made an error that is called a type II error.

   (d) The probability with which we are willing to risk a type I error is called the level of significance of a test. The probability of making a type II error is denoted by β.

2. The alternate hypothesis is used to determine which type of critical region is used. An alternate hypothesis is constructed in such a way that it is the one to be accepted when the null hypothesis must be rejected.

3. No. if we fail to reject the null hypothesis, we have not proven it to be true beyond all doubt. The evidence is not sufficient to merit rejecting H_0.

4. No. if we reject the null hypothesis, we have not proven it to be false beyond all doubt. The test was conducted with a level of significance, α, which is the probability with which we are willing to risk a type I error (rejecting H_0 when it is in fact true).

5. (a) The claim is $\mu = 60$ kg, so you would use $H_0: \mu = 60$ kg.

   (b) We want to know if the average weight is less than 60 kg, so you would use $H_1: \mu < 60$ kg.

   (c) We want to know if the average weight is greater than 60 kg. so you would use $H_1: \mu > 60$ kg.

   (d) We want to know if the average weight is different from (more or less than) 60 kg, so you would use $H_1: \mu \neq 60$ kg.

   (e) Since part (b) is a left-tailed test, the critical region is on the left. Since part (c) is a right-tailed test, the critical region is on the right. Since part (d) is a two-tailed test, the critical region is on both sides of the mean.

6. (a) The claim is $\mu = 8.3$ min. so you would use $H_0: \mu = 8.3$ min. If you believe the average is less than 8.3 min, then you would use $H_1: \mu < 8.3$ min. Since this is a left-tailed test, the critical region is on the left side of the mean.

   (b) The claim is $\mu = 8.3$ min. so you would use $H_0: \mu = 8.3$ min. If you believe the average is different from 8.3 min, then you would use $H_1: \mu \neq 8.3$ min. Since this is a two-tailed test. the critical region is on both sides of the mean.

   (c) The claim is $\mu = 4.5$ min, so you would use $H_0: \mu = 4.5$ min. If you believe the average is more than 4.5 min, then you would use $H_1: \mu > 4.5$ min. Since this is a right-tailed test, the critical region is on the right side of the mean.

(d) The claim is $\mu = 4.5$ min, so you would use $H_0: \mu = 4.5$ min. If you believe the average is different from 4.5 min, then you would use $H_1: \mu \neq 4.5$ min. Since this is a two-tailed test, the critical region is on both sides of the mean.

7. (a) The claim is $\mu = 16.4$ ft, so $H_0: \mu = 16.4$ ft.

(b) You want to know if the average is getting larger, so $H_1: \mu > 16.4$ ft.

(c) You want to know if the average is getting smaller, so $H_1: \mu < 16.4$ ft.

(d) You want to know if the average is different from 16.4 ft, so $H_1: \mu \neq 16.4$ ft.

(e) Since part (b) is a right-tailed test, the critical region is on the right. Since part (c) is a left-tailed test, the critical region is on the left. Since part (d) is a two-tailed test, the critical region is on both sides of the mean.

8. (a) The claim is $\mu = 8.7$ sec, so $H_0: \mu = 8.7$ sec.

(b) You want to know if the average is longer (larger), so $H_1: \mu > 8.7$ sec.

(c) You want to know if the average is reduced (smaller), so $H_1: \mu < 8.7$ sec.

(d) Since part (b) is a right-tailed test, the critical region is on the right. Since part (c) is a left-tailed test, the critical region is on the left.

9. (a) The claim is $\mu = 288$ lb, so $H_0: \mu = 288$ lb.

(b) If you want to know if the average is higher (larger), $H_1: \mu > 288$ lb. Since this is a right-tailed test, the critical region is on the right.

If you want to know if the average is lower (smaller), $H_1: \mu < 288$ lb. Since this is a left-tailed test, the critical region is on the left.

If you want to know if the average is different, $H_1: \mu \neq 288$ lb. Since this is a two-tailed test, the critical region is in both tails.

Section 9.2

1. $H_0: \mu = 16.4$ ft

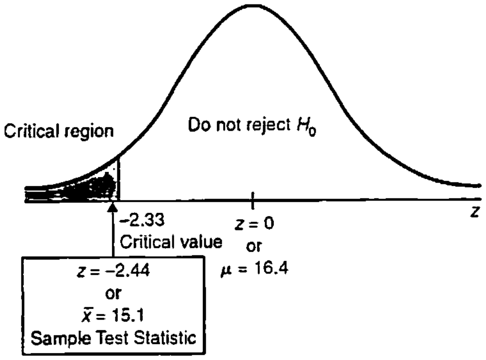
$H_1: \mu < 16.4$ ft

Since < is in H_1, a left-tailed test is used.

Since the sample size $n = 36$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

For $\alpha = 0.01$, the critical value is $z_0 = -2.33$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{15.1 - 16.4}{3.2/\sqrt{36}} = -2.44$$



The sample test statistic falls in the critical region (−2.44 < −2.33). Therefore, we reject H_0. We conclude that the storm is lessening. The data are statistically significant.

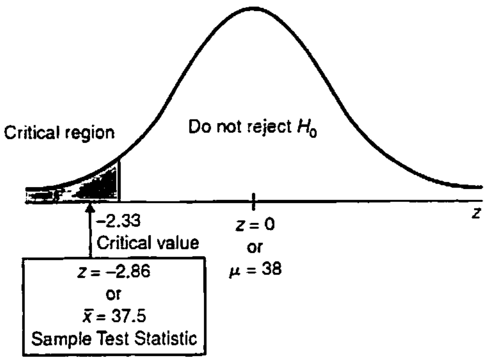
2. H_0: $\mu = 38$ hr
   H_1: $\mu < 38$ hr

   Since < is in H_1, a left-tailed test is used.

   Since the sample size $n = 47$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem. and we can estimate σ by s.

   For $\alpha = 0.01$, the critical value is $z_0 = -2.33$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{37.5 - 38}{1.2/\sqrt{47}} = -2.86$$



The sample test statistic falls in the critical region (−2.86 < −2.33). Therefore, we reject H_0. We conclude that the average assembly time is less. The data are statistically significant.

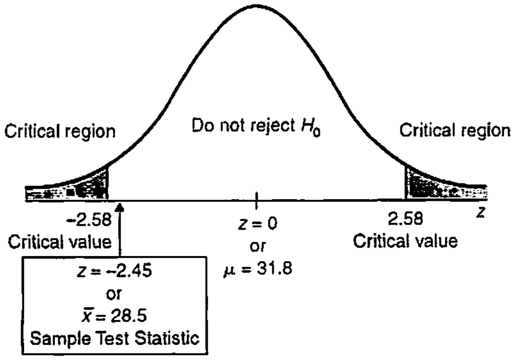
3. H_0: $\mu = 31.8$ calls/day
   H_1: $\mu \neq 31.8$ calls/day

   Since ≠ is in H_1, a two-tailed test is used.

   Since the sample size $n = 63$ is large. the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

   For $\alpha = 0.01$. the critical value is $z_0 = \pm 2.58$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{28.5 - 31.8}{10.7/\sqrt{63}} = -2.45$$



The sample test statistic does not fall in the critical region (−2.58 < −2.45 < 2.58). Therefore, we do not reject H_0. There is not enough evidence to conclude that the mean number of messages has changed. The data are not statistically significant.

4. H_0: $\mu = 3218$

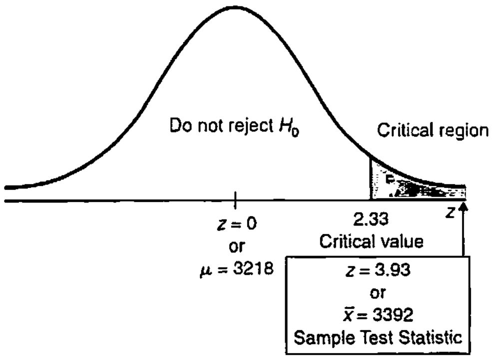
   H_1: $\mu > 3218$

   Since > is in H_1, a right-tailed test is used.

   Since the sample size $n = 42$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

   For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{3392 - 3218}{287/\sqrt{42}} = 3.93$$



The sample test statistic falls in the critical region (3.93 > 2.33). Therefore, we reject H_0. We conclude the average number of people entering the store each day has increased. The data are statistically significant.

5. H_0: $\mu = \$4.75$

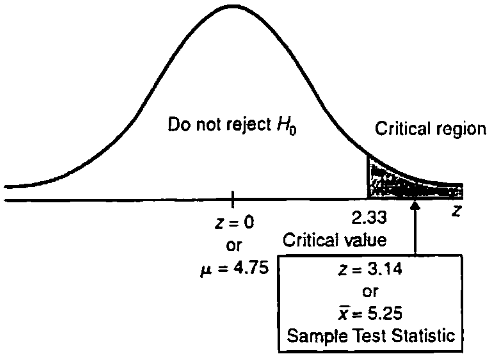
   H_1: $\mu > \$4.75$

   Since > is in H_1, a right-tailed test is used.

   Since the sample size $n = 52$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

   For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{5.25 - 4.75}{1.15/\sqrt{52}} = 3.14$$



The sample test statistic falls in the critical region (3.14 > 2.33). Therefore, we reject H_0. We conclude that her average tip is more than \$4.75. The data are statistically significant.

6. H_0: $\mu = 17.2\%$

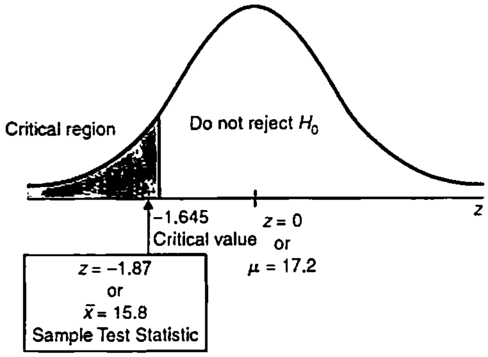
   H_1: $\mu < 17.2\%$

   Since < is in H_1, a left-tailed test is used.

   Since the sample size $n = 50$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

   For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{15.8 - 17.2}{5.3/\sqrt{50}} = -1.87$$



The sample test statistic falls in the critical region (−1.87 < −1.645). Therefore, we reject H_0. We conclude that this hay has lower protein content. The data are statistically significant.

7. H_0: $\mu = 10.2$ sec

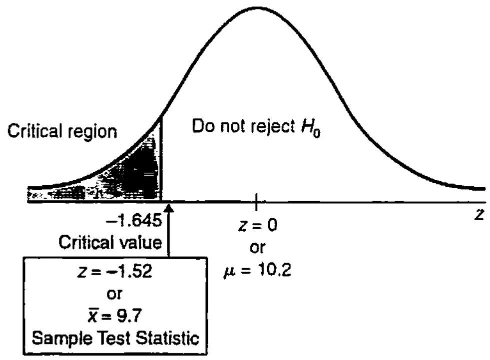
   H_1: $\mu < 10.2$ sec

   Since < is in H_1, a left-tailed test is used.

   Since the sample size $n = 41$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

   For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{9.7 - 10.2}{2.1/\sqrt{41}} = -1.52$$



The sample test statistic does not fall in the critical region $(-1.645 < -1.52)$. Therefore, we do not reject H_0. There is not enough evidence to conclude that the mean acceleration time is less. The data are not statistically significant.

8. $H_0: \mu = 159$ ft

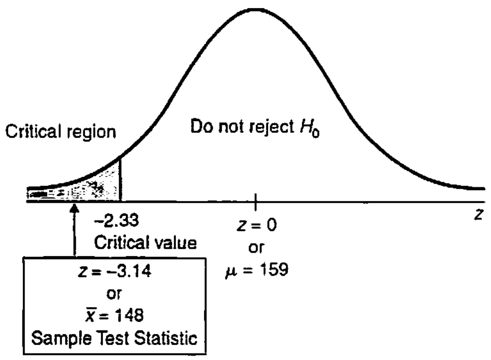
$H_1: \mu < 159$ ft

Since < is in H_1, a left-tailed test is used.

Since the sample size $n = 45$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

For $\alpha = 0.01$, the critical value is $z_0 = -2.33$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{148 - 159}{23.5/\sqrt{45}} = -3.14$$



The sample test statistic falls in the critical region $(-3.14 < -2.33)$. Therefore, we reject H_0. We conclude the mean braking distance is reduced for the new tire tread. The data are statistically significant.

9. $H_0: \mu = 19.0$ ml/dl

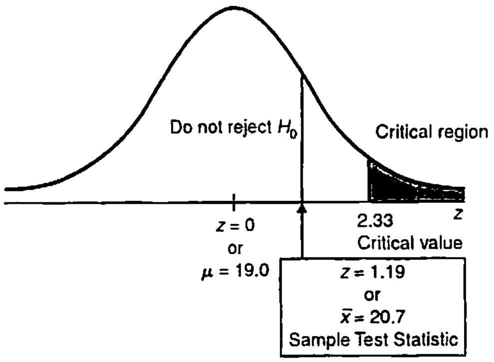
$H_1: \mu > 19.0$ ml/dl

Since > is in H_1, a right-tailed test is used.

Since the sample size $n = 48$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{20.7 - 19.0}{9.9/\sqrt{48}} = 1.19$$



The sample test statistic does not fall in the critical region (1.19 < 2.33). Therefore, we do not reject H_0. There is not sufficient evidence to conclude that the average oxygen capacity has increased. The data are not statistically significant.

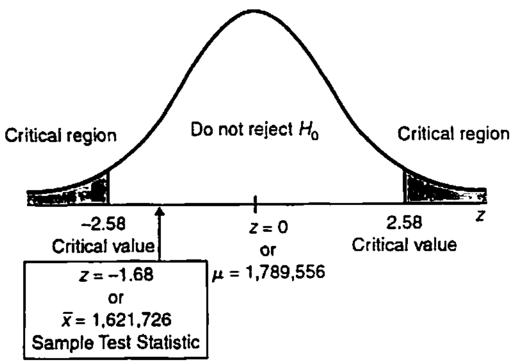
10. H_0: μ = \$1,789,556
H_1: $\mu \neq$ \$1,789,556

Since $\neq$ is in H_1, a two-tailed test is used.

Since the sample size $n = 35$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

For $\alpha = 0.01$, the critical values are $z_0 = \pm 2.58$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{1{,}621{,}726 - 1{,}789{,}556}{591{,}218/\sqrt{35}} = -1.68$$



The sample test statistic does not fall in the critical region (−2.58 < −1.68 < 2.58). Therefore, we do not reject H_0. There is not sufficient evidence to conclude that the average salary of major league baseball players in Florida is different from the national average. The data are not statistically significant.

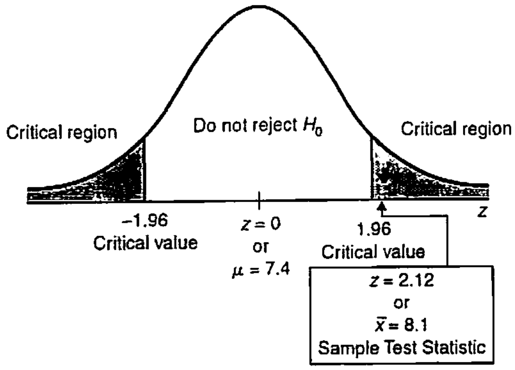
11. H_0: $\mu = 7.4$ pH
H_1: $\mu \neq 7.4$ pH

Since $\neq$ is in H_1, a two-tailed test is used.

Since the sample size $n = 33$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

For $\alpha = 0.05$, the critical values are $z_0 = \pm 1.96$.

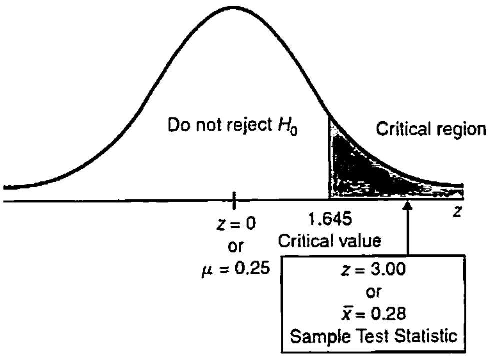
$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{8.1 - 7.4}{1.9/\sqrt{33}} = 2.12$$



The sample test statistic falls in the critical region (2.12 > 1.96). Therefore, we reject H_0. We conclude that the drug has changed the mean pH of the blood. The data are statistically significant.

12. H_0: $\mu = 0.25$ gal
H_1: $\mu > 0.25$ gal
Since > is in H_1, a right-tailed test is used.
Since the sample size n = 100 is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.
For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{0.28 - 0.25}{0.10/\sqrt{100}} = 3.00$$



The sample test statistic falls in the critical region (3.00 > 1.645). Therefore, we reject H_0. We conclude that the supplier's claim is too low. The data are statistically significant.

13. The mean and the standard deviation round to the values given.

H_0: $\mu = \$13.9$ thousand

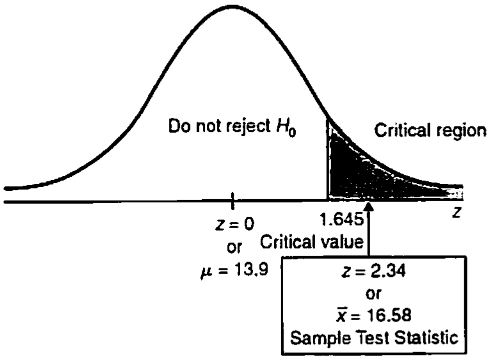
H_1: $\mu > \$13.9$ thousand

Since > is in H_1, a right-tailed test is used.

Since the sample size $n = 50$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{16.58 - 13.9}{8.11/\sqrt{50}} = 2.34$$



The sample test statistic falls in the critical region (2.34 > 1.645). Therefore, we reject H_0. We conclude that the mean franchise costs for pizza businesses are higher. The data are statistically significant.

14. (a) One-tailed test; if the null hypothesis is rejected, then one has the additional information from the test that the true population mean is larger/smaller than stated in H_0. Also, the critical value for a one-tailed test is nearer to zero than the critical values of a two-tailed test, meaning that *if* one is able to correctly surmise the direction of H_1, there is a greater chance of rejecting H_0. For example, for a right-tailed test at $\alpha = 0.05$, $z = 1.7$ would result in rejecting H_0, but in a two-tailed test at $\alpha = 0.05$ for the same $z = 1.7$, one would fail to reject H_0.

(b) Two-tailed test; for a given α-level the absolute value of the critical value for a one-tailed test is less than that of a two-tailed test, making the one-tailed test more likely to reject H_0.

(c) Yes. The rejection regions are different for one- and two-tailed tests.

15. Essay or class discussion.

16. (a) H_0: $\mu = 20$

H_1: $\mu \neq 20$

For $\alpha = 0.01$, $c = 1 - 0.01 = 0.99$, $s = 4$, and the critical value $z_c = 2.58$.

$$E \approx z_c \frac{s}{\sqrt{n}} = 2.58 \frac{4}{\sqrt{36}} = 1.72$$

$$\bar{x} - E < \mu < \bar{x} + E$$

$$22 - 1.72 < \mu < 22 + 1.72$$

$$20.28 < \mu < 23.72$$

The hypothesized mean $\mu = 20$ is not in the interval. Therefore, we reject H_0.

(b) For $\alpha = 0.01$, the two-tailed test's critical values are $z_0 = \pm 2.58$. Because $n = 36$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{22 - 20}{4/\sqrt{36}} = 3.00$$

Since the sample test statistic falls inside the critical region ($3.00 > 2.58$), we reject H_0. The results are the same.

17. (a) $H_0: \mu = 21$

$H_1: \mu \neq 21$

For $\alpha = 0.01$, $c = 1 - 0.01 = 0.99$, $s = 4$, and the critical value $z_c = 2.58$.

$$E \approx z_c \frac{s}{\sqrt{n}} = 2.58 \frac{4}{\sqrt{36}} = 1.72$$

$$\bar{x} - E < \mu < \bar{x} + E$$
$$22 - 1.72 < \mu < 22 + 1.72$$
$$20.28 < \mu < 23.72$$

The hypothesized mean $\mu = 21$ falls into the confidence interval. Therefore, we do not reject H_0.

(b) For $\alpha = 0.01$, the two-tailed test's critical values are $z_0 = \pm 2.58$. Because $n = 36$ is large, the sampling distribution of $\bar{x}$ is approximately normal by the central limit theorem, and we can estimate σ by s.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{22 - 21}{4/\sqrt{36}} = 1.50$$

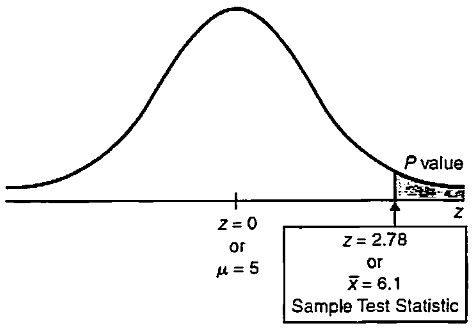
Since the sample test statistic falls outside the critical region ($-2.58 < 1.50 < 2.58$), we do not reject H_0. The results are the same.

Section 9.3

1. $H_0: \mu = 5$

$H_1: \mu > 5$

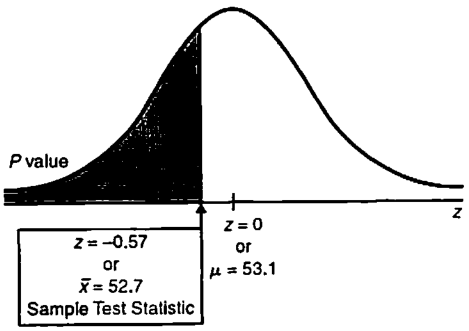
$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{6.1 - 5}{2.5/\sqrt{40}} = 2.78$$



$$P \text{ value} = P(\bar{x} \geq 6.1)$$
$$= P(z \geq 2.78)$$
$$= 1 - 0.9973$$
$$= 0.0027$$

Since $0.0027 < 0.01$, the data are significant at the 1% level.

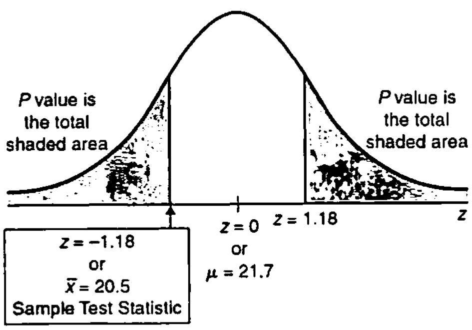
2. $H_0: \mu = 53.1$
   $H_1: \mu < 53.1$
   $$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{52.7 - 53.1}{4.5/\sqrt{41}} = -0.57$$



$$P \text{ value} = P(\bar{x} \leq 52.7)$$
$$= P(z \leq -0.57)$$
$$= 0.2843$$

Since $0.2843 > 0.01$, the data are not significant at the 1% level.

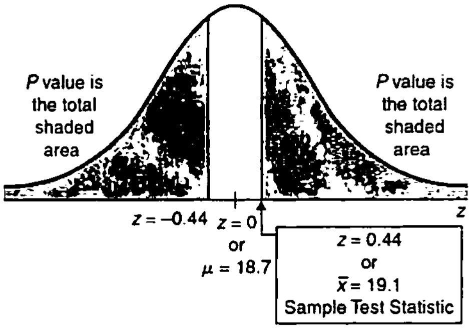
3. $H_0: \mu = 21.7$
   $H_1: \mu \neq 21.7$
   $$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{20.5 - 21.7}{6.8/\sqrt{45}} = -1.18$$



$$\begin{aligned} P \text{ value} &= 2P(\bar{x} \le 20.5) \\ &= 2P(z \le -1.18) \\ &= 2(0.1190) \\ &= 0.2380 \end{aligned}$$

Since 0.2380 > 0.05, the data are not significant at the 5% level.

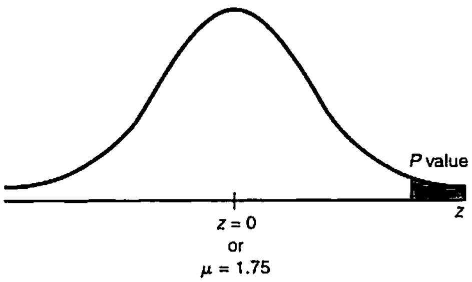
4. $H_0: \mu = 18.7$
   $H_1: \mu \ne 18.7$
   $$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{19.1 - 18.7}{5.2/\sqrt{32}} = 0.44$$



$$\begin{aligned} P \text{ value} &= 2P(\bar{x} \ge 19.1) \\ &= 2P(z \ge 0.44) \\ &= 2(1 - 0.6700) \\ &= 2(0.3300) \\ &= 0.6600 \end{aligned}$$

Since 0.6600 > 0.05, the data are not significant at the 5% level.

5. $H_0: \mu = 1.75$ yr
   $H_1: \mu > 1.75$ yr
   $$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{2.05 - 1.75}{0.82/\sqrt{68}} = 3.02$$



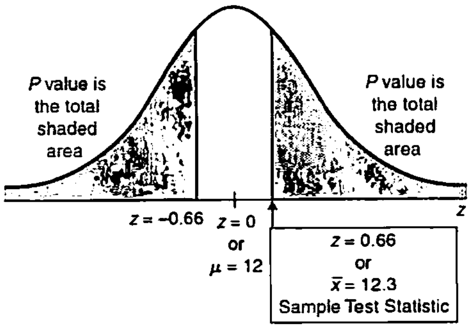
$$\begin{aligned} P \text{ value} &= P(\bar{x} \geq 2.05) \\ &= P(z \geq 3.02) \\ &= 1 - 0.9987 \\ &= 0.0013 \end{aligned}$$

Since $0.0013 < 0.01$, the data are significant at the 1% level. Coyotes in this region appear to live longer.

6. $H_0\colon \mu = 12 \text{ m}^2$

$H_1\colon \mu \neq 12\, m^2$

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{12.3 - 12}{3.4/\sqrt{56}} = 0.66$$



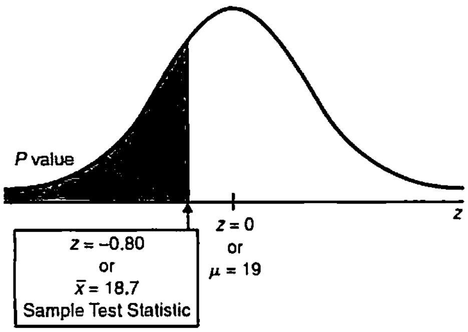
$$\begin{aligned} P \text{ value} &= 2P(\bar{x} \geq 12.3) \\ &= 2P(z \geq 0.66) \\ &= 2(1 - 0.7454) \\ &= 2(0.2546) \\ &= 0.5092 \end{aligned}$$

Since $0.5092 > 0.01$, the data are not significant at the 1% level. The evidence does not support the idea that Mesa Verdi Rivas have an average floor space size different from 12 square meters.

7. $H_0\colon \mu = 19$ in.

$H_1\colon \mu < 19$ in.

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{18.7 - 19}{3.2/\sqrt{73}} = -0.80$$



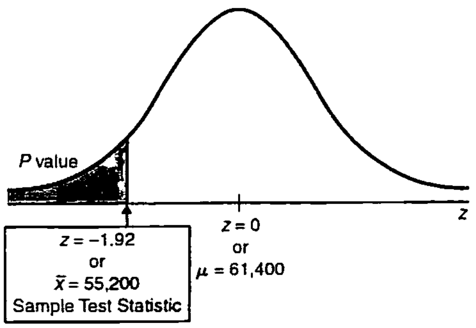
$$P \text{ value} = P(\bar{x} \le 18.7)$$
$$= P(z \le -0.80)$$
$$= 0.2119$$

Since 0.2119 > 0.05, the data are not significant at the 5% level. The data support the new hypothesis that average trout length is 19 inches.

8. H_0: $\mu = \$61{,}400$

H_1: $\mu < \$61{,}400$

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{55{,}200 - 61{,}400}{18{,}800/\sqrt{34}} = -1.92$$



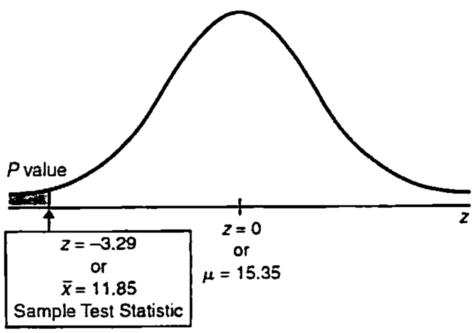
$$P \text{ value} = P(\bar{x} \le 55{,}200)$$
$$= P(z \le -1.92)$$
$$= 0.0274$$

Since 0.0274 < 0.05, the data are significant at the 5% level. The data tend to support a smaller start-up cost than $61,400.

9. H_0: $\mu = \$15.35$

H_1: $\mu < \$15.35$

$$z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}} = \frac{11.85 - 15.35}{6.21/\sqrt{34}} = -3.29$$



P value $= P(\bar{x} \leq 11.85)$
$= P(z \leq -3.29)$
$= 0.0005$

Since $0.0005 < 0.05$, the data are significant at the 5% level. The data support the claim that college students have lower daily ownership costs.

10. **(a)** H_0: $\mu = 19.5$ mpg
H_1: $\mu < 19.5$ mpg
The sample mean is $\bar{x} = 18.750$.
The P value is 0.047.
Reject H_0 for all $\alpha \geq 0.047$.

(b) H_0: $\mu = 19.5$ mpg
H_1: $\mu \neq 19.5$ mpg
The sample mean is $\bar{x} = 18.750$.
The P value is 0.094.
Reject H_0 for all $\alpha \geq 0.094$.

(c) The P value for a two-tailed test is twice that of the one-tailed test $[2(0.047) = 0.094]$.

Section 9.4

1. In this case we use the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = n - 1 = 9 - 1 = 8$. This gives us $t = 1.860$. For a left-tailed test, we use symmetry of the distribution to get $t_0 = -1.860$.

2. In this case we use the column headed by $\alpha' = 0.01$ and the row headed by $d.f. = n - 1 = 13 - 1 = 12$. The critical value is $t_0 = 2.681$.

3. In this case we use the column headed by $\alpha'' = 0.01$ and the row headed by $d.f. = n - 1 = 24 - 1 = 23$. By the symmetry of the curve, the critical values are $t_0 = \pm 2.807$.

4. In this case we use the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = n - 1 = 18 - 1 = 17$. This gives $t = 1.740$. For a left-tailed test, we use symmetry of the distribution to get $t_0 = -1.740$.

5. In this case we use the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = n - 1 = 12 - 1 = 11$. By the symmetry of the curve, the critical values are $t_0 = \pm 2.201$.

6. In this case we use the column headed by $\alpha' = 0.01$ and the row headed by $d.f. = n - 1 = 29 - 1 = 28$. The critical value is $t_0 = 2.467$.

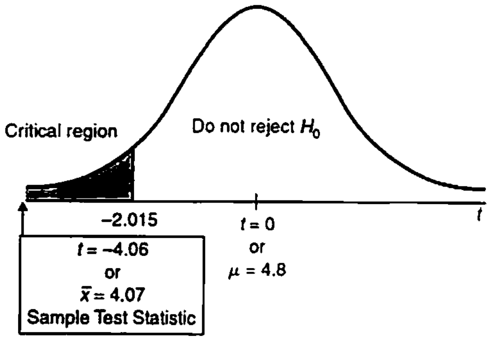
7. **(a)** Answers are used in part (b).

(b) $H_0: \mu = 4.8$

$H_1: \mu < 4.8$

Since < is in H_1, a left-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by *d.f.* = 6 − 1 = 5. The critical value is $t_0 = -2.015$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{4.07 - 4.8}{0.44/\sqrt{6}} = -4.06$$



To find the P-value interval, use the α' value since our test is one-tailed and look in the row headed by *d.f.* = 5. We find that the sample t value $t = -4.06$ falls to the left of −4.032. Therefore, P value < 0.005.

The sample test statistic falls in the critical region (−4.06 < −2.015) and the P value is less than the level of significance $\alpha = 0.05$. Therefore, we reject H_0. We conclude at the 5% significance level that this patient's average red blood cell count is less than 4.8.

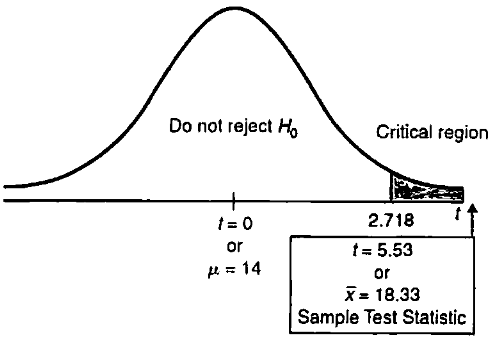
8. (a) Answers are used in part (b).

(b) $H_0: \mu = 14$

$H_1: \mu > 14$

Since > is in H_1, a right-tailed test is used. Since the sample size is small and the data distribution is approximately normal, and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.01$ and the row headed by *d.f.* = 12 − 1 = 11. The critical value is $t_0 = 2.718$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{18.33 - 14}{2.71/\sqrt{12}} = 5.53$$



To find the P-value interval, use the α' values since our test is one-tailed and look in the row headed by $d.f. = 11$. We find that the sample t value, $t = 5.53$, falls to the right of 3.106. Therefore, P value < 0.005.

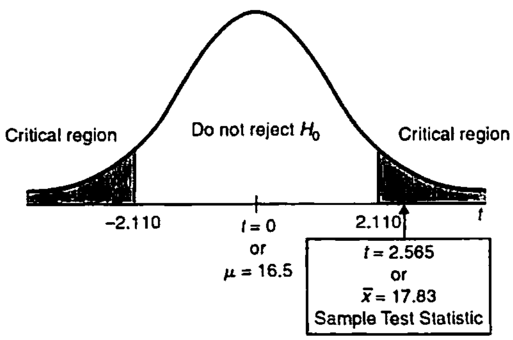
The sample test statistic falls in the critical region (5.53 > 2.718) and the P value is less than the level of significance $\alpha = 0.01$. Therefore, we reject H_0. We conclude that the population average HC for this patient is higher than 14.

9. (a) Answers are used in part (b).

(b) $H_0: \mu = 16.5$ days
$H_1: \mu \neq 16.5$ days

Since ≠ is in H_1, a two-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = 18 - 1 = 17$. The critical values are
$t_0 = \pm 2.110$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{17.83 - 16.5}{2.20/\sqrt{18}} = 2.565$$



To find the P-value interval, use the α'' values since our test is two-tailed and look in the row headed by $d.f. = 17$. We find that the sample t value $t = 2.565$ falls between 2.110 and 2.567. Therefore, $0.02 < P$ value < 0.05.

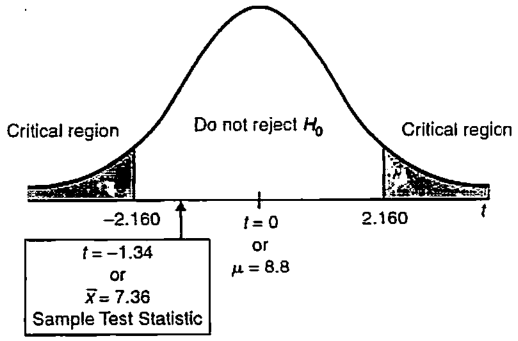
The sample test statistic falls in the critical region (2.565 > 2.110) and the P value is less than the level of significance $\alpha = 0.05$. Therefore, we reject H_0. We conclude at the 5% significance level that the mean incubation time above 8000 feet is different from 16.5 days.

10. (a) Answers are used in part (b).

(b) $H_0: \mu = 8.8$
$H_1: \mu \neq 8.8$

Since ≠ is in H_1, a two-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = 14 - 1 = 13$. The critical values are
$t_0 = \pm 2.160$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{7.36 - 8.8}{4.03/\sqrt{14}} = -1.34$$



To find the P-value interval, use the α'' values since our test is two-tailed and look in the row headed by $d.f. = 13$. We find that the sample t value $t = -1.34$ falls between −1.204 and −1.350. Therefore, $0.200 < P$ value < 0.250.

The sample test statistic does not fall in the critical region ($-2.160 < -1.34 < 2.160$) and the P value is greater than the level of significance $\alpha = 0.05$. Therefore, we fail to reject H_0. We cannot conclude that the average catch is different from 8.8 fish per day.

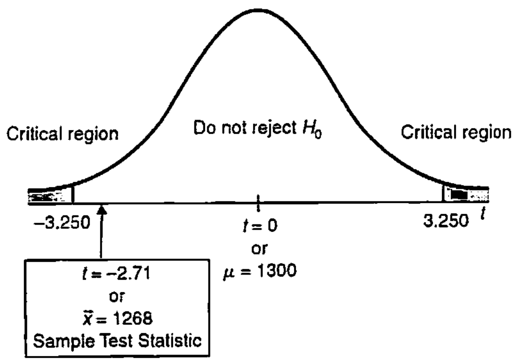
11. (a) Answers are used in part (b).

(b) $H_0: \mu = 1300$

$H_1: \mu \neq 1300$

Since $\neq$ is in H_1, a two-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.01$ and the row headed by $d.f. = 10 - 1 = 9$. The critical values are $t_0 = \pm 3.250$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{1268 - 1300}{37.29/\sqrt{10}} = -2.71$$



To find the P-value interval, use the α'' values since our test is two-tailed and look in the row headed by $d.f. = 9$. We find that the sample t value, $t = -2.71$, falls between −2.262 and −2.821. Therefore, $0.020 < P$ value < 0.050.

The sample test statistic does not fall in the critical region ($-3.250 < -2.71 < 3.250$) and the P value is greater than the level of significance $\alpha = 0.01$. Therefore, do not reject H_0. There is not enough evidence to conclude that the population mean of tree ring dates is different from 1300.

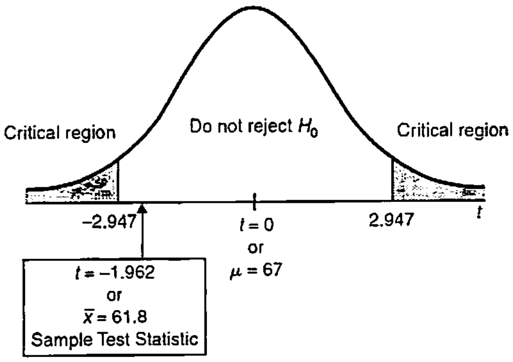
12. (a) Answers are used in part (b).

(b) $H_0: \mu = 67$

$H_1: \mu \neq 67$

Since $\neq$ is in H_1, a two-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.01$ and the row headed by $d.f. = 16 - 1 = 15$. The critical values are $t_0 = \pm 2.947$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{61.8 - 67}{10.6/\sqrt{16}} = -1.962$$



To find the P-value interval, use the α'' values since our test is two-tailed and look in the row headed by $d.f. = 15$. We find that the sample t value, $t = -1.962$, falls between -1.753 and -2.131. Therefore, $0.050 < P \text{ value} < 0.100$.

The sample test statistic does not fall in the critical region ($-2.947 < -1.962 < 2.947$) and the P value is greater than the level of significance $\alpha = 0.01$. Therefore, do not reject H_0. There is not enough evidence to conclude that the average thickness of slab avalanches in Vail is different from those in Canada.

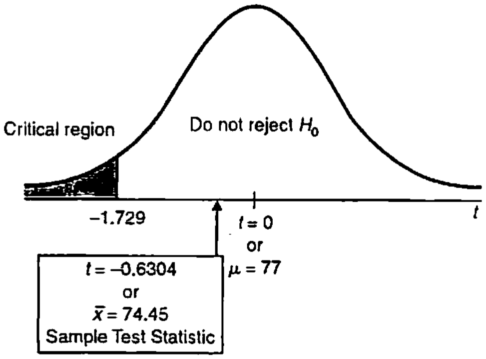
13. (a) Answers are used in part (b).

(b) $H_0: \mu = 77$ yr

$H_1: \mu < 77$ yr

Since $<$ is in H_1, a left-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 20 - 1 = 19$. The critical value is $t_0 = -1.729$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{74.45 - 77}{18.09/\sqrt{20}} = -0.6304$$



To find the P-value interval, use the α' values since our test is one-tailed and look in the row headed by $d.f. = 19$. We find that the sample t value, $t = -0.6304$, falls to the right of -1.187. Therefore, P value > 0.125.

The sample test statistic does not fall in the critical region ($-1.729 < -0.6304$) and the P value is greater than the level of significance $\alpha = 0.05$. Therefore, do not reject H_0. There is not enough evidence to conclude that the population mean life span is less than 77 years.

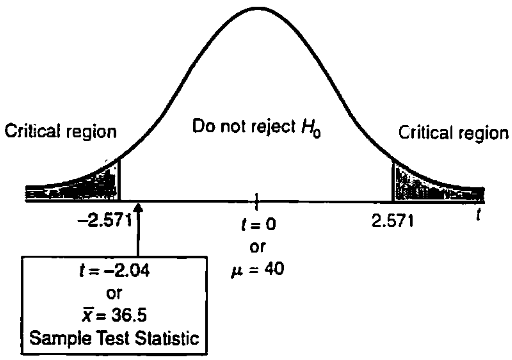
14. (a) Answers are used in part (b).

(b) $H_0: \mu = 40$

$H_1: \mu \neq 40$

Since $\neq$ is in H_1, a two-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = 6 - 1 = 5$. The critical values are $\pm t_0 = \pm 2.571$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{36.5 - 40}{4.2/\sqrt{6}} = -2.04$$



To find the P-value interval, use the α'' values since our test is two-tailed and look in the row headed by $d.f. = 5$. We find that the sample t value, $t = -2.04$, falls between -2.015 and -2.571. Therefore, $0.050 < P$ value < 0.100.

The sample test statistic does not fall in the critical region ($-2.571 < -2.04 < 2.571$) and the P value is greater than the level of significance $\alpha = 0.05$. Therefore, do not reject H_0. There is not enough evidence to conclude that the population average heart rate of the lion is different from 40 beats per minute.

15. **(a)** Answers are used in part (b).

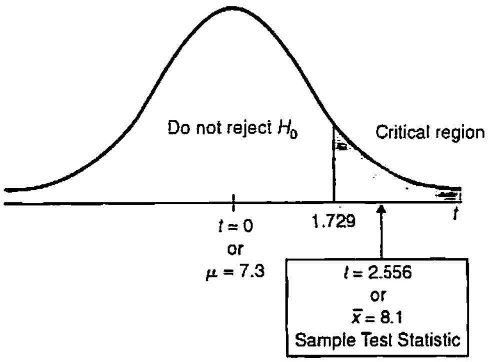
(b) $H_0: \mu = 7.3$

$H_1: \mu > 7.3$

Since > is in H_1, a right-tailed test is used. Since the sample size is small and the data distribution is approximately normal, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by *d.f.* = 20 − 1 = 19. The critical value is

$t_0 = 1.729$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{8.1 - 7.3}{1.4/\sqrt{20}} = 2.556$$



To find the P-value interval, use the α' values since our test is one-tailed and look in the row headed by *d.f.* = 19. We find that the sample t value, $t = 2.556$, falls between 2.539 and 2.861. Therefore, $0.005 < P$ value < 0.010.

The sample test statistic falls in the critical region (2.555 > 1.729) and the P value is less than the level of significance $\alpha = 0.05$. Therefore, reject H_0. We conclude that the evidence supports the claim that the average time women with children spend shopping in houseware stores in Cherry Creek Mall is higher than the national average.

Section 9.5

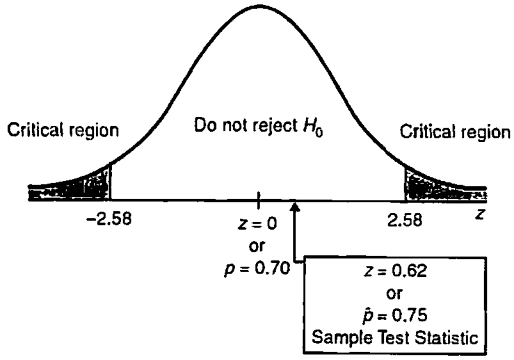
1. $H_0: p = 0.70$

$H_1: p \neq 0.70$

Since ≠ is in H_1, a two-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, since $np = 32(0.7) = 22.4$ and $nq = 32(0.3) = 9.6$ are both > 5. For $\alpha = 0.01$, the critical values are $z_0 = \pm 2.58$.

$$\hat{p} = \frac{r}{n} = \frac{24}{32} = 0.75$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.75 - 0.70}{\sqrt{\frac{0.70(0.30)}{32}}} = 0.62$$



Next, find the P value associated with $z = 0.62$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \geq 0.62) \\ &= 2(1 - 0.7324) \\ &= 2(0.2676) \\ &= 0.5352 \end{aligned}$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is not enough evidence to conclude that the population proportion of such arrests is different from 0.70.

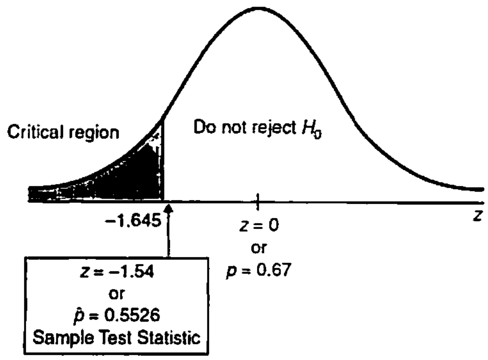
2. $H_0\colon p = 0.67$

$H_1\colon p < 0.67$

Since < is in H_1, a left-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, since $np = 38(0.67) = 25.46$ and $nq = 38(0.33) = 12.54$ are both > 5. For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$\hat{p} = \frac{r}{n} = \frac{21}{38} = 0.5526$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.5526 - 0.67}{\sqrt{\frac{0.67(0.33)}{38}}} = -1.54$$



Next, find the P value associated with $z = -1.54$ and a one-tailed test.

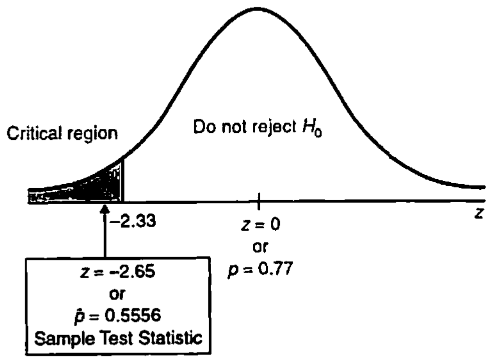
$$P \text{ value} = P(z \le -1.54)$$
$$= 0.0618$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is not enough evidence to conclude that the population proportion of women athletes who graduate at CU Boulder is now less than 67%.

3. $H_0: p = 0.77$
   $H_1: p < 0.77$

   Since < is in H_1, a left-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 27(0.77) = 20.79$ and $nq = 27(0.23) = 6.21$ are both > 5. For $\alpha = 0.01$, the critical value is $z_0 = -2.3$.

$$\hat{p} = \frac{r}{n} = \frac{15}{27} = 0.5556$$
$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.5556 - 0.77}{\sqrt{\frac{0.77(0.23)}{27}}} = -2.65$$



Next, find the P value associated with $z = -2.65$ and a one-tailed test.

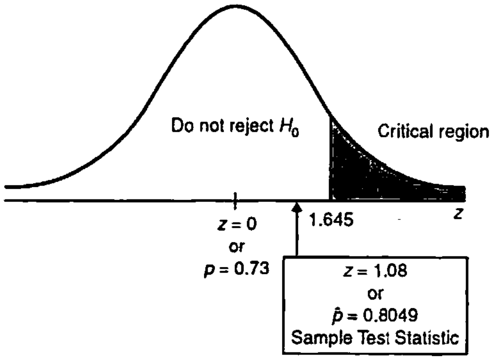
$$P \text{ value} = P(z \le -2.65)$$
$$= 0.0040$$

Since the sample z value falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.01$, we reject H_0. We conclude the population proportion of driver fatalities related to alcohol is less than 77%.

4. $H_0: p = 0.73$
   $H_1: p > 0.73$

   Since > is in H_1, a right-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 41(0.73) = 29.93$ and $nq = 41(0.27) = 11.07$ are both > 5. For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$\hat{p} = \frac{r}{n} = \frac{33}{41} = 0.8049$$
$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.8049 - 0.73}{\sqrt{\frac{0.73(0.27)}{41}}} = 108$$



Next, find the P value associated with $z = 1.08$ and a one-tailed test.

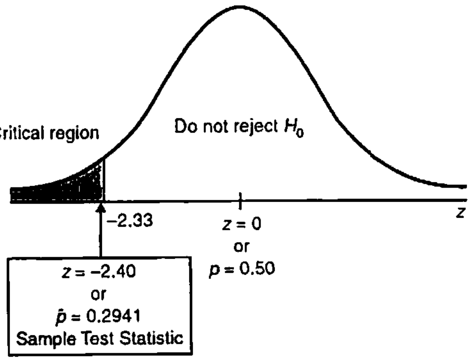
$$\begin{aligned} P \text{ value} &= P(z \geq 1.08) \\ &= 1 - 0.8599 \\ &= 0.1401 \end{aligned}$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is not enough evidence to conclude that the population proportion of such accidents is higher than 73% in the Fargo district.

5. $H_0: p = 0.50$
   $H_1: p < 0.50$

   Since < is in H_1, a left-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, and it is here because $np = 34(0.50) = 17$ and $nq = 17$ are both > 5. For $\alpha = 0.01$, the critical value is $z_0 = -2.33$.

$$\hat{p} = \frac{r}{n} = \frac{10}{34} = 0.2941$$
$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.2941 - 0.50}{\sqrt{\frac{0.5(0.5)}{34}}} = -2.40$$



Next, find the P value associated with $z = -2.40$ and a one-tailed test.

$$\begin{aligned} P \text{ value} &= P(z \le -2.40) \\ &= 0.0082 \end{aligned}$$

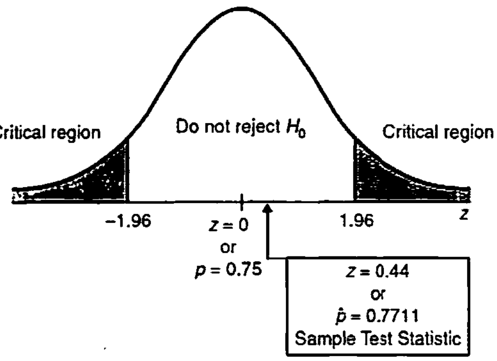
Since the sample z value falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.01$, we reject H_0. We conclude that the population proportion of female wolves is less than 50%.

6. $H_0: p = 0.75$
$H_1: p \ne 0.75$

Since $\ne$ is in H_1, a two-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 83(0.75) = 62.25$ and $nq = 83(0.25) = 20.75$ are both > 5. For $\alpha =$ 0.05, the critical values are $z_0 = \pm 1.96$.

$$\hat{p} = \frac{r}{n} = \frac{64}{83} = 0.7711$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.7711 - 0.75}{\sqrt{\frac{0.75(0.25)}{83}}} = 0.44$$



Next, find the P value associated with $z = 0.44$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \geq 0.44) \\ &= 2(1-0.6700) \\ &= 2(0.3300) \\ &= 0.6600 \end{aligned}$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that the population proportion is different from 75%.

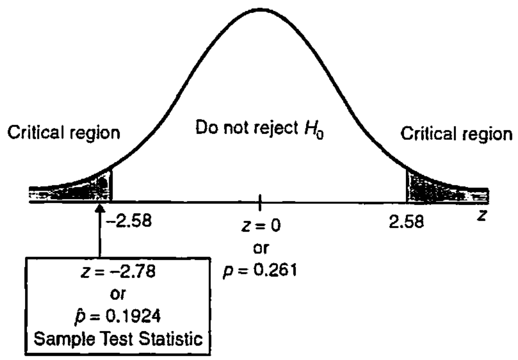
7. $H_0: p = 0.261$

   $H_1: p \neq 0.261$

   Since $\neq$ is in H_1, a two-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 317(0.261) = 82.737$ and $nq = 317(0.739) = 234.263$ are both > 5. For $\alpha = 0.01$, the critical values are $z_0 = \pm 2.58$.

$$\hat{p} = \frac{r}{n} = \frac{61}{317} = 0.1924$$

$$z = \frac{\hat{p}-p}{\sqrt{\frac{pq}{n}}} = \frac{0.1924-0.261}{\sqrt{\frac{0.261(0.739)}{317}}} = -2.78$$



Next, find the P value associated with $z = -2.78$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \leq -2.78) \\ &= 2(0.0027) \\ &= 0.0054 \end{aligned}$$

Since the sample z value falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.01$, we reject H_0. We conclude that the population proportion of this type of five-syllable sequence is significantly different from that of Plato's *Republic*.

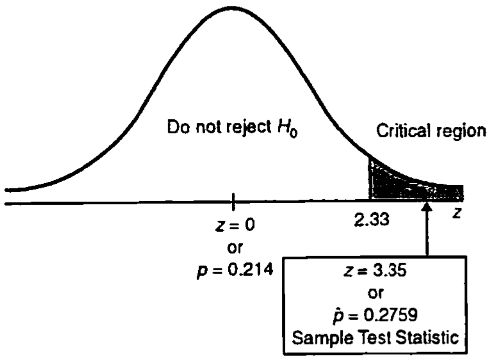
8. $H_0: p = 0.214$

$H_1: p > 0.214$

Since > is in H_1, a right-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 493(0.214) = 105.502$ and $nq = 493(0.786) = 387.498$ are both > 5. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$\hat{p} = \frac{r}{n} = \frac{136}{493} = 0.2759$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.2759 - 0.214}{\sqrt{\frac{0.214(0.786)}{493}}} = 3.35$$



Next, find the P value associated with $z = 3.35$ and a one-tailed test.

$$\begin{aligned} P \text{ value} &= P(z \geq 3.35) \\ &= 1 - 0.9996 \\ &= 0.0004 \end{aligned}$$

Since the sample z value falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.01$, we reject H_0. We conclude that the population proportion is higher than 21.4%

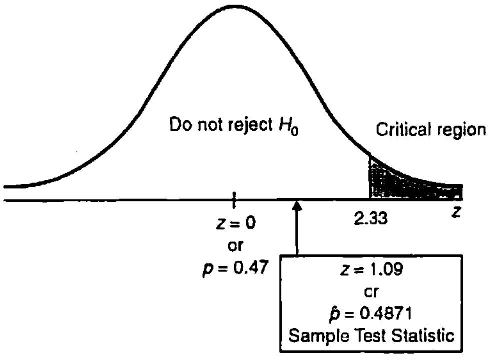
9. $H_0: p = 0.47$

$H_1: p > 0.47$

Since > is in H_1, a right-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 1006(0.47) = 472.82$ and $nq = 1006(0.53) = 533.18$ are both > 5. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$\hat{p} = \frac{r}{n} = \frac{490}{1006} = 0.4871$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.4871 - 0.47}{\sqrt{\frac{0.47(0.53)}{1006}}} = 1.09$$



Next, find the P value associated with $z = 1.09$ and a one-tailed test.

$$\begin{aligned} P \text{ value} &= P(z \ge 1.09) \\ &= 1 - 0.8621 \\ &= 0.1379 \end{aligned}$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the population proportion is more than 47%.

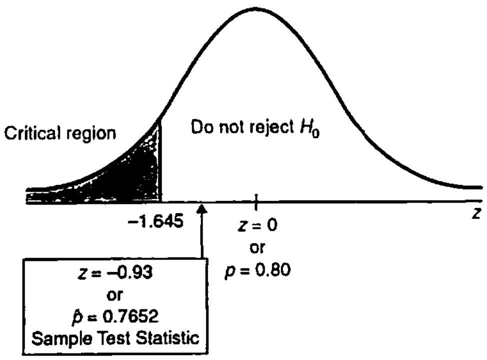
10. $H_0: p = 0.80$

$H_1: p < 0.80$

Since < is in H_1, a left-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 115(0.8) = 92$ and $nq = 115(0.2) = 23$ are both > 5. For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$\hat{p} = \frac{r}{n} = \frac{88}{115} = 0.7652$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.7652 - 0.80}{\sqrt{\frac{0.80(0.20)}{115}}} = -0.93$$



Next, find the P value associated with $z = -0.93$ and a one-tailed test.

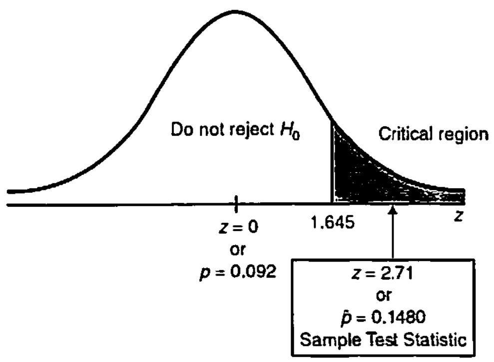
$$P \text{ value} = P(z \le -0.93)$$
$$= 0.1762$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude less than 80% of the prices in the store end in the digits 9 or 5.

11. $H_0: p = 0.092$
$H_1: p > 0.092$

Since > is in H_1, a right-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 196(0.092) = 18.032$ and $nq = 196(0.908) = 177.968$ are both > 5. For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$\hat{p} = \frac{r}{n} = \frac{29}{196} = 0.1480$$
$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.1480 - 0.092}{\sqrt{\frac{0.092(0.908)}{196}}} = 2.71$$



Next, find the P value associated with $z = 2.71$ and a one-tailed test.

$$P \text{ value} = P(z \ge 2.71)$$
$$= 1 - 0.9966$$
$$= 0.0034$$

Since the sample z value falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.05$, we reject H_0. We conclude that the population proportion of students with hypertension during final exams week is higher than 9.2%.

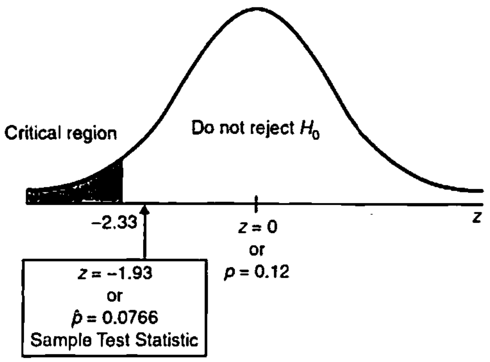
12. $H_0: p = 0.12$

$H_1: p < 0.12$

Since < is in H_1, a left-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 209(0.12) = 25.08$ and $nq = 209(0.88) = 183.92$ are both > 5. For $\alpha = 0.01$, the critical value is $z_0 = -2.33$.

$$\hat{p} = \frac{r}{n} = \frac{16}{209} = 0.0766$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.0766 - 0.12}{\sqrt{\frac{0.12(0.88)}{209}}} = -1.93$$



Next, find the P value associated with $z = -1.93$ and a one-tailed test.

$$P \text{ value} = P(z \le -1.93) = 0.0268$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that there has been a reduction in the population proportion of patients having headaches.

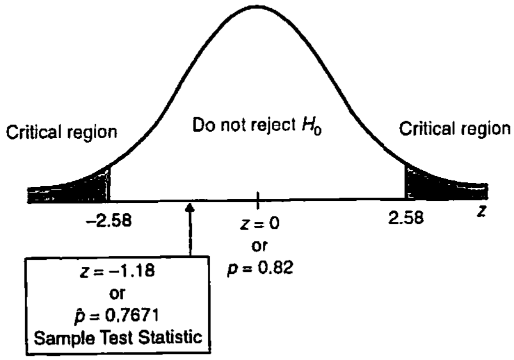
13. $H_0: p = 0.82$

$H_1: p \ne 0.82$

Since ≠ is in H_1, a two-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 73(0.82) = 59.86$ and $nq = 73(0.18) = 13.14$ are both > 5. For $\alpha = 0.01$, the critical values are $z_0 = \pm 2.58$.

$$\hat{p} = \frac{r}{n} = \frac{56}{73} = 0.7671$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.7671 - 0.82}{\sqrt{\frac{0.82(0.18)}{73}}} = -1.18$$



Next, find the P value associated with $z = -1.18$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \le -1.18) \\ &= 2(0.1190) \\ &= 0.2380 \end{aligned}$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the population proportion is different from 82%.

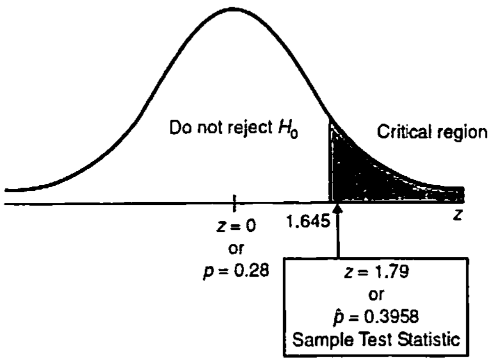
14. H_0: $p = 0.28$

H_1: $p > 0.28$

Since > is in H_1, a right-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 48(0.28) = 13.44$ and $nq = 48(0.72) = 34.56$ are both > 5. For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$\hat{p} = \frac{r}{n} = \frac{19}{48} = 0.3958$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.3958 - 0.28}{\sqrt{\frac{0.28(0.72)}{48}}} = 1.79$$



Next, find the P value associated with $z = 1.79$ and a one-tailed test.

$$\begin{aligned} P \text{ value} &= P(z \geq 1.79) \\ &= 1 - 0.9633 \\ &= 0.0367 \end{aligned}$$

Since the sample z value falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.05$, we reject H_0. We conclude that the population proportion of interstate truckers who believe NAFTA benefits America is higher than 28%.

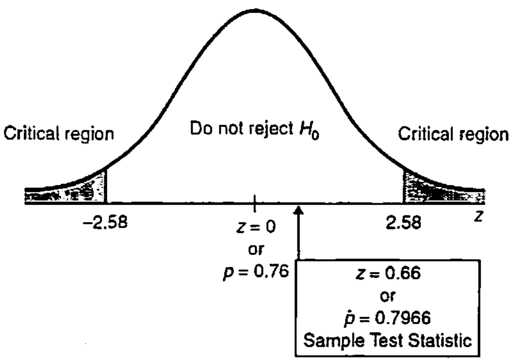
15. H_0: $p = 0.76$

H_1: $p \neq 0.76$

Since $\neq$ is in H_1, a two-tailed test is used. The $\hat{p}$ distribution is approximately normal when n is sufficiently large, which it is here, because $np = 59(0.76) = 44.84$ and $nq = 59(0.24) = 14.16$ are both > 5. For $\alpha = 0.01$, the critical values are $z_0 = \pm 2.58$.

$$\hat{p} = \frac{r}{n} = \frac{47}{59} = 0.7966$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.7966 - 0.76}{\sqrt{\frac{0.76(0.24)}{59}}} = 0.66$$



Next, find the P value associated with $z = 0.66$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \geq 0.66) \\ &= 2(1 - 0.7454) \\ &= 2(0.2546) \\ &= 0.5092 \end{aligned}$$

Since the sample z value falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the population proportion of professors in Colorado who would choose the career again is different from 76%.

Section 9.6

Note: In the following problems, we will make the assumption that the data are (approximately) normally distributed.

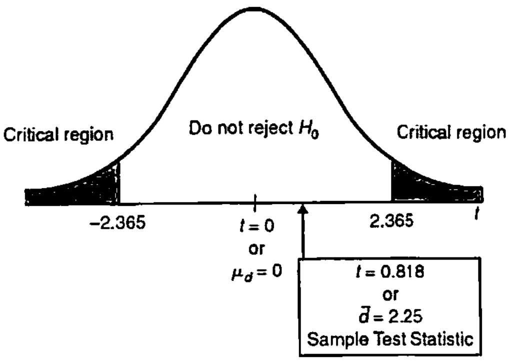
1. H_0: $\mu_d = 0$

   H_1: $\mu_d \neq 0$

   Since ≠ is in H_1, a two-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = 8 - 1 = 7$. The critical values are $t_0 = \pm 2.365$.

$$\bar{d} = 2.25,\ s_d = 7.78$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{2.25 - 0}{7.78/\sqrt{8}} = 0.818$$



   To find the P value interval, use the α'' values since the test is two-tailed and look in the row headed by $d.f. = 7$. We find that the sample t value, $t = 0.818$, falls to the left of 1.254. Therefore, P value > 0.250.

   Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is not enough evidence to conclude that there is a significant difference between the population mean percentage increase in corporate revenue and the population mean percentage increase in CEO salary.

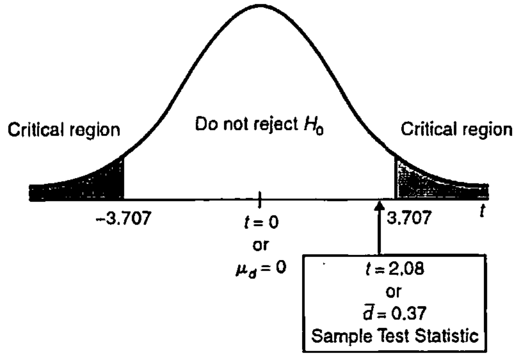
2. H_0: $\mu_d = 0$

   H_1: $\mu_d \neq 0$

   Since ≠ is in H_1, a two-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.01$ and the row headed by $d.f. = 7 - 1 = 6$. The critical values are $t_0 = \pm 3.707$.

$$\bar{d} = 0.37,\ s_d = 0.47$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{0.37 - 0}{0.47/\sqrt{7}} = 2.08$$



To find the P value interval, use the α'' values since the test is two-tailed and look in the row headed by $d.f. = 6$. We find that the sample t value, $t = 2.08$, falls between 1.943 and 2.447. Therefore, $0.050 < P \text{ value} < 0.100$.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is not enough evidence to conclude that there is a difference in the population mean hours per fish using a boat compared to the population mean hours per fish fishing from the shore.

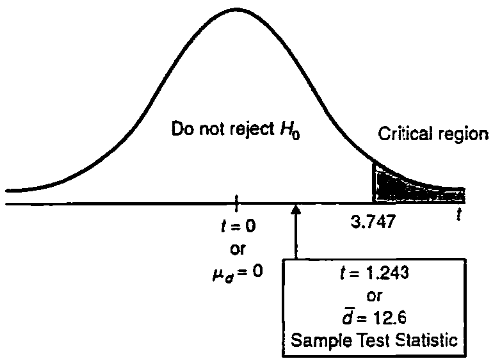
3. $H_0: \mu_d = 0$

   $H_1: \mu_d > 0$

   Since > is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.01$ and the row headed by $d.f. = 5 - 1 = 4$. The critical value is $t_0 = 3.747$.

$$\bar{d} = 12.6,\ s_d = 22.66$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{12.6 - 0}{22.66/\sqrt{5}} = 1.243$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 4$. We find that the sample t value, $t = 1.243$, falls to the left of 1.344. Therefore, $P \text{ value} > 0.125$.

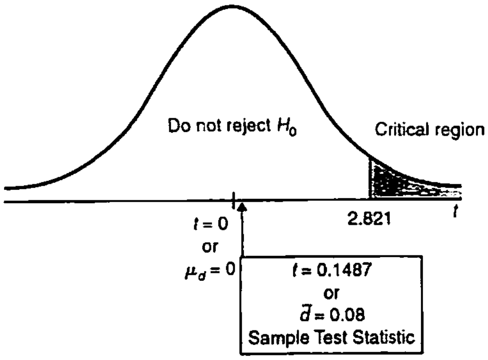
Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that, on average, peak wind gusts are higher in January than they are in April.

4. H_0: $\mu_d = 0$
   H_1: $\mu_d > 0$

Since > is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.01$ and the row headed by $d.f. = 10 - 1 = 9$. The critical value is $t_0 = 2.821$.

$$\bar{d} = 0.08, \; s_d = 1.701$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{0.08 - 0}{1.701/\sqrt{10}} = 0.1487$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 9$. We find that the sample t value, $t = 0.1487$, falls to the left of 1.230. Therefore, P value > 0.125.

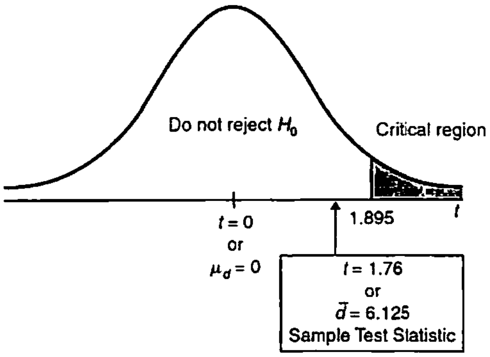
Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the January population mean has dropped.

5. H_0: $\mu_d = 0$
   H_1: $\mu_d > 0$

Since > is in H_1, right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 8 - 1 = 7$. The critical value is $t_0 = 1.895$.

$$\bar{d} = 6.125, \; s_d = 9.83$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{6.125 - 0}{9.83/\sqrt{8}} = 1.76$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 7$. We find that the sample t value, $t = 1.76$, falls between 1.617 and 1.895. Therefore, $0.050 < P \text{ value} < 0.075$.

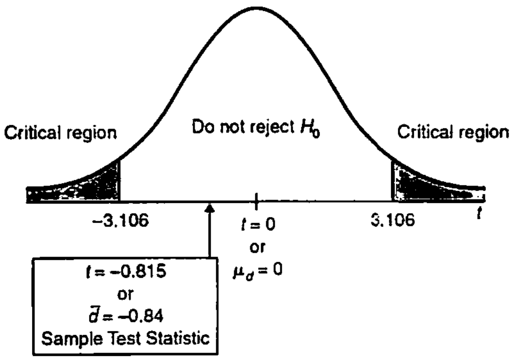
Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is not enough evidence to conclude that average percentage of males in a wolf pack is higher in winter.

6. $H_0: \mu_d = 0$
   $H_1: \mu_d \neq 0$

   Since $\neq$ is in H_1, a two-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.01$ and the row headed by $d.f. = 12 - 1 = 11$. The critical values are $t_0 = \pm 3.106$.

$$\bar{d} = -0.84;\ s_d = 3.57$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{-0.84 - 0}{3.57/\sqrt{12}} = -0.815$$



To find the P value interval, use the α'' values since the test is two-tailed and look in the row headed by $d.f. = 11$. We find that the sample t value, $t = -0.815$, falls to the right of -1.214. Therefore, $P \text{ value} > 0.250$.

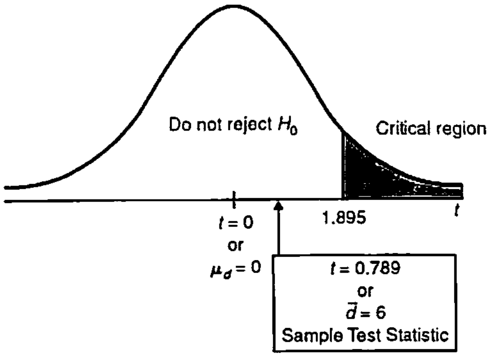
Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the average temperature in Miami is different from that in Honolulu.

7. $H_0: \mu_d = 0$
   $H_1: \mu_d > 0$

   Since $>$ is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 8 - 1 = 7$. The critical value is $t_0 = 1.895$.

$$\bar{d} = 6,\ s_d = 21.5$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{6 - 0}{21.5/\sqrt{8}} = 0.789$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 7$. We find that the sample t value, $t = 0.789$, falls to the left of 1.254. Therefore, P value > 0.125.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. We do not have enough evidence to conclude that the average number of inhabited houses is greater than the average number of inhabited hogans on the Navajo Reservation.

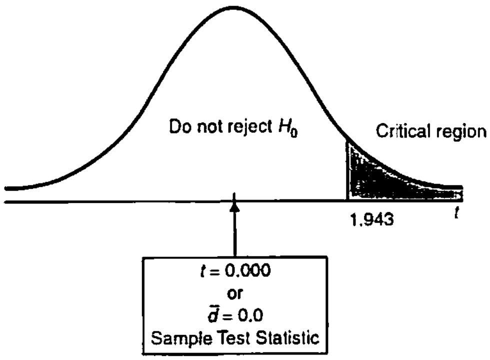
8. $H_0: \mu_d = 0$

$H_1: \mu_d > 0$

Since > is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 7 - 1 = 6$. The critical value is $t_0 = 1.943$.

$$\bar{d} = 0.0, \ s_d = 8.76$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{0.0 - 0}{8.76/\sqrt{7}} = 0.000$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 6$. We find that the sample t value, $t = 0$, falls to the left of 1.273. Therefore, P value > 0.125.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. We do not have enough evidence to conclude that there tend to be more flaked stone tools than nonflaked stone tools at this excavation site. Note: In fact, there is no reason to do a hypothesis test or "find" the P value for this data. Since d = the hypothesized mean, there is absolutely no evidence for H_1.

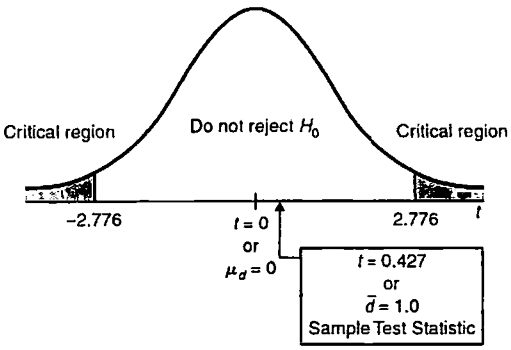
9. $H_0: \mu_d = 0$

$H_1: \mu_d \neq 0$

Since ≠ is in H_1, a two-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = 5 - 1 = 4$. The critical values are $t_0 = \pm 2.776$.

$$\bar{d} = 1.0,\ s_d = 5.24$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{1.0 - 0}{5.24/\sqrt{5}} = 0.427$$



To find the P value interval, use the α'' values since the test is two-tailed and look in the row headed by $d.f. = 4$. We find that the sample t value, $t = 0.427$, falls to the left of 1.344. Therefore, P value > 0.250.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is not enough evidence to conclude that there is a difference in the average number of service ware sherds in subarea 1 compared to subarea 2.

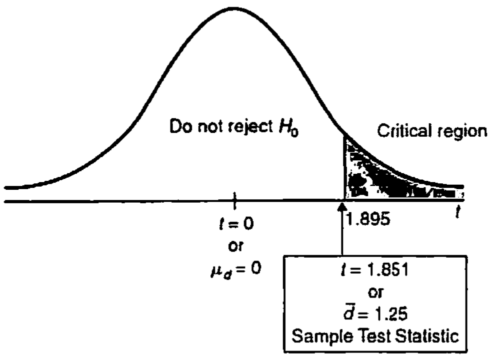
10. $H_0: \mu_d = 0$

$H_1: \mu_d > 0$

Since > is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 8 - 1 = 7$. The critical value is $t_0 = 1.895$.

$$\bar{d} = 1.25,\ s_d = 1.91$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{1.25 - 0}{1.91/\sqrt{8}} = 1.851$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 7$. We find that the sample t value, $t = 1.851$, falls between 1.617 and 1.895. Therefore, $0.050 < P$ value < 0.075.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. We do not have sufficient evidence to conclude that the mothers are more successful in picking out their own babies when a hunger cry is involved.

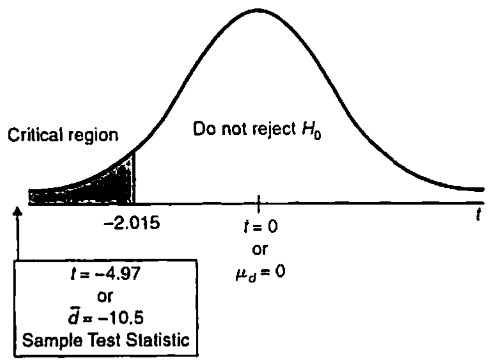
11. $H_0: \mu_d = 0$

$H_1: \mu_d < 0$

Since < is in H_1, a left-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 6 - 1 = 5$. The critical value is $t_0 = -2.015$.

$$\bar{d} = -10.5, \quad s_d = 5.17$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{-10.5 - 0}{5.17/\sqrt{6}} = -4.97$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 5$. We find that the sample t value, $t = -4.97$, falls to the left of -4.032. Therefore, P value > 0.005.

Since the sample test statistic falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.05$, we reject H_0. We conclude that the population mean heart rate after the test is higher than that before the test.

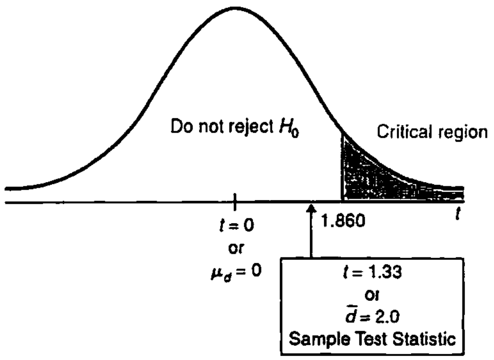
12. $H_0: \mu_d = 0$

$H_1: \mu_d \neq 0$

Since ≠ is in H_1, a two-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = 6 - 1 = 5$. The critical values are $t_0 = \pm 2.571$.

$$\bar{d} = -3.33, \quad s_d = 7.34$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{-3.33 - 0}{7.34/\sqrt{6}} = -1.111$$



To find the P value interval, use the α'' values since the test is two-tailed and look in the row headed by $d.f. = 5$. We find that the sample t value, $t = -1.111$, falls to the right of -1.301. Therefore, P value > 0.250.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that the population mean systolic blood pressure is different before and 6 minutes after the treadmill test.

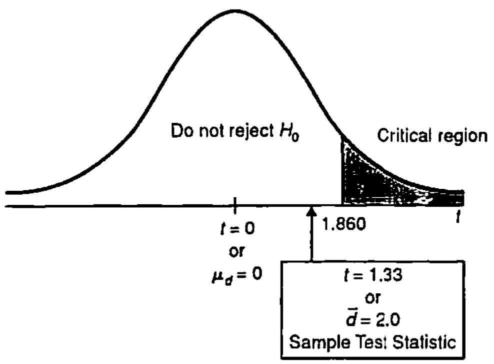
13. H_0: $\mu_d = 0$

H_1: $\mu_d > 0$

Since > is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 9 - 1 = 8$. The critical value is $t_0 = 1.860$.

$$\bar{d} = 2.0, \ s_d = 4.5$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{2.0 - 0}{4.5/\sqrt{9}} = 1.33$$



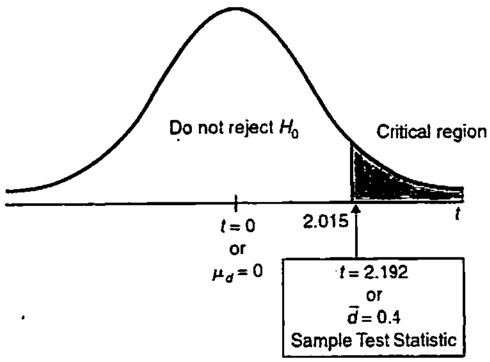
To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 8$. We find that the sample t value, $t = 1.33$, falls between 1.240 and 1.397. Therefore, $0.100 < P$ value < 0.125.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that the population mean score on the last round is significantly higher than the population mean score on the first round.

14. $H_0: \mu_d = 0$
$H_1: \mu_d > 0$
Since > is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 6 - 1 = 5$. The critical value is $t_0 = 2.015$.

$$\bar{d} = 0.4,\ s_d = 0.447$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{0.4 - 0}{0.447/\sqrt{6}} = 2.192$$



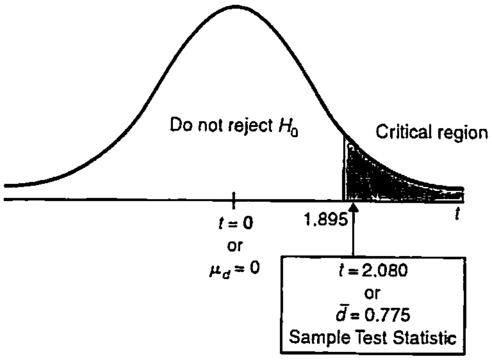
To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 5$. We find that the sample t value, $t = 2.192$, falls between 2.015 and 2.571. Therefore, $0.025 < P$ value < 0.050.

Since the sample test statistic falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.05$, we reject H_0. We conclude that the rats receiving larger rewards tend to run the maze in less time.

15. $H_0: \mu_d = 0$
$H_1: \mu_d > 0$
Since > is in H_1, a right-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a one-tailed test, look in the column headed by $\alpha' = 0.05$ and the row headed by $d.f. = 8 - 1 = 7$. The critical value is $t_0 = 1.895$.

$$\bar{d} = 0.775,\ s_d = 1.0539$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{0.775 - 0}{1.0539/\sqrt{8}} = 2.080$$



To find the P value interval, use the α' values since the test is one-tailed and look in the row headed by $d.f. = 7$. We find that the sample t value, $t = 2.080$, falls between 1.895 and 2.365. Therefore, $0.025 < P$ value < 0.050.

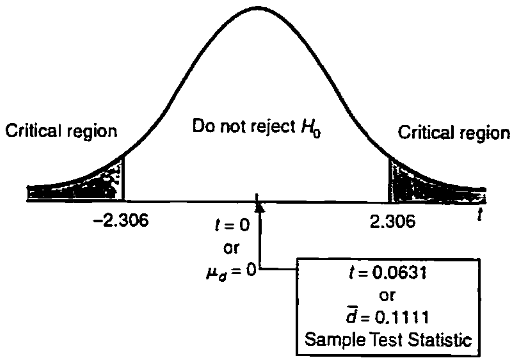
Since the sample test statistic falls inside the critical region and the P value is less than the level of significance, $\alpha = 0.05$, we reject H_0. We conclude that the rats receiving larger rewards tend to perform the ladder climb in less time.

16. $H_0: \mu_d = 0$
$H_1: \mu_d \neq 0$

Since $\neq$ is in H_1, a two-tailed test is used. Since the sample size is small, critical values are found using the Student's t distribution (use Table 6 in Appendix II). For a two-tailed test, look in the column headed by $\alpha'' = 0.05$ and the row headed by $d.f. = 9 - 1 = 8$. The critical values are $t_0 = \pm 2.306$.

$$\bar{d} = 0.1111, \; s_d = 5.2784$$

$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{0.1111 - 0}{5.2784/\sqrt{9}} = 0.0631$$



To find the P value interval, use the α'' values since the test is two-tailed and look in the row headed by $d.f. = 8$. We find that the sample t value, $t = 0.0631$, falls to the left of 1.240. Therefore, P value > 0.250.

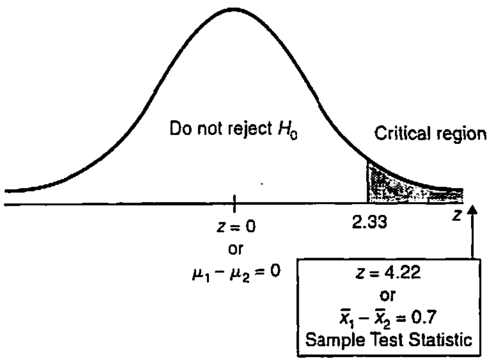
Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance, $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that there is a difference in the population mean of male versus female assistant professors.

Section 9.7

1. $H_0: \mu_1 = \mu_2$
   $H_1: \mu_1 > \mu_2$
   Since > is in H_1, a right-tailed test is used. Since the samples are both large, we use the normal distribution and approximate σ_1^2 and σ_2^2 by s_1^2 and s_2^2, respectively. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$\bar{x}_1 - \bar{x}_2 = 2.6 - 1.9 = 0.7$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{0.7 - 0}{\sqrt{\frac{0.5^2}{33} + \frac{0.8^2}{32}}} = 4.22$$



Next, find the P value associated with $z = 4.22$ and a one-tailed test.

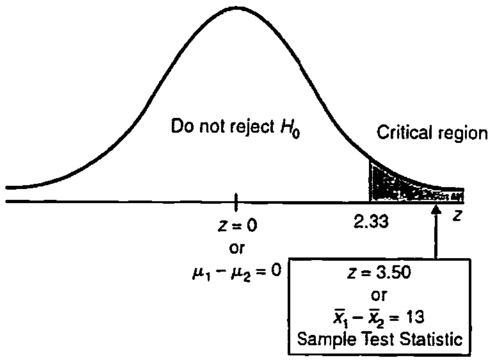
$$P \text{ value} = P(z > 4.22) \approx 0$$

Since the sample z falls inside the critical region and the P value is less than the level of significance $\alpha = 0.01$, we reject H_0. We conclude that, on average, 10-year-old children have more REM sleep than do 35-year-old adults.

2. $H_0: \mu_1 = \mu_2$
   $H_1: \mu_1 > \mu_2$
   Since > is in H_1, a right-tailed test is used. Since the samples are both large, we use the normal distribution and approximate σ_1^2 and σ_2^2 by s_1^2 and s_2^2, respectively. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$\bar{x}_1 - \bar{x}_2 = 43 - 30 = 13$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{13 - 0}{\sqrt{\frac{22^2}{45} + \frac{12^2}{47}}} = 3.50$$



Next, find the P value associated with $z = 3.50$ and a one-tailed test.

$$P \text{ value} = P(z \geq 3.50)$$
$$< 0.0002$$

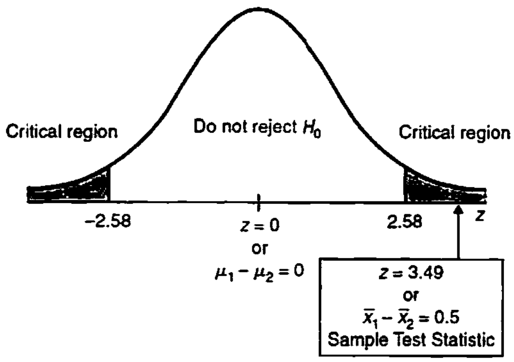
Since the sample z falls inside the critical region and the P value is less than the level of significance $\alpha = 0.01$, we reject H_0. We conclude that the mean population pollution index for Englewood is less than that for Denver in the winter.

3. $H_0: \mu_1 = \mu_2$

   $H_1: \mu_1 \neq \mu_2$

   Since $\neq$ is in H_1, a two-tailed test is used. Since the samples are both large, we use the normal distribution and approximate ${\sigma_1}^2$ and ${\sigma_2}^2$ by ${s_1}^2$ and ${s_2}^2$, respectively. For $\alpha = 0.01$, the critical values are $z_0 = \pm 2.58$.

$$\bar{x}_1 - \bar{x}_2 = 4.7 - 4.2 = 0.5$$
$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{0.5 - 0}{\sqrt{\frac{1.1^2}{201} + \frac{1.4^2}{135}}} = 3.49$$



Next, find the P value associated with $z = 3.49$ and a two-tailed test.

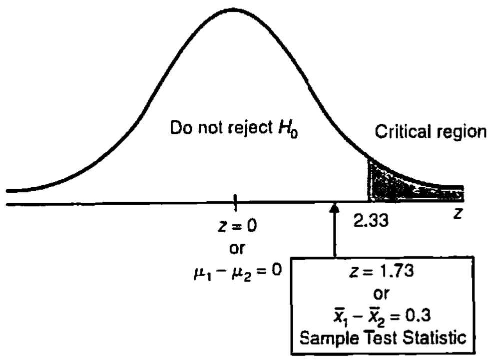
$$\begin{aligned} P \text{ value} &= 2P(z \geq 3.49) \\ &= 2(1-0.9998) \\ &= 2(0.0002) \\ &= 0.0004 \end{aligned}$$

Since the sample z falls inside the critical region and the P value is less than the level of significance $\alpha = 0.01$, we reject H_0. We conclude that a difference exists regarding preference for camping or preference for fishing as an outdoor activity.

4. $H_0: \mu_1 = \mu_2$
$H_1: \mu_1 > \mu_2$
Since > is in H_1, a right-tailed test is used. Since the samples are both large, we use the normal distribution and approximate σ_1^2 and σ_2^2 by s_1^2 and s_2^2, respectively. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$\bar{x}_1 - \bar{x}_2 = 4.3 - 4.0 = 0.3$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{0.3 - 0}{\sqrt{\frac{1.3^2}{122} + \frac{1.3^2}{104}}} = 1.73$$



Next, find the P value associated with $z = 1.73$ and a one-tailed test.

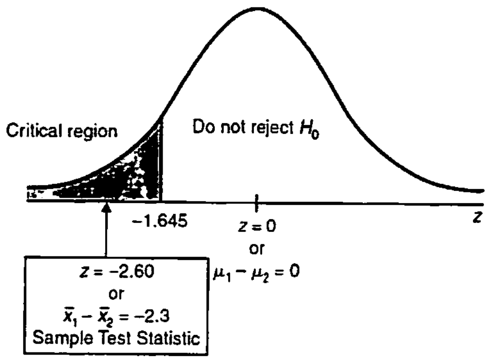
$$\begin{aligned} P \text{ value} &= P(z \geq 1.73) \\ &= 1 - 0.9582 \\ &= 0.0418 \end{aligned}$$

Since the sample z falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the population mean preference for lake fishing is greater than the population mean preference for stream fishing.

5. $H_0: \mu_1 = \mu_2$
   $H_1: \mu_1 < \mu_2$
   Since < is in H_1, a left-tailed test is used. Since the samples are both large, we use the normal distribution and approximate σ_1^2 and σ_2^2 by s_1^2 and s_2^2, respectively. For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$\bar{x}_1 - \bar{x}_2 = 10.6 - 12.9 = -2.3$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{-2.3 - 0}{\sqrt{\frac{3.3^2}{38} + \frac{4.5^2}{41}}} = -2.60$$



Next, find the P value associated with $z = -2.60$ and a one-tailed test.

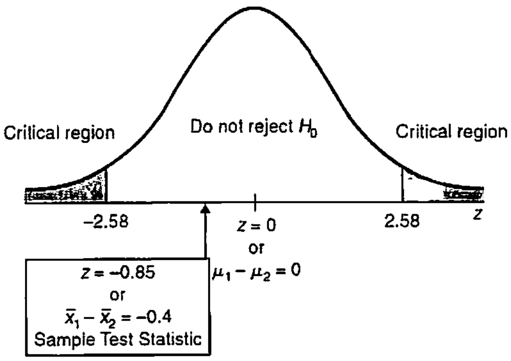
$$P \text{ value} = P(z \le -2.60) = 0.0047$$

Since the sample z falls inside the critical region and the P value is less than the level of significance $\alpha = 0.05$, we reject H_0. We conclude that the average sick leave for night workers is more than that for day workers.

6. $H_0: \mu_1 = \mu_2$
   $H_1: \mu_1 \ne \mu_2$
   Since $\ne$ is in H_1, a two-tailed test is used. Since the samples are both large, we use the normal distribution and approximate σ_1^2 and σ_2^2 by s_1^2 and s_2^2, respectively. For $\alpha = 0.01$, the critical values are $\pm z_0 = \pm 2.58$.

$$\bar{x}_1 - \bar{x}_2 = 4.7 - 5.1 = -0.4$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{-0.4 - 0}{\sqrt{\frac{2.1^2}{53} + \frac{2.5^2}{46}}} = -0.85$$



Next, find the P value associated with $z = -0.85$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \le -0.85) \\ &= 2(0.1977) \\ &= 0.3954 \end{aligned}$$

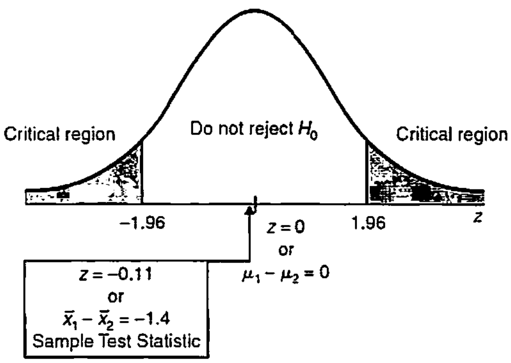
Since the sample z falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that a difference exists between student opinion and community opinion about this bill.

7. H_0: $\mu_1 = \mu_2$
   H_1: $\mu_1 \ne \mu_2$

   Since $\ne$ is in H_1, a two-tailed test is used. Since the samples are both large, we use the normal distribution and approximate ${\sigma_1}^2$ and ${\sigma_2}^2$ by ${s_1}^2$ and ${s_2}^2$, respectively. For $\alpha = 0.05$, the critical values are $z_0 = 1.96$.

$$\bar{x}_1 - \bar{x}_2 = 344.5 - 345.9 = -1.4$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{-1.4 - 0}{\sqrt{\frac{49.1^2}{30} + \frac{50.9^2}{30}}} = -0.11$$



Next, find the P value associated with $z = -0.11$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \le -0.11) \\ &= 2(0.4562) \\ &= 0.9124 \end{aligned}$$

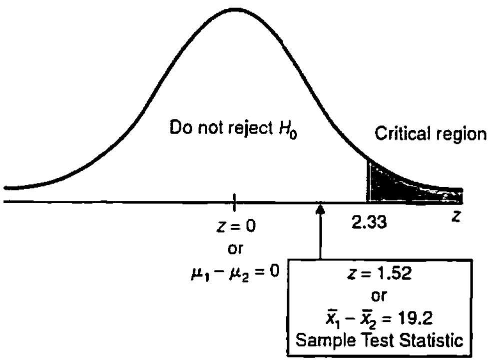
Since the sample z falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude there is a difference in the vocabulary scores of the two groups before the instruction began.

8. $H_0: \mu_1 = \mu_2$
$H_1: \mu_1 > \mu_2$

Let Group 1 be the experimental group and group 2 be the control group as in problem 7 above. Since > is in H_1, a right-tailed test is used. Since the samples are both large, we use the normal distribution and approximate σ_1^2 and σ_2^2 by s_1^2 and s_2^2, respectively. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$\bar{x}_1 - \bar{x}_2 = 368.4 - 349.2 = 19.2$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{19.2 - 0}{\sqrt{\frac{39.5^2}{30} + \frac{56.6^2}{30}}} = 1.52$$



Next, find the P value associated with $z = 1.52$ and a one-tailed test.

$$\begin{aligned} P \text{ value} &= P(z \ge 1.52) \\ &= 1 - 0.9357 \\ &= 0.0643 \end{aligned}$$

Since the sample z falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the experimental group performed better than the control group.

9. **(a)** The means and standard deviations round to the results given.

(b) H_0: $\mu_1 = \mu_2$

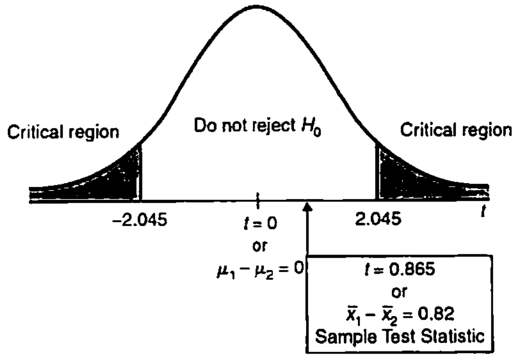
H_1: $\mu_1 \neq \mu_2$

Since ≠ is in H_1, a two-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha'' = 0.05$ and $d.f. = 16 + 15 - 2 = 29$, the critical values are $t_0 = \pm 2.045$.

$$s = \sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{15(2.82)^2+14(2.43)^2}{16+15-2}} = 2.6389$$

$$\bar{x}_1 - \bar{x}_2 = 4.75 - 3.93 = 0.82$$

$$t = \frac{(\bar{x}_1-\bar{x}_2)-(\mu_1-\mu_2)}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{0.82-0}{2.6389\sqrt{\frac{1}{16}+\frac{1}{15}}} = 0.865$$



Next, find the P value interval using the α'' values and the row headed by $d.f. = 29$. We find the sample t value, $t = 0.85$, falls to the left of 1.174. Therefore, P value > 0.250.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude a difference exists in the mean number of cases of fox rabies between the two regions.

10. **(a)** The means and standard deviations round to the results given.

(b) H_0: $\mu_1 = \mu_2$

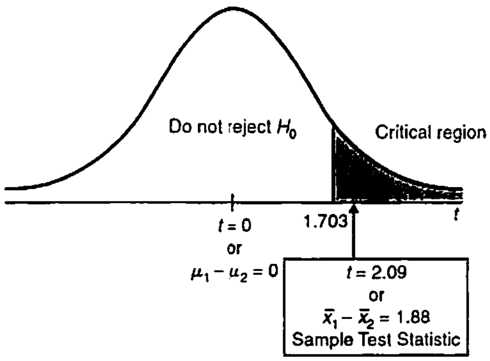
H_1: $\mu_1 > \mu_2$

Since > is in H_1, a right-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha' = 0.05$ and $d.f. = 14 + 15 - 2 = 27$, the critical value is $t_0 = 1.703$.

$$s = \sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{13(2.39)^2+14(2.44)^2}{14+15-2}} = 2.416$$

$$\bar{x}_1 - \bar{x}_2 = 12.53 - 10.65 = 1.88$$

$$t = \frac{(\bar{x}_1-\bar{x}_2)-(\mu_1-\mu_2)}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{1.88-0}{2.416\sqrt{\frac{1}{14}+\frac{1}{15}}} = 2.09$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 27$. We find the sample t value, $t = 2.09$, falls between 2.052 and 2.473. Therefore, $0.010 < P$ value < 0.025.

Since the sample test statistic falls inside the critical region and the P value is less than the level of significance $\alpha = 0.05$, we reject H_0. We conclude that field A has on average higher soil water content than field B.

11. (a) The means and standard deviations round to the results given.

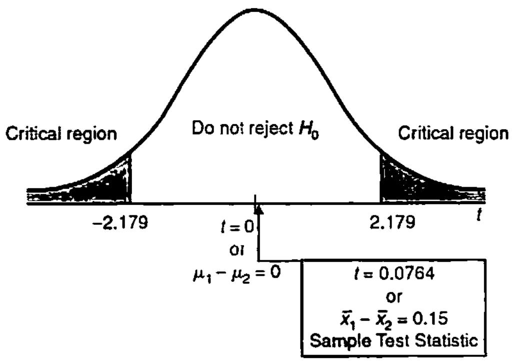
(b) $H_0: \mu_1 = \mu_2$
$H_1: \mu_1 \neq \mu_2$

Since $\neq$ is in H_1, a two-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha'' = 0.05$ and $d.f. = 7 + 7 - 2 = 12$, the critical values are $t_0 = \pm 2.179$.

$$s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{6(3.18)^2 + 6(4.11)^2}{7+7-2}} = 3.6745$$

$$\bar{x}_1 - \bar{x}_2 = 4.86 - 4.71 = 0.15$$

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} = \frac{0.15 - 0}{3.6745\sqrt{\frac{1}{7} + \frac{1}{7}}} = 0.0764$$



Next, find the P value interval using the α'' values and the row headed by $d.f. = 12$. We find the sample t value, $t = 0.0764$, falls to the left of 1.209. Therefore, P value > 0.250.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that the population mean time lost for hot tempers is different from that lost due to disputes.

12. (a) The means and standard deviations round to the results given.

(b) $H_0: \mu_1 = \mu_2$

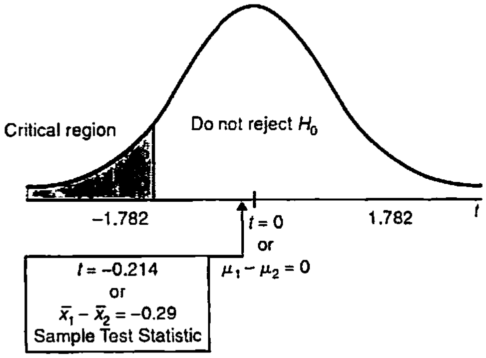
$H_1: \mu_1 < \mu_2$

Since < is in H_1, a left-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha' = 0.05$ and $d.f. = 7 + 7 - 2 = 12$, the critical value is $t_0 = -1.782$.

$$s = \sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{6(2.38)^2+6(2.69)^2}{7+7-2}} = 2.5397$$

$$\bar{x}_1 - \bar{x}_2 = 4.00 - 4.29 = -0.29$$

$$t = \frac{(\bar{x}_1-\bar{x}_2)-(\mu_1-\mu_2)}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{-0.29-0}{2.5397\sqrt{\frac{1}{7}+\frac{1}{7}}} = -0.214$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 12$. We find the sample t value, $t = -0.214$, falls to the right of -1.209. Therefore, P value > 0.125.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.05$, we fail to reject H_0. There is insufficient evidence to conclude that the population mean time lost due to stressors is greater than the population mean time lost due to intimidators.

13. (a)-(b) The means and standard deviations round to the results given.

(c) $H_0: \mu_1 = \mu_2$

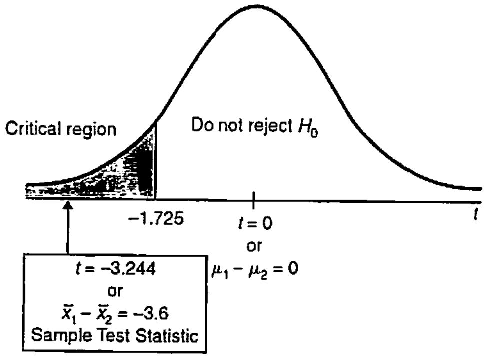
$H_1: \mu_1 < \mu_2$

Since < is in H_1, a left-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha' = 0.05$ and $d.f. = 10 + 12 - 2 = 20$, the critical value is $t_0 = -1.725$.

$$s = \sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{9(2.7)^2+11(2.5)^2}{10+12-2}} = 2.592$$

$$\bar{x}_1 - \bar{x}_2 = 7.2 - 10.8 = -3.6$$

$$t = \frac{(\bar{x}_1-\bar{x}_2)-(\mu_1-\mu_2)}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{-3.6-0}{2.592\sqrt{\frac{1}{10}+\frac{1}{12}}} = -3.244$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 20$. We find the sample t value, $t = -3.244$, falls to the left of −2.845. Therefore, P value < 0.005.

Since the sample test statistic falls inside the critical region and the P value is less than the level of significance $\alpha = 0.05$, we reject H_0. We conclude that the average change in water temperature has increased.

14. $H_0\colon \mu_1 = \mu_2$

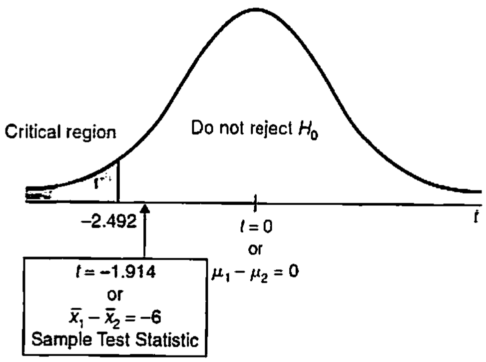
$H_1\colon \mu_1 < \mu_2$

Since < is in H_1, a left-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha' = 0.01$ and $d.f. = 11 + 15 - 2 = 24$, the critical value is $t_0 = -2.492$.

$$s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{10(9)^2 + 14(7)^2}{11+15-2}} = 7.895$$

$$\bar{x}_1 - \bar{x}_2 = 76 - 82 = -6$$

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} = \frac{-6-0}{7.895\sqrt{\frac{1}{11} + \frac{1}{15}}} = -1.914$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 24$. We find the sample t value, $t = -1.914$, falls between −1.711 and −2.064. Therefore, $0.025 < P$ value < 0.050.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.01$, we do not reject H_0. We have insufficient evidence to conclude that airplane pilots are less susceptible to perceptual illusions than the general population.

15. **(a)-(b)** The means and standard deviations round to the results given.

(c) H_0: $\mu_1 = \mu_2$

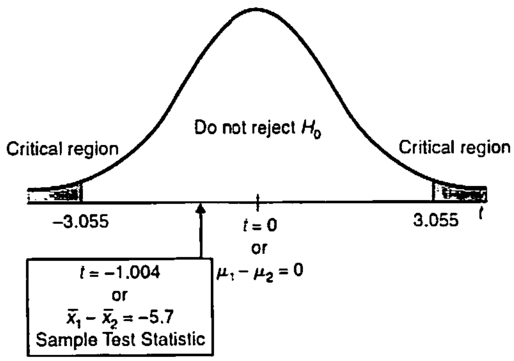
H_1: $\mu_1 \neq \mu_2$

Since ≠ is in H_1, a two-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha'' = 0.01$ and $d.f. = 7 + 7 - 2 = 12$, the critical values are $t_0 = \pm 3.055$.

$$s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{6(10.47)^2 + 6(10.78)^2}{7+7-2}} = 10.626$$

$$\bar{x}_1 - \bar{x}_2 = 72 - 77.7 = -5.7$$

$$t = \frac{(\bar{x}_1-\bar{x}_2)-(\mu_1-\mu_2)}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{-5.7-0}{10.626\sqrt{\frac{1}{7}+\frac{1}{7}}} = -1.004$$



Next, find the P value interval using the α'' values and the row headed by $d.f. = 12$. We find the sample t value, $t = -1.004$, falls to the right of −1.209. Therefore, P value > 0.250.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.01$, we do not reject H_0. There is not sufficient evidence to conclude that the average number of emergency calls during the day differs from the average number at night.

16. **(a)-(b)** The means and standard deviations round to the results given.

(b) H_0: $\mu_1 = \mu_2$

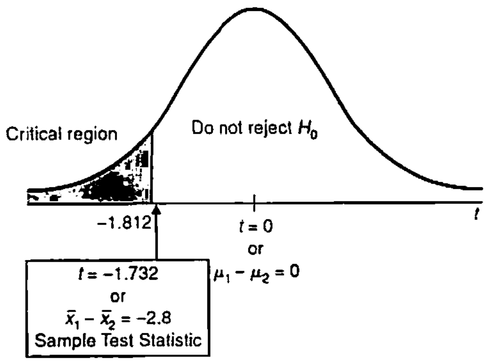
H_1: $\mu_1 < \mu_2$

Since < is in H_1, a left-tailed test is used. Since the samples are both small, we use the Student's t distribution. For $\alpha' = 0.05$ and $d.f. = 6 + 6 - 2 = 10$, the critical value is $t_0 = -1.812$.

$$s = \sqrt{\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}} = \sqrt{\frac{5(2.8)^2 + 5(2.8)^2}{6+6-2}} = 2.8$$

$$\bar{x}_1 - \bar{x}_2 = 12.2 - 15.0 = -2.8$$

$$t = \frac{(\bar{x}_1-\bar{x}_2)-(\mu_1-\mu_2)}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = \frac{-2.8-0}{2.8\sqrt{\frac{1}{6}+\frac{1}{6}}} = -1.732$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 10$. We find the sample t value, $t = -1.732$, falls between -1.559 and -1.812. Therefore, $0.050 < P$ value < 0.075.

Since the sample test statistic falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that it takes longer on average to put out the gasoline fire using a type II extinguisher.

17. $H_0: p_1 = p_2$

$H_1: p_1 \neq p_2$

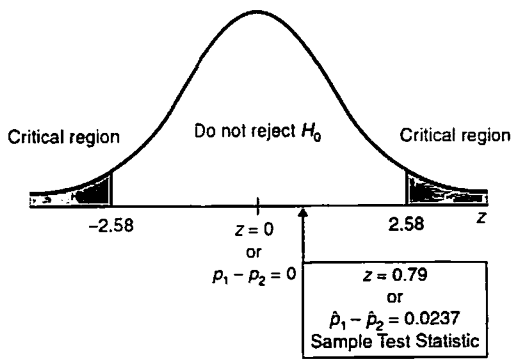
Since $\neq$ is in H_1, a two-tailed test is used. Since the samples are both large ($n_2\hat{p} = 8.7807 > 5$ so $n_1\hat{p}$, $n_1\hat{q}$, and $n_2\hat{q}$ are > 5 too), we use the normal distribution. For $\alpha = 0.01$, the critical values are $z_0 = \pm 2.58$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{12 + 7}{153 + 128} = 0.0676$$

$$\hat{q} = 1 - \hat{p} = 1 - 0.0676 = 0.9324$$

$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{12}{153} - \frac{7}{128} = 0.0237$$

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{0.0237 - 0}{\sqrt{\frac{0.0676(0.9324)}{153} + \frac{0.0676(0.9324)}{128}}} = 0.79$$



Next, find the P value associated with $z = -0.79$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \geq 0.79) \\ &= 2(1 - 0.7852) \\ &= 2(0.2148) \\ &= 0.4296 \end{aligned}$$

Since the sample z falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.01$, we do not reject H_0. There is insufficient evidence to conclude that the population proportions of high school dropouts are different.

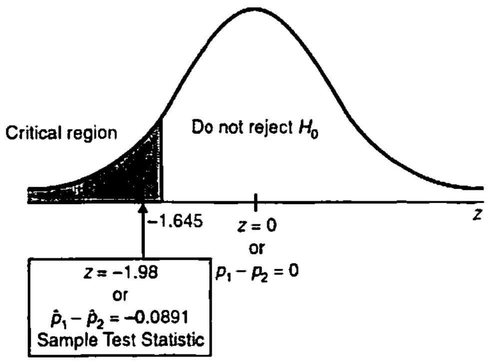
18. $H_0\colon p_1 = p_2$
$H_1\colon p_1 < p_2$
Since < is in H_1, a left-tailed test is used. Since the samples are both large ($n_2\hat{q} = 216(0.4722) = 101.9952 > 5$ so $n_1\hat{p}, n_1\hat{q}$, and $n_2\hat{p}$ are > 5), we use the normal distribution. For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{141 + 125}{288 + 216} = 0.5278$$

$$\hat{q} = 1 - \hat{p} = 1 - 0.5278 = 0.4722$$

$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{141}{288} - \frac{125}{216} = -0.0891$$

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{-0.0891 - 0}{\sqrt{\frac{0.5278(0.4722)}{288} + \frac{0.5278(0.4722)}{216}}} = -1.98$$



Next, find the P value associated with $z = -1.98$ and a one-tailed test.

$$\begin{aligned} P \text{ value} &= P(z \leq -1.98) \\ &= 0.0239 \end{aligned}$$

Since the sample z falls inside the critical region and the P value is less than the level of significance $\alpha = 0.01$, we reject H_0. We conclude that the population proportion of voter turnout in Colorado is higher than that in California.

19. Let p_1 = proportion who did not attend college and who believe in extraterrestrials and p_2 = proportion who did attend college and who believe in extraterrestrials.

$$H_0: p_1 = p_2$$
$$H_1: p_1 < p_2$$

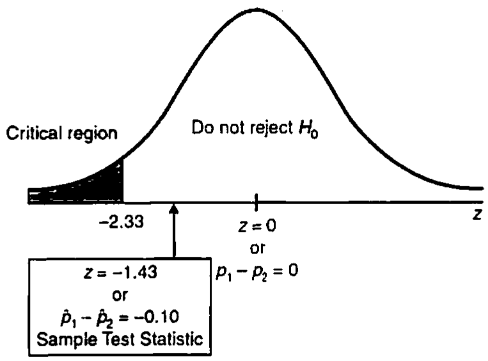
Since < is in H_1, a left-tailed test is used. Since the samples are both large ($n_i\hat{p} = 100(0.42) = 42 > 5$ so $n_i\hat{q}$ is also > 5), we use the normal distribution. For $\alpha = 0.05$, the critical value is $z_0 = -2.33$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{37+47}{100+100} = 0.42$$

$$\hat{q} = 1 - \hat{p} = 1 - 0.42 = 0.58$$

$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{37}{100} - \frac{47}{100} = -0.10$$

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{-0.10 - 0}{\sqrt{\frac{0.42(0.58)}{100} + \frac{0.42(0.58)}{100}}} = -1.43$$



Next, find the P value associated with $z = -1.43$ and a one-tailed test.

$$P \text{ value} = P(z \le -1.43)$$
$$= 0.0764$$

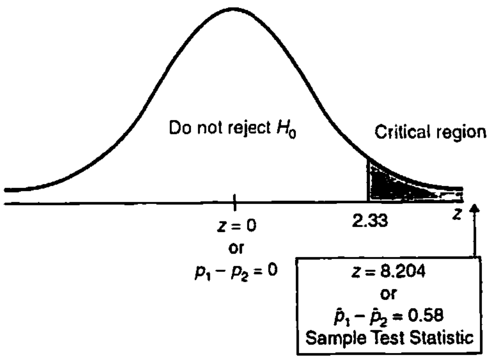
Since the sample z falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.01$, we do not reject H_0. There is not enough evidence to conclude that the proportion of believers who attended college is greater than the proportion of believers who did not attend college.

20. Let p_1 = proportion who would donate a loved one's organs and p_2 = proportion who would donate their own organs.

$$H_0: p_1 = p_2$$
$$H_1: p_1 > p_2$$

Since > is in H_1, a right-tailed test is used. Since the samples are both large ($n_i\hat{p} = 100(0.49) = 49 > 5$ so $n_i\hat{q}$ is also > 5), we use the normal distribution. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{78+20}{100+100} = 0.49$$
$$\hat{q} = 1 - \hat{p} = 1 - 0.49 = 0.51$$
$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{78}{100} - \frac{20}{100} = 0.58$$
$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{0.58 - 0}{\sqrt{\frac{0.49(0.51)}{100} + \frac{0.49(0.51)}{100}}} = 8.204$$



Next, find the P value associated with $z = 8.204$ and a one-tailed test.

$$P \text{ value} = P(z \geq 8.204)$$
$$\approx 0$$

Since the sample z falls inside the critical region and the P value is less than the level of significance $\alpha = 0.01$, we reject H_0. We conclude that the proportion of adult Americans who would donate a loved one's organs is higher than the proportion who would donate their own organs.

21. Let p_1 = proportion who requested nonsmoking rooms one year ago and p_2 = proportion who requested nonsmoking rooms recently.

$$H_0: p_1 = p_2$$
$$H_1: p_1 < p_2$$

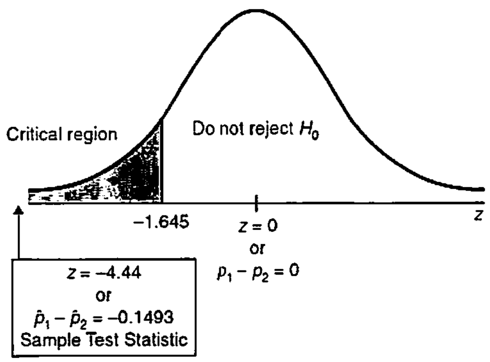
Since < is in H_1, a left-tailed test is used. Since the samples are both large ($n_1\hat{q}$ = 378(0.5570) = 210.546 > 5 so $n_1\hat{p}$, $n_2\hat{p}$, and $n_2\hat{q}$ are > 5), we use the normal distribution. For α = –0.05, the critical value is $z_0 = -1.645$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{178 + 320}{378 + 516} = 0.5570$$

$$\hat{q} = 1 - \hat{p} = 1 - 0.5570 = 0.4430$$

$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{178}{378} - \frac{320}{516} = -0.1493$$

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{-0.1493 - 0}{\sqrt{\frac{0.5570(0.4430)}{378} + \frac{0.5570(0.4430)}{516}}} = -4.44$$



Next, find the *P* value associated with $z = -4.44$ and a one-tailed test.

$$P \text{ value} = P(z \le -4.44)$$
$$\approx 0$$

Since the sample z falls inside the critical region and the *P* value is less than the level of significance α = 0.05, we reject H_0. We conclude that the population proportion of hotel guests requesting nonsmoking rooms has increased.

22. $H_0: p_1 = p_2$

$H_1: p_1 \neq p_2$

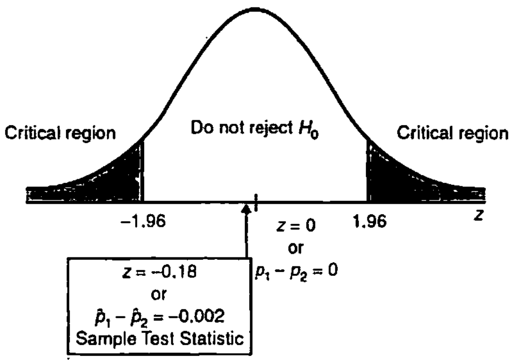
Since $\neq$ is in H_1, a two-tailed test is used. Since the samples are both large ($n_2\hat{p}$ = 326(0.0234) = 7.6284 > 5 so $n_1\hat{p}$, $n_1\hat{q}$, and $n_2\hat{q}$ are > 5), we use the normal distribution. For $\alpha = 0.05$, the critical values are $z_0 = \pm 1.96$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{10+8}{444+326} = 0.0234$$

$$\hat{q} = 1 - \hat{p} = 1 - 0.0234 = 0.9766$$

$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{10}{444} - \frac{8}{326} = -0.0020$$

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{-0.002 - 0}{\sqrt{\frac{0.0234(0.9766)}{444} + \frac{0.0234(0.9766)}{326}}} = -0.18$$



Next, find the P value associated with $z = -0.18$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \le -0.18) \\ &= 2(0.4286) \\ &= 0.8572 \end{aligned}$$

Since the sample z falls outside the critical region and the P value is greater than the level of significance $\alpha = 0.05$, we do not reject H_0. We have insufficient evidence to conclude that the population proportions of this category of artifacts are different.

23. $H_0: p_1 = p_2$

$H_1: p_1 > p_2$

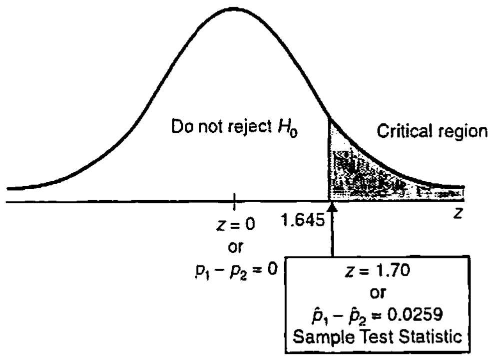
Since > is in H_1, a right-tailed test is used. Since the samples are both large ($n_2\hat{p} = 329(0.0405) = 13.3245 > 5$ so $n_1\hat{p}$, $n_1\hat{q}$, and $n_2\hat{q}$ are all > 5), we use the normal distribution. For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{18+9}{338+329} = 0.0405$$

$$\hat{q} = 1 - \hat{p} = 1 - 0.0405 = 0.9595$$

$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{18}{338} - \frac{9}{329} = 0.0259$$

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{0.0259 - 0}{\sqrt{\frac{0.0405(0.9595)}{338} + \frac{0.0405(0.9595)}{329}}} = 1.70$$



Next, find the P value associated with $z = 1.70$ and a one-tailed test.

$$P \text{ value} = P(z \geq 1.70) = 1 - 0.9554 = 0.0446$$

Since the sample z falls inside the critical region and the P value is less than the level of significance $\alpha = 0.05$, we reject H_0. We conclude that the population proportion of such artifacts is higher in the general region around the first site.

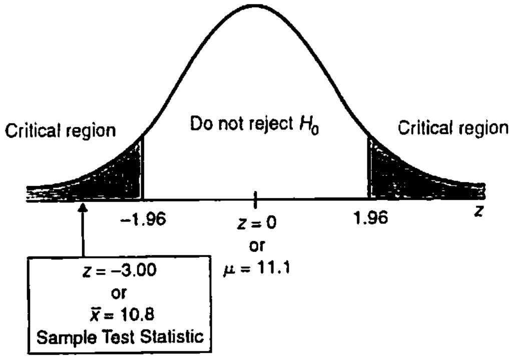
Chapter 9 Review

1. We are testing a single mean with a large sample.

$$H_0: \mu = 11.1$$

$$H_1: \mu \neq 11.1$$

Since $\neq$ is in H_1, a two-tailed test is used. For $\alpha = 0.05$, the critical values are $z_0 = \pm 1.96$.



Next, find the P value associated with $z = -3.00$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \le -3.00) \\ &= 2(0.0013) \\ &= 0.0026 \end{aligned}$$

Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.05$, we reject H_0. We conclude that the average number of miles driven per vehicle is different from the national average.

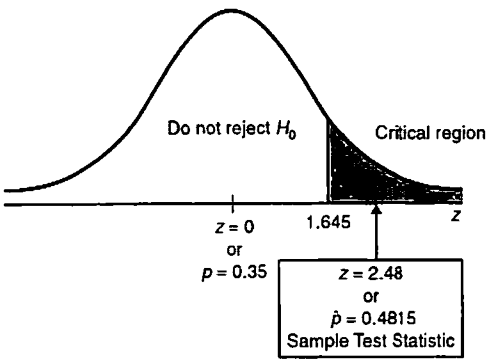
2. We are testing a single proportion with a large sample.

$$H_0: p = 0.35$$
$$H_1: p > 0.35$$

Since > is in H_1, a right-tailed test is used. For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$\hat{p} = \frac{r}{n} = \frac{39}{81} = 0.4815$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.4815 - 0.35}{\sqrt{\frac{0.35(0.65)}{81}}} = 2.48$$



Next, find the P value associated with $z = 2.48$ and a one-tailed test.

$$\begin{aligned} P \text{ value} &= P(z \ge 2.48) \\ &= 0.0066 \end{aligned}$$

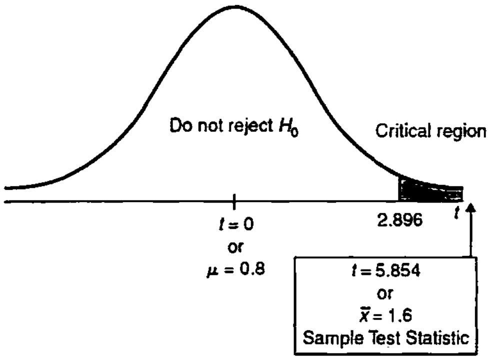
Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.05$, we reject H_0. We conclude that more than 35% of the students have jobs.

3. We are testing a single mean with a small sample.

$$H_0: \mu = 0.8$$
$$H_1: \mu > 0.8$$

Since > is in H_1, a right-tailed test is used. For $\alpha' = 0.01$ and $d.f. = 9 - 1 = 8$, the critical value is $t_0 = 2.896$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{1.6 - 0.8}{0.41/\sqrt{9}} = 5.854$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 8$. We find that the sample t value, $t = 5.854$, falls to the right of 3.355. Therefore, $P < 0.005$.

Since the sample t falls inside the critical region and the P value is less than $\alpha = 0.01$, we reject H_0. We conclude that the Toylot claim is too low.

4. We are testing the difference of means with small independent samples.

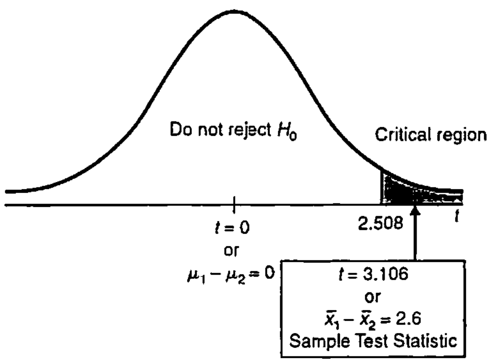
$$H_0: \mu_1 = \mu_2$$
$$H_1: \mu_1 > \mu_2$$

Since > is in H_1, a right-tailed test is used. For $\alpha' = 0.01$ and $d.f. = 12 + 12 - 2 = 22$, the critical value is $t_0 = 2.508$.

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} = \sqrt{\frac{11(2.1)^2 + 11(2.0)^2}{12 + 12 - 2}} = 2.0506$$

$$\bar{x}_1 - \bar{x}_2 = 9.4 - 6.8 = 2.6$$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} = \frac{2.6}{2.0506\sqrt{\frac{1}{12} + \frac{1}{12}}} = 3.106$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 22$. We find the sample t value, $t = 3.106$, falls to the right of 2.819. Therefore, P value < 0.005.

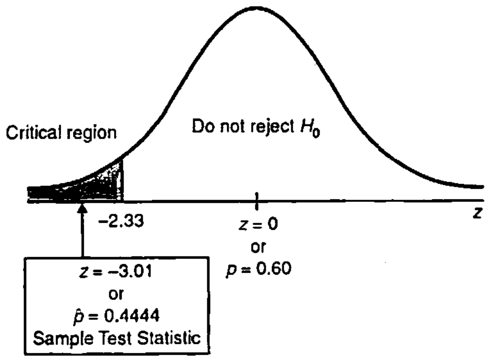
Since the sample t falls inside the critical region and the P value is less than $\alpha = 0.01$, we reject H_0. We conclude that the yellow paint has less visibility after 1 year.

5. We are testing a single proportion with a large sample.

$$H_0: p = 0.60$$
$$H_1: p < 0.60$$

Since < is in H_1, a left-tailed test is used. For $\alpha = 0.01$, the critical value is $z_0 = -2.33$.

$$\hat{p} = \frac{r}{n} = \frac{40}{90} = 0.4444$$
$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.4444 - 0.60}{\sqrt{\frac{0.60(0.40)}{90}}} = -3.01$$



Next, find the P value associated with $z = 3.01$ and a one-tailed test.

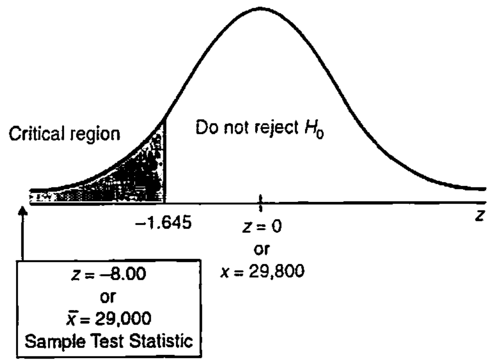
$$P \text{ value} = P(z \leq -3.01)$$
$$= 0.0013$$

Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.01$, we reject H_0. We conclude that the population mortality rate has dropped.

6. We are testing a single mean with a large sample.

$$H_0: \mu = 29{,}800$$
$$H_1: \mu < 29{,}800$$

Since < is in H_1, a left-tailed test is used. For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.



Next, find the P value associated with $z = -8.00$ and a two-tailed test.

$$P \text{ value} = P(z \le -8.00)$$
$$< 0.0001$$

Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.05$, we reject H_0. We conclude that the average yearly salary is less than $29,800.

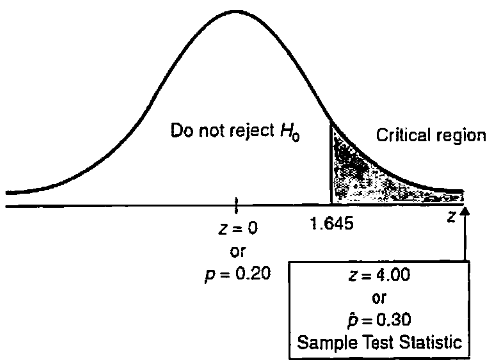
7. We are testing a single proportion with a large sample.

$$H_0: p = 0.20$$
$$H_1: p > 0.20$$

Since > is in H_1, a right-tailed test is used. For $\alpha = 0.05$, the critical value is $z_0 = 1.645$.

$$\hat{p} = \frac{r}{n} = \frac{77}{256} = 0.30$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.30 - 0.20}{\sqrt{\frac{0.20(0.80)}{256}}} = 4.00$$



Next, find the P value associated with $z = 4.00$ and a one-tailed test.

$$P \text{ value} = P(z \ge 4.00)$$
$$\approx 0.0001$$

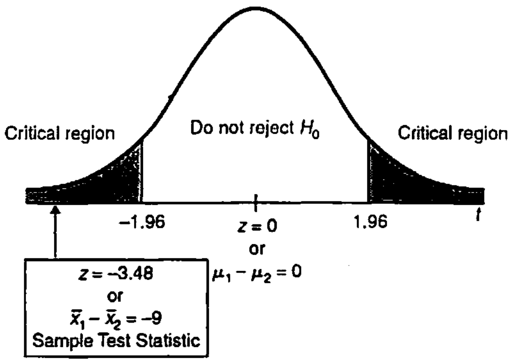
Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.05$, we reject H_0. We conclude that the proportion of students who read the poetry magazine is more than 20%.

8. We are testing the difference of means with large independent samples.

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

Since $\neq$ is in H_1, a two-tailed test is used. For $\alpha = 0.05$, the critical values are $z_0 = \pm 1.96$.

$$\bar{x}_1 - \bar{x}_2 = 53 - 62 = -9$$
$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{-9 - 0}{\sqrt{\frac{19^2}{81} + \frac{15^2}{100}}} = -3.48$$



Next, find the P value associated with $z = -3.48$ and a two-tailed test.

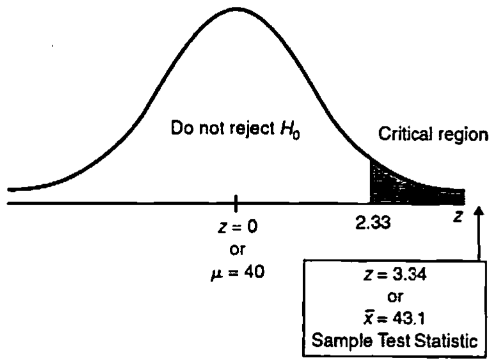
$$P \text{ value} = 2P(z \leq -3.48)$$
$$= 2(0.0003)$$
$$= 0.0006$$

Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.05$, we reject H_0. We conclude that a significant difference exists in average off-schedule times.

9. We are testing a single mean with a large sample.

$$H_0: \mu = 40$$
$$H_1: \mu > 40$$

Since $>$ is in H_1, a right-tailed test is used. For $\alpha = 0.01$, the critical value is $z_0 = 2.33$.



Next, find the P value associated with $z = 3.34$ and a one-tailed test.

$$P \text{ value} = P(z \geq 3.34) = 0.0004$$

Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.01$, we reject H_0. We conclude that the mean number of matches per box is more than 40.

10. We are testing a single mean with a large sample.

$$H_0: p_1 = p_2$$
$$H_1: p_1 < p_2$$

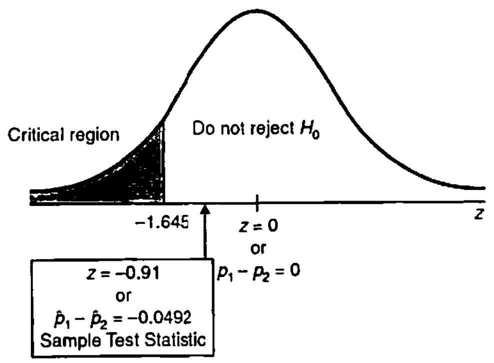
Since < is in H_1, a left-tailed test is used. For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$\hat{p} = \frac{r_1 + r_2}{n_1 + n_2} = \frac{12+18}{88+97} = 0.1622$$

$$\hat{q} = 1 - \hat{p} = 1 - 0.1622 = 0.8378$$

$$\hat{p}_1 - \hat{p}_2 = \frac{r_1}{n_1} - \frac{r_2}{n_2} = \frac{12}{88} - \frac{18}{97} = -0.0492$$

$$z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\frac{\hat{p}\hat{q}}{n_1} + \frac{\hat{p}\hat{q}}{n_2}}} = \frac{-0.0492}{\sqrt{\frac{0.1622(0.8378)}{88} + \frac{0.1622(0.8378)}{97}}} = -0.91$$



Next, find the P value associated with $z = -0.91$ and a one-tailed test.

$$P \text{ value} = P(z \leq -0.91) = 0.1814$$

Since the sample z falls outside the critical region and the P value is greater than $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that a higher proportion of suburban residents subscribe to *Sporting News*.

11. We are testing the difference of means with small independent samples.

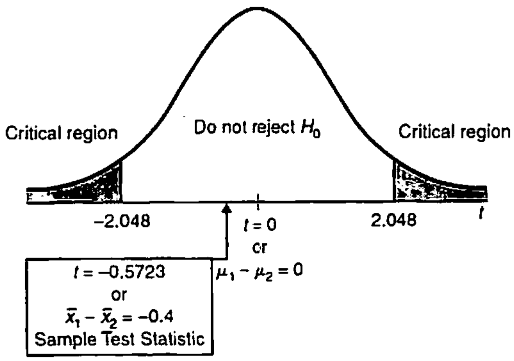
$$H_0: \mu_1 = \mu_2$$
$$H_1: \mu_1 \neq \mu_2$$

Since ≠ is in H_1, a two-tailed test is used. For $\alpha'' = 0.05$ and $d.f. = 16 + 14 - 2 = 28$, the critical values are $t_0 = \pm 2.048$.

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} = \sqrt{\frac{15(2.0)^2 + 13(1.8)^2}{16 + 14 - 2}} = 1.9097$$

$$\bar{x}_1 - \bar{x}_2 = 4.8 - 5.2 = -0.4$$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} = \frac{-0.4}{1.9097\sqrt{\frac{1}{16} + \frac{1}{14}}} = -0.5723$$



Next, find the P value interval using the α'' values and the row headed by $d.f. = 28$. We find the sample t value, $t = -0.5723$, falls to the right of -1.175. Therefore, P value > 0.250.

Since the sample test statistic falls outside the critical region and the P value is greater than $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude a difference in average waiting time.

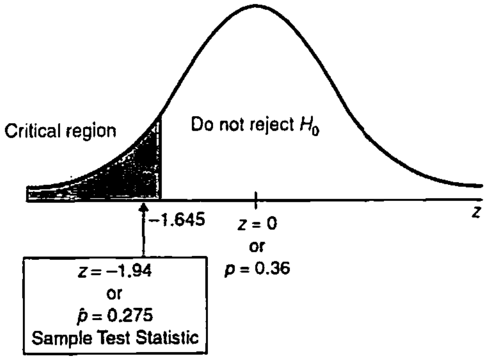
12. We are testing a single proportion with a large sample.

$$H_0: p = 0.36$$
$$H_1: p < 0.36$$

Since < is in H_1, a left-tailed test is used. For $\alpha = 0.05$, the critical value is $z_0 = -1.645$.

$$\hat{p} = \frac{r}{n} = \frac{33}{120} = 0.275$$

$$z = \frac{\hat{p} - p}{\sqrt{\frac{pq}{n}}} = \frac{0.275 - 0.36}{\sqrt{\frac{0.36(0.64)}{120}}} = -1.94$$



Next, find the P value associated with $z = -1.94$ and a one-tailed test.

$$P \text{ value} = P(z \le -1.94) = 0.0262$$

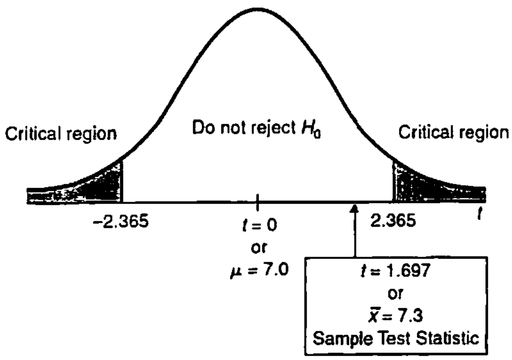
Since the sample z falls inside the critical region and the P value is less than $\alpha = 0.05$, we reject H_0. We conclude that the percentage is less than 36%.

13. We are testing a single mean with a small sample.

$$H_0: \mu = 7.0$$
$$H_1: \mu \ne 7.0$$

Since $\ne$ is in H_1, a two-tailed test is used. For $\alpha'' = 0.05$ and $d.f. = 8 - 1 = 7$, the critical values are $t_0 = \pm 2.365$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{7.3 - 7.0}{0.5/\sqrt{8}} = 1.697$$



Next, find the P value interval using the α'' values and the row headed by $d.f. = 7$. We find that the sample t value, $t = 1.697$, falls between 1.617 and 1.895. Therefore, $0.10 < P < 0.15$.

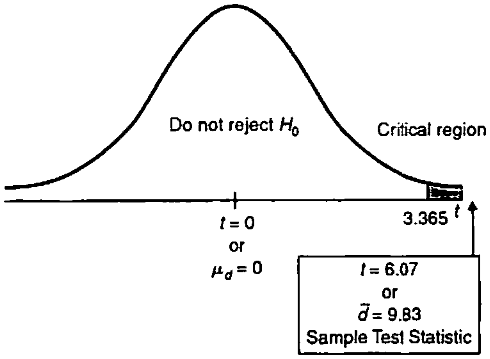
Since the sample t falls outside the critical region and the P value is greater than $\alpha = 0.05$, we do not reject H_0. There is not enough evidence to conclude that the machine has slipped out of adjustment.

14. We are performing a paired difference test with small samples.

$$H_0: \mu_d = 0$$
$$H_1: \mu_d > 0$$

Since > is in H_1, a right-tailed test is used. For $\alpha' = 0.01$ and $d.f. = 6 - 1 = 5$, the critical value is $t_0 = 3.365$.

$$\bar{d} = 9.83$$
$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{9.83 - 0}{3.97/\sqrt{6}} = 6.07$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 5$. We find the sample t value, $t = 6.07$, falls to the right of 4.032. Therefore, P value < 0.005.

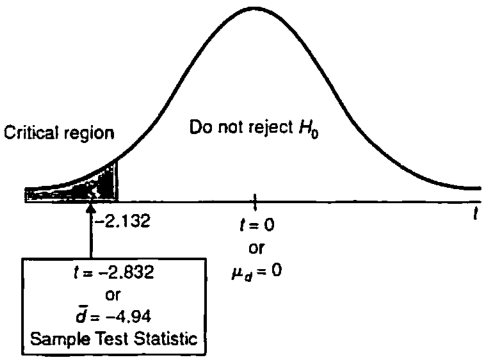
Since the sample t falls inside the critical region and the P value is less than $\alpha = 0.01$, we reject H_0. We conclude that the program of the experimental group did promote creative problem solving.

15. We are performing a paired difference test with small samples.

$$H_0: \mu_d = 0$$
$$H_1: \mu_d < 0$$

Since < is in H_1, a left-tailed test is used. For $\alpha' = 0.05$ and $d.f. = 5 - 1 = 4$, the critical value is $t_0 = -2.132$.

$$\bar{d} = -4.94$$
$$t = \frac{\bar{d} - \mu_d}{s_d/\sqrt{n}} = \frac{-4.94 - 0}{3.90/\sqrt{5}} = -2.832$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 4$. We find the sample t value, $t = 2.832$, falls between −2.776 and −3.747. Therefore, $0.010 < P$ value < 0.025.

Since the sample t falls inside the critical region and the P value is less than $\alpha = 0.05$, we reject H_0. We conclude that the average net sales have improved.

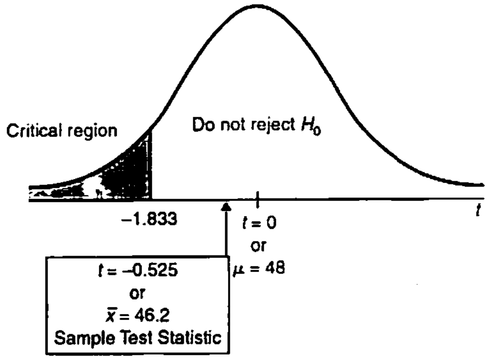
16. (a) The mean and standard deviation round to the results given.

(b) We are testing a single mean with a small sample.

$$H_0: \mu_d = 48$$
$$H_1: \mu_d < 48$$

Since < is in H_1, a left-tailed test is used. For $\alpha' = 0.05$ and $d.f. = 10 - 1 = 9$, the critical value is $t_0 = -1.833$.

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}} = \frac{46.2 - 48}{10.85/\sqrt{10}} = -0.525$$



Next, find the P value interval using the α' values and the row headed by $d.f. = 9$. We find that the sample t value, $t = -0.525$, falls to the right of -1.230. Therefore, P value > 0.125.

Since the sample t falls outside the critical region and the P value is greater than $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that the average is less than 48 months.

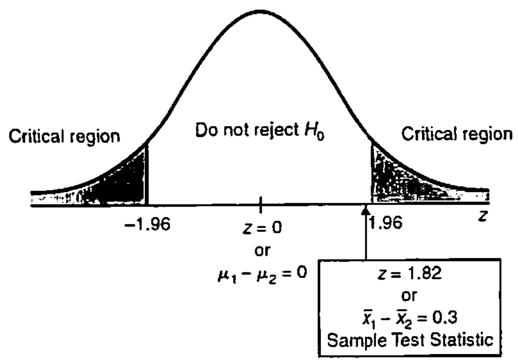
17. We are testing the difference of means with large independent samples.

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

Since ≠ is in H_1, a two-tailed test is used. For $\alpha = 0.05$, the critical values are $z_0 = \pm 1.96$.

$$\bar{x}_1 - \bar{x}_2 = 3.0 - 2.7 = 0.3$$

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{0.3 - 0}{\sqrt{\frac{0.8^2}{55} + \frac{0.9^2}{52}}} = 1.82$$



Next, find the P value associated with $z = 1.82$ and a two-tailed test.

$$\begin{aligned} P \text{ value} &= 2P(z \geq 1.82) \\ &= 2(0.0344) \\ &= 0.0688 \end{aligned}$$

Since the sample z falls outside the critical region and the P value is greater than $\alpha = 0.05$, we do not reject H_0. There is insufficient evidence to conclude that a difference exists in the population mean lengths of the two types of projectile points.

18. **(a)** Do not reject H_0 since P value > 0.01.

(b) Reject H_0 since P value < 0.05.

19. **(a)** Reject H_0 since P value < 0.01.

(b) Reject H_0 since P value < 0.05.