## Problem Solving *(page 215)*

**1.** Answers will vary.
**3.** 2 inches × 2 inches × 5 inches
**5.** (a) and (b) $y = -x^2 + 5x - 4$
**7.** (a) $f(x) = (x - 2)x^2 + 5 = x^3 - 2x^2 + 5$
(b) $f(x) = -(x + 3)x^2 + 1 = -x^3 - 3x^2 + 1$
**9.** $(a + bi)(a - bi) = a^2 + abi - abi - b^2i^2$
$= a^2 + b^2$
**11.** (a) As $|a|$ increases, the graph stretches vertically. For $a < 0$, the graph is reflected in the $x$-axis.
(b) As $|b|$ increases, the vertical asymptote is translated. For $b > 0$, the graph is translated to the right. For $b < 0$, the graph is reflected in the $x$-axis and is translated to the left.

# Chapter 3

## Section 3.1 *(page 226)*

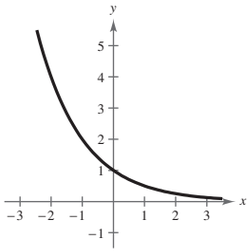
### Vocabulary Check *(page 226)*

**1.** algebraic **2.** transcendental
**3.** natural exponential; natural **4.** $A = P\left(1 + \frac{r}{n}\right)^{nt}$
**5.** $A = Pe^{rt}$

**1.** 946.852 **3.** 0.006 **5.** 1767.767
**7.** d **8.** c **9.** a **10.** b

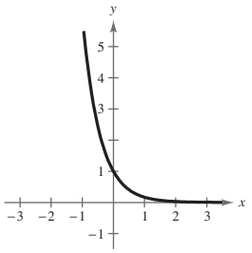
**11.**

| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $f(x)$ | 4 | 2 | 1 | 0.5 | 0.25 |



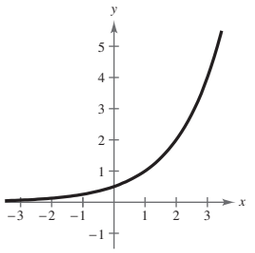
**13.**

| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $f(x)$ | 36 | 6 | 1 | 0.167 | 0.028 |



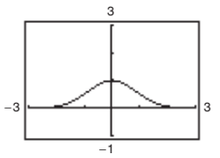
**15.**

| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $f(x)$ | 0.125 | 0.25 | 0.5 | 1 | 2 |

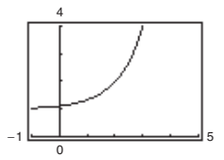


**17.** Shift the graph of $f$ four units to the right.
**19.** Shift the graph of $f$ five units upward.
**21.** Reflect the graph of $f$ in the $x$-axis and $y$-axis and shift six units to the right.

**23.**



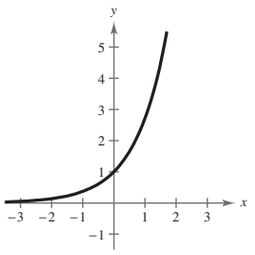
**25.**



**27.** 0.472 **29.** $3.857 \times 10^{-22}$ **31.** 7166.647

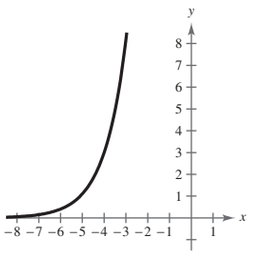
**33.**

| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $f(x)$ | 0.135 | 0.368 | 1 | 2.718 | 7.389 |



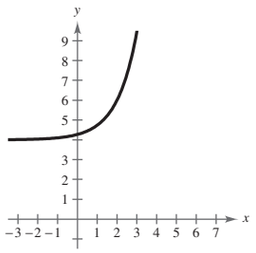
**35.**

| $x$ | $-8$ | $-7$ | $-6$ | $-5$ | $-4$ |
|---|---|---|---|---|---|
| $f(x)$ | 0.055 | 0.149 | 0.406 | 1.104 | 3 |

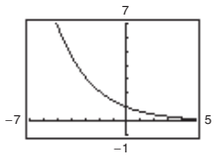


**37.**

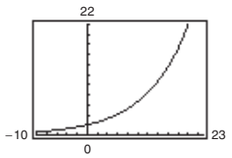
| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $f(x)$ | 4.037 | 4.100 | 4.271 | 4.736 | 6 |



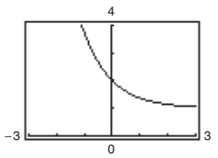

**39.**




**41.**




**43.**




**45.** $x = 2$ **47.** $x = -3$ **49.** $x = \frac{1}{3}$ **51.** $x = 3, -1$

**53.**

| $n$ | 1 | 2 | 4 |
|---|---|---|---|
| $A$ | \$3200.21 | \$3205.09 | \$3207.57 |

| $n$ | 12 | 365 | Continuous |
|---|---|---|---|
| $A$ | \$3209.23 | \$3210.06 | \$3210.06 |

**55.**

| $n$ | 1 | 2 | 4 |
|---|---|---|---|
| $A$ | \$4515.28 | \$4535.05 | \$4545.11 |

| $n$ | 12 | 365 | Continuous |
|---|---|---|---|
| $A$ | \$4551.89 | \$4555.18 | \$4555.30 |

**57.**

| $t$ | 10 | 20 | 30 |
|---|---|---|---|
| $A$ | \$17,901.90 | \$26,706.49 | \$39,841.40 |

| $t$ | 40 | 50 |
|---|---|---|
| $A$ | \$59,436.39 | \$88,668.67 |

**59.**

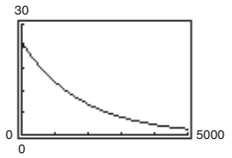
| $t$ | 10 | 20 | 30 |
|---|---|---|---|
| $A$ | \$22,986.49 | \$44,031.56 | \$84,344.25 |

| $t$ | 40 | 50 |
|---|---|---|
| $A$ | \$161,564.86 | \$309,484.08 |

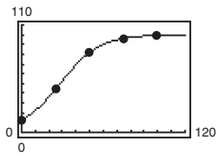
**61.** \$222,822.57 **63.** \$35.45

**65.** (a) $V(1) = 10{,}000.298$ (b) $V(1.5) = 100{,}004.47$
(c) $V(2) = 1{,}000{,}059.6$

**67.** (a) 25 grams (b) 16.21 grams
(c)




**69.** (a)




(b)

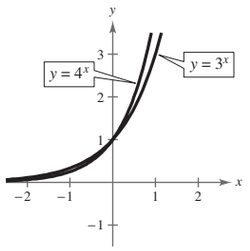
| $x$ | 0 | 25 | 50 | 75 | 100 |
|---|---|---|---|---|---|
| Model | 12.5 | 44.5 | 81.82 | 96.19 | 99.3 |
| Actual | 12 | 44 | 81 | 96 | 99 |

(c) 63.14% (d) 38 masses

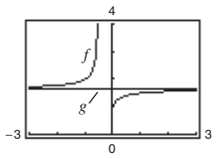
**71.** True. As $x \to -\infty$, $f(x) \to -2$ but never reaches $-2$.

**73.** $f(x) = h(x)$ **75.** $f(x) = g(x) = h(x)$

**77.** (a) $x < 0$ (b) $x > 0$



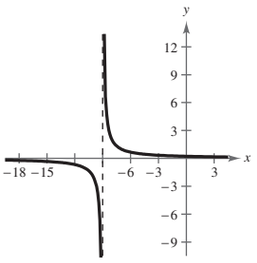

**79.**




As $x \to \infty$, $f(x) \to g(x)$.
As $x \to -\infty$, $f(x) \to g(x)$.

**81.** $y = \pm\sqrt{25 - x^2}$

**83.**



**85.** Answers will vary.

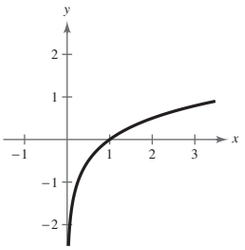
## Section 3.2 *(page 236)*

**Vocabulary Check** *(page 236)*

**1.** logarithmic **2.** 10 **3.** natural; $e$
**4.** $a^{\log_a x} = x$ **5.** $x = y$

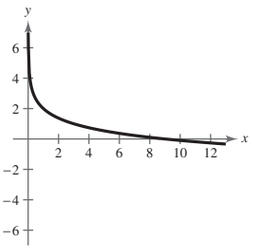
**1.** $4^3 = 64$ **3.** $7^{-2} = \frac{1}{49}$ **5.** $32^{2/5} = 4$
**7.** $36^{1/2} = 6$ **9.** $\log_5 125 = 3$ **11.** $\log_{81} 3 = \frac{1}{4}$
**13.** $\log_6 \frac{1}{36} = -2$ **15.** $\log_7 1 = 0$ **17.** 4 **19.** 0
**21.** 2 **23.** $-0.0972$ **25.** 1.097 **27.** 4 **29.** 1

**31.**



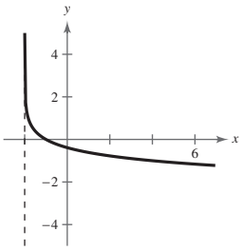
Domain: $(0, \infty)$
$x$-intercept: $(1, 0)$
Vertical asymptote: $x = 0$

**33.**



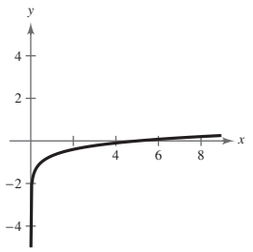
Domain: $(0, \infty)$
$x$-intercept: $(9, 0)$
Vertical asymptote: $x = 0$

**35.**



Domain: $(-2, \infty)$
$x$-intercept: $(-1, 0)$
Vertical asymptote: $x = -2$

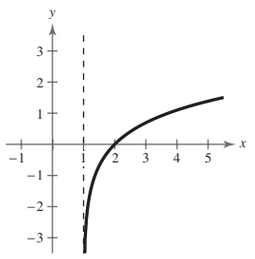
**37.**



Domain: $(0, \infty)$
$x$-intercept: $(5, 0)$
Vertical asymptote: $x = 0$

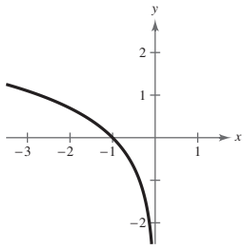
**39.** c **40.** f **41.** d **42.** e **43.** b **44.** a
**45.** $e^{-0.693\ldots} = \frac{1}{2}$ **47.** $e^{1.386\ldots} = 4$
**49.** $e^{5.521\ldots} = 250$ **51.** $e^0 = 1$
**53.** $\ln 20.0855\ldots = 3$ **55.** $\ln 1.6487\ldots = \frac{1}{2}$
**57.** $\ln 0.6065\ldots = -0.5$ **59.** $\ln 4 = x$ **61.** 2.913
**63.** $-0.575$ **65.** 3 **67.** $-\frac{2}{3}$

**69.**



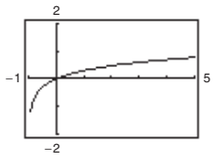
Domain: $(1, \infty)$
$x$-intercept: $(2, 0)$
Vertical asymptote: $x = 1$

**71.**

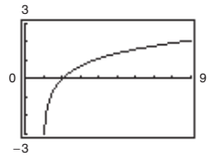


Domain: $(-\infty, 0)$
$x$-intercept: $(-1, 0)$
Vertical asymptote: $x = 0$

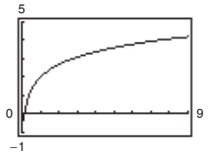
**73.**



**75.**

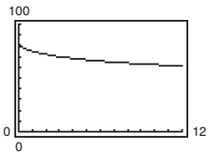


**77.**



**79.** $x = 3$ **81.** $x = 7$ **83.** $x = 4$ **85.** $x = -5, 5$
**87.** (a) 30 years; 20 years (b) \$396,234; \$301,123.20
(c) \$246,234; \$151,123.20
(d) $x = 1000$; The monthly payment must be greater than \$1000.

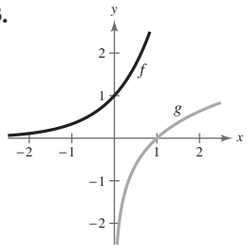
**89.** (a)




(b) 80
(c) 68.1
(d) 62.3

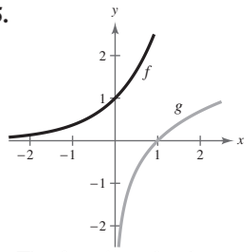
**91.** False. Reflecting $g(x)$ about the line $y = x$ will determine the graph of $f(x)$.

**93.**



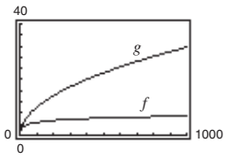

The functions $f$ and $g$ are inverses.

**95.**



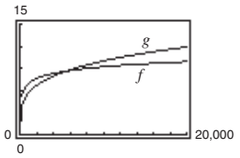

The functions $f$ and $g$ are inverses.

**97.** (a)




$g(x)$; The natural log function grows at a slower rate than the square root function.

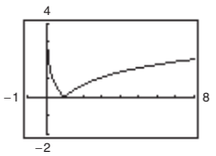
(b)




$g(x)$; The natural log function grows at a slower rate than the fourth root function.

**99.** (a) False (b) True (c) True (d) False

**101.** (a)




(b) Increasing: $(1, \infty)$
Decreasing: $(0, 1)$

(c) Relative minimum: $(1, 0)$

**103.** 15 **105.** 4300 **107.** 1028

## Section 3.3 *(page 243)*

**Vocabulary Check** *(page 243)*

**1.** change-of-base **2.** $\dfrac{\log x}{\log a} = \dfrac{\ln x}{\ln a}$

**3.** c **4.** a **5.** b

**1.** (a) $\dfrac{\log x}{\log 5}$ (b) $\dfrac{\ln x}{\ln 5}$ **3.** (a) $\dfrac{\log x}{\log \frac{1}{5}}$ (b) $\dfrac{\ln x}{\ln \frac{1}{5}}$

**5.** (a) $\dfrac{\log \frac{3}{10}}{\log x}$ (b) $\dfrac{\ln \frac{3}{10}}{\ln x}$ **7.** (a) $\dfrac{\log x}{\log 2.6}$ (b) $\dfrac{\ln x}{\ln 2.6}$

**9.** 1.771 **11.** $-2.000$ **13.** $-0.417$ **15.** 2.633

**17.** $\frac{3}{2}$ **19.** $-3 - \log_5 2$ **21.** $6 + \ln 5$ **23.** 2

**25.** $\frac{3}{4}$ **27.** 2.4 **29.** $-9$ is not in the domain of $\log_3 x$.

**31.** 4.5 **33.** $-\frac{1}{2}$ **35.** 7 **37.** 2

**39.** $\log_4 5 + \log_4 x$ **41.** $4 \log_8 x$ **43.** $1 - \log_5 x$

**45.** $\frac{1}{2} \ln z$ **47.** $\ln x + \ln y + 2 \ln z$

**49.** $\ln z + 2 \ln(z - 1)$ **51.** $\frac{1}{2} \log_2(a - 1) - 2 \log_2 3$

**53.** $\frac{1}{3} \ln x - \frac{1}{3} \ln y$ **55.** $4 \ln x + \frac{1}{2} \ln y - 5 \ln z$

**57.** $2 \log_5 x - 2 \log_5 y - 3 \log_5 z$

**59.** $\dfrac{3}{4} \ln x + \dfrac{1}{4} \ln(x^2 + 3)$ **61.** $\ln 3x$ **63.** $\log_4 \dfrac{z}{y}$

**65.** $\log_2(x + 4)^2$ **67.** $\log_3 \sqrt[4]{5x}$ **69.** $\ln \dfrac{x}{(x + 1)^3}$

**71.** $\log \dfrac{xz^3}{y^2}$ **73.** $\ln \dfrac{x}{(x^2 - 4)^4}$ **75.** $\ln \sqrt[3]{\dfrac{x(x + 3)^2}{x^2 - 1}}$

**77.** $\log_8 \dfrac{\sqrt[3]{y(y + 4)^2}}{y - 1}$

**79.** $\log_2 \frac{32}{4} = \log_2 32 - \log_2 4$; Property 2

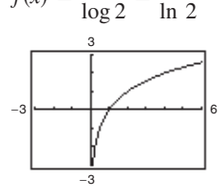
**81.** $\beta = 10(\log I + 12)$; 60 dB **83.** $\approx 3$

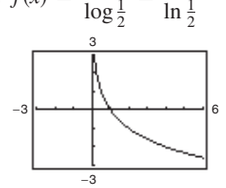
**85.** $y = 256.24 - 20.8 \ln x$

**87.** False. $\ln 1 = 0$ **89.** False. $\ln(x - 2) \neq \ln x - \ln 2$

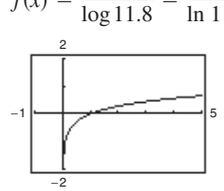
**91.** False. $u = v^2$ **93.** Answers will vary.

**95.** $f(x) = \dfrac{\log x}{\log 2} = \dfrac{\ln x}{\ln 2}$ **97.** $f(x) = \dfrac{\log x}{\log \frac{1}{2}} = \dfrac{\ln x}{\ln \frac{1}{2}}$

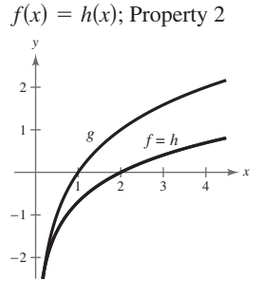



**99.** $f(x) = \dfrac{\log x}{\log 11.8} = \dfrac{\ln x}{\ln 11.8}$




**101.** $f(x) = h(x)$; Property 2



**103.** $\dfrac{3x^4}{2y^3}$, $x \neq 0$ **105.** $1, x \neq 0, y \neq 0$

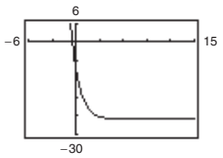
**107.** $-1, \dfrac{1}{3}$ **109.** $\dfrac{-1 \pm \sqrt{97}}{6}$

## Section 3.4 *(page 253)*

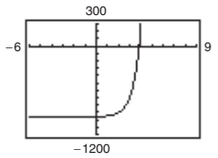
### Vocabulary Check *(page 253)*

**1.** solve
**2.** (a) $x = y$ (b) $x = y$ (c) $x$ (d) $x$
**3.** extraneous

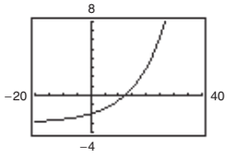
**1.** (a) Yes (b) No
**3.** (a) No (b) Yes (c) Yes, approximate
**5.** (a) Yes, approximate (b) No (c) Yes
**7.** (a) No (b) Yes (c) Yes, approximate
**9.** 2 **11.** $-5$ **13.** 2 **15.** $\ln 2 \approx 0.693$
**17.** $e^{-1} \approx 0.368$ **19.** 64 **21.** (3, 8) **23.** (9, 2)
**25.** $2, -1$ **27.** $\approx 1.618, \approx -0.618$
**29.** $\dfrac{\ln 5}{\ln 3} \approx 1.465$ **31.** $\ln 5 \approx 1.609$ **33.** $\ln 28 \approx 3.332$
**35.** $\dfrac{\ln 80}{2 \ln 3} \approx 1.994$ **37.** 2 **39.** 4
**41.** $3 - \dfrac{\ln 565}{\ln 2} \approx -6.142$ **43.** $\dfrac{1}{3}\log\left(\dfrac{3}{2}\right) \approx 0.059$
**45.** $1 + \dfrac{\ln 7}{\ln 5} \approx 2.209$ **47.** $\dfrac{\ln 12}{3} \approx 0.828$
**49.** $-\ln \dfrac{3}{5} \approx 0.511$ **51.** 0 **53.** $\dfrac{\ln \frac{8}{3}}{3 \ln 2} + \dfrac{1}{3} \approx 0.805$
**55.** $\ln 5 \approx 1.609$ **57.** $\ln 4 \approx 1.386$
**59.** $2 \ln 75 \approx 8.635$ **61.** $\dfrac{1}{2} \ln 1498 \approx 3.656$
**63.** $\dfrac{\ln 4}{365 \ln\left(1 + \frac{0.065}{365}\right)} \approx 21.330$
**65.** $\dfrac{\ln 2}{12 \ln\left(1 + \frac{0.10}{12}\right)} \approx 6.960$

**67.**


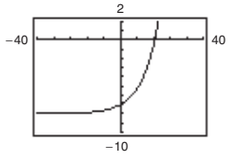
$-0.427$

**69.**


3.847

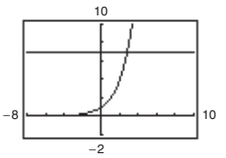
**71.**


12.207

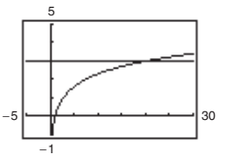
**73.**


16.636

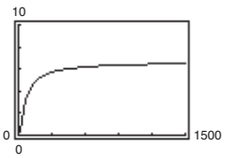
**75.** $e^{-3} \approx 0.050$ **77.** $\dfrac{e^{2.4}}{2} \approx 5.512$ **79.** 1,000,000
**81.** $\dfrac{e^{10/3}}{5} \approx 5.606$ **83.** $e^2 - 2 \approx 5.389$
**85.** $e^{-2/3} \approx 0.513$ **87.** $2(3^{11/6}) \approx 14.988$
**89.** No solution **91.** $1 + \sqrt{1 + e} \approx 2.928$
**93.** No solution **95.** 7 **97.** $\dfrac{-1 + \sqrt{17}}{2} \approx 1.562$
**99.** 2 **101.** $\dfrac{725 + 125\sqrt{33}}{8} \approx 180.384$

**103.**


2.807

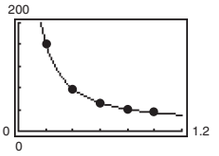
**105.**


20.086

**107.** (a) 8.2 years (b) 12.9 years
**109.** (a) 1426 units (b) 1498 units
**111.** (a)


(b) $V = 6.7$; The yield will approach 6.7 million cubic feet per acre.
(c) 29.3 years
**113.** 2001
**115.** (a) $y = 100$ and $y = 0$; The range falls between 0% and 100%.
(b) Males: 69.71 inches Females: 64.51 inches
**117.** (a)

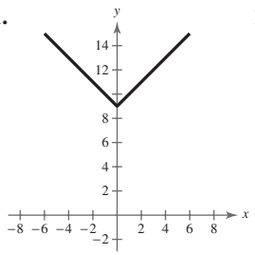
| $x$ | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 |
|---|---|---|---|---|---|
| $y$ | 162.6 | 78.5 | 52.5 | 40.5 | 33.9 |

(b)


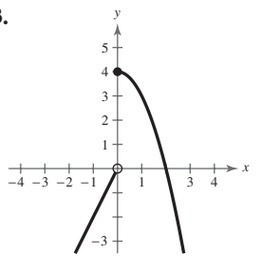
The model appears to fit the data well.
(c) 1.2 meters
(d) No. According to the model, when the number of $g$'s is less than 23, $x$ is between 2.276 meters and 4.404 meters, which isn't realistic in most vehicles.
**119.** $\log_b uv = \log_b u + \log_b v$
True by Property 1 in Section 5.3.
**121.** $\log_b(u - v) = \log_b u - \log_b v$
False.
$1.95 \approx \log(100 - 10) \neq \log 100 - \log 10 = 1$
**123.** Yes. See Exercise 93.
**125.** Yes. Time to double: $t = \dfrac{\ln 2}{r}$;
Time to quadruple: $t = \dfrac{\ln 4}{r} = 2\left(\dfrac{\ln 2}{r}\right)$

**127.** $4|x|y^2\sqrt{3y}$ **129.** $5\sqrt[3]{3}$

**131.**



**133.**



**135.** 1.226 **137.** $-5.595$

## Section 3.5 *(page 264)*

### Vocabulary Check *(page 264)*

1. $y = ae^{bx}$; $y = ae^{-bx}$
2. $y = a + b \ln x$; $y = a + b \log x$
3. normally distributed **4.** bell; average value
5. sigmoidal

**1.** c **2.** e **3.** b **4.** a **5.** d **6.** f

| | *Initial Investment* | *Annual % Rate* | *Time to Double* | *Amount After 10 years* |
|---|---|---|---|---|
| **7.** | \$1000 | 3.5% | 19.8 yr | \$1419.07 |
| **9.** | \$750 | 8.9438% | 7.75 yr | \$1834.36 |
| **11.** | \$500 | 11.0% | 6.3 yr | \$1505.00 |
| **13.** | \$6376.28 | 4.5% | 15.4 yr | \$10,000.00 |

**15.** \$112,087.09

**17.** (a) 6.642 years (b) 6.330 years
(c) 6.302 years (d) 6.301 years

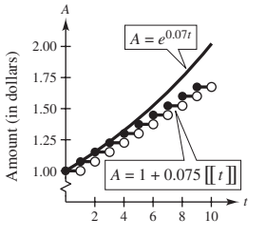
**19.**

| $r$ | 2% | 4% | 6% | 8% | 10% | 12% |
|---|---|---|---|---|---|---|
| $t$ | 54.93 | 27.47 | 18.31 | 13.73 | 10.99 | 9.16 |

**21.**

| $r$ | 2% | 4% | 6% | 8% | 10% | 12% |
|---|---|---|---|---|---|---|
| $t$ | 55.48 | 28.01 | 18.85 | 14.27 | 11.53 | 9.69 |

**23.** Continuous compounding




| | *Half-life (years)* | *Initial Quantity* | *Amount After 1000 Years* |
|---|---|---|---|
| **25.** | 1599 | 10 g | 6.48 g |
| **27.** | 5715 | 2.26 g | 2 g |
| **29.** | 24,100 | 2.16 g | 2.1 g |

**31.** $y = e^{0.7675x}$ **33.** $y = 5e^{-0.4024x}$

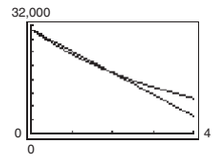
**35.** (a) Decreasing due to the negative exponent.
(b) 2000: population of 2430 thousand
2003: population of 2408.95 thousand
(c) 2018

**37.** $k = 0.2988$; $\approx$ 5,309,734 hits **39.** 3.15 hours

**41.** (a) $\approx$ 12,180 years old (b) $\approx$ 4797 years old

**43.** (a) $V = -6394t + 30{,}788$ (b) $V = 30{,}788e^{-0.268t}$

(c)




The exponential model depreciates faster.

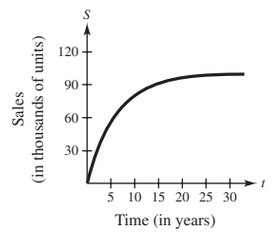
(d)

| $t$ | 1 | 3 |
|---|---|---|
| $V = -6394t + 30{,}788$ | 24,394 | 11,606 |
| $V = 30{,}788e^{-0.268t}$ | 23,550 | 13,779 |

(e) Answers will vary.

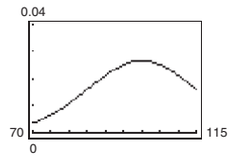
**45.** (a) $S(t) = 100(1 - e^{-0.1625t})$

(b)




(c) 55,625

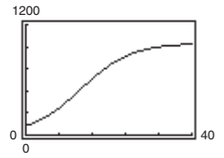
**47.** (a)




(b) 100

**49.** (a) 203 animals (b) 13 years

(c)




Horizontal asymptotes: $y = 0$, $y = 1000$. The population size will approach 1000 as time increases.

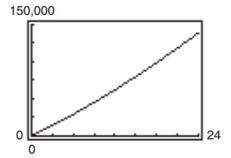
**51.** (a) $10^{7.9} \approx 79{,}432{,}823$ (b) $10^{8.3} \approx 199{,}526{,}231$
(c) $10^{4.2} \approx 15{,}849$

**53.** (a) 20 decibels (b) 70 decibels
(c) 40 decibels (d) 120 decibels

**55.** 95% **57.** 4.64 **59.** $1.58 \times 10^{-6}$ moles per liter

**61.** $10^{5.1}$ **63.** 3:00 A.M.

**65.** (a)



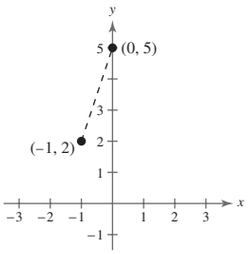

(b) $\approx$ 21 years; Yes

**67.** False. The domain can be the set of real numbers for a logistic growth function.

**69.** False. The graph of $f(x)$ is the graph of $g(x)$ shifted upward five units.

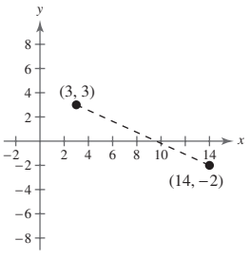
**71.** (a) Logarithmic (b) Logistic (c) Exponential (d) Linear (e) None of the above (f) Exponential

**73.** (a)



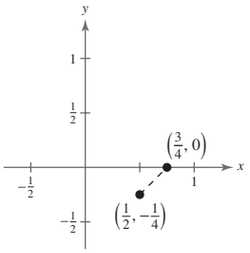

(b) $\sqrt{10}$
(c) $\left(-\frac{1}{2}, \frac{7}{2}\right)$
(d) 3

**75.** (a)



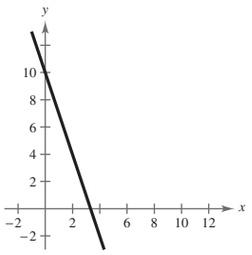

(b) $\sqrt{146}$
(c) $\left(\frac{17}{2}, \frac{1}{2}\right)$
(d) $-\frac{5}{11}$

**77.** (a)

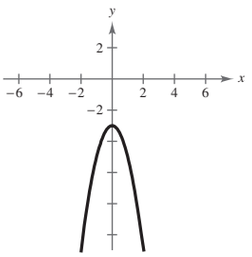



(b) $\sqrt{\frac{1}{8}}$
(c) $\left(\frac{5}{8}, -\frac{1}{8}\right)$
(d) 1

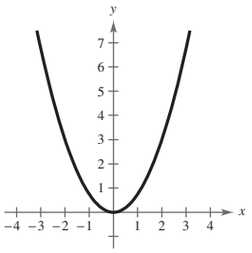
**79.**



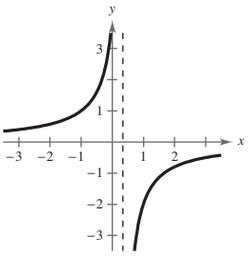
**81.**



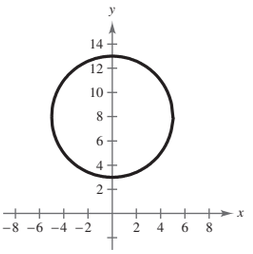
**83.**



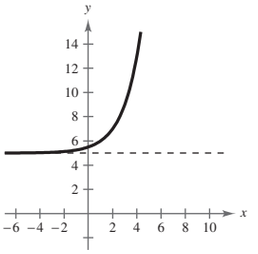
**85.**



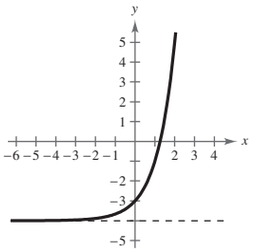
**87.**



**89.**



**91.**

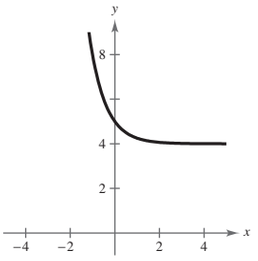


**93.** Answers will vary.

## Review Exercises *(page 271)*

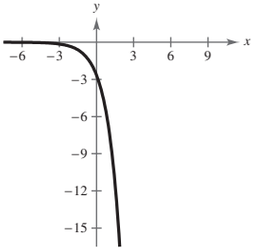
**1.** 76.699 **3.** 0.337 **5.** 1456.529
**7.** c **8.** d **9.** a **10.** b
**11.** Shift the graph of $f$ one unit to the right.
**13.** Reflect $f$ in the $x$-axis and shift two units to the left.
**15.**

| $x$ | $-1$ | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|
| $f(x)$ | 8 | 5 | 4.25 | 4.063 | 4.016 |



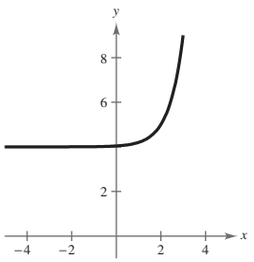
**17.**

| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $f(x)$ | $-0.377$ | $-1$ | $-2.65$ | $-7.023$ | $-18.61$ |



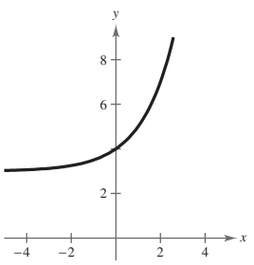
**19.**

| $x$ | $-1$ | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|
| $f(x)$ | 4.008 | 4.04 | 4.2 | 5 | 9 |



**21.**

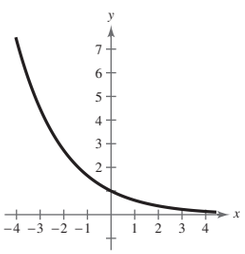
| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $f(x)$ | 3.25 | 3.5 | 4 | 5 | 7 |



**23.** $x = -4$ **25.** $x = \frac{22}{5}$ **27.** 2980.958 **29.** 0.183

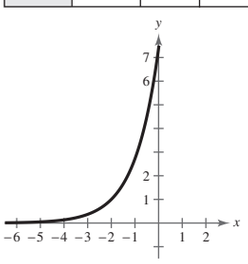
**31.**

| $x$ | $-2$ | $-1$ | 0 | 1 | 2 |
|---|---|---|---|---|---|
| $h(x)$ | 2.72 | 1.65 | 1 | 0.61 | 0.37 |



**33.**

| $x$ | $-3$ | $-2$ | $-1$ | 0 | 1 |
|---|---|---|---|---|---|
| $f(x)$ | 0.37 | 1 | 2.72 | 7.39 | 20.09 |



**35.**

| $n$ | 1 | 2 | 4 | 12 |
|---|---|---|---|---|
| $A$ | \$6569.98 | \$6635.43 | \$6669.46 | \$6692.64 |

| $n$ | 365 | Continuous |
|---|---|---|
| $A$ | \$6704.00 | \$6704.39 |

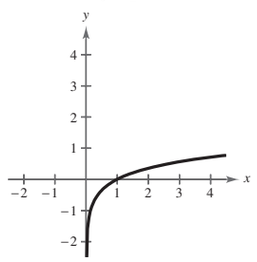
**37.** (a) 0.154 (b) 0.487 (c) 0.811

**39.** (a) \$1,069,047.14 (b) 7.9 years

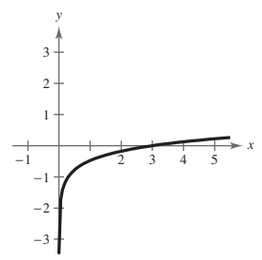
**41.** $\log_4 64 = 3$ **43.** $\ln 2.2255 \ldots = 0.8$

**45.** 3 **47.** $-3$ **49.** $x = 7$ **51.** $x = -5$

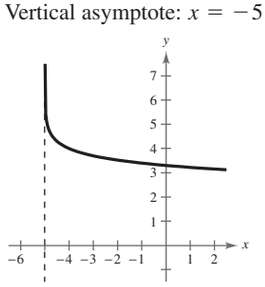
**53.** Domain: $(0, \infty)$
$x$-intercept: $(1, 0)$
Vertical asymptote: $x = 0$



**55.** Domain: $(0, \infty)$
$x$-intercept: $(3, 0)$
Vertical asymptote: $x = 0$

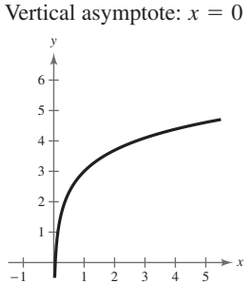


**57.** Domain: $(-5, \infty)$
$x$-intercept: $(9995, 0)$
Vertical asymptote: $x = -5$

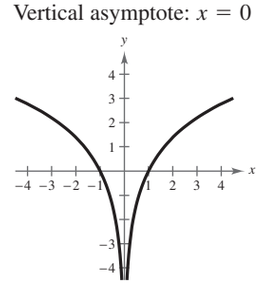


**59.** 3.118 **61.** $-12$ **63.** 2.034

**65.** Domain: $(0, \infty)$
$x$-intercept: $(e^{-3}, 0)$
Vertical asymptote: $x = 0$



**67.** Domain: $(-\infty, 0), (0, \infty)$
$x$-intercept: $(\pm 1, 0)$
Vertical asymptote: $x = 0$



**69.** 53.4 inches **71.** 1.585 **73.** $-2.322$

**75.** $\log 2 + 2 \log 3 \approx 1.255$ **77.** $2 \ln 2 + \ln 5 \approx 2.996$

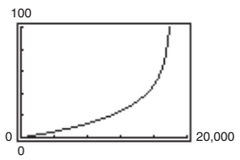
**79.** $1 + 2\log_5 x$ **81.** $1 + \log_3 2 - \frac{1}{3}\log_3 x$

**83.** $2\ln x + 2\ln y + \ln z$ **85.** $\ln(x + 3) - \ln x - \ln y$

**87.** $\log_2 5x$ **89.** $\ln \dfrac{x}{\sqrt[4]{y}}$ **91.** $\log_8 y^7\sqrt[3]{x + 4}$

**93.** $\ln \dfrac{\sqrt{2x - 1}}{(x + 1)^2}$

**95.** (a) $0 \le h < 18{,}000$

(b) 


Vertical asymptote: $h = 18{,}000$

(c) The plane is climbing at a slower rate, so the time required increases.

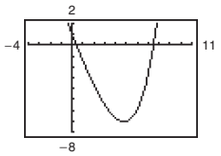
(d) 5.46 minutes

**97.** 3 **99.** $\ln 3 \approx 1.099$ **101.** 16

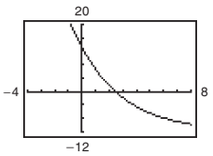
**103.** $e^4 \approx 54.598$ **105.** $\ln 12 \approx 2.485$ **107.** $x = 1, 3$

**109.** $\dfrac{\ln 22}{\ln 2} \approx 4.459$ **111.** $\dfrac{\ln 17}{\ln 5} \approx 1.760$

**113.** $\ln 2 \approx 0.693$, $\ln 5 \approx 1.609$

**115.** 


7.480; 0.392

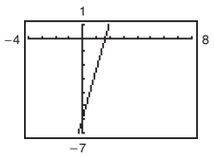
**117.** 


2.447

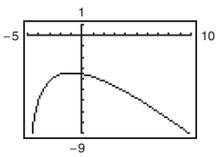
**119.** $\frac{1}{3}e^{8.2} \approx 1213.650$ **121.** $\frac{1}{4}e^{7.5} \approx 452.011$

**123.** $3e^2 \approx 22.167$ **125.** $e^4 - 1 \approx 53.598$

**127.** No solution **129.** 0.900

**131.** 


1.643

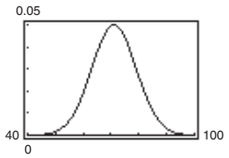
**133.** 


No solution

**135.** 15.2 years **137.** e **138.** b **139.** f

**140.** d **141.** a **142.** c **143.** $y = 2e^{0.1014x}$

**145.** 2008 **147.** (a) 13.8629% (b) \$11,486.98

**149.** (a) 


(b) 71

**151.** $10^{-3.5}$ watt per square centimeter

**153.** True by the inverse properties

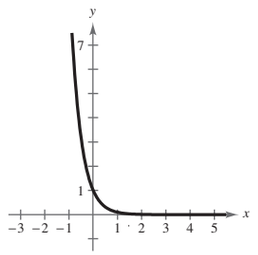
**155.** $b$ and $d$ are negative.
$a$ and $c$ are positive.
Answers will vary.

## Chapter Test *(page 275)*

**1.** 1123.690 **2.** 687.291 **3.** 0.497 **4.** 22.198

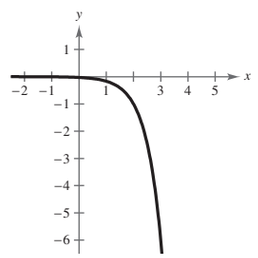
**5.**

| $x$ | $-1$ | $-\frac{1}{2}$ | 0 | $\frac{1}{2}$ | 1 |
|---|---|---|---|---|---|
| $f(x)$ | 10 | 3.162 | 1 | 0.316 | 0.1 |



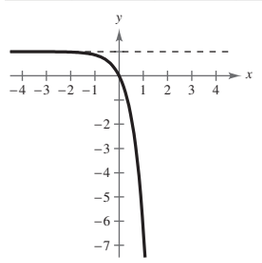

**6.**

| $x$ | $-1$ | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|
| $f(x)$ | $-0.005$ | $-0.028$ | $-0.167$ | $-1$ | $-6$ |




**7.**

| $x$ | $-1$ | $-\frac{1}{2}$ | 0 | $\frac{1}{2}$ | 1 |
|---|---|---|---|---|---|
| $f(x)$ | 0.865 | 0.632 | 0 | $-1.718$ | $-6.389$ |

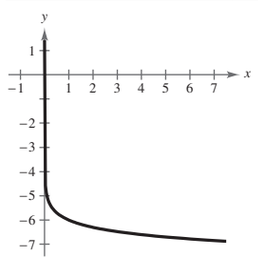



**8.** (a) $-0.89$ (b) 9.2

**9.**

| $x$ | $\frac{1}{2}$ | 1 | $\frac{3}{2}$ | 2 | 4 |
|---|---|---|---|---|---|
| $f(x)$ | $-5.699$ | $-6$ | $-6.176$ | $-6.301$ | $-6.602$ |

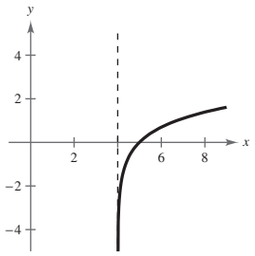
Vertical asymptote: $x = 0$



**10.**

| $x$ | 5 | 7 | 9 | 11 | 13 |
|---|---|---|---|---|---|
| $f(x)$ | 0 | 1.099 | 1.609 | 1.946 | 2.197 |

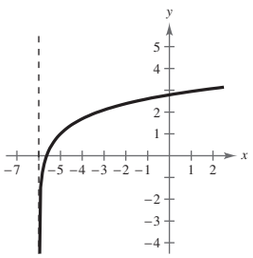
Vertical asymptote: $x = 4$



**11.**

| $x$ | $-5$ | $-3$ | $-1$ | 0 | 1 |
|---|---|---|---|---|---|
| $f(x)$ | 1 | 2.099 | 2.609 | 2.792 | 2.946 |

Vertical asymptote: $x = -6$



**12.** 1.945 **13.** 0.115 **14.** 1.328

**15.** $\log_2 3 + 4 \log_2 |a|$ **16.** $\ln 5 + \frac{1}{2}\ln x - \ln 6$

**17.** $(\log 7 + 2 \log x) - (\log y + 3 \log z)$

**18.** $\log_3 13y$ **19.** $\ln \dfrac{x^4}{y^4}$ **20.** $\ln \dfrac{x^2(x-5)}{y^3}$

**21.** $x = -2$ **22.** $x = \dfrac{\ln 44}{-5} \approx -0.757$

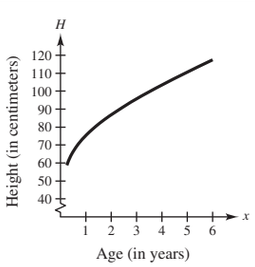
**23.** $\dfrac{\ln 197}{4} \approx 1.321$ **24.** $e^{1/2} \approx 1.649$

**25.** $e^{-11/4} \approx 0.0639$ **26.** $\frac{800}{501} \approx 1.597$

**27.** $y = 2745e^{0.1570x}$ **28.** 55%

**29.** (a)

| $x$ | $\frac{1}{4}$ | 1 | 2 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $H$ | 58.720 | 75.332 | 86.828 | 103.43 | 110.59 | 117.38 |

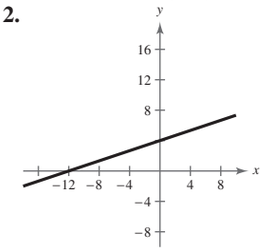



(b) 103 centimeters; 103.43 centimeters

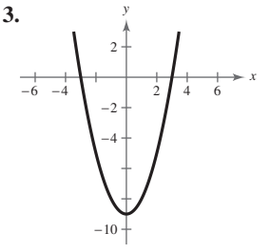
## Cumulative Test for Chapters 1–3 *(page 276)*

**1.** (a) Midpoint: $\left(1, \frac{3}{2}\right)$; Distance: $\sqrt{41}$

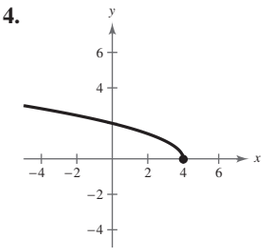
**2.**



**3.**



**4.**



**5.** $y = 2x + 2$

**6.** For some values of $x$ there correspond two values of $y$.

**7.** (a) $\dfrac{3}{2}$ (b) Division by 0 is undefined. (c) $\dfrac{s+2}{s}$

**8.** (a) Vertical shrink by $\frac{1}{2}$
(b) Vertical shift of two units upward
(c) Horizontal shift of two units to the left

**9.** (a) $5x - 2$ (b) $-3x - 4$ (c) $4x^2 - 11x - 3$
(d) $\dfrac{x-3}{4x+1}$; Domain: all real numbers $x$ except $x = -\dfrac{1}{4}$

**10.** (a) $\sqrt{x-1} + x^2 + 1$ (b) $\sqrt{x-1} - x^2 - 1$
(c) $x^2\sqrt{x-1} + \sqrt{x-1}$
(d) $\dfrac{\sqrt{x-1}}{x^2+1}$; Domain: all real numbers $x$ such that $x \geq 1$

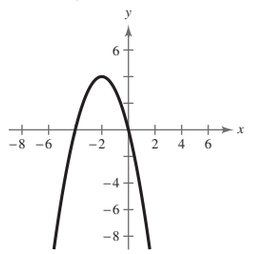
**11.** (a) $2x + 12$ (b) $\sqrt{2x^2 + 6}$
Domain of $f \circ g$: all real numbers $x$ such that $x \geq -6$
Domain of $g \circ f$: all real numbers

**12.** (a) $|x| - 2$ (b) $|x - 2|$
Domain of $f \circ g$ and $g \circ f$: all real numbers

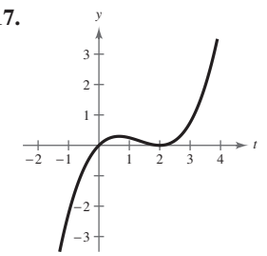
**13.** Yes; $h^{-1}(x) = \frac{1}{5}(x + 2)$ **14.** 2438.65 kilowatts

**15.** $y = -\frac{3}{4}(x + 8)^2 + 5$

**16.**

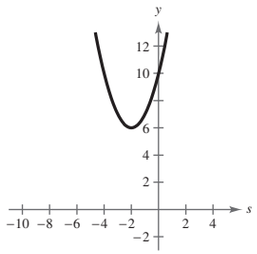


**17.**



CHAPTER 3

**18.**




**19.** $-2, \pm 2i$; $(x + 2)(x + 2i)(x - 2i)$

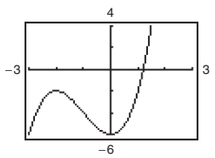
**20.** $-7, 0, 3$; $x(x)(x - 3)(x + 7)$

**21.** $4, -\frac{1}{2}, 1 \pm 3i$; $(x - 4)(2x + 1)(x - 1 + 3i)(x - 1 - 3i)$

**22.** $3x - 2 - \dfrac{3x - 2}{2x^2 + 1}$

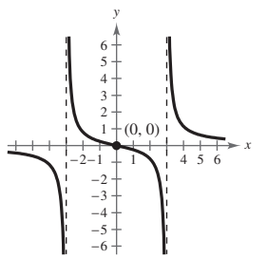
**23.** $2x^3 - x^2 + 2x - 10 + \dfrac{25}{x + 2}$

**24.**

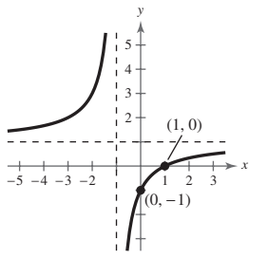



Interval: $[1, 2]$; 1.20

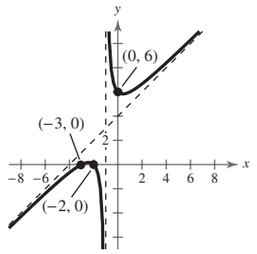
**25.** Intercept: $(0, 0)$
Vertical asymptotes: $x = \pm 3$
Horizontal asymptote: $y = 0$



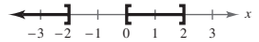

**26.** $y$-intercept: $(0, -1)$
$x$-intercept: $(1, 0)$
Horizontal asymptote: $y = 1$
Vertical asymptote: $x = -1$



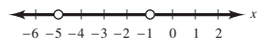

**27.** $y$-intercept: $(0, 6)$
$x$-intercepts: $(-2, 0), (-3, 0)$
Slant asymptote: $y = x + 4$
Vertical asymptote: $x = -1$



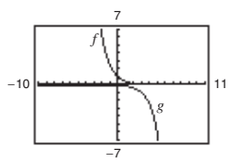

**28.** $x \le -2$ or $0 \le x \le 2$



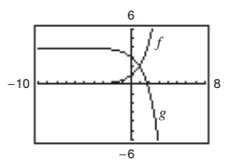

**29.** All real numbers $x$ such that $x < -5$ or $x > -1$




**30.** Reflect $f$ in the $x$-axis and $y$-axis, and shift three units to the right.




**31.** Reflect $f$ in the $x$-axis, and shift four units upward.




**32.** 1.991 **33.** $-0.067$ **34.** 1.717 **35.** 0.281

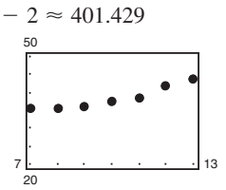
**36.** $\ln(x + 4) + \ln(x - 4) - 4 \ln x, x > 4$

**37.** $\ln \dfrac{x^2}{\sqrt{x + 5}}, x > 0$ **38.** $x = \dfrac{\ln 12}{2} \approx 1.242$

**39.** $\ln 3 \approx 1.099$ or $3 \ln 2 \approx 2.079$

**40.** $e^6 - 2 \approx 401.429$

**41.** (a)




(b) $S = 0.274t^2 - 4.08t + 50.6$