For #9–16, use the formula $s = r\theta$, and the equivalent forms $r = s/\theta$ and $\theta = s/r$.

9. $60° \cdot \frac{\pi}{180°} = \frac{\pi}{3}$ rad

10. $90° \cdot \frac{\pi}{180°} = \frac{\pi}{2}$ rad

11. $120° \cdot \frac{\pi}{180°} = \frac{2\pi}{3}$ rad

12. $150° \cdot \frac{\pi}{180°} = \frac{5\pi}{6}$ rad

13. $71.72° \cdot \frac{\pi}{180°} \approx 1.2518$ rad

14. $11.83° \cdot \frac{\pi}{180°} \approx 0.2065$ rad

15. $61°24' = \left(61 + \frac{24}{60}\right)^{\circ} = 61.4° \cdot \frac{\pi}{180°} \approx 1.0716$ rad

16. $75°30' = \left(75 + \frac{30}{60}\right)^{\circ} = 75.5° \cdot \frac{\pi}{180°} \approx 1.3177$ rad

17. $\frac{\pi}{6} \cdot \frac{180°}{\pi} = 30°$

18. $\frac{\pi}{4} \cdot \frac{180°}{\pi} = 45°$

19. $\frac{\pi}{10} \cdot \frac{180°}{\pi} = 18°$

20. $\frac{3\pi}{5} \cdot \frac{180°}{\pi} = 108°$

21. $\frac{7\pi}{9} \cdot \frac{180°}{\pi} = 140°$

22. $\frac{13\pi}{20} \cdot \frac{180°}{\pi} = 117°$

23. $2 \cdot \frac{180}{\pi} \approx 114.59°$

24. $1.3 \cdot \frac{180}{\pi} \approx 74.48°$

25. $s = 50$ in.

26. $s = 70$ cm

27. $r = 6/\pi$ ft

28. $r = 7.5/\pi$ cm

29. $\theta = 3$ radians

30. $\theta = \frac{4}{7}$ radians

31. $r = \frac{360}{\pi}$ cm

32. $s = (5\text{ ft})(18°)\left(\dfrac{2\pi}{360°}\right) = \dfrac{\pi}{2}$ ft

33. $\theta = s_1/r_1 = \dfrac{9}{11}$ rad and $s_2 = r_2\theta = 36$ cm

34. $\theta = s_1/r_1 = 4.5$ rad and $r_2 = s_2/\theta = 16$ km

35. The angle is $10° \cdot \dfrac{\pi}{180°} = \dfrac{\pi}{18}$ rad, so the curved side measures $\dfrac{11\pi}{18}$ in. The two straight sides measure 11 in. each, so the perimeter is $11 + 11 + \dfrac{11\pi}{18} \approx 24$ in.

36. The angle is $100° \cdot \dfrac{\pi}{180°} = \dfrac{5\pi}{9}$ rad, so

$$7 = \frac{5\pi}{9}r.$$

Then

$$r = \frac{63}{5\pi} \approx 4 \text{ cm}.$$

37. Five pieces of track form a semicircle, so each arc has a central angle of $\pi/5$ radians. The inside arc length is $r_i(\pi/5)$ and the outside arc length is $r_o(\pi/5)$. Since $r_o(\pi/5) - r_i(\pi/5) = 3.4$ inches, we conclude that $r_o - r_i = 3.4(5/\pi) \approx 5.4$ inches.

38. Let the diameter of the inner (red) circle be d. The inner circle's perimeter is 37.7 inches, which equals πd. Then the next-largest (yellow) circle has a perimeter of $\pi(d + 6 + 6) = \pi d + 12\pi = 37.7 + 12\pi \approx 75.4$ inches.

39. **(a)** NE is 45°. **(b)** NNE is 22.5°. **(c)** WSW is 247.5°.

40. **(a)** SSW is 202.5°. **(b)** WNW is 292.5°. **(c)** NNW is 337.5°.

41. ESE is closest at 112.5°.

42. SW is closest at 225°.

43. The angle between them is $\theta = 9°42' = 9.7° \approx 0.1693$ radians, so the distance is about $s = r\theta = (25)(0.1693) \approx 4.23$ statute miles.

44. Since $C = \pi d$, a tire travels a distance πd with each revolution.

(a) Each tire travels at a speed of 800 πd in. per min, or

$$\left(\frac{800\pi d\text{ in.}}{1\text{ min}}\right)\left(\frac{60\text{ min}}{1\text{ hr}}\right)\left(\frac{1\text{ mi}}{63{,}360\text{ in.}}\right) \approx 2.38d\text{ mi/hr}.$$

Vehicle	d	Speed $\approx 2.38d$
Nissan Leaf SL	25.5	60.7 mph
Chevy Volt	26.3	62.6 mph
Tesla S	27.7	65.9 mph

(b) $\left(\dfrac{\pi d\text{ in.}}{1\text{ rev}}\right)\left(\dfrac{1\text{ mi}}{63{,}360\text{ in.}}\right) = \dfrac{\pi d}{63{,}360}$ mi/rev, so each mile requires $\dfrac{63{,}360}{\pi d} \approx \dfrac{20{,}168}{d}$ revolutions.

Leaf: $\dfrac{20{,}168}{25.5} \approx 790.90$ revolutions

Tesla: $\dfrac{20{,}168}{27.7} \approx 728.09$ revolutions

The Leaf must make just over 62 more revolutions.

(c) In each revolution, the tire would cover a distance of πd_{new} rather than πd_{old}, so that the car would travel $(\pi d_{new})/(\pi d_{old}) = d_{new}/d_{old} = 27.7/25.5 \approx 1.086$ miles for every mile the car's instruments would show. Both the odometer and speedometer readings would be low.

45. $v = 24$ ft/sec and $r = 10$ in., so

$$\omega = v/r = \left(24\frac{\text{ft}}{\text{sec}} \cdot 60\frac{\text{sec}}{\text{min}}\right) \div \left(10\text{ in.} \cdot \frac{1}{12}\frac{\text{ft}}{\text{in.}} \cdot 2\pi\frac{\text{rad}}{\text{rev}}\right)$$

≈ 275.02 rpm.

46. **(a)** $\dfrac{S}{W} = \dfrac{R}{100} \Rightarrow S = \dfrac{WR}{100}$ mm.

25.4 mm = 1 in., so $S = \dfrac{WR}{100} \cdot \dfrac{1}{25.4} = \dfrac{WR}{2540}$ in.

(b) $D + 2S = D + 2\left(\dfrac{WR}{2540}\right) = D + \dfrac{WR}{1270}$ in.

(c) Leaf: $D = 17 + \dfrac{215 \cdot 50}{1270} \approx 25.5$ in.

Volt: $D = 17 + \dfrac{215 \cdot 55}{1270} \approx 26.3$ in.

Tesla S: $D = 19 + \dfrac{245 \cdot 45}{1270} \approx 27.7$ in.

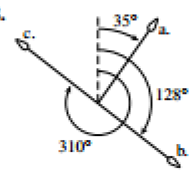
Escalade: $D = 18 + \dfrac{265 \cdot 65}{1270} \approx 31.6$ in.

47. $\omega = 2000$ rpm and $r = 5$ in., so

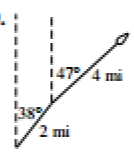
$$v = r\omega = \left(5\text{ in.} \cdot 12\frac{\text{teeth}}{\text{in.}}\right)\cdot$$

$\left(2000\dfrac{\text{rev}}{\text{min}} \cdot 2\pi\dfrac{\text{rad}}{\text{rev}} \cdot \dfrac{1}{60}\dfrac{\text{min}}{\text{sec}}\right) \approx 12{,}566.37$ teeth per second.

48.



49.



50. 257 naut mi $\cdot \dfrac{3956\pi\text{ stat mi}}{10{,}800\text{ naut mi}} \approx 296$ statute miles

51. 895 stat mi $\cdot \dfrac{10{,}800\text{ naut mi}}{3956\pi\text{ stat mi}} \approx 778$ nautical miles

52. **(a)** Lane 5 has inside radius 37 m, while the inside radius of lane 6 is 38 m, so over the whole semicircle, the difference is $38\pi - 37\pi = \pi \approx 3.142$ m. (This would be the answer for any two adjacent lanes.)

(b) $38\pi - 33\pi = 5\pi \approx 15.708$ m.

53. **(a)** $s = r\theta = (4)(4\pi) = 16\pi \approx 50.265$ in., or $\frac{4}{3}\pi \approx 4.189$ ft

(b) $r\theta = 2\pi \approx 6.283$ ft

54. $s = r\theta = (52)\left(\frac{\pi}{180}\right) = \frac{13}{45}\pi \approx 0.908$ ft

55. **(a)** $\omega_1 = 120\,\frac{\text{rev}}{\text{min}} \cdot 2\pi\,\frac{\text{rad}}{\text{rev}} \cdot \frac{1}{60}\,\frac{\text{min}}{\text{sec}} = 4\pi$ rad/sec

(b) $v = R\omega_1 = (7\text{ cm})\left(4\pi\,\frac{\text{rad}}{\text{sec}}\right) = 28\pi$ cm/sec

(c) $\omega_2 = v/r = \left(28\pi\,\frac{\text{cm}}{\text{sec}}\right) \div (4\text{ cm}) = 7\pi$ rad/sec

56. **(a)** $\omega = 135\,\frac{\text{rev}}{\text{min}} \cdot 2\pi\,\frac{\text{rad}}{\text{rev}} \cdot \frac{1}{60}\,\frac{\text{min}}{\text{sec}} = 4.5\pi$ rad/sec

(b) $v = r\omega = (1.2\text{ m})\left(4.5\pi\,\frac{\text{rad}}{\text{sec}}\right) = 5.4\pi$ m/sec

(c) The radius to this halfway point is $r^* = \frac{1}{2}r = 0.6$ m,

so $v = r^*\omega = (0.6\text{ m})\left(4.5\pi\,\frac{\text{rad}}{\text{sec}}\right) = 2.7\pi$ m/sec.

57. True. In the amount of time it takes for the merry-go-round to complete one revolution, horse *B* travels a distance of $2\pi r$, where r is *B*'s distance from the center. In the same time, horse *A* travels a distance of $2\pi(2r) = 2(2\pi r)$ — twice as far as *B*.

58. False. If all three radian measures were integers, their sum would be an integer. But the sum must equal π, which is not an integer.

59. $x° = x°\left(\frac{\pi\text{ rad}}{180°}\right) = \frac{\pi x}{180}$. The answer is C.