To find how fast this measure was changing in 1988 (8 years since 1980), evaluate the derivative for $t = 8$.

$$P'(8) = \frac{8^3 + 72\cdot 8}{(8^2 + 36)^{\frac{3}{2}}} = \frac{512 + 576}{(100)^{\frac{3}{2}}} = \frac{1088}{1000} = 1.088$$

In 1988, the air pollution measure was increasing at a rate of 1.088 units per year.

11.2 EXERCISES

PRACTICE

Find the derivative for each function given in Exercises 1–40 and simplify your answer.

1. $f(x) = (2x-5)^4$
2. $f(x) = (7x+2)^3$
3. $f(x) = (1-4x)^3$
4. $f(x) = (3-5x)^5$
5. $g(x) = (x^2+4)^{-2}$
6. $g(x) = (x^2-8)^{-1}$
7. $h(t) = (2t^2+3t)^{-3}$
8. $h(t) = (4t^2-t)^{-2}$
9. $y = (2x^2+5x-7)^2$
10. $y = (4x^2+9x-3)^3$
11. $y = (x^3+1)^{\frac{1}{2}}$
12. $y = (2x^3-5)^{\frac{1}{3}}$
13. $y = \sqrt[3]{4x^2+1}$
14. $y = \sqrt{7+4x^2}$
15. $y = \sqrt[4]{1-2x^3}$
16. $y = \sqrt[3]{5x^3-4}$
17. $f(t) = 5t(t^3+3)^4$
18. $f(x) = -7x(x^4-2)^3$
19. $f(x) = 2x^3(x^2-8)^3$
20. $f(t) = t(4-3t^2)^2$
21. $g(x) = \dfrac{1}{\sqrt{x^2-6}}$
22. $g(x) = \dfrac{5}{\sqrt{x^3+4}}$
23. $g(t) = \dfrac{t}{\sqrt{t^2+8}}$
24. $g(x) = \dfrac{x^2}{\sqrt[3]{x^2+6}}$
25. $h(x) = \dfrac{\sqrt[3]{2x+3}}{x^2}$
26. $h(x) = \dfrac{\sqrt{5x-2}}{x^3}$
27. $y = (2x+1)\sqrt{3x-4}$
28. $y = (4x+3)\sqrt{x^2+3}$
29. $y = (3x-2)^2(5x+1)^{-2}$
30. $y = (2x+7)^3(3x+1)^{-4}$
31. $f(t) = \dfrac{5t+1}{(t-1)^{\frac{2}{3}}}$
32. $f(t) = \dfrac{t^2+t+1}{\sqrt{t^4-1}}$
33. $g(t) = \left(\dfrac{2t+5}{t+1}\right)^3$
34. $g(t) = \left(\dfrac{5t+4}{t^2-3}\right)^4$
35. $y = \left(\dfrac{x+3}{4-2x}\right)^{\frac{1}{2}}$
36. $y = \left(\dfrac{x^2}{4x+1}\right)^{\frac{1}{3}}$
37. $y = \sqrt{\dfrac{x+2}{3x-1}}$
38. $y = \sqrt{\dfrac{x^2+6}{x^3}}$

39. $y=\dfrac{x^2+x}{\sqrt{7-2x}}$

40. $y=\dfrac{\left(x^2+2\right)^2}{\sqrt{5x-3}}$

In Exercises 41–50, find $\dfrac{dy}{du}$, $\dfrac{du}{dx}$, and $\dfrac{dy}{dx}$. Then evaluate $\dfrac{dy}{dx}$ for the given value of *x*.

41. $y=u^2+2,\ u=3x^2+1;\ x=-1$

42. $y=\sqrt{u+4},\ u=x^2+x-1;\ x=2$

43. $y=\dfrac{1}{u^2},\ u=2x^3-3x+3;\ x=1$

44. $y=\sqrt[3]{u},\ u=2x^3-4x;\ x=2$

45. $y=u^{\frac{3}{2}},\ u=x^3-2x^2;\ x=3$

46. $y=\dfrac{1}{u^3},\ u=3x+1;\ x=1$

47. $y=\sqrt[3]{u},\ u=7x^2+1;\ x=-3$

48. $y=u^2+3u+4,\ u=x^3-5x-2;\ x=-2$

49. $y=2u^2-5u+3,\ u=5x+6;\ x=2$

50. $y=2u^3-3u+1,\ u=x^3+8;\ x=1$

In Exercises 51–56, use the given information to find $h'(2)$: $f(2)=3$, $f'(2)=-1$, $g(2)=4$, $g'(2)=10$, $g(3)=8$, and $g'(3)=7$.

51. $h(x)=\left(f(x)+1\right)^3$

52. $h(x)=\left(\dfrac{f(x)}{g(x)}\right)^2$

53. $h(x)=g\left(f(x)\right)$

54. $h(x)=\sqrt{f(x)+g(x)}$

55. $h(x)=\left(g(x)\right)^3$

56. $h(x)=\left(2+3\cdot f(x)\right)\left(g(x)\right)^3$

Determine the equation of the tangent line for $f(x)$ at the *x*-value indicated in Exercises 57–60.

57. $f(x)=(3x-1)^3;\ x=1$

58. $f(x)=\left(\dfrac{x^2+1}{x+1}\right)^3;\ x=2$

59. $f(x)=\left(3x^2+2x+8\right)^{\frac{1}{2}};\ x=4$

60. $f(x)=\sqrt{10x+1};\ x=8$

APPLICATIONS

61. Marginal revenue: A dealer of microwave ovens estimates that he can sell *x* ovens per month when the demand function (price) is $p=D(x)=20\sqrt{280-4x}$ dollars.

- **a.** Find the revenue function *R*(*x*).
- **b.** Find *R*(21).
- **c.** Find the marginal revenue function *R′*(*x*).
- **d.** Find *R′*(21).

62. **Marginal revenue:** The demand function (price) for a particular product is given by $D(x)=8\sqrt{25-5x+0.25x^2}$ dollars, where x is the number of units (in hundreds) sold.
    a. Find the revenue function $R(x)$.
    b. Find $R(2)$.
    c. Find the marginal revenue function $R'(x)$.
    d. Find $R'(2)$.

63. **Population growth:** It is estimated that t years from now the population of Castle City will be $P(t)=10(40+2t)^2-1600t$.
    a. What will the population be in 8 years?
    b. Find the rate of change in population in 8 years.

64. **Air pollution:** It is estimated that t years from now the level of air pollution in Bohrberg will be $P(t)=\dfrac{0.6\sqrt{8t^2+11t+60}}{(t+1)^2}$ parts per million. Find the rate of change in the pollution level in 7 years.

65. **Pollution:** After a sewage spill, the level of pollution in San Remo Bay is estimated by $P(t)=\dfrac{200t^2}{\sqrt{t^2+11}}$, where t is the time in days since the spill occurred. How fast is the level changing after 5 days? Round to the nearest whole number.

66. **Bacterial growth:** It is estimated that in t hours the population of bacteria in a culture will be $P(t)=\dfrac{8000}{\sqrt{8-0.5t}}$.
    a. What will be the population in 8 hours?
    b. Find the rate of change in the population in 8 hours.

67. **Rate of change of cost:** A manufacturer of vacuum cleaners estimates that the total cost of producing x vacuum cleaners is given by $C(x)=-0.5x^2+56x+800$ dollars. Records show that after t hours on a typical day, the number of units produced is given by $x=5\sqrt{t^2+5t}$. Find the rate of change of total cost with respect to time at the end of
    a. 4 hours.
    b. 5 hours.

68. **Rate of change of profit:** A manufacturer has determined that the weekly profit from the sale of x items is given by $P(x)=-x^2+280x-4000$ dollars. It is estimated that after t days in any week, $x=0.5t^2+5t$ items will have been produced. Find the rate of change of profit with respect to time at the end of
    a. 4 days.
    b. 5 days.

69. Pollution: Studies show that the average level of certain pollutants in the air is given by $L = 1 + 0.2x + 0.001x^2$ parts per million when the population is x thousand people. It is estimated that t years from now the population will be $x = \frac{200}{\sqrt{7 - 0.5t}}$ in thousands. Find the rate of change of the level of pollutants after

a. 6 years.
b. 12 years.

70. Security costs: The annual cost for campus security is given by $C(x) = 3x^2 - 32x + 16$ in thousands of dollars. It is estimated that the enrollment in t years will be $x = 16 + 0.5t + 0.02t^2$ in thousands. Find the rate of change in security costs after

a. 3 years.
b. 4 years.

71. Baseball attendance: The average home attendance per week at a Class AA baseball park varied according to the formula $N(t) = (3 + 0.2t)^{\frac{1}{2}}$, where t is the number of weeks into the season ($0 \le t \le 12$) and N is in thousands of persons.

a. What was the attendance during the first week into the season?
b. Determine the number $N'(5)$.
c. Interpret the meaning of $N'(5)$.

72. Weekly attendance: The semester after its student team won an intercollegiate Duplicate Bridge championship, the average weekly attendance at the University Union Building varied according to the formula $B(t) = 100 - 50\left(1 - \frac{t}{16}\right)^{\frac{3}{2}}$, where t is the number of weeks after the championship ($0 \le t \le 16$) and B is the number of persons.

a. What is $B(0)$ and what does it represent?
b. Determine $B'(t)$.
c. What is $B'(7)$? Interpret the meaning of this number.

73. Class registration: The annual registration in university calculus classes varies according to the formula $P(t) = 1 + \left(1 - \frac{t}{30}\right)^{2.5}$, where t is the number of years since 1995 and P is in millions of students.

a. Determine $P(0)$ and explain its meaning.
b. Determine $P'(t)$.
c. Calculate $P'(10)$ and explain its meaning.

74. Travel: The number of passengers traveling from California to Central America and back on cruise ships is given by $C(t) = (10t + 50)^{1.5}$, where t is the number of years since 1990 and C is passenger count in thousands.

a. When did the number of passengers hit 1,000,000 people ($C = 1000$)?
b. Compute $C'(t)$.
c. Calculate $C'(12)$ and intrepret its meaning.