CIRCULAR MOTION

Tangential Position and Displacement

1. Which of the following are examples of objects in circular motion? (Select all that apply)
   - A A person riding on a Ferris wheel (the person)
   - B A record playing on a record player (the record)
   - C A spinning ceiling fan (the fan)
   - D A fly sitting on a blade of a ceiling fan (the fly)

2. What is the circumference of a circle with a radius of 5 m?
   - A 10 m
   - B 15.7 m
   - C 31.4 m
   - D 62.8 m

3. If the circumference of a circle is 12 m, what is the diameter?
   - A 3.14 m
   - B 3.8 m
   - C 6 m
   - D 12 m

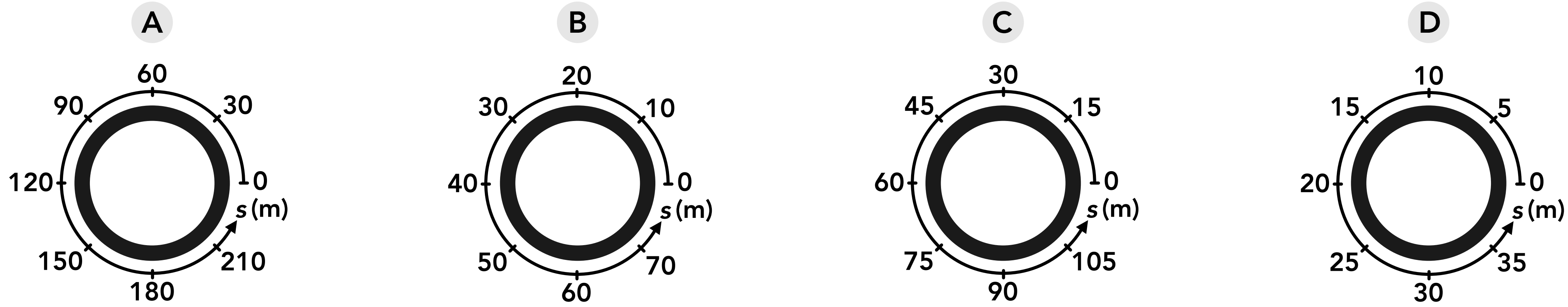
4. What is the SI unit for tangential position?
   - A rad
   - B km
   - C deg
   - D m

5. What is the SI unit for tangential displacement?
   - A m
   - B rad
   - C km
   - D rev

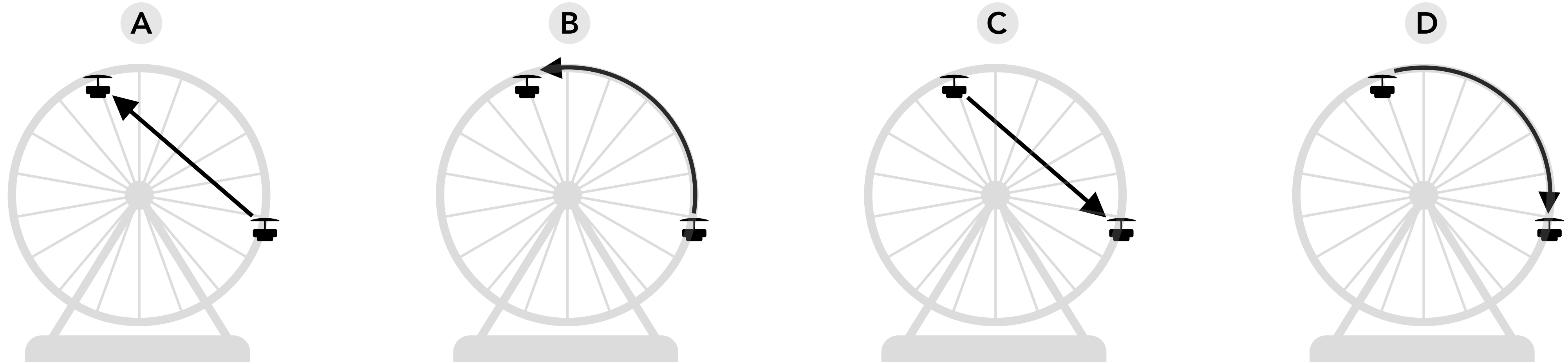
6. If the diameter of a circular race track is 0.5 km, what is the circumference of the track in m?
   - A 314 m
   - B 500 m
   - C 785 m
   - D 1,571 m

7. If a speed skater races around a circular ice rink counterclockwise for 30 m, is the skater's displacement positive or negative (using convention)?
   - A Positive
   - B Negative

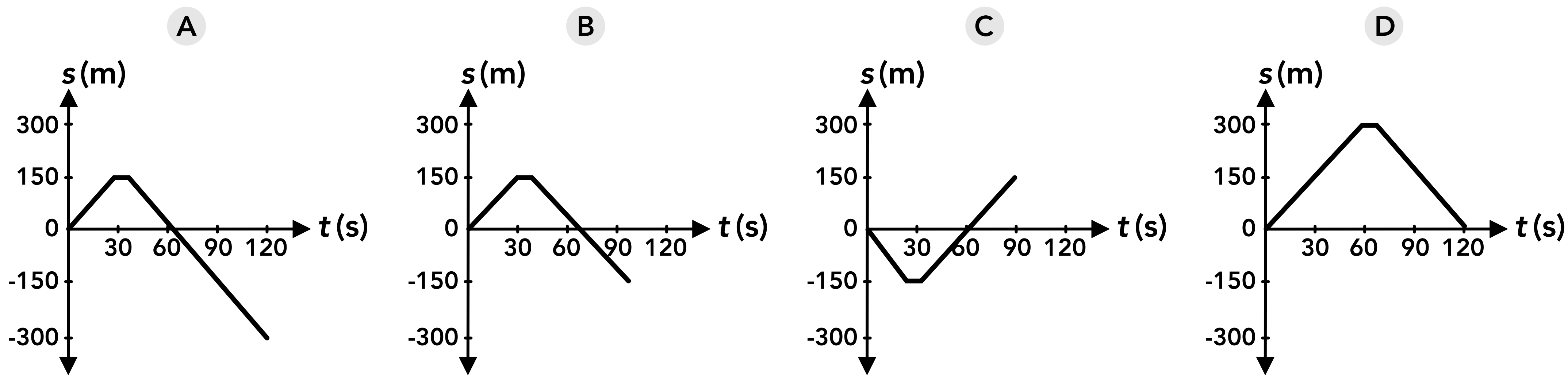
8. If the radius of a circular track is 19.1 m, which axis shown below would be labeled correctly?



9. Which of the arrows below shows the length of a positive tangential displacement of a Ferris wheel car?



10. A person is ice skating around the outside of a circular rink with a radius of 24 m. They skate 1 lap counterclockwise, stop, then skate 2 laps clockwise. Which graph represents that motion of the skater?



11. A cyclist is riding around a circular track with a circumference of 200 m. If they travel 1 full lap (1 revolution) and end in the same location where they started, what is the cyclist's final tangential position?

12. A satellite is in a circular orbit around the Earth. If the diameter of the Earth is 12,742 km (assuming the Earth is a sphere) and the satellite is 1,500 km above the surface of the Earth, what is the circumference of the satellite's orbit in km?

13. If a race car on circular race track starts at a position of 270 m then drives to a position of 50 m, what is the car's tangential displacement?

14. A runner is on a circular track. If they start at a position of 32 m and run a distance of 57 m clockwise, what is their final position?

15. A car resets its odometer to zero, then drives along half of a circular track and stops. If the car's odometer reads 1.70 km, what is the radius of the track in km?

16. A running coach has the team perform a drill where they run around a circular track and reverse directions when he blows a whistle. If one runner starts at a position of 10 m, then runs 20 m clockwise, then 35 m counterclockwise, then 5 m clockwise, what is the runner's final position?

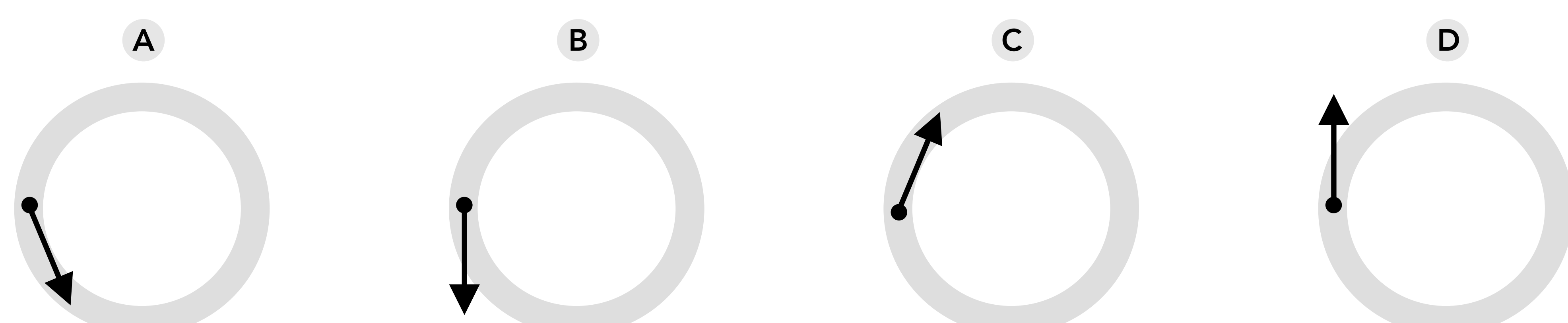
Tangential Velocity

17. What is the SI unit for tangential velocity?
    - A rad/s
    - B m/s
    - C km/h
    - D rpm

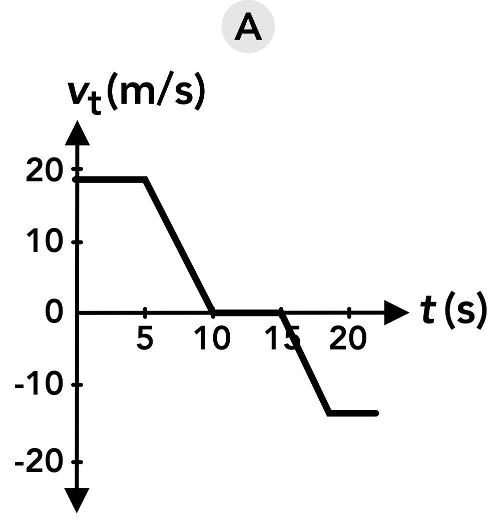
18. If a cyclist is riding around a circular track with a tangential velocity of 5 km/h, what is their velocity in m/s?
    - A 5 m/s
    - B 1.4 m/s
    - C 5,000 m/s
    - D 83.3 m/s

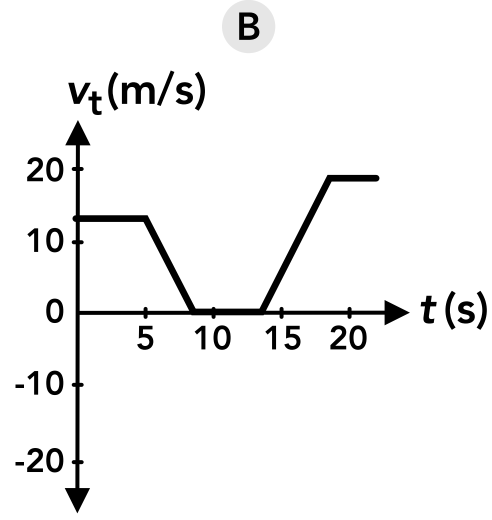
19. A figure skater is spinning clockwise with their arms stretched out. Using convention, the tangential velocity of their hands is
    - A positive
    - B negative

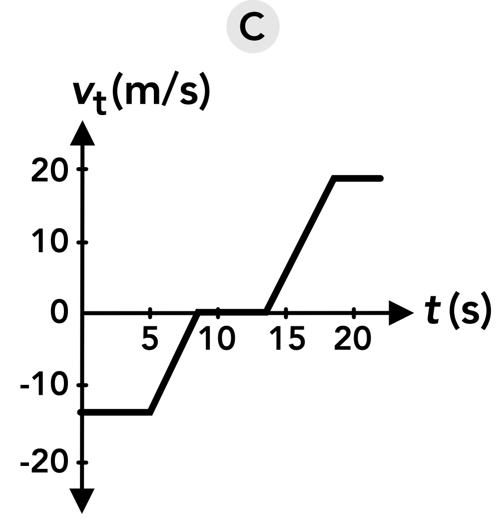
20. A car is driving clockwise around a circular track. What is the direction of the instantaneous tangential velocity of the car when it's in the position indicated by the dot shown in the figures below?

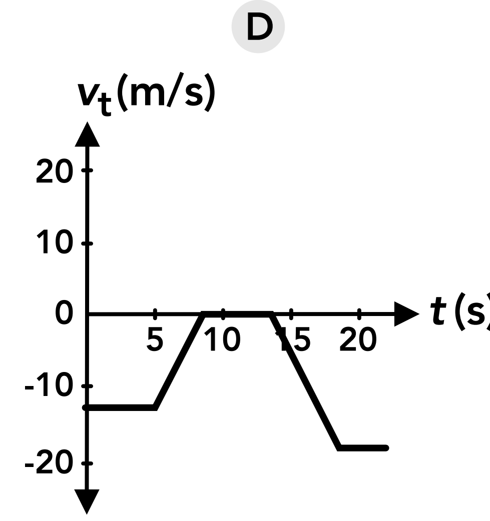


21. A car is driving clockwise around a circular track at a speed of 14 m/s when it slows down, stops, turns around, then accelerates to a speed of 19 m/s counterclockwise. Which of these graphs could represent the motion of the car?









22. If a car on a circular track travels 160 m counterclockwise in 7 s, what is its average tangential velocity?

23. If a runner on a circular race track travels from a position of 17 m to a position of -5 m over a period of 16 s, what is the average tangential velocity of the runner?

24. A Ferris wheel rotates counterclockwise. When the ride starts, one person on the Ferris wheel is at a tangential position of 12 m. If the cars move at a constant tangential velocity of 1.5 m/s, what is the tangential position of that person after 15 s?

25. If a car on a circular track is at a position of 35 m and is driving at -15 m/s, how long does it take for the car to reach a position of -50 m?

26. If a car on a circular track travels 230 m in the counterclockwise direction in 9.5 s, what is the average tangential velocity of the car in km/h?

27. A go-kart is driving at a velocity of 6 m/s counterclockwise around a circular race track. What is the position of the go-kart 4 s after it passes the 10 m mark?

28. A truck in circular motion around a track drives from a position of -52 m to a position of 14 m in 5.2 s. What is the average tangential velocity of the truck in km/h?

Tangential Acceleration

29. What is the SI unit for tangential acceleration?
    - A rad/s
    - B m/s
    - C m/s^2
    - D rad/s^2

30. A car is driving counterclockwise around a circular track. If the car increases its speed, the car's tangential acceleration is
    - A positive
    - B negative

31. A car is driving clockwise around a circular track. If the car slows down, the car's tangential acceleration is
    - A positive
    - B negative

32. If a sprinter on a circular race track starts from rest and then speeds up to a tangential velocity of 5 m/s over a period of 3 s, what was the sprinter's tangential acceleration?

33. A truck is driving around a section of road that follows a circular path. It's moving at 16 m/s when it hits the brakes and slows down to 12 m/s over period of 3 s. What was the truck's tangential acceleration?

34. If someone says their car can go from 0 to 100 km/h in 5 seconds, what would be the tangential acceleration of their car around a circular track in m/s^2 ?

35. If a car has a maximum acceleration of 4 m/s^2, how many seconds would it take the car to go from a tangential velocity of 20 km/h to 50 km/h?

36. Two cars line up for the start of a race at the 0 m line. When the gun goes off, one car accelerates at 5 m/s². What is the car's position after 3 s of accelerating?

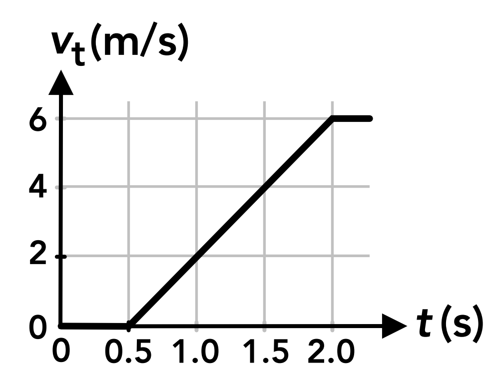
37. A person is riding on a Ferris wheel which is turning slowly at a constant speed. The ride operator then turns up the speed and person experiences a tangential acceleration of 1.5 m/s² for 6 s. If the person travels a tangential displacement of 30 m during that time period, what was the initial tangential velocity of the person?

38. A cyclist on a circular track is moving 6 m/s. When they pass the 50 m mark they decide to pedal harder and accelerate. After 4 s of accelerating they pass the 90 m mark. What was the tangnetial acceleration of the cyclist during that time?

39. A car on a circular track is driving 16 m/s. When it passes the 30 m mark it accelerates at 5 m/s². What is the position of the car when it reaches a tangential velocity of 23 m/s?

40. A bolt near the end of a spinning wind turbine blade traces out a counterclockwise circular path with a tangential velocity of 8 m/s. The wind suddenly stops, and the bolt travels a circular displacement of 112 m as the turbine comes to a stop. What was the tangential acceleration of the bolt while the turbine slowed down?

41. The graph on the right represents the motion of a sprinter that starts from rest then accelerates at the start of a race. What is the acceleration of the sprinter between 0.5 s and 2.0 s?



42. A circular race track has a radius of 0.04 km. A car starts from rest then accelerates at a constant 4 m/s^2. How long does it take the car to cover 1 lap?

43. A cyclist is riding around a circular track with a tangential velocity of 27 km/h. When the cyclist is at a position of 25 m, it accelerates at 2 m/s^2. When the cyclist reaches the 50 m mark, what is the cyclist's tangential velocity in km/h?

44. A Ferris wheel car starts from rest. When the ride begins, the car experiences a tangential accleration of 0.2 m/s^2 for 1 entire rotation of the Ferris wheel. By the time it completes 1 rotation the car has a tangential velocity of -5 m/s. What is the diameter of the Ferris wheel (the circular path of the car)?

45. During a race around a circular track, a car is driving at 80 km/h. When it passes the 35 m mark on the track, it accelerates until it passes the 140 m mark. If it takes 4 sec to travel between those two marks, what is the final velocity of the car in km/h?

Answers

1. A, D
2. C
3. B
4. D
5. A
6. D
7. A
8. C
9. B
10. B
11. 200 m
12. 49,455 km
13. -220 m
14. -25 m
15. 0.54 km
16. 20 m
17. B
18. B
19. B
20. D
21. C
22. 22.9 m/s
23. -1.4 m/s
24. 34.5 m
25. 5.7 s
26. 87.2 km/h
27. 34 m
28. 45.7 km/h
29. C
30. A
31. A
32. 1.7 m/s²
33. -1.3 m/s²
34. 5.6 m/s²
35. 2.1 s
36. 22.5 m
37. 0.5 m/s
38. 2 m/s²
39. 57.3 m
40. -0.29 m/s²
41. 4 m/s²
42. 11.2 s
43. 45 km/h
44. 19.9 m
45. 109.1 km/h

Answers - Tangential Position and Displacement

1. **Answer: A, D**
   A person on a Ferris wheel and a fly on a can blade follow circular paths so they are in circular motion. The record and the fan are objects that rotate so they are in rotational motion.

2. **Answer: C**
   The equation for the circumference of a circle (using the radius) is: $\boldsymbol{C = 2\pi r = 2\pi(5\text{ m}) = 31.4\text{ m}}$

3. **Answer: B**
   The equation for the circumference of a circle (using the diamter) is: $\boldsymbol{C = \pi d}$

   $$\boldsymbol{d = \frac{C}{\pi} = \frac{(12\text{ m})}{\pi} = 3.8\text{ m}}$$

4. **Answer: D**
   The SI unit for tangential position is meters (m), the same as for linear position. Radians (rad) is the SI unit for angular position. Kilometers (km) is a valid unit for tangential position but is not the SI unit. Degrees (deg) is a valid unit for angular position but is not the SI unit.

5. **Answer: A**
   The SI unit for tangential displacement is meters (m), the same as for tangential position and linear position and displacement. Radians (rad) is the SI unit for angular displacement. Kilometers (km) is a valid unit for tangential displacement but is not the SI unit. Revolutions (rev) is a valid unit for angular displacement but is not the SI unit.

6. **Answer: D**
   First we can convert the diameter from km to m:

   $$\boldsymbol{\frac{0.5\text{ km}}{} \times \frac{1000\text{ m}}{1\text{ km}} = 500\text{ m}}$$

   The circumference of the track is:
   $\boldsymbol{C = \pi d = \pi(500\text{ m}) = 1{,}571\text{ m}}$

7. **Answer: A**
   By convention, the counterclockwise direction is the positive direction.

8. **Answer: C**
   The circumference of the track is: $\boldsymbol{C = 2\pi r = 2\pi(19.1\text{ m}) = 120\text{ m}}$
   The axis in option C is the only one with a circumference of 120 m.

9. **Answer: B**
By convention, counterclockwise is the positive direction. The tangential displacement is the arc length of the path of the car, not the straight line displacement.

10. **Answer: B**
The circumference of the rink is: $\mathbf{C = 2\pi r = 2\pi(24\ m) = 150.8\ m}$
By convention, counterclockwise is the positive direction. They move 150.8 m in the positive direction, stay at that position for a period of time, then they move 2(150.8 m) = 301.6 m in the negative direction and end at a final position of -150.8 m.

11. **Answer: 200 m**
Their initial position would be 0 m and their tangential displacement is 200 m (the circumference of the track) so their final position is 200 m. The displacement is assumed to be positive because no direction was given.

12. **Answer: 49,455 km**
The radius of the satellite's circular orbit is the radius of the earth (half of the diameter) plus the height of the satellite above the ground:
$$r_{\text{orbit}} = \frac{12{,}742\ \text{km}}{2} + 1{,}500\ \text{km} = 7{,}871\ \text{km}$$
The circumference of the orbit is:
$\mathbf{C = 2\pi r = 2\pi(7{,}871\ km) = 49{,}455\ km}$

13. **Answer: -220 m**
The tangential displacement (or the arc length the path) is equal to the final position minus the initial position:
$\Delta s = s_f - s_i = (50\ \text{m}) - (270\ \text{m}) = -220\ \text{m}$

14. **Answer: -25 m**
The final position can be found using the equation for tangential displacement:
$\Delta s = s_f - s_i \qquad (-57\ \text{m}) = s_f - (32\ \text{m}) \qquad s_f = -25\ \text{m}$

15. **Answer: 0.54 km**
The car drives half of a full circle so the circumference of the track is: **2(1.70 km) = 3.40 km**
The radius of the track can be found from the circumference:
$C = 2\pi r \qquad (3.40\ \text{km}) = 2\pi r \qquad r = 0.54\ \text{km}$

16. **Answer: 20 m**
The runner's total tangential displacement is the sum of the individual displacements:
$\Delta s = (-20\ \text{m}) + (35\ \text{m}) + (-5\ \text{m}) = 10\ \text{m}$
The final position of the runner can be found using the equation for tangential displacement:
$\Delta s = s_f - s_i \qquad (10\ \text{m}) = s_f - (10\ \text{m}) \qquad s_f = 20\ \text{m}$

Answers - Tangential Velocity

17. **Answer: B**
The SI unit for tangential velocity is meters per second (m/s), the same as for linear velocity. Radians per second (rad/s) is the SI unit for angular velocity. Kilometers per hour (km/h) is a valid unit for tangential velocity but is not the SI unit. Revolutions per minute (rpm) is a valid unit for angular velocity but is not the SI unit.

18. **Answer: B**
We only need to convert from km/h to m/s:

$$\frac{5\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 1.4\text{ m/s}$$

19. **Answer: B**
By convention, clockwise is the negative direction.

20. **Answer: D**
The direction of the tangential velocity is always tangent to the circular path. The car is on the left side of the circle and moving clockwise so the velocity must be pointing upwards (from this top-down view).

21. **Answer: C**
By convention, counterclockwise is the positive direction. The car starts with a velocity of -14 m/s, then it slows down and stops so the speed decreases to 0 m/s, then it speeds up to a velocity of positive 19 m/s.

22. **Answer: 22.9 m/s**
The average tangential velocity is the tangential displacement (160 m) divided by the period of time (7 s).

$$v_t = \frac{\Delta s}{\Delta t} = \frac{(160\text{ m})}{(7\text{ s})} = 22.9\text{ m/s}$$

23. **Answer: -1.4 m/s**
The average tangential velocity is the tangential displacement divided by the period of time.

$$v_t = \frac{\Delta s}{\Delta t} = \frac{s_f - s_i}{\Delta t} = \frac{(-5\text{ m}) - (17\text{ m})}{(16\text{ s})} = -1.4\text{ m/s}$$

24. **Answer: 34.5 m**
The final tangential position can be found using the equation for tangential velocity.

$$v_t = \frac{s_f - s_i}{\Delta t} \qquad (1.5\text{ m/s}) = \frac{s_f - (12\text{ m})}{(15\text{ s})} \qquad s_f = 34.5\text{ m}$$

25. **Answer: 5.7 s**
The period of time can be found using the equation for tangential velocity.

$$v_t = \frac{s_f - s_i}{\Delta t} \qquad (-15\text{ m/s}) = \frac{(-50\text{ m}) - (35\text{ m})}{\Delta t} \qquad \Delta t = 5.7\text{ s}$$

26. **Answer: 87.2 km/h**
First we can find the average tangential velocity:

$$v_t = \frac{\Delta s}{\Delta t} = \frac{(230\text{ m})}{(9.5\text{ s})} = 24.21\text{ m/s}$$

Then we can convert that from m/s to km/h:

$$\frac{24.21\text{ m}}{\text{s}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ h}} = 87.2\text{ km/h}$$

27. **Answer: 34 m**
The final tangential position can be found using the equation for tangential velocity.

$$v_t = \frac{s_f - s_i}{\Delta t} \qquad (6\text{ m/s}) = \frac{s_f - (10\text{ m})}{(4\text{ s})} \qquad s_f = 34\text{ m}$$

28. **Answer: 45.7 km/h**

First we can find the average tangential velocity:

$$v_t = \frac{s_f - s_i}{\Delta t} = \frac{(14\text{ m}) - (\text{-}52\text{ m})}{(5.2\text{ s})} = 12.69\text{ m/s}$$

Then we can convert that from m/s to km/h:

$$\frac{12.69\text{ m}}{\text{s}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ h}} = 45.7\text{ km/h}$$

Answers - Tangential Acceleration

29. **Answer: C**

The SI unit for tangential acceleration is meters per second squared (m/s²), the same as for linear acceleration. Radians per second (rad/s) is the SI unit for angular velocity. Meters per second (m/s) is the SI unit for tangential and linear velocity. Radians per second squared (rad/s²) is the SI unit for angular acceleration.

30. **Answer: A**

By convention, counterclockwise is the positive direction. The car's velocity is counterclockwise (positive) and the velocity increases in magnitude so the acceleration is in the same direction as the velocity (positive).

31. **Answer: A**

By convention, counterclockwise is the positive direction. The car's velocity is clockwise (negative) and the velocity decreases in magnitude so the acceleration is in the opposite direction as the velocity (positive).

32. **Answer: 1.7 m/s²**

We can solve this using the equation for tangential acceleration. The initial velocity is 0 m/s (starts from rest).

$$a_t = \frac{\Delta v_t}{\Delta t} = \frac{v_{tf} - v_{ti}}{\Delta t} = \frac{(5\text{ m/s}) - (0\text{ m/s})}{(3\text{ s})} = 1.7\text{ m/s}^2$$

33. **Answer: -1.3 m/s²**

We can solve this using the equation for tangential acceleration.

$$a_t = \frac{\Delta v_t}{\Delta t} = \frac{v_{tf} - v_{ti}}{\Delta t} = \frac{(12\text{ m/s}) - (16\text{ m/s})}{(3\text{ s})} = \text{-}1.3\text{ m/s}^2$$

34. **Answer: 5.6 m/s²**

First we can convert 100 km/h to m/s:

$$\frac{100\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 27.78\text{ m/s}$$

Then we can find the tangential acceleration:

$$a_t = \frac{\Delta v_t}{\Delta t} = \frac{v_{tf} - v_{ti}}{\Delta t} = \frac{(27.78\text{ m/s}) - (0\text{ m/s})}{(5\text{ s})} = 5.6\text{ m/s}^2$$

35. **Answer: 2.1 s**

First we can convert the velocities from km/h to m/s:

$$\frac{20\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 5.56\text{ m/s}$$

$$\frac{50\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 13.89\text{ m/s}$$

Then we can find the period of time using the equation for tangential acceleration:

$$a_t = \frac{\Delta v_t}{\Delta t} \qquad (4\text{ m/s}^2) = \frac{(13.89\text{ m/s}) - (5.56\text{ m/s})}{\Delta t} \qquad \Delta t = 2.1\text{ s}$$

36. **Answer: 22.5 m**

The final tangential position can be found using this kinematic equation. The initial position and velocity are 0.

$$s_f = s_i + v_{ti}t + \frac{1}{2}a_t t^2 = (0\text{ m}) + (0\text{ m/s})(3\text{ s}) + \frac{1}{2}(5\text{ m/s}^2)(3\text{ s})^2 = 22.5\text{ m}$$

37. **Answer: 0.5 m/s**

The initial tangential velocity can be found using this kinematic equation. Using 0 for the initial position:

$$s_f = s_i + v_{ti}t + \frac{1}{2}a_t t^2 \qquad (30\text{ m}) = (0\text{ m}) + v_{ti}(6\text{ s}) + \frac{1}{2}(1.5\text{ m/s}^2)(6\text{ s})^2 \qquad v_{ti} = 0.5\text{ m/s}$$

38. **Answer: 2 m/s²**

The tangential acceleration can be found using this kinematic equation.

$$s_f = s_i + v_{ti}t + \frac{1}{2}a_t t^2 \qquad (90\text{ m}) = (50\text{ m}) + (6\text{ m/s})(4\text{ s}) + \frac{1}{2}a_t(4\text{ s})^2 \qquad a_t = 2\text{ m/s}^2$$

39. **Answer: 57.3 m**

The final tangential position can be found using this kinematic equation.

$$v_{tf}^2 = v_{ti}^2 + 2a_t(s_f - s_i) \qquad (23\text{ m/s})^2 = (16\text{ m/s})^2 + 2(5\text{ m/s}^2)(s_f - 30\text{ m}) \qquad s_f = 57.3\text{ m}$$

40. **Answer: -0.29 m/s²**

The tangential acceleration can be found using this kinematic equation. The final velocity is 0 (it comes to a stop).

$$v_{tf}^2 = v_{ti}^2 + 2a_t(s_f - s_i) \qquad (0\text{ m/s})^2 = (8\text{ m/s})^2 + 2a_t(112\text{ m} - 0\text{ m}) \qquad a_f = -0.29\text{ m/s}^2$$

41. **Answer: 4 m/s²**

This is a graph of the sprinter's tangential velocity vs time. Acceleration is equal to the slope of the velocity-time graph. The slope (acceleration) can be found using the two points at 0.5 s and 2.0 s:

Acceleration (slope) from 0.5 s to 2.0 s: $a_t = \frac{\Delta v_t}{\Delta t} = \frac{(6\text{ m/s}) - (0\text{ m/s})}{(2.0\text{ s}) - (0.5\text{ s})} = 4\text{ m/s}^2$

42. **Answer: 11.2 s**

First we can find the tangential displacement equal to 1 lap (in m) which is the circumference of the circular track:

$\Delta s = C = 2\pi r = 2\pi(40\text{ m}) = 251.33\text{ m}$

Then we can find the period of time using this kinematic equation, using 0 for the initial position and velocity:

$$s_f = s_i + v_{ti}t + \frac{1}{2}a_t t^2 \qquad (251.33\text{ m}) = (0\text{ m}) + (0\text{ m/s})t + \frac{1}{2}(4\text{ m/s}^2)t^2 \qquad t = 11.2\text{ s}$$

43. **Answer: 45 km/h**

First we can convert the initial tangential velocity from km/h to m/s:

$$\frac{27\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 7.5\text{ m/s}$$

Then we can find the final tangential velocity using this kinematic equation:

$v_{tf}^2 = v_{ti}^2 + 2a_t(s_f - s_i)$ $\quad$ $v_{tf}^2 = (7.5\text{ m/s})^2 + 2(2\text{ m/s}^2)(50\text{ m} - 25\text{ m})$ $\quad$ $v_{tf} = 12.5\text{ m/s}$

Then we can convert that from m/s to km/h:

$$\frac{12.5\text{ m}}{\text{s}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ h}} = 45\text{ km/h}$$

44. **Answer: 19.9 m**

We can find the tangential displacement of 1 rotation using this kinematic equation. The initial velocity is 0.

$v_{tf}^2 = v_{ti}^2 + 2a_t(s_f - s_i)$ $\quad$ $(-5\text{ m/s})^2 = (0\text{ m/s})^2 + 2(-0.2\text{ m/s}^2)\Delta s$ $\quad$ $\Delta s = 62.5\text{ m}$

That tangential displacement is equal to 1 circumference of the circular path:

$C = \pi d$ $\quad$ $(62.5\text{ m}) = \pi d$ $\quad$ $d = 19.9\text{ m}$

45. **Answer: 109.1 km/h**

First we can convert the initial velocity from km/h to m/s:

$$\frac{80\text{ km}}{\text{h}} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1\text{ h}}{60\text{ min}} \times \frac{1\text{ min}}{60\text{ s}} = 22.22\text{ m/s}$$

Then we can find the tangential acceleration using this kinematic equation:

$s_f = s_i + v_{ti}t + \frac{1}{2}a_t t^2$ $\quad$ $(140\text{ m}) = (35\text{ m}) + (22.22\text{ m/s})(4\text{ s}) + \frac{1}{2}a_t(4\text{ s})^2$ $\quad$ $a_t = 2.02\text{ m/s}^2$

Then we can find the final tangential velocity using that tangential acceleration:

$a_t = \frac{\Delta v_t}{\Delta t}$ $\quad$ $(2.02\text{ m/s}^2) = \frac{v_{tf} - (22.22\text{ m/s})}{(4\text{ s})}$ $\quad$ $v_{tf} = 30.3\text{ m/s}$

Then we can convert that from m/s to km/h:

$$\frac{30.3\text{ m}}{\text{s}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{60\text{ s}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ h}} = 109.1\text{ km/h}$$