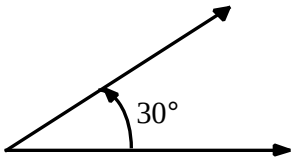
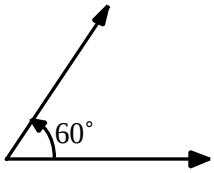
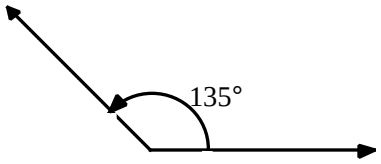
Chapter 7

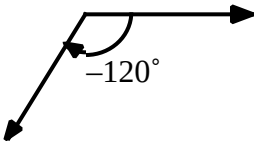
Trigonometric Functions

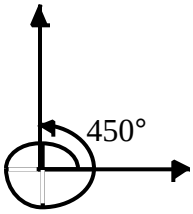
7.1 Angles and Their Measure

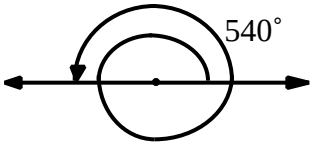
1. 

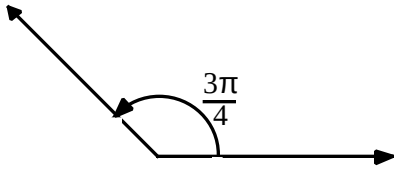
2. 

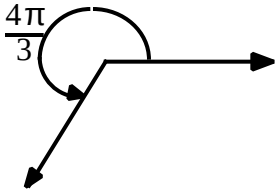
3. 

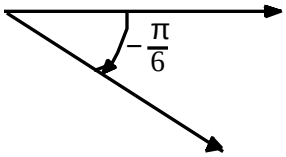
4. 

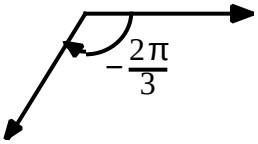
5. 

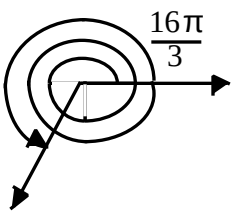
6. 

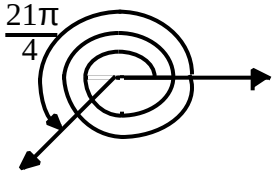
7. 

8. 

9. 

10. 

11. 

12. 

13. $30° = 30\ \frac{\pi}{180}$ radian $= \frac{\pi}{6}$ radians

14. $120° = 120\ \frac{\pi}{180}$ radian $= \frac{2\pi}{3}$ radians

15. $240° = 240\ \frac{\pi}{180}$ radian $= \frac{4\pi}{3}$ radians

16. $330° = 330\ \frac{\pi}{180}$ radian $= \frac{11\pi}{6}$ radians

17. $-60° = -60\ \frac{\pi}{180}$ radian $= -\frac{\pi}{3}$ radians

18. $-30° = -30\ \frac{\pi}{180}$ radian $= -\frac{\pi}{6}$ radians

19. $180° = 180\ \frac{\pi}{180}$ radian $= \pi$ radians

20. $270° = 270\ \frac{\pi}{180}$ radian $= \frac{3\pi}{2}$ radians

21. $-135° = -135\ \frac{\pi}{180}$ radian $= -\frac{3\pi}{4}$ radians

22. $-225° = -225\ \frac{\pi}{180}$ radian $= -\frac{5\pi}{4}$ radians

23. $-90° = -90\ \frac{\pi}{180}$ radian $= -\frac{\pi}{2}$ radians

24. $-180° = -180\ \frac{\pi}{180}$ radian $= -\pi$ radians

25. $\frac{\pi}{3} = \frac{\pi}{3}\ \frac{180}{\pi}$ degrees $= 60°$

26. $\frac{5\pi}{6} = \frac{5\pi}{6}\ \frac{180}{\pi}$ degrees $= 150°$

27. $-\frac{5\pi}{4} = -\frac{5\pi}{4}\ \frac{180}{\pi}$ degrees $= -225°$

28. $-\frac{2\pi}{3} = -\frac{2\pi}{3}\ \frac{180}{\pi}$ degrees $= -120°$

29. $\frac{\pi}{2} = \frac{\pi}{2}\ \frac{180}{\pi}$ degrees $= 90°$

30. $4\pi = 4\pi\ \frac{180}{\pi}$ degrees $= 720°$

31. $\frac{\pi}{12} = \frac{\pi}{12}\ \frac{180}{\pi}$ degrees $= 15°$

32. $\frac{5\pi}{12} = \frac{5\pi}{12}\ \frac{180}{\pi}$ degrees $= 75°$

33. $-\frac{\pi}{2} = -\frac{\pi}{2}\ \frac{180}{\pi}$ degrees $= -90°$

34. $-\pi = -\pi\ \frac{180}{\pi}$ degrees $= -180°$

35. $-\frac{\pi}{6} = -\frac{\pi}{6}\ \frac{180}{\pi}$ degrees $= -30°$

36. $-\frac{3\pi}{4} = -\frac{3\pi}{4}\ \frac{180}{\pi}$ degrees $= -135°$

37. $r = 10$ meters; $\theta = \frac{1}{2}$ radian; $s = r\theta = 10\ \frac{1}{2} = 5$ meters

38. $r = 6$ feet; $\theta = 2$ radian; $s = r\theta = 6\ \ 2 = 12$ feet

39. $\theta = \frac{1}{3}$ radian; $s = 2$ feet; $s = r\theta$ or $r = \frac{s}{\theta} = \frac{2}{\frac{1}{3}} = 6$ feet

40. $\theta = \frac{1}{4}$ radian; $s = 6$ cm; $s = r\theta$ or $r = \frac{s}{\theta} = \frac{6}{\frac{1}{4}} = 24$ cm

41. $r = 5$ miles; $s = 3$ miles; $s = r\theta$ or $\theta = \frac{s}{r} = \frac{3}{5} = 0.6$ radians

42. $r = 6$ meters; $s = 8$ meters; $s = r\theta$ or $\theta = \frac{s}{r} = \frac{8}{6} = \frac{4}{3}$ radians

43. $r = 2$ inches; $\theta = 30°$; Convert to radians: $30° \cdot \frac{\pi}{180} = \frac{\pi}{6}$ radians

$s = r\theta = 2\ \frac{\pi}{6} = \frac{\pi}{3}$ inches

44. $r = 3$ meters; $\theta = 120°$; Convert to radians: $120° \cdot \frac{\pi}{180} = \frac{2\pi}{3}$ radians

$s = r\theta = 3\ \frac{2\pi}{3} = 2\pi$ meters

45. $r = 10$ meters; $\theta = \frac{1}{2}$ radian

$$A = \frac{1}{2}r^2\theta = \frac{1}{2}(10)^2\left(\frac{1}{2}\right) = \frac{100}{4} = 25 \text{ square meters}$$

46. $r = 6$ feet; $\theta = 2$ radians

$$A = \frac{1}{2}r^2\theta = \frac{1}{2}(6)^2(2) = 36 \text{ square feet}$$

47. $\theta = \frac{1}{3}$ radian; $A = 2$ square feet

$$A = \frac{1}{2}r^2\theta \rightarrow 2 = \frac{1}{2}r^2\left(\frac{1}{3}\right) = \frac{1}{6}r^2$$

$$2 = \frac{1}{6}r^2 \rightarrow 12 = r^2 \rightarrow r = \sqrt{12} \approx 3.464 \text{ feet}$$

48. $\theta = \frac{1}{4}$ radian; $A = 6$ square centimeters

$$A = \frac{1}{2}r^2\theta \rightarrow 6 = \frac{1}{2}r^2\left(\frac{1}{4}\right) = \frac{1}{4}r^2$$

$$6 = \frac{1}{8}r^2 \rightarrow 48 = r^2 \rightarrow r = \sqrt{48} \approx 6.928 \text{ cm}$$

49. $r = 5$ miles; $A = 3$ square miles

$$A = \frac{1}{2}r^2\theta \rightarrow 3 = \frac{1}{2}(5)^2\theta = \frac{25}{2}\theta$$

$$3 = \frac{25}{2}\theta \rightarrow \frac{6}{25} = \theta \rightarrow \theta \approx 0.24 \text{ radians}$$

50. $r = 6$ meters; $A = 8$ square meters

$$A = \frac{1}{2}r^2\theta \rightarrow 8 = \frac{1}{2}(6)^2\theta = \frac{36}{2}\theta = 18\theta$$

$$3 = 18\theta \rightarrow \frac{3}{18} = \theta \rightarrow \theta \approx 0.167 \text{ radians}$$

51. $r = 2$ inches; $\theta = 30^\circ$; Convert to radians: $30^\circ = 30\ \frac{\pi}{180} = \frac{\pi}{6}$ radians

$$A = \frac{1}{2}r^2\theta = \frac{1}{2}(2)^2\left(\frac{\pi}{6}\right) = \frac{1}{2}\ 4\left(\frac{\pi}{6}\right) = \frac{\pi}{3} \approx 1.047 \text{ square inches}$$

52. $r = 3$ meters; $\theta = 120^\circ$; Convert to radians: $120^\circ = 120\ \frac{\pi}{180} = \frac{2\pi}{3}$ radians

$$A = \frac{1}{2}r^2\theta = \frac{1}{2}(3)^2\left(\frac{2\pi}{3}\right) = \frac{1}{2}\ 9\left(\frac{2\pi}{3}\right) = 3\pi \approx 9.425 \text{ square meters}$$

53. $r = 2$ feet; $\theta = \frac{\pi}{3}$ radians

$s = r\theta = 2\left(\frac{\pi}{3}\right) = \frac{2\pi}{3} \approx 2.094$ feet

$A = \frac{1}{2}r^2\theta = \frac{1}{2}(2)^2\left(\frac{\pi}{3}\right) = \frac{1}{2}(4)\left(\frac{\pi}{3}\right) = \frac{2\pi}{3} \approx 2.094$ square feet

54. $r = 4$ meters; $\theta = \frac{\pi}{6}$ radians

$s = r\theta = 4\left(\frac{\pi}{6}\right) = \frac{2\pi}{3} \approx 2.094$ meters

$A = \frac{1}{2}r^2\theta = \frac{1}{2}(4)^2\left(\frac{\pi}{6}\right) = \frac{1}{2}(16)\left(\frac{\pi}{6}\right) = \frac{4\pi}{3} \approx 4.189$ square meters

55. $r = 12$ yards; $\theta = 70^\circ$; Convert to radians: $70\left(\frac{\pi}{180}\right) = \frac{7\pi}{18}$ radians

$s = r\theta = 12\left(\frac{7\pi}{18}\right) \approx 14.661$ yards

$A = \frac{1}{2}r^2\theta = \frac{1}{2}(12)^2\left(\frac{7\pi}{18}\right) = \frac{1}{2}(144)\left(\frac{7\pi}{18}\right) = 72\left(\frac{7\pi}{18}\right) \approx 87.965$ square yards

56. $r = 9$ cm; $\theta = 50^\circ$; Convert to radians: $50\left(\frac{\pi}{180}\right) = \frac{5\pi}{18}$ radians

$s = r\theta = 9\left(\frac{5\pi}{18}\right) \approx 7.854$ cm

$A = \frac{1}{2}r^2\theta = \frac{1}{2}(9)^2\left(\frac{5\pi}{18}\right) = \frac{1}{2}(81)\left(\frac{5\pi}{18}\right) \approx 35.343$ square cm

57. $17^\circ = 17\left(\frac{\pi}{180}\right)$ radian $= \frac{17\pi}{180}$ radians ≈ 0.30 radians

58. $73^\circ = 73\left(\frac{\pi}{180}\right)$ radian $= \frac{73\pi}{180}$ radians ≈ 1.27 radians

59. $-40^\circ = -40\left(\frac{\pi}{180}\right)$ radian $= -\frac{2\pi}{9}$ radians ≈ -0.70 radians

60. $-51^\circ = -51\left(\frac{\pi}{180}\right)$ radian $= -\frac{17\pi}{60}$ radians ≈ -0.89 radians

61. $125^\circ = 125\left(\frac{\pi}{180}\right)$ radian $= \frac{25\pi}{36}$ radians ≈ 2.18 radians

62. $350^\circ = 350\ \frac{\pi}{180}$ radian $= \frac{35\pi}{18}$ radians ≈ 6.11 radians

63. 3.14 radians $= 3.14\ \frac{180}{\pi}$ degrees $\approx 179.91^\circ$

64. 0.75 radians $= 0.75\ \frac{180}{\pi}$ degrees $\approx 42.97^\circ$

65. 2 radians $= 2\ \frac{180}{\pi}$ degrees $\approx 114.59^\circ$

66. 3 radians $= 3\ \frac{180}{\pi}$ degrees $\approx 171.89^\circ$

67. 6.32 radians $= 6.32\ \frac{180}{\pi}$ degrees $\approx 362.11^\circ$

68. $\sqrt{2}$ radians $= \sqrt{2}\ \frac{180}{\pi}$ degrees $\approx 81.03^\circ$

69. $40^\circ 10' 25'' = \left(40 + 10\ \frac{1}{60} + 25\ \frac{1}{60}\ \frac{1}{60}\right)^\circ \approx (40 + 0.1667 + 0.00694)^\circ \approx 40.17^\circ$

70. $61^\circ 42' 21'' = \left(61 + 42\ \frac{1}{60} + 21\ \frac{1}{60}\ \frac{1}{60}\right)^\circ \approx (61 + 0.7000 + 0.00583)^\circ \approx 61.71^\circ$

71. $1^\circ 2' 3'' = \left(1 + 2\ \frac{1}{60} + 3\ \frac{1}{60}\ \frac{1}{60}\right)^\circ \approx (1 + 0.0333 + 0.00083)^\circ \approx 1.03^\circ$

72. $73^\circ 40' 40'' = \left(73 + 40\ \frac{1}{60} + 40\ \frac{1}{60}\ \frac{1}{60}\right)^\circ \approx (73 + 0.6667 + 0.0111)^\circ \approx 73.68^\circ$

73. $9^\circ 9' 9'' = \left(9 + 9\ \frac{1}{60} + 9\ \frac{1}{60}\ \frac{1}{60}\right)^\circ = (9 + 0.15 + 0.0025)^\circ \approx 9.15^\circ$

74. $98^\circ 22' 45'' = \left(98 + 22\ \frac{1}{60} + 45\ \frac{1}{60}\ \frac{1}{60}\right)^\circ \approx (98 + 0.3667 + 0.0125)^\circ \approx 98.38^\circ$

75. $40.32^\circ = ?$

$0.32^\circ = 0.32(1^\circ) = 0.32(60') = 19.2'$

$0.2' = 0.2(1') = 0.2(60'') = 12''$

$40.32^\circ = 40^\circ + 0.32^\circ = 40^\circ + 19.2' = 40^\circ + 19' + 0.2' = 40^\circ + 19' + 12'' = 40^\circ 19' 12''$

76. $61.24^\circ = ?$

$0.24^\circ = 0.24(1^\circ) = 0.24(60') = 14.4'$
$0.4' = 0.4(1') = 0.4(60'') = 24''$
$61.24^\circ = 61^\circ + 0.24^\circ = 61^\circ + 14.4' = 61^\circ + 14' + 0.4' = 61^\circ + 14' + 24'' = 61^\circ 14' 24''$

77. $18.255^\circ = ?$
$0.255^\circ = 0.255(1^\circ) = 0.255(60') = 15.3'$
$0.3' = 0.3(1') = 0.3(60'') = 18''$
$18.255^\circ = 18^\circ + 0.255^\circ = 18^\circ + 15.3' = 18^\circ + 15' + 0.3' = 18^\circ + 15' + 18'' = 18^\circ 15' 18''$

78. $29.411^\circ = ?$
$0.411^\circ = 0.411(1^\circ) = 0.411(60') = 24.66'$
$0.66' = 0.66(1') = 0.66(60'') = 39.6''$
$29.411^\circ = 29^\circ + 0.411^\circ = 29^\circ + 24.66' = 29^\circ + 24' + 0.66' = 29^\circ + 24' + 39.6'' = 29^\circ 24' 40''$

79. $19.99^\circ = ?$
$0.99^\circ = 0.99(1^\circ) = 0.99(60') = 59.4'$
$0.4' = 0.4(1') = 0.4(60'') = 24''$
$19.99^\circ = 19^\circ + 0.99^\circ = 19^\circ + 59.4' = 19^\circ + 59' + 0.4' = 19^\circ + 59' + 24'' = 19^\circ 59' 24''$

80. $44.01^\circ = ?$
$0.01^\circ = 0.01(1^\circ) = 0.01(60') = 0.6'$
$0.6' = 0.6(1') = 0.6(60'') = 36''$
$44.01^\circ = 44^\circ + 0.01^\circ = 44^\circ + 0.6' = 44^\circ + 0' + 0.6' = 44^\circ + 0' + 36'' = 44^\circ 0' 36''$

81. $r = 6$ inches; $\theta = 90^\circ = \frac{\pi}{2}$ radians
$s = r\theta = 6\left(\frac{\pi}{2}\right) = 3\pi$ inches ≈ 9.42 inches
$r = 6$ inches; $\theta = \frac{25}{60}$ rev $= \frac{5}{12}(360^\circ) = 150^\circ = \frac{5\pi}{6}$ radians
$s = r\theta = 6\left(\frac{5\pi}{6}\right) = 5\pi$ inches ≈ 15.71 inches

82. $r = 40$ inches; $\theta = 20^\circ = \frac{\pi}{9}$ radians
$s = r\theta = 40\left(\frac{\pi}{9}\right) = \frac{40\pi}{9}$ inches ≈ 13.96 inches

83. $r = 4$ m; $\theta = 45^\circ$; Convert to radians: $45^\circ(45)\frac{\pi}{180} = \frac{\pi}{4}$ radians
$A = \frac{1}{2}r^2\theta = \frac{1}{2}(4)^2\left(\frac{\pi}{4}\right) = \frac{1}{2}(16)\left(\frac{\pi}{4}\right) = 2\pi \approx 6.283$ square meters

84. $r = 3$ cm; $\theta = 60^\circ$; Convert to radians: $60^\circ(60)\frac{\pi}{180} = \frac{\pi}{3}$ radians

$$A = \frac{1}{2} r^2\theta = \frac{1}{2}(3)^2\left(\frac{\pi}{3}\right) = \frac{1}{2}\ 9\left(\frac{\pi}{3}\right) = \frac{3\pi}{2} \approx 4.712 \text{ square cm}$$

85. $s = 30$ feet; $\theta = 135^\circ$; Convert to radians: $135^\circ = 135\ \frac{\pi}{180} = \frac{3\pi}{4}$ radians

$$s = r\theta \rightarrow 30 = r\ \frac{3\pi}{4} \rightarrow r = \frac{40}{p}$$

$$A = \frac{1}{2} r^2\theta = \frac{1}{2}\left(\frac{40}{\pi}\right)^2\left(\frac{3\pi}{4}\right) = \frac{1}{2}\ \frac{1600}{\pi^2}\left(\frac{\pi}{3}\right) = \frac{800}{3\pi} \approx 84.883 \text{ square feet}$$

86. $r = 50$ yards; $A = 100$ square yards

$$A = \frac{1}{2} r^2\theta \rightarrow 100 = \frac{1}{2}(50)^2\theta = \frac{2500}{2}\theta = 1250\ \theta$$

$$100 = 1250\ \theta \rightarrow \frac{100}{1250} = \theta \rightarrow \theta \approx 0.08 \text{ radians}$$

87. $r = 5$ cm.; $t = 20$ seconds; $\theta = \frac{1}{3}$ radian

$$\omega = \frac{\theta}{t} = \frac{\left(\frac{1}{3}\right)}{20} = \frac{1}{3}\ \frac{1}{20} = \frac{1}{60} \text{ radian/sec}$$

$$v = \frac{s}{t} = \frac{r\theta}{t} = \frac{5\left(\frac{1}{3}\right)}{20} = \frac{5}{3}\ \frac{1}{20} = \frac{1}{12} \text{ cm/sec}$$

88. $r = 2$ meters; $t = 20$ seconds; $s = 5$ meters

$$\omega = \frac{\theta}{t} = \frac{\left(\frac{s}{r}\right)}{t} = \frac{\left(\frac{5}{2}\right)}{20} = \frac{5}{2}\ \frac{1}{20} = \frac{1}{8} \text{ radian/sec}$$

$$v = \frac{s}{t} = \frac{5}{20} = \frac{1}{4} \text{ m/sec}$$

89. $d = 26$ inches; $r = 13$ inches; $v = 35$ mi / hr

$$v = \frac{35 \text{ mi}}{\text{hr}}\ \frac{5280 \text{ ft}}{\text{mi}}\ \frac{12 \text{ in}}{\text{ft}}\ \frac{1 \text{ hr}}{60 \text{ min}} = 36960 \text{ in / min}$$

$$\omega = \frac{v}{r} = \frac{36960 \text{ in / min}}{13 \text{ in}} = 2843.08 \text{ radians / min}$$

$$= \frac{2843.08 \text{ rad}}{\text{min}}\ \frac{1 \text{ rev}}{2\pi \text{ rad}} = 452.5 \text{ rev / min}$$

90. $r = 15$ inches; $\omega = 3$ rev / sec $= 6\pi$ rad / sec

$v = r\omega = 15 \ 6\pi \text{ in / sec} = 90\pi \text{ in / sec}$

$v = 90\pi \frac{\text{in}}{\text{sec}} \ \frac{1}{12}\frac{\text{ft}}{\text{in}} \ \frac{1}{5280}\frac{\text{mi}}{\text{ft}} \ \frac{3600}{1}\frac{\text{sec}}{\text{hr}} \approx 16.06 \text{ mi / hr}$

91. $r = 3960$ miles; $\theta = 35^\circ 9' 29'' 57'' = 5^\circ 12' = 5.2^\circ = 5.2 \ \frac{\pi}{180} \approx 0.09076$ radian

$s = r\theta = 3960 \ 0.09076 \approx 359.4$ miles

92. $r = 3960$ miles; $\theta = 38^\circ 21' 30^\circ 20'' = 8^\circ 1' = 8.017^\circ = 8.017 \ \frac{\pi}{180} \approx 0.1399$ radian

$s = r\theta = 3960 \ 0.1399 \approx 554$ miles

93. $r = 3429.5$ miles; $\omega = 1 \text{ rev / day} = 2\pi \text{ radians / day} = \frac{\pi}{12} \text{ radians / hr}$

$v = r\omega = 3429.5 \ \frac{\pi}{12} \approx 897.8$ miles/hr

94. $r = 3033.5$ miles; $\omega = 1 \text{ rev / day} = 2\pi \text{ radians / day} = \frac{\pi}{12} \text{ radians / hr}$

$v = r\omega = 3033.5 \ \frac{\pi}{12} \approx 794.2$ miles/hr

95. $r = 2.39 \times 10^5$ miles;

$\omega = 1 \text{ rev/27.3 days} = 2\pi \text{ radians/27.3 day} = \frac{\pi}{12 \ 27.3} \text{ radians/hr}$

$v = r\omega = \left(2.39 \times 10^5\right) \ \frac{\pi}{327.6} \approx 2292$ miles/hr

96. $r = 9.29 \times 10^7$ miles;

$\omega = 1 \text{ rev / 365 days} = 2\pi \text{ radians / 365 day} = \frac{\pi}{12 \ 365} \text{ radians / hr}$

$v = r\omega = \left(9.29 \times 10^7\right) \ \frac{\pi}{4380} \approx 66{,}633 \text{ miles / hr}$

97. $r_1 = 2$ inches; $r_2 = 8$ inches; $\omega_1 = 3 \text{ rev / min} = 6\pi \text{ radians / min}$

Find ω_2:

$v_1 = v_2$

$r_1\omega_1 = r_2\omega_2 \rightarrow 2(6\pi) = 8\omega_2$

$\omega_2 = \frac{12\pi}{8} = 1.5\pi \text{ radians/min} = \frac{1.5\pi}{2\pi} \text{ rev/min} = \frac{3}{4} \text{ rev/min}$

98. $r = 30$ feet; $\omega = \frac{1 \text{ rev}}{70 \text{ sec}} = \frac{2\pi}{70 \text{ sec}} = \frac{\pi}{35} \text{ rad / sec}$

$v = r\omega = 30 \text{ feet} \ \frac{\pi}{35}\frac{\text{rad}}{\text{sec}} = \frac{6\pi}{7} \ \frac{\text{ft}}{\text{sec}} \approx 2.69 \text{ feet / sec}$

99. $r = 4$ feet; $\omega = 10 \text{ rev / min} = 20\pi \text{ radians / min}$

$$v = r\omega = 4 \ \ 20\pi = 80\pi \ \frac{\text{ft}}{\text{min}} = \frac{80\pi \text{ ft}}{\text{min}} \ \ \frac{1 \text{ mi}}{5280 \text{ ft}} \ \ \frac{60 \text{ min}}{\text{hr}} \approx 2.86 \text{ mi/hr}$$

100. $d = 26$ inches; $r = 13$ inches; $\omega = 480$ rev / min $= 960\pi$ radians / min

$$v = r\omega = 13 \ \ 960\pi = 12480\pi \ \frac{\text{in}}{\text{min}} = \frac{12480\pi \text{ in}}{\text{min}} \ \ \frac{1 \text{ ft}}{12 \text{ in}} \ \ \frac{1 \text{ mi}}{5280 \text{ ft}} \ \ \frac{60 \text{ min}}{\text{hr}}$$

$$\approx 37.13 \text{ mi / hr}$$

$$\omega = \frac{v}{r} = \frac{80 \text{ mi / hr}}{13 \text{ in}} \ \ \frac{12 \text{ in}}{1 \text{ ft}} \ \ \frac{5280 \text{ ft}}{1 \text{ mi}} \ \ \frac{1 \text{ hr}}{60 \text{ min}} \ \ \frac{1 \text{ rev}}{2\pi \text{ rad}} \approx 1034 \text{ rev / min}$$

101. $d = 8.5$ feet; $r = 4.25$ feet; $v = 9.55$ mi/hr

$$\omega = \frac{v}{r} = \frac{9.55 \text{ mi/hr}}{4.25 \text{ ft}} = \frac{9.55 \text{ mi}}{\text{hr}} \ \ \frac{1}{4.25 \text{ ft}} \ \ \frac{5280 \text{ ft}}{\text{mi}} \ \ \frac{1 \text{ hr}}{60 \text{ min}} \ \ \frac{1 \text{ rev}}{2\pi} \approx 31.47 \text{ rev/min}$$

102. Let t represent the time for the earth to rotate 90 miles.

$$\frac{t}{90} = \frac{24}{2\pi(3150)} \quad \rightarrow \quad t = \frac{90(24)}{2\pi(3150)} \approx 0.1091 \text{ hours} \approx 6.55 \text{ minutes}$$

103. The earth makes one full rotation in 24 hours. The distance traveled in 24 hours is the circumference of the earth. At the equator the circumference is $2\pi(3960)$ miles. Therefore, the linear velocity a person must travel to keep up with the sun is:

$$v = \frac{s}{t} = \frac{2\pi(3960)}{24} \approx 1037 \text{ miles / hr}$$

104. Find s, when $r = 3960$ miles and $\theta = 1'$.

$$\theta = 1' \ \frac{1 \text{ degree}}{60 \text{ min}} \ \ \frac{\pi \text{ radians}}{180 \text{ degrees}} \approx 0.00029 \text{ radians}$$

$$s = r\theta = 3960(0.00029) \approx 1.1484 \text{ miles}$$

1 nautical mile is approximately 1.15 statute miles.

105. r_1 rotates at ω_1 rev / min; r_2 rotates at ω_2 rev / min;
$v = r_1\omega_1 = r_2\omega_2$

So, $\frac{r_1}{r_2} = \frac{\omega_2}{\omega_1}$