Chapter 9
Hypothesis Testing

Learning Objectives

1. Learn how to formulate and test hypotheses about a population mean and/or a population proportion.

2. Understand the types of errors possible when conducting a hypothesis test.

3. Be able to determine the probability of making various errors in hypothesis tests.

4. Know how to compute and interpret *p*-values.

5. Be able to use critical values to draw hypothesis testing conclusions.

6. Know the definition of the following terms:

    null hypothesis
    alternative hypothesis
    Type I error
    Type II error
    one-tailed test
    two-tailed test
    p-value
    level of significance
    critical value

Chapter 9
Solutions:

1. a. H_0: $\mu \leq 600$ Manager's claim.

   H_a: $\mu > 600$

   b. We are not able to conclude that the manager's claim is wrong.

   c. The manager's claim can be rejected. We can conclude that $\mu > 600$.

2. a. H_0: $\mu \leq 14$

   H_a: $\mu > 14$ Research hypothesis

   b. There is no statistical evidence that the new bonus plan increases sales volume.

   c. The research hypothesis that $\mu > 14$ is supported. We can conclude that the new bonus plan increases the mean sales volume.

3. a. H_0: $\mu = 32$ Specified filling weight

   H_a: $\mu \neq 32$ Overfilling or underfilling exists

   b. There is no evidence that the production line is not operating properly. Allow the production process to continue.

   c. Conclude $\mu \neq 32$ and that overfilling or underfilling exists. Shut down and adjust the production line.

4. a. H_0: $\mu \geq 220$

   H_a: $\mu < 220$ Research hypothesis to see if mean cost is less than $220.

   b. We are unable to conclude that the new method reduces costs.

   c. Conclude $\mu < 220$. Consider implementing the new method based on the conclusion that it lowers the mean cost per hour.

5. a. The Type I error is rejecting H_0 when it is true. This error occurs if the researcher concludes that young men in Germany spend more than 56.2 minutes per day watching prime-time TV when the national average for Germans is not greater than 56.2 minutes.

   b. The Type II error is accepting H_0 when it is false. This error occurs if the researcher concludes that the national average for German young men is ≤ 56.2 minutes when in fact it is greater than 56.2 minutes.

6. a. H_0: $\mu \leq 1$ The label claim or assumption.

   H_a: $\mu > 1$

   b. Claiming $\mu > 1$ when it is not. This is the error of rejecting the product's claim when the claim is true.

   c. Concluding $\mu \leq 1$ when it is not. In this case, we miss the fact that the product is not meeting its label specification.

7. a. H_0: $\mu \le 8000$

   H_a: $\mu > 8000$ Research hypothesis to see if the plan increases average sales.

   b. Claiming $\mu > 8000$ when the plan does not increase sales. A mistake could be implementing the plan when it does not help.

   c. Concluding $\mu \le 8000$ when the plan really would increase sales. This could lead to not implementing a plan that would increase sales.

8. a. H_0: $\mu \ge 220$

   H_a: $\mu < 220$

   b. Claiming $\mu < 220$ when the new method does not lower costs. A mistake could be implementing the method when it does not help.

   c. Concluding $\mu \ge 220$ when the method really would lower costs. This could lead to not implementing a method that would lower costs.

9. a. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{19.4 - 20}{2 / \sqrt{50}} = -2.12$

   b. Lower tail *p*-value is the area to the left of the test statistic

   Using normal table with z = -2.12: *p*-value =.0170

   c. *p*-value ≤ .05, reject H_0

   d. Reject H_0 if $z \le -1.645$

   -2.12 ≤ -1.645, reject H_0

10. a. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{26.4 - 25}{6 / \sqrt{40}} = 1.48$

   b. Upper tail *p*-value is the area to the right of the test statistic

   Using normal table with z = 1.48: *p*-value = 1.0000 - .9306 = .0694

   c. *p*-value > .01, do not reject H_0

   d. Reject H_0 if $z \ge 2.33$

   1.48 < 2.33, do not reject H_0

11. a. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{14.15 - 15}{3 / \sqrt{50}} = -2.00$

   b. Because $z < 0$, *p*-value is two times the lower tail area

   Using normal table with z = -2.00: *p*-value = 2(.0228) = .0456

c. p-value ≤ .05, reject H_0

d. Reject H_0 if $z \leq -1.96$ or $z \geq 1.96$

$-2.00 \leq -1.96$, reject H_0

12. a. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{78.5 - 80}{12 / \sqrt{100}} = -1.25$

Lower tail p-value is the area to the left of the test statistic

Using normal table with $z = -1.25$: p-value =.1056

p-value > .01, do not reject H_0

b. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{77 - 80}{12 / \sqrt{100}} = -2.50$

Lower tail p-value is the area to the left of the test statistic

Using normal table with $z = -2.50$: p-value =.0062

p-value ≤ .01, reject H_0

c. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{75.5 - 80}{12 / \sqrt{100}} = -3.75$

Lower tail p-value is the area to the left of the test statistic

Using normal table with $z = -3.75$: p-value ≈ 0

p-value ≤ .01, reject H_0

d. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{81 - 80}{12 / \sqrt{100}} = .83$

Lower tail p-value is the area to the left of the test statistic

Using normal table with $z = .83$: p-value =.7967

p-value > .01, do not reject H_0

13. Reject H_0 if $z \geq 1.645$

a. $z = \dfrac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \dfrac{52.5 - 50}{8 / \sqrt{60}} = 2.42$

$2.42 \geq 1.645$, reject H_0

b. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{51 - 50}{8 / \sqrt{60}} = .97$

.97 < 1.645, do not reject H_0

c. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{51.8 - 50}{8 / \sqrt{60}} = 1.74$

1.74 ≥ 1.645, reject H_0

14. a. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{23 - 22}{10 / \sqrt{75}} = .87$

Because $z > 0$, *p*-value is two times the upper tail area

Using normal table with $z = .87$: *p*-value = 2(1 - .8078) = .3844

p-value > .01, do not reject H_0

b. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{25.1 - 22}{10 / \sqrt{75}} = 2.68$

Because $z > 0$, *p*-value is two times the upper tail area

Using normal table with $z = 2.68$: *p*-value = 2(1 - .9963) = .0074

p-value ≤ .01, reject H_0

c. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{20 - 22}{10 / \sqrt{75}} = -1.73$

Because $z < 0$, *p*-value is two times the lower tail area

Using normal table with $z = -1.73$: *p*-value = 2(.0418) = .0836

p-value > .01, do not reject H_0

15. a. H_0: $\mu \geq 1056$

H_a: $\mu < 1056$

b. $z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{910 - 1056}{1600 / \sqrt{400}} = -1.83$

Lower tail *p*-value is the area to the left of the test statistic

Using normal table with $z = -1.83$: *p*-value =.0336

c. *p*-value ≤ .05, reject H_0. Conclude the mean refund of "last minute" filers is less than $1056.

d. Reject H_0 if $z \leq -1.645$

$-1.83 \leq -1.645$, reject H_0

16. a. H_0: $\mu \leq 895$

H_a: $\mu > 895$

b. $$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{915 - 895}{225/\sqrt{180}} = 1.19$$

Upper tail *p*-value is the area to the right of the test statistic

Using normal table with $z = 1.19$: *p*-value = 1.0000 - .8830 = .1170

c. Do not reject H_0. We cannot conclude the rental rates have increased.

d. Recommend withholding judgment and collecting more data on apartment rental rates before drawing a final conclusion.

17. a. H_0: $\mu = 125{,}500$

H_a: $\mu \neq 125{,}500$

b. $$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{118{,}000 - 125{,}500}{30{,}000/\sqrt{40}} = -1.58$$

Because $z < 0$, *p*-value is two times the lower tail area

Using normal table with $z = -1.58$: *p*-value = 2(.0571) = .1142

c. *p*-value > .05, do not reject H_0. We cannot conclude that the year-end bonuses paid by Jones & Ryan

differ significantly from the population mean of $125,500.

d. Reject H_0 if $z \leq -1.96$ or $z \geq 1.96$

$z = -1.58$; cannot reject H_0

18. a. H_0: $\mu = 4.1$

H_a: $\mu \neq 4.1$

b. $$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{3.4 - 4.1}{2/\sqrt{40}} = -2.21$$

Because $z < 0$, *p*-value is two times the lower tail area

Using normal table with $z = -2.21$: *p*-value = 2(.0136) = .0272

c. p-value = .0272 < .05

Reject H_0 and conclude that the return for Mid-Cap Growth Funds differs significantly from that for U.S. Diversified funds.

19. H_0: $\mu \le 14.32$

H_a: $\mu > 14.32$

$$z = \frac{\bar{x} - \mu_0}{\sigma/\sqrt{n}} = \frac{14.68 - 14.32}{1.45/\sqrt{75}} = 2.15$$

Upper tail p-value is the area to the right of the test statistic

Using normal table with z = 2.15: p-value = 1.0000 - .9842 = .0158

p-value ≤ .05, reject H_0. Conclude that there has been an increase in the mean hourly wage of production workers.

20. a. H_0: $\mu \ge 32.79$

H_a: $\mu < 32.79$

b. $$z = \frac{\bar{x} - \mu_0}{\sigma/\sqrt{n}} = \frac{30.63 - 32.79}{5.6/\sqrt{50}} = -2.73$$

c. Lower tail p-value is area to left of the test statistic.

Using normal table with z = -2.73: p-value = .0032.

d. p-value ≤ .01; reject H_0. Conclude that the mean monthly internet bill is less in the southern state.

21. a. H_0: $\mu \le 15$

H_a: $\mu > 15$

b. $$z = \frac{\bar{x} - \mu}{\sigma / \sqrt{n}} = \frac{17 - 15}{4/\sqrt{35}} = 2.96$$

c. Upper tail p-value is the area to the right of the test statistic

Using normal table with z = 2.96: p-value = 1.0000 - .9985 = .0015

d. p-value ≤ .01; reject H_0; the premium rate should be charged.

22. a. H_0: $\mu = 8$

H_a: $\mu \ne 8$

b. Because $z > 0$, p-value is two times the upper tail area

Using normal table with z = 1.37: p-value = 2(1 - .9147) = .1706

c. Do not reject H_0. Cannot conclude that the population mean waiting time differs from 8 minutes.

d. $\bar{x} \pm z_{.025}(\sigma / \sqrt{n})$

$8.4 \pm 1.96\,(3.2 / \sqrt{120})$

$8.4 \pm .57$ (7.83 to 8.97)

Yes; $\mu = 8$ is in the interval. Do not reject H_0.

23. a. $t = \dfrac{\bar{x} - \mu_0}{s / \sqrt{n}} = \dfrac{14 - 12}{4.32 / \sqrt{25}} = 2.31$

b. Degrees of freedom = $n - 1 = 24$

Upper tail p-value is the area to the right of the test statistic

Using t table: p-value is between .01 and .025

Exact p-value corresponding to $t = 2.31$ is .0149

c. p-value $\leq .05$, reject H_0.

d. With $df = 24$, $t_{.05} = 1.711$

Reject H_0 if $t \geq 1.711$

$2.31 > 1.711$, reject H_0.

24. a. $t = \dfrac{\bar{x} - \mu_0}{s / \sqrt{n}} = \dfrac{17 - 18}{4.5 / \sqrt{48}} = -1.54$

b. Degrees of freedom = $n - 1 = 47$

Because $t < 0$, p-value is two times the lower tail area

Using t table: area in lower tail is between .05 and .10; therefore, p-value is between .10 and .20.

Exact p-value corresponding to $t = -1.54$ is .1303

c. p-value $> .05$, do not reject H_0.

d. With $df = 47$, $t_{.025} = 2.012$

Reject H_0 if $t \leq -2.012$ or $t \geq 2.012$

$t = -1.54$; do not reject H_0

25. a. $t = \dfrac{\bar{x} - \mu_0}{s / \sqrt{n}} = \dfrac{44 - 45}{5.2 / \sqrt{36}} = -1.15$

Degrees of freedom = $n - 1 = 35$

Lower tail p-value is the area to the left of the test statistic

Using t table: p-value is between .10 and .20

Exact p-value corresponding to t = -1.15 is .1290

p-value > .01, do not reject H_0

b. $$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{43 - 45}{4.6/\sqrt{36}} = -2.61$$

Lower tail p-value is the area to the left of the test statistic

Using t table: p-value is between .005 and .01

Exact p-value corresponding to t = -2.61 is .0066

p-value ≤ .01, reject H_0

c. $$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{46 - 45}{5/\sqrt{36}} = 1.20$$

Lower tail p-value is the area to the left of the test statistic

Using t table: p-value is between .80 and .90

Exact p-value corresponding to t = 1.20 is .8809

p-value > .01, do not reject H_0

26. a. $$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{103 - 100}{11.5/\sqrt{65}} = 2.10$$

Degrees of freedom = n – 1 = 64

Because t > 0, p-value is two times the upper tail area

Using t table; area in upper tail is between .01 and .025; therefore, p-value is between .02 and .05.

Exact p-value corresponding to t = 2.10 is .0397

p-value ≤ .05, reject H_0

b. $$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{96.5 - 100}{11/\sqrt{65}} = -2.57$$

Because t < 0, p-value is two times the lower tail area

Using t table: area in lower tail is between .005 and .01; therefore, p-value is between .01 and .02.

Exact p-value corresponding to t = -2.57 is .0125

p-value ≤ .05, reject H_0

c. $t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{102 - 100}{10.5/\sqrt{65}} = 1.54$

Because $t > 0$, p-value is two times the upper tail area

Using t table: area in upper tail is between .05 and .10; therefore, p-value is between .10 and .20.

Exact p-value corresponding to $t = 1.54$ is .1285

p-value > .05, do not reject H_0

27. a. H_0: $\mu \geq 238$

H_a: $\mu < 238$

b. $t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{231 - 238}{80/\sqrt{100}} = -.88$

Degrees of freedom = $n - 1 = 99$

Lower tail p-value is the area to the left of the test statistic

Using t table: p-value is between .10 and .20

Exact p-value corresponding to $t = -.88$ is .1905

c. p-value > .05; do not reject H_0. Cannot conclude mean weekly benefit in Virginia is less than the national mean.

d. $df = 99$ $t_{.05} = -1.66$

Reject H_0 if $t \leq -1.66$

$-.88 > -1.66$; do not reject H_0

28. a. H_0: $\mu \geq 9$

H_a: $\mu < 9$

b. $t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{7.27 - 9}{6.38/\sqrt{85}} = -2.50$

Degrees of freedom = $n - 1 = 84$

Lower tail p-value is the area to the left of the test statistic

Using t table: p-value is between .005 and .01

Exact p-value corresponding to $t = -2.50$ is .0072

c. p-value ≤ .01; reject H_0. The mean tenure of a CEO is significantly lower than 9 years. The claim of the shareholders group is not valid.

29. a. H_0: $\mu = 5600$

H_a: $\mu \neq 5600$

b. $t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{5835 - 5600}{520/\sqrt{25}} = 2.26$

Degrees of freedom = $n - 1 = 24$

Because $t < 0$, p-value is two times the upper tail area

Using t table: area in lower tail is between .01 and .025; therefore, p-value is between .02 and .05.

Exact p-value corresponding to $t = 2.26$ is .0332

c. p-value $\leq .05$; reject H_0. The mean diamond price in New York City differs.

d. $df = 24$ $\quad\quad t_{.025} = 2.064$

Reject H_0 if $t < -2.064$ or $t > 2.064$

$2.26 > 2.064$; reject H_0

30. a. H_0: $\mu = 600$

H_a: $\mu \neq 600$

b. $t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{612 - 600}{65/\sqrt{40}} = 1.17$

$df = n - 1 = 39$

Because $t > 0$, p-value is two times the upper tail area

Using t table: area in upper tail is between .10 and .20; therefore, p-value is between .20 and .40.

Exact p-value corresponding to $t = 1.17$ is .2491

c. With $\alpha = .10$ or less, we cannot reject H_0. We are unable to conclude there has been a change in the mean CNN viewing audience.

d. The sample mean of 612 thousand viewers is encouraging but not conclusive for the sample of 40 days. Recommend additional viewer audience data. A larger sample should help clarify the situation for CNN.

31. H_0: $\mu \leq 47.50$

H_a: $\mu > 47.50$

$t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{51 - 47.50}{12/\sqrt{64}} = 2.33$

Degrees of freedom = $n - 1 = 63$

Upper tail p-value is the area to the right of the test statistic

Using t table: p-value is between .01 and .025

Exact p-value corresponding to t = 2.33 is .0110

Reject H_0; Atlanta customers are paying a higher mean water bill.

32. a. H_0: $\mu = 10{,}192$

H_a: $\mu \neq 10{,}192$

b. $t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{9750 - 10{,}192}{1400/\sqrt{50}} = -2.23$

Degrees of freedom = n – 1 = 49

Because $t < 0$, p-value is two times the lower tail area

Using t table: area in lower tail is between .01 and .025; therefore, p-value is between .02 and .05.

Exact p-value corresponding to t = -2.23 is .0304

c. p-value ≤ .05; reject H_0. The population mean price at this dealership differs from the national mean price $10,192.

33. a. H_0: $\mu \leq 21.6$

H_a: $\mu > 21.6$

b. 24.1 – 21.6 = 2.5 gallons

c. $t = \dfrac{\bar{x} - \mu_0}{s/\sqrt{n}} = \dfrac{24.1 - 21.6}{4.8/\sqrt{16}} = 2.08$

Degrees of freedom = n – 1 = 15

Upper tail p-value is the area to the right of the test statistic

Using t table: p-value is between .025 and .05

Exact p-value corresponding to t = 2.08 is .0275

d. p-value ≤ .05; reject H_0. The population mean consumption of milk in Webster City is greater than the National mean.

34. a. H_0: $\mu = 2$

H_a: $\mu \neq 2$

b. $\bar{x} = \dfrac{\Sigma x_i}{n} = \dfrac{22}{10} = 2.2$

c. $s = \sqrt{\frac{\Sigma\left(x_i - \bar{x}\right)^2}{n-1}} = .516$

d. $t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{2.2 - 2}{.516/\sqrt{10}} = 1.22$

Degrees of freedom = n - 1 = 9

Because $t > 0$, p-value is two times the upper tail area

Using t table: area in upper tail is between .10 and .20; therefore, p-value is between .20 and .40.

Exact p-value corresponding to t = 1.22 is .2535

e. p-value > .05; do not reject H_0. No reason to change from the 2 hours for cost estimating purposes.

35. a. $z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.175 - .20}{\sqrt{\frac{.20(1-.20)}{400}}} = -1.25$

b. Because $z < 0$, p-value is two times the lower tail area

Using normal table with z = -1.25: p-value = 2(.1056) = .2112

c. p-value > .05; do not reject H_0

d. $z_{.025} = 1.96$

Reject H_0 if $z \le -1.96$ or $z \ge 1.96$

$z = -1.25$; do not reject H_0

36. a. $z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.68 - .75}{\sqrt{\frac{.75(1-.75)}{300}}} = -2.80$

Lower tail p-value is the area to the left of the test statistic

Using normal table with z = -2.80: p-value =.0026

p-value ≤ .05; Reject H_0

b. $z = \frac{.72 - .75}{\sqrt{\frac{.75(1-.75)}{300}}} = -1.20$

Lower tail p-value is the area to the left of the test statistic

Using normal table with z = -1.20: p-value =.1151

p-value > .05; Do not reject H_0

c. $z = \frac{.70-.75}{\sqrt{\frac{.75(1-.75)}{300}}} = -2.00$

Lower tail p-value is the area to the left of the test statistic

Using normal table with z = -2.00: p-value =.0228

p-value ≤ .05; Reject H_0

d. $z = \frac{.77-.75}{\sqrt{\frac{.75(1-.75)}{300}}} = .80$

Lower tail p-value is the area to the left of the test statistic

Using normal table with z = .80: p-value =.7881

p-value > .05; Do not reject H_0

37. a. H_0: $p \leq .125$

H_a: $p > .125$

b. $\bar{p} = \frac{52}{400} = .13$

$$z = \frac{\bar{p}-p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.13-.125}{\sqrt{\frac{.125(1-.125)}{400}}} = .30$$

Upper tail p-value is the area to the right of the test statistic

Using normal table with z = .30: p-value = 1.0000 - .6179 = .3821

c. p-value > .05; do not reject H_0. We cannot conclude that there has been an increase in union membership.

38. a. H_0: $p = .64$

H_a: $p \neq .64$

b. $\bar{p} = \frac{52}{100} = .52$

$$z = \frac{\bar{p}-p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.52-.64}{\sqrt{\frac{.64(1-.64)}{100}}} = -2.50$$

Because $z < 0$, p-value is two times the lower tail area

Using normal table with z = -2.50: p-value = 2(.0062) = .0124

c. p-value ≤ .05; reject H_0. Proportion differs from the reported .64.

d. Yes. Since $\bar{p} = .52$, it indicates that fewer than 64% of the shoppers believe the supermarket brand is as good as the name brand.

39. a. H_0: $p = .70$

H_a: $p \neq .70$

b. Wisconsin $\bar{p} = \frac{252}{350} = .72$

$$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.72 - .70}{\sqrt{\frac{.70(1-.70)}{350}}} = .82$$

Because $z > 0$, p-value is two times the upper tail area

Using normal table with z = .72: p-value = 2(.2061) = .4122

Cannot reject H_0.

California $\bar{p} = \frac{189}{300} = .63$

$$z = \frac{.63 - .70}{\sqrt{\frac{.70(1-.70)}{300}}} = -2.65$$

Because $z < 0$, p-value is two times the lower tail area

Using normal table with z = -2.65: p-value = 2(.0040) = .0080

Reject H_0. California has a different (lower) percentage of adults who do not exercise regularly.

40. a. $\bar{p} = \frac{414}{1532} = .2702$ (27%)

b. H_0: $p \leq .22$

H_a: $p > .22$

$$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.2702 - .22}{\sqrt{\frac{.22(1-.22)}{1532}}} = 4.75$$

Upper tail p-value is the area to the right of the test statistic

Using normal table with z = 4.75: p-value ≈ 0

c. These studies help companies and advertising firms evaluate the impact and benefit of commercials.

41. a. H_0: $p \geq .70$

H_a: $p < .70$

b. $$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.67 - .70}{\sqrt{\frac{.70(1-.70)}{300}}} = -1.13$$

Lower tail *p*-value is the area to the left of the test statistic

Using normal table with z = -1.13: *p*-value =.1292

c. *p*-value > .05; do not reject H_0. The executive's claim cannot be rejected.

42. a. $\bar{p}$ = 12/80 = .15

b. $$\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \sqrt{\frac{.15(.85)}{80}} = .0399$$

$$\bar{p} \pm z_{.025}\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

.15 ± 1.96 (.0399)

.15 ± .0782 or .0718 to .2218

c. We can conduct a hypothesis test concerning whether the return rate for the Houston store is equal to .06 at an □ = .05 level of significance using the 95% confidence interval in part (b). Since the confidence interval does not include .06, we conclude that the return rate for the Houston store is different than the U.S. national return rate.

43. a. H_0: $p \leq .10$

H_a: $p > .10$

b. There are 13 "Yes" responses in the Eagle data set.

$$\bar{p} = \frac{13}{100} = .13$$

c. $$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.13 - .10}{\sqrt{\frac{.10(1-.10)}{100}}} = 1.00$$

Upper tail *p*-value is the area to the right of the test statistic

Using normal table with z = 1.00: *p*-value = 1 - .8413 = .1587

p-value > .05; do not reject H_0.

The statistical results do not allow us to conclude that $p > .10$. But, given that $\overline{p} = .13$, management may want to authorize a larger study before deciding not to go national.

44. a. H_0: $p \le .51$

H_a: $p > .51$

b. $\overline{p} = \dfrac{232}{400} = .58$

$$z = \frac{\overline{p} - p_0}{\sqrt{\dfrac{p_0(1-p_0)}{n}}} = \frac{.58 - .51}{\sqrt{\dfrac{(.51)(.49)}{400}}} = 2.80$$

Upper tail *p*-value is the area to the right of the test statistic

Using normal table with $z = 2.80$: *p*-value = 1 – .9974 = .0026

c. Since *p*-value = .0026 ≤ .01, we reject H_0 and conclude that people working the night shift get drowsy while driving more often than the average for the entire population.

45. a. H_0: $p = .30$

H_a: $p \ne .30$

b. $\overline{p} = \dfrac{24}{50} = .48$

c. $$z = \frac{\overline{p} - p_0}{\sqrt{\dfrac{p_0(1-p_0)}{n}}} = \frac{.48 - .30}{\sqrt{\dfrac{.30(1-.30)}{50}}} = 2.78$$

Because $z > 0$, *p*-value is two times the upper tail area

Using normal table with $z = 2.78$: *p*-value = 2(.0027) = .0054

p-value ≤ .01; reject H_0.

We would conclude that the proportion of stocks going up on the NYSE is not 30%. This would suggest not using the proportion of DJIA stocks going up on a daily basis as a predictor of the proportion of NYSE stocks going up on that day.

46. a. H_0: $\mu = 16$

H_a: $\mu \ne 16$

b. $$z = \frac{\overline{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{16.32 - 16}{.8 / \sqrt{30}} = 2.19$$

Because $z > 0$, *p*-value is two times the upper tail area

Using normal table with $z = 2.19$: *p*-value = 2(.0143) = .0286

p-value ≤ .05; reject H_0. Readjust production line.

c. $$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{15.82 - 16}{.8 / \sqrt{30}} = -1.23$$

Because $z < 0$, p-value is two times the lower tail area

Using normal table with z = -1.23: p-value = 2(.1093) = .2186

p-value > .05; do not reject H_0. Continue the production line.

d. Reject H_0 if $z \le -1.96$ or $z \ge 1.96$

For $\bar{x}$ = 16.32, z = 2.19; reject H_0

For $\bar{x}$ = 15.82, z = -1.23; do not reject H_0

Yes, same conclusion.

47. a. H_0: $\mu = 900$

H_a: $\mu \ne 900$

b. $$\bar{x} \pm z_{.025} \frac{\sigma}{\sqrt{n}}$$

$$935 \pm 1.96 \frac{180}{\sqrt{200}}$$

935 ± 25 (910 to 960)

c. Reject H_0 because $\mu = 900$ is not in the interval.

d. $$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{935 - 900}{180 / \sqrt{200}} = 2.75$$

Because $z > 0$, p-value is two times the upper tail area

Using normal table with z = 2.75: p-value = 2(.0030) = .0060

48. a. H_0: $\mu \le 119{,}155$

H_a: $\mu > 119{,}155$

b. $$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}} = \frac{126{,}100 - 119{,}155}{20{,}700 / \sqrt{60}} = 2.60$$

Upper tail p-value is the area to the right of the test statistic

Using normal table with z = 2.60: p-value = 1.0000 - .9953 = .0047

c. p-value $\leq$ .01, reject H_0. We can conclude that the mean annual household income for theater goers in the San Francisco Bay area is higher than the mean for all *Playbill* readers.

49. The hypothesis test that will allow us to conclude that the consensus estimate has increased is given below.

H_0: $\mu \leq 250{,}000$

H_a: $\mu > 250{,}000$

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{266{,}000 - 250{,}000}{24{,}000/\sqrt{20}} = 2.981$$

Degrees of freedom = n – 1 = 19

Upper tail p-value is the area to the right of the test statistic

Using t table: p-value is less than .005

Exact p-value corresponding to t = 2.981 is .0038

p-value ≤ .01; reject H_0. The consensus estimate has increased.

50. H_0: $\mu = 6000$

H_a: $\mu \neq 6000$

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{5812 - 6000}{1140/\sqrt{32}} = -.93$$

Degrees of freedom = n – 1 = 31

Because t < 0, p-value is two times the lower tail area

Using t table: area in lower tail is between .10 and .20; therefore, p-value is between .20 and .40.

Exact p-value corresponding to t = -.93 is .3596

Do not reject H_0. There is no evidence to conclude that the mean number of freshman applications has changed.

51. a. H_0: $\mu \geq 6883$

H_a: $\mu < 6883$

b. $$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{6130 - 6883}{2518/\sqrt{40}} = -1.89$$

Degrees of freedom = n – 1 = 39

Lower tail p-value is the area to the left of the test statistic

Using t table: p-value is between .05 and .025

Exact p-value corresponding to t = -1.89 is .0331

c. We should conclude that Medicare spending per enrollee in Indianapolis is less than the national average.

d. Using the critical value approach we would:

Reject H_0 if $t \le -t_{.05} = -1.685$

Since $t = -1.89 \le -1.685$, we reject H_0.

52. H_0: $\mu \le 125{,}000$

H_a: $\mu > 125{,}000$

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{130{,}000 - 125{,}000}{12{,}500/\sqrt{32}} = 2.26$$

Degrees of freedom = 32 – 1 = 31

Upper tail p-value is the area to the right of the test statistic

Using t table: p-value is between .01 and .025

Exact p-value corresponding to t = 2.26 is .0155

p-value ≤ .05; reject H_0. Conclude that the mean cost is greater than $125,000 per lot.

53. H_0: $\mu = 2.357$

H_a: $\mu \ne 2.357$

$$\bar{x} = \frac{\Sigma x_i}{n} = 2.3496$$

$$s = \sqrt{\frac{\Sigma\left(x_i - \bar{x}\right)^2}{n-1}} = .0444$$

$$t = \frac{\bar{x} - \mu_0}{s/\sqrt{n}} = \frac{2.3496 - 2.3570}{.0444/\sqrt{50}} = -1.18$$

Degrees of freedom = 50 - 1 = 49

Because $t < 0$, p-value is two times the lower tail area

Using t table: area in lower tail is between .10 and .20; therefore, p-value is between .20 and .40.

Exact p-value corresponding to t = -1.18 is .2437

p-value > .05; do not reject H_0.

There is not a statistically significant difference between the National mean price per gallon and the mean price per gallon in the Lower Atlantic states.

54. a. H_0: $p \le .50$

H_a: $p > .50$

b. $$\bar{p} = \frac{64}{100} = .64$$

c. $$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.64 - .50}{\sqrt{\frac{.50(1-.50)}{100}}} = 2.80$$

Upper tail *p*-value is the area to the right of the test statistic

Using normal table with $z = 2.80$: *p*-value = 1.0000 - .9974 = .0026

p-value ≤ .01; reject H_0. College graduates have a greater stop-smoking success rate.

55. a. H_0: $p = .6667$

H_a: $p \ne .6667$

b. $$\bar{p} = \frac{355}{546} = .6502$$

c. $$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.6502 - .6667}{\sqrt{\frac{.6667(1-.6667)}{546}}} = -.82$$

Because $z < 0$, *p*-value is two times the lower tail area

Using normal table with $z = -.82$: *p*-value = 2(.2061) = .4122

p-value > .05; do not reject H_0; Cannot conclude that the population proportion differs from 2/3.

56. a. H_0: $p \le .80$

H_a: $p > .80$

b. $$\bar{p} = \frac{252}{300} = .84 \quad (84\%)$$

c. $$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.84 - .80}{\sqrt{\frac{.80(1-.80)}{300}}} = 1.73$$

Upper tail *p*-value is the area to the right of the test statistic

Using normal table with $z = 1.73$: *p*-value = 1.0000 - .9582 = .0418

d. p-value ≤ .05; reject H_0. Conclude that more than 80% of the customers are satisfied with the service provided by the home agents. Regional Airways should consider implementing the home agent system.

57. a. $\bar{p} = \frac{503}{910} = .553$

b. H_0: $p \le .50$

H_a: $p > .50$

c. $z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.553 - .500}{\sqrt{\frac{(.5)(.5)}{910}}} = 3.19$

Upper tail p-value is the area to the right of the test statistic

Using normal table with $z = 3.19$: p-value ≈ 0

You can tell the manager that the observed level of significance is very close to zero and that this means the results are highly significant. Any reasonable person would reject the null hypotheses and conclude that the proportion of adults who are optimistic about the national outlook is greater than .50

58. H_0: $p \ge .90$

H_a: $p < .90$

$\bar{p} = \frac{49}{58} = .8448$

$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.8448 - .90}{\sqrt{\frac{.90(1-.90)}{58}}} = -1.40$

Lower tail p-value is the area to the left of the test statistic

Using normal table with $z = -1.40$: p-value =.0808

p-value > .05; do not reject H_0. Claim of at least 90% cannot be rejected.

59. a. H_0: $p \ge .24$

H_a: $p < .24$

b. $\bar{p} = \frac{81}{400} = .2025$

c. $$z = \frac{\bar{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}} = \frac{.2025 - .24}{\sqrt{\frac{.24(1-.24)}{400}}} = -1.76$$

Lower tail *p*-value is the area to the left of the test statistic

Using normal table with $z = -1.76$: *p*-value =.0392

p-value ≤ .05; reject H_0.

The proportion of workers not required to contribute to their company sponsored health care plan has declined. There seems to be a trend toward companies requiring employees to share the cost of health care benefits.