PRACTICE PROBLEMS

# CIRCULAR MOTION

## Basics

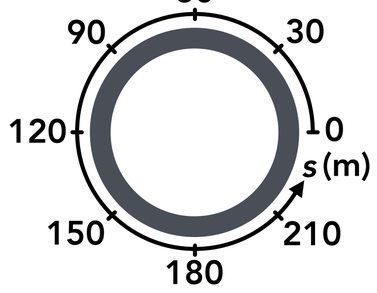
1. Which of the following are examples of an object in circular motion? (Select all that apply)
   - A A person riding on a Ferris wheel (the person)
   - B A record playing on a record player (the record)
   - C A spinning ceiling fan (the fan)
   - D A fly sitting on a blade of a ceiling fan (the fly)

2. What is the circumference of a circle with a radius of 5 m?

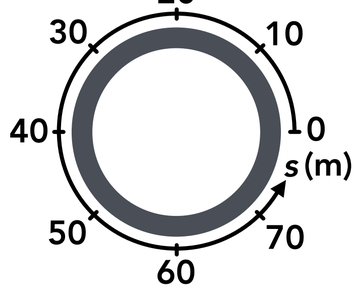
3. If the circumference of a circle is 12 m, what is the diameter?

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

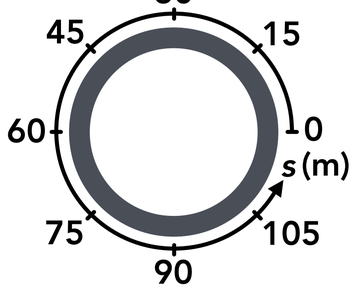
A



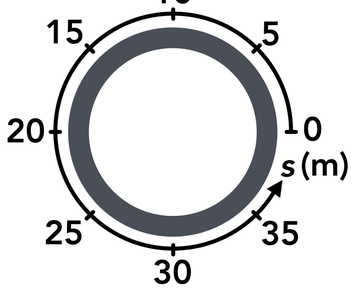

B




C




D




5. What are the SI units for each of the following: tangential position, tangential displacement, tangential velocity, and tangential acceleration?

6. Which of these would be valid units of tangential position and displacement? (Select all that apply)

   A km  B m/s  C rad  D cm  E s

7. Which of these would be valid units of tangential velocity? (Select all that apply)

   A rpm  B cm/s  C mm  D rad/s  E km/h

8. Which of these would be valid units of tangential acceleration? (Select all that apply)

   A $rad/s^2$  B rpm/s  C $km/h^2$  D $mm/s^2$  E rpm/h

9. If the diameter of a circular race track is 0.5 km, what is the circumference of the track in m?

10. If a cyclist is riding around a circular track with a tangential velocity of 5 km/h, what is the velocity in m/s?

## Level 1

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 position?

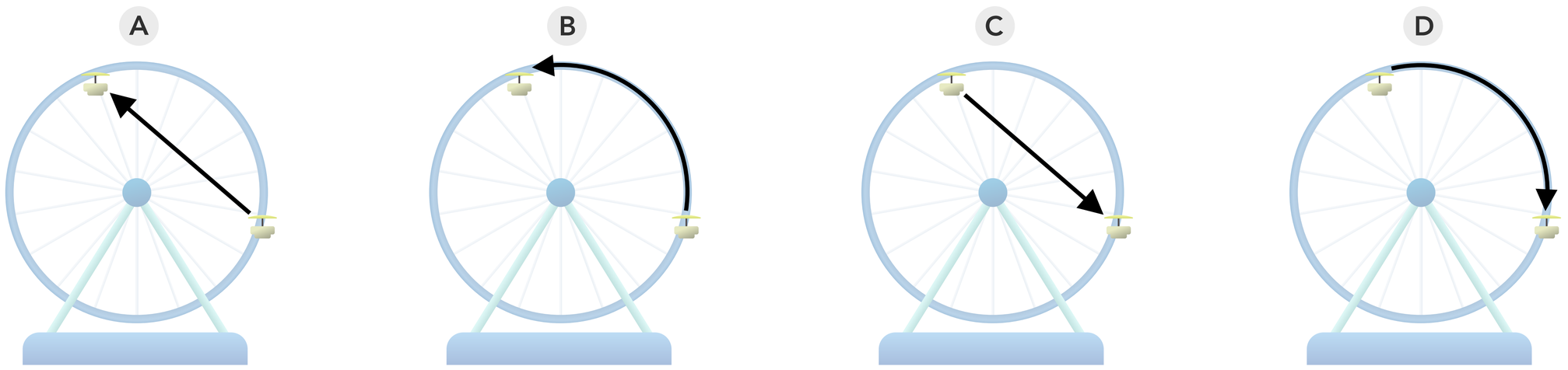
12. A satellite is in a circular orbit around the Earth. If the diameter of the Earth is 12,742 km (assuming the Earth is a sphere) and the satellite is 1,500 km above the surface of the Earth, what is the circumference of the satellite's orbit in km?

13. If a speed skater races around a circular ice rink counterclockwise for 30 m, is the skater's displacement positive or negative?

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

15. 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?

16. Which of the arrows below represent a positive tangential displacement of a Ferris wheel car?



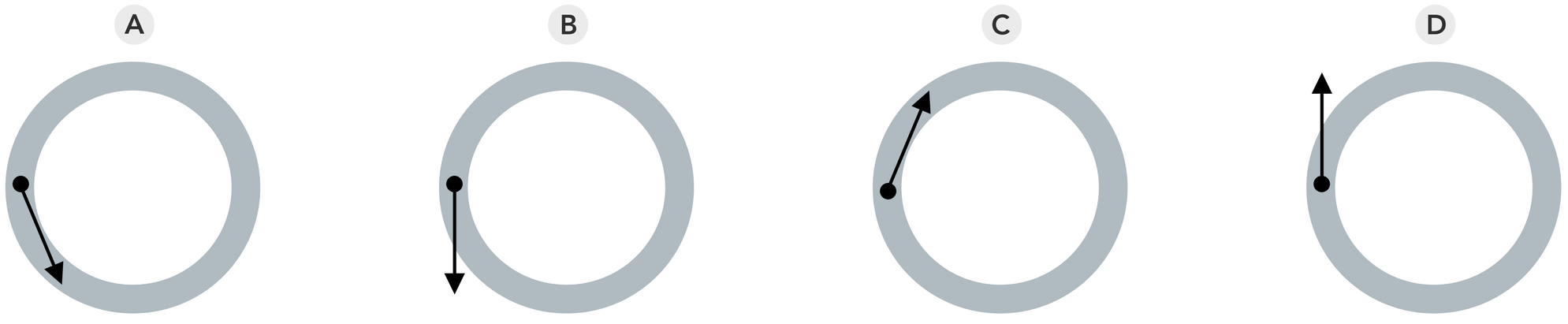

17. A car resets its odometer to zero, then drives along half of a circular track and stops. If the car's odometer reads 1.70 km, what is the radius of the track in km?

18. A fly is sitting on a spinning record and follows a circular path. During a brief section of the song, the fly moves from a position of -8 cm to a position of 13 cm. What was the fly's displacement in cm during that time?

19. A figure skater is spinning around clockwise with their arms stretched out. Would the tangential velocity of their hands be positive or negative?

20. If a car on a circular track travels 160 m counterclockwise in 7 s, what was the average tangential velocity of the car in m/s?

21. 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?




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

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

24. 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?

25. A car is driving counterclockwise around a circular track. If the car increases its speed, is the car's tangential acceleration positive or negative?

26. A car is driving clockwise around a circular track. If the car slows down, is the car's tangential acceleration positive or negative?

27. 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?

28. 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?

## Level 2

29. 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?

30. 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?

31. 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?

32. 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?

33. 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 $m/s^2$ ?

34. 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?

35. 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 $m/s^2$. What is the car's position after 3 s of accelerating?

36. 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 $m/s^2$ for 6 s. If the person covers a circular distance of 30 m during that time period, what was the initial tangential velocity of the person?

37. 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 acceleration of the cyclist during that time?

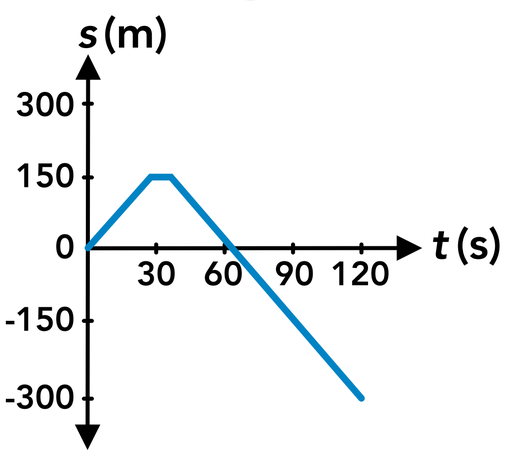
38. A car on a circular track is driving 16 m/s. When it passes the 30 m mark it accelerates at 5 $m/s^2$. What is the position of the car when it reaches a tangential velocity of 23 m/s?

39. 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?

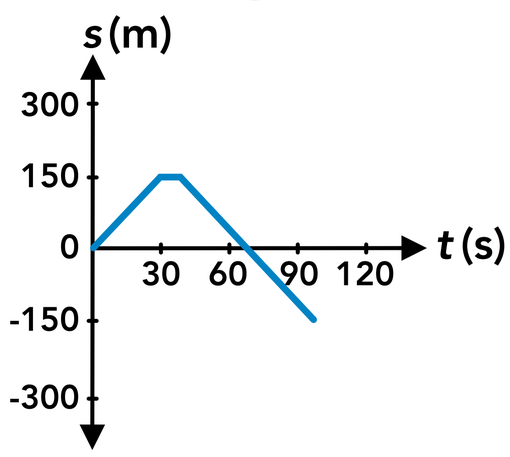
## Level 3

40. 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 of these graphs represents that motion of the skater?

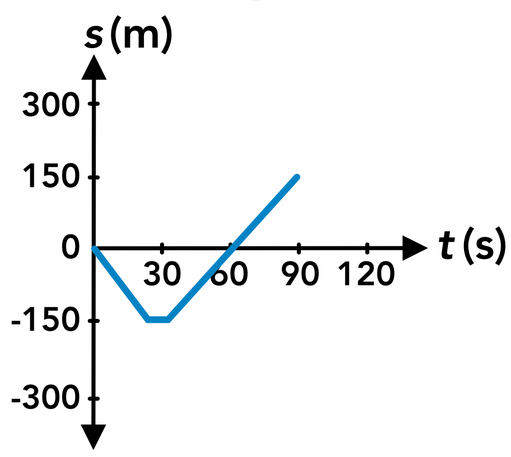
A



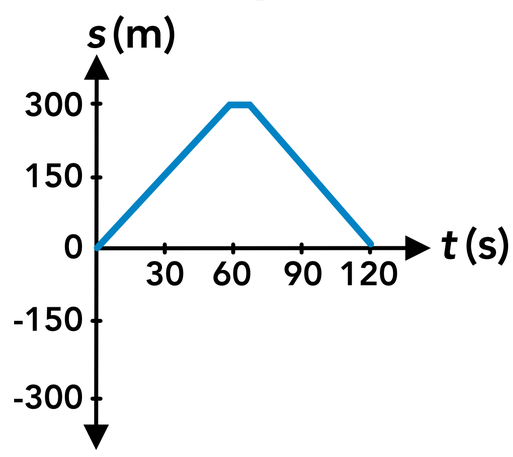

B




C

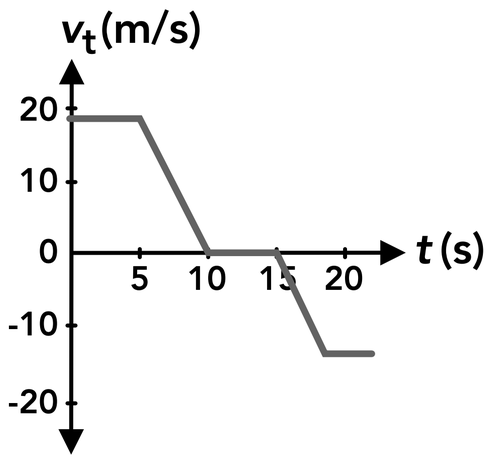



D

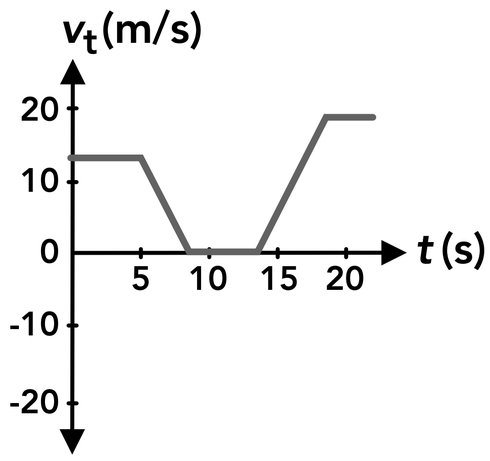


41. A car is driving clockwise around a circular track at a speed of 14 m/s when it slows down, stops, turns around, then accelerates to a speed of 19 m/s counterclockwise. Which of these graphs could represent the motion of the car?

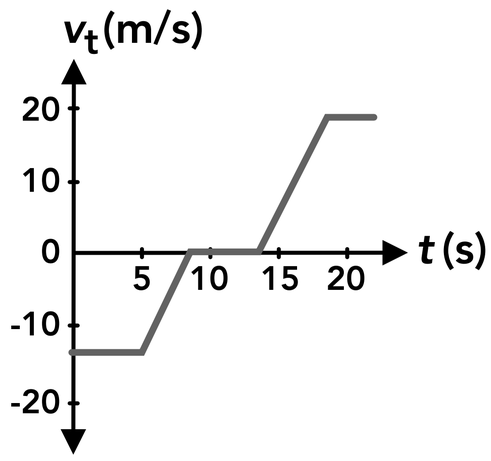
A



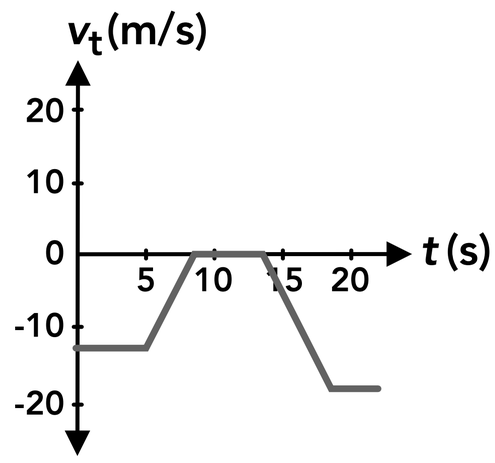

B



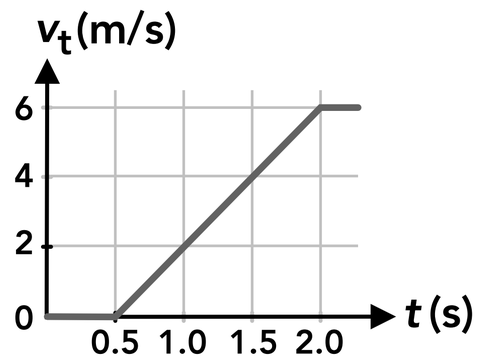

C




D




42. 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?




43. A circular race track has a radius of 0.04 km. A car starts from rest then accelerates at a constant 4 m/s². How long does it take the car to cover 1 lap?

44. The tip of a 1.2 m long helicopter blade is in circular motion with a tangential velocity of 25 m/s. The helicopter increases the speed of the blades in order to lift off, and the tips of the blades experience a tangential acceleration of 6 m/s² for a period of 5.2 s. During this period, how many revolutions does one blade experience?

45. 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/s². When the cyclist reaches the 50 m mark, what is the cyclist's tangential velocity in km/h?

46. A Ferris wheel car starts from rest. When the ride begins, the car experiences a tangential accleration of -0.2 m/s² 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)?

47. 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. 31.4 m
3. 3.8 m
4. C
5. Circular position: m  circular displacement: m  tangential velocity: m/s  tangential acceleration: m/s²
6. A, D
7. B, E
8. C, D
9. 1,571 m
10. 1.4 m/s
11. 200 m
12. 49,455 km
13. Positive
14. -220 m
15. -25 m
16. B
17. 0.54 km
18. 21 cm
19. Negative
20. 22.9 m/s
21. D
22. -1.4 m/s
23. 34.5 m
24. 5.7 s
25. Positive
26. Positive
27. 1.7 m/s²
28. -1.3 m/s²
29. 20 m
30. 87.2 km/h
31. 34 m
32. 45.7 km/h
33. 5.6 m/s²
34. 1.8 s
35. 22.5 m
36. 0.5 m/s
37. 2 m/s²
38. 57.3 m
39. -0.29 m/s²
40. B
41. C
42. 4 m/s²
43. 11.2 s
44. 28 rev
45. 45 km/h
46. 19.9 m
47. 109 km/h

PRACTICE PROBLEMS

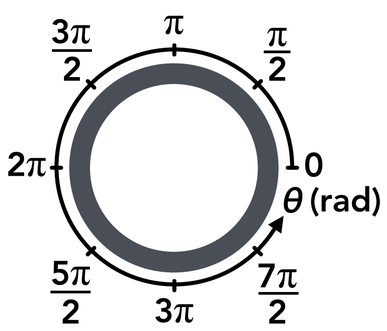
# ROTATIONAL MOTION

## Basics

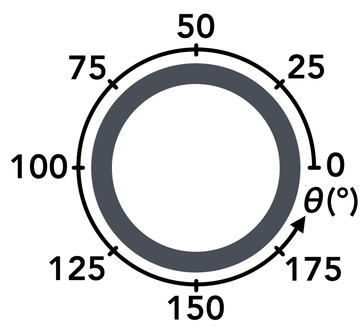
1. Which of the following are examples of an object in rotational motion? (Select all that apply)
   - A A CD spinning in a CD player (the CD)
   - B The knob on a door being opened or closed (the knob)
   - C A screw being tightened with a screwdriver (the screw)
   - D A person riding on a Ferris wheel (the person)

2. Which of these are valid axes? (Select all that apply)

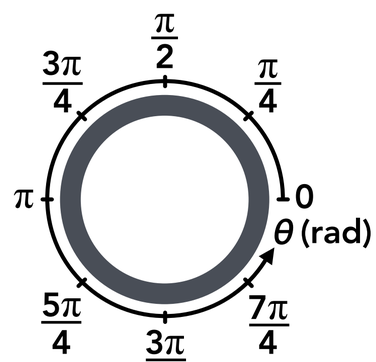
A



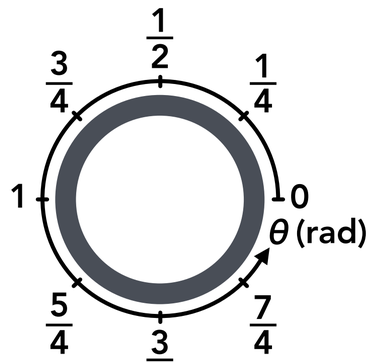

B



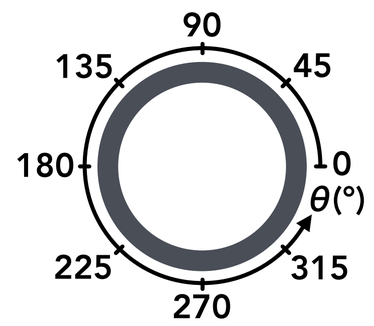

C




D




E




3. What are the SI units for each of the following: angular position, angular displacement, angular velocity, and angular acceleration?

4. Which of these would be valid units of angular position and displacement? (Select all that apply)
   - A rev
   - B rad/s
   - C m
   - D km
   - E deg

5. Which of these would be valid units of angular velocity? (Select all that apply)
   - A m/s
   - B rev/s
   - C km/h
   - D deg/s
   - E rpm

6. Which of these would be valid units of angular acceleration? (Select all that apply)
   - A $m/s^2$
   - B deg/s
   - C rpm/s
   - D $deg/s^2$
   - E km/h

7. If a bike wheel rotates 270° over a short period, how many radians does the wheel rotate?

8. A carousel at a local fair rotates at an angular velocity of 18 rad/s. What is the angular velocity in rpm?

9. If the Earth rotates once per day counterclockwise (as seen from a point above the North Pole), what is the angular velocity of the Earth in rad/s?

10. When a blender is turned on, the blades inside experience an angular acceleration of 20 $rev/s^2$. What is the angular acceleration in $rad/s^2$ ?

## Level 1

11. If the solid black line on the spinning CD to the right rotates 270°, how many degrees does the dotted black line rotate in the same amount of time?

12. A wrench is used to tighten a bolt clockwise 3 revolutions. Is the angular displacement of the bolt positive or negative?

13. 1 - If a door starts at an angular position of -15° and rotates clockwise 45°, what is the final angular position?

14. The drum in a washing machine starts at an angular position of $3\pi/2$ rad and rotates counterclockwise 2.5 revolutions. What is the final angular position of the drum in radians?

15. An olympic diver jumps and begins flipping through the air. During a short period of time, an observer sees the diver rotate from an angular position of 115° to a position of -80°. What was the angular displacement of the diver based on that point of view?

16. A football is passed down the field with some spin added to it. From one perspective, if the ball is spinning counterclockwise, is the angular velocity of the ball positive or negative?

17. What is the angular speed of the hour, minute, and second hands on a clock (a 12-hour clock) in rpm?

18. If a vinyl record rotates 700° in the clockwise direction in 3.5 s, what is the angular velocity of the record in deg/s?

19. An art student is using a potter's wheel to make a vase. Over a period of 0.5 s, the potter's wheel rotates from an angular position of $-\pi/2$ radians to a position of $3\pi/2$ radians. What is the angular velocity of the wheel in rad/s?

20. If a Ferris wheel is currently at an angular position of $\pi/8$ rad and rotating at a constant angular velocity of $-\pi/60$ rad/s, how long does it take for the Ferris wheel to reach an angular position of $-4\pi/3$ rad?

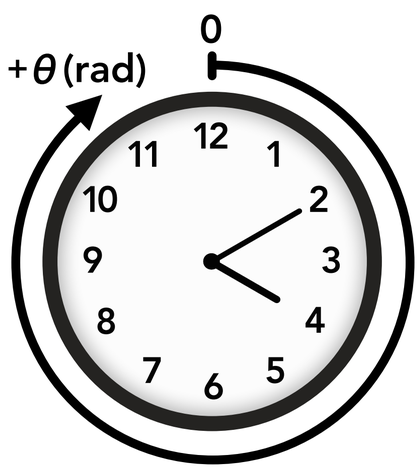
21. At the start of a drag race with spectators on both sides of the track, 2 cars accelerate forward at the same time. For the spectators who see the cars driving to the left, is the angular acceleration of the wheels positive or negative? For the spectators on the other side of the track, is the angular acceleration of the wheels positive or negative?

22. A lab centrifuge spinning counterclockwise at 100 rad/s has its speed turned up. If it takes 8 s to reach an angular speed of 500 rad/s, what was the angular acceleration of the centrifuge?

23. A cyclist is stopped on a hill. The moment they release the brakes, the bike accelerates down the hill and the wheels experience an angular acceleration of 1.5 rad/s². After 4 s, what is the angular speed of the wheels in rad/s?

## Level 2

24. If we overlay a circular axis on clock as seen to the right, what would be the angular positions of the hour hand at the following times, in radians: 3:00, 6:30, 10:45 ?



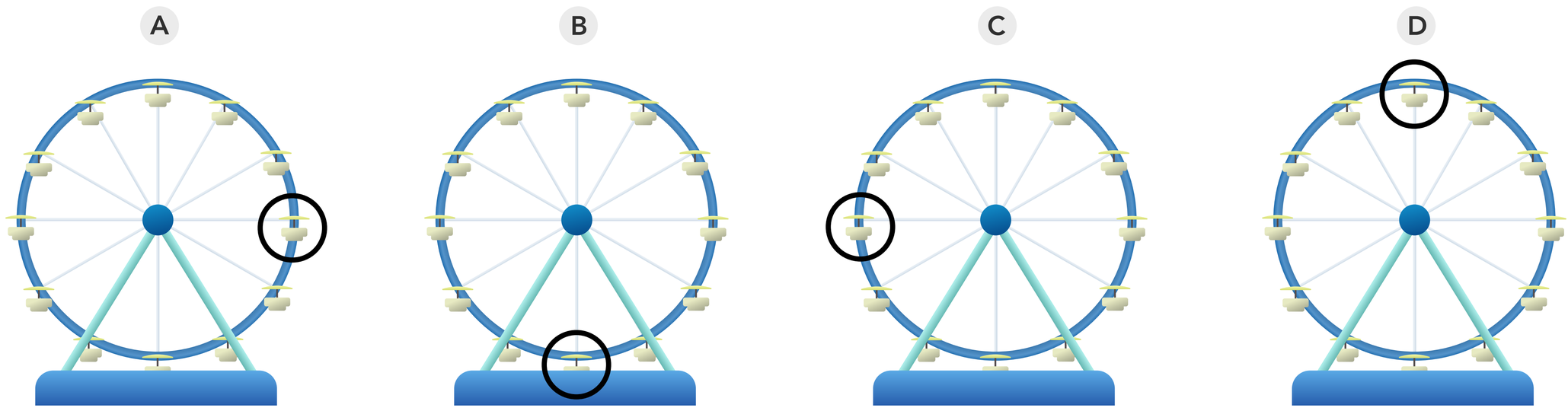

25. A carousel ride starts at an angular position of 270° and rotates clockwise $5.5\pi$ radians. What is the final angular position of the carousel in deg?

26. If a wheel rotates $500\pi$ rad in the counterclockwise direction in 4 min, what was the average angular velocity of the wheel in deg/s?

27. What is the angular speed of the hour, minute, and second hands on a clock (a 12-hour clock) in rad/s?

28. A vinyl record is spinning at 33 1/3 rpm. How many seconds does it take for the record to rotate $3\pi$ radians?

29. You're watching your friend on a Ferris wheel which is rotating clockwise at a constant 1.5 rpm. When you look away, your friend is at the top of the Ferris wheel. When you look back 30 sec later, where is your friend?




30. You're in the mood to listen to some music. You pick an album, and when you turn on your record player the record (starting from rest) takes 2 s to speed up to an angular velocity of 45 rpm clockwise. What was the angular acceleration of the record during that period in rad/s² ?

31. After a few seconds of listening to the record you start to wonder why the singer's voice is a higher pitch than you remember. You suddenly realize the record is supposed to be played at 33 1/3 rpm, so you press the button for that speed. If it takes 0.6 s for the record to change from 45 rpm to 33 1/3 rpm (both clockwise), what is the angular accleration of the record during that time in rad/s² ?

32. When the first side of the record is finished playing, you hit "Stop" the record that was spinning at 33 1/3 rpm clockwise comes to a stop in 1.5 s. What was the angular acceleration of the record during that time in rad/s² ?

33. If a lab centrifuge starts from rest at an angular position of 0 deg and accelerates counterclockwise at 200 deg/s², what is the final angular position in deg after 3.5 s, in deg?

34. The operator of a carousel ride that is spinning counterclockwise decides to increase the speed. Over a period of 6 s the ride accelerates at 1.5 rad/s² and rotates through an angular displacement of 35 rad during that time. What was the initial angular velocity of the ride?

35. The axle connected to the front wheels of a car is spinning at a constant 400 rpm as the car drives forwards. The car then accelerates and the axle experiences a constant angular acceleration. After a period of 4 s the axle has turned 50 revolutions since the car began accelerating. What was the angular acceleration of the axle in rev/s² during that time?

36. A vinyl record starts from rest and then accelerates, reaching an angular velocity of -3.5 rad/s while rotating through an angular displacement of -10 rad. What was the angular acceleration of the record?

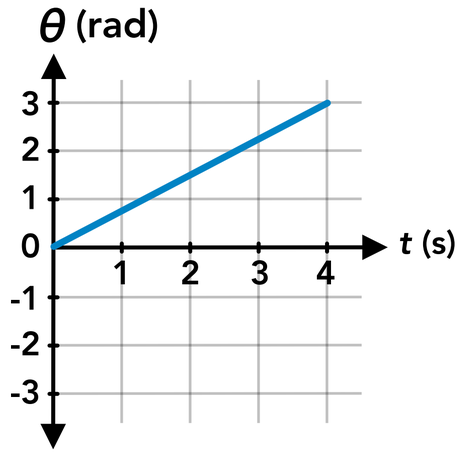
37. A CD is spinning counterclockwise at 20 rad/s and then the CD accelerates at a constant 8 rad/s². From the moment the CD begins to accelerate, how many radians does the CD rotate by the time it reaches an angular velocity of 50 rad/s?

38. The wheels on a bike are spinning at 6.3 rad/s counterclockwise as seen by an observer. When the rider hits the brakes, the wheels experience a constant angular acceleration and rotate 25 rad as the bike and wheels come to a full stop. What was the angular acceleration of the wheels as seen by the observer?

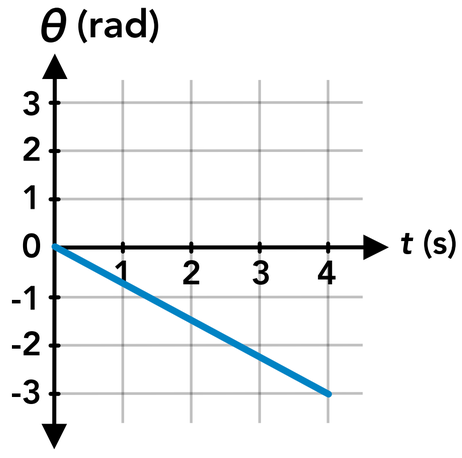
## Level 3

39. A vinyl record is spinning at a constant 45 rpm clockwise. Which of these graphs could represent its motion?

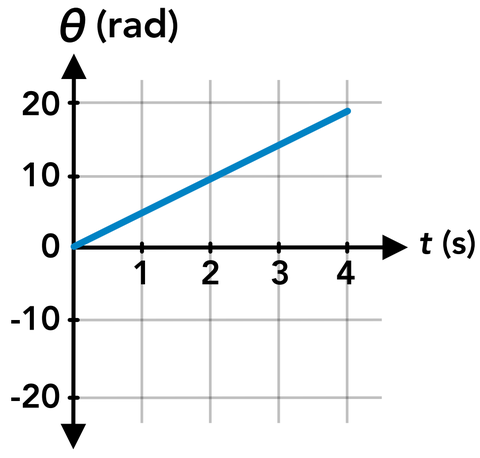
A



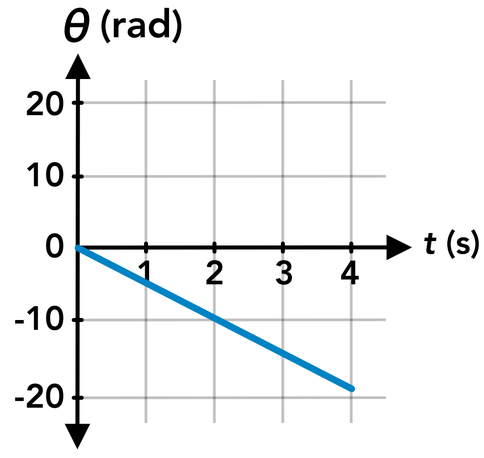

B




C

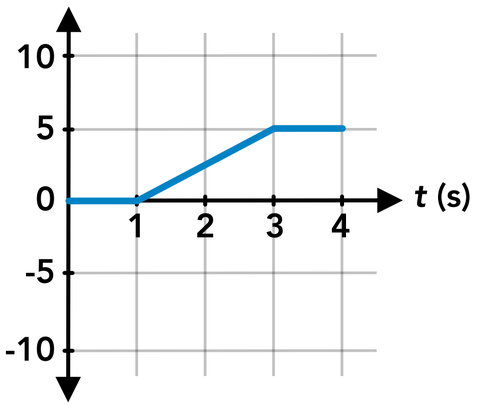



D

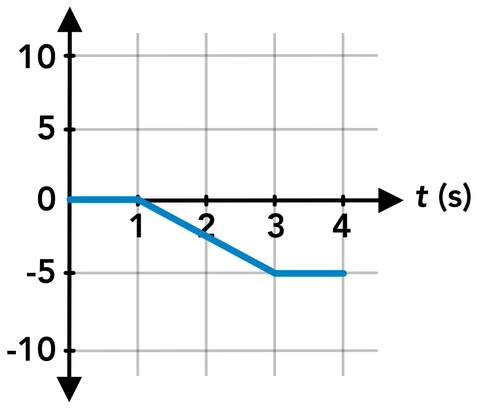



40. A vinyl record starts from rest and accelerates clockwise at 2.5 rad/s² for 2 s, then maintains its speed. Which of these graphs could represent its motion?

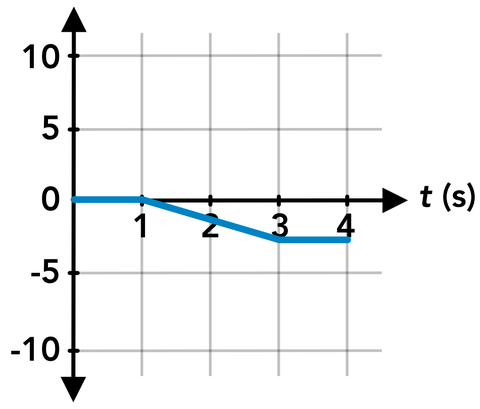
A



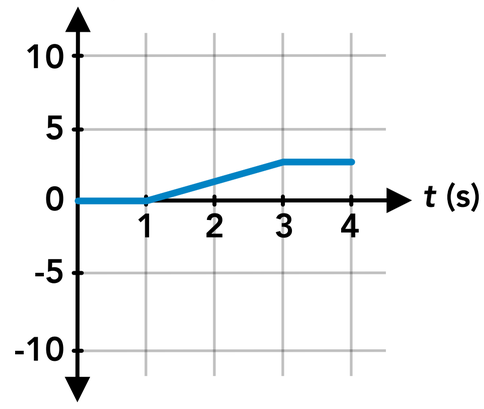

B




C

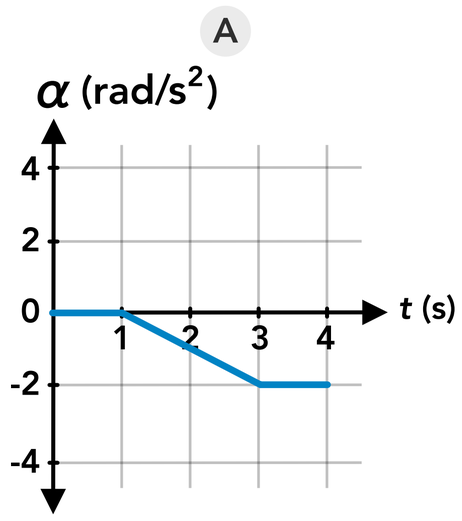



D

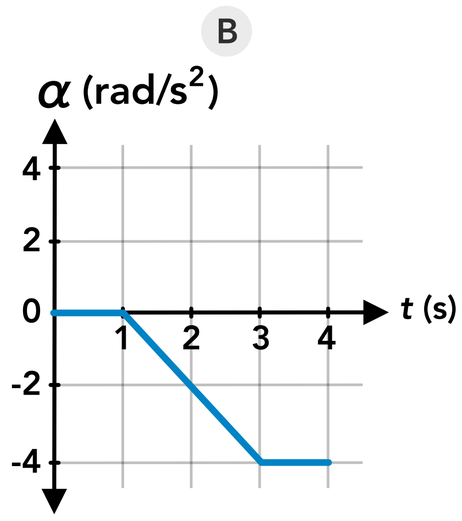



41. A vinyl record starts from rest and accelerates clockwise for 2 s, reaching a final angular velocity of -4 rad/s. Which of these graphs could represent its motion?

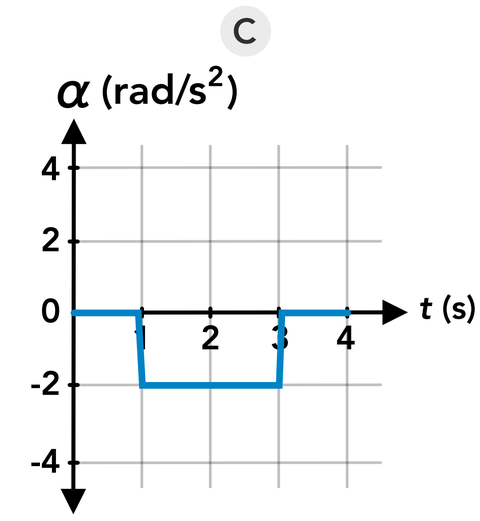
A



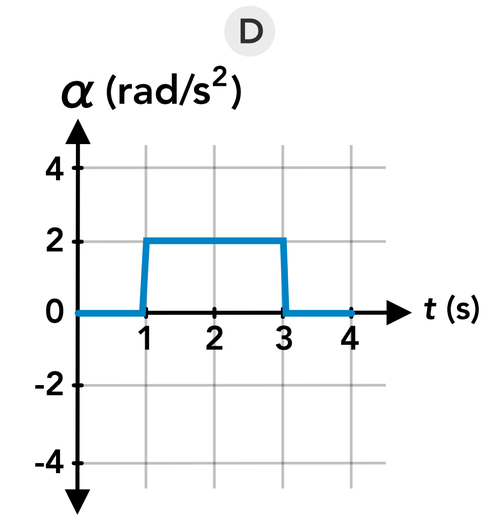

B




C




D




42. When a ceiling fan is turned on, it accelerates (from rest) at a constant 3 rad/s². How long does it take the fan to rotate 10 revolutions?

43. A ceiling fan is spinning counterclockwise at a constant speed. The fan is turned off and experiences an angular acceleration of -2 rad/s². During the 8 s it takes the fan to come to a stop, the fan turns 7 revolutions. What was the initial angular speed of the fan, in rpm?

44. A wheel on a car is spinning at 840 rpm. The car accelerates, and the wheel experiences an angular acceleration for 3 s. If the wheel rotates 50 revolutions during that period of time, what is the angular velocity of the wheel after those 3 s, in rpm?

45. An amusement park ride is turning at 2 rad/s clockwise when the operator hits a button. The ride slows down to a stop, then reverses direction and accelerates to an angular velocity of 3 rad/s counterclockwise. If the magnitude of the angular acceleration was 0.5 rad/s² both when the ride slowed down and sped up, what was the total angular displacement of the ride (in rad) between the moment the operator hit the button and the moment the ride reached 3 rad/s counterclockwise?

## Answers

1. A, C
2. C, E
3. Angular position: rad  angular displacement: rad  angular velocity: rad/s  angular acceleration: rad/s²
4. A, E
5. B, D, E
6. C, D
7. 3π/2 rad (4.7 rad)
8. 171.9 rpm
9. 7.27 x $10^{-5}$ rad/s
10. 40π rad (125.7 rad)
11. 270°
12. Negative
13. -60°
14. 6.5π rad, or 13π/2 rad, or 20.4 rad
15. -195°
16. Positive
17. Hour hand: 1/720 rpm  minute hand: 1/60 rpm  second hand: 1 rpm
18. -200 deg/s
19. 4π rad/s, or 12.6 rad/s
20. 87.5 s
21. Positive, negative
22. 50 rad/s²
23. 6 rad/s
24. 3:00 = π/2 rad  6:30 = 13π/12 rad  10:45 = 43π/24 rad
25. -720°
26. 375 deg/s
27. Hour hand: π/21,600 rad/s  minute hand: π/1,800 rad/s  second hand: π/30 rad/s
28. 2.7 s
29. C
30. -2.4 rad/s²
31. 2.0 rad/s²
32. 2.3 rad/s²
33. 1,225°
34. 1.3 rad/s
35. 2.9 rev/s²
36. -0.6 rad/s²
37. 131.3 rad
38. -0.8 rad/s²
39. D
40. B
41. C
42. 6.5 s
43. 128.9 rpm
44. 1160 rpm
45. 5 rad

PRACTICE PROBLEMS

# TANGENTIAL & ANGULAR DESCRIPTIONS

## Basics

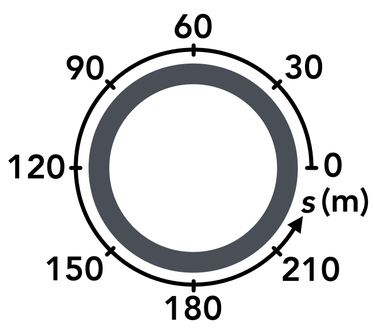
1. 1 revolution is associated with: (Select all that apply)

   A 1 circumference  B 180°  C $2\pi$ radians  D 360°  E $\pi$ radians

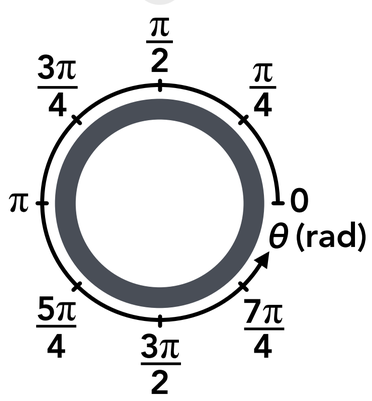
2. If the circumference of a circle is 20 m, what is the radius?

3. Which of the following axes represent the tangential description of motion? (Select all that apply)

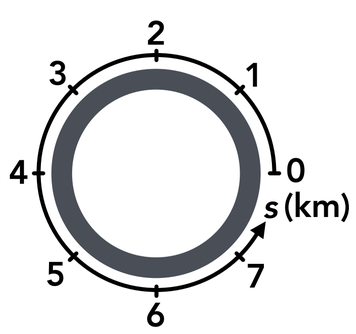
A



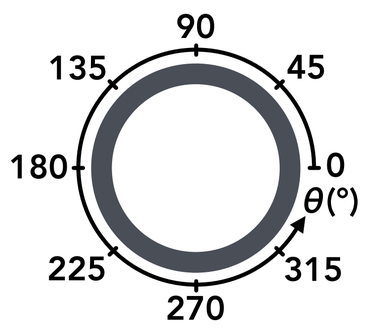

B




C

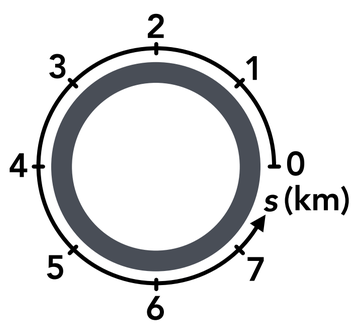



D

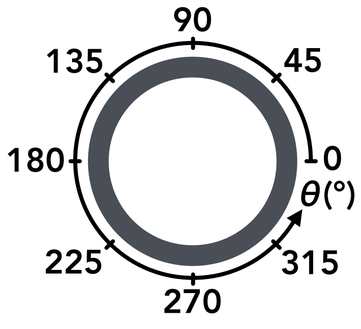



4. Which of the following axes represent the angular description of motion? (Select all that apply)

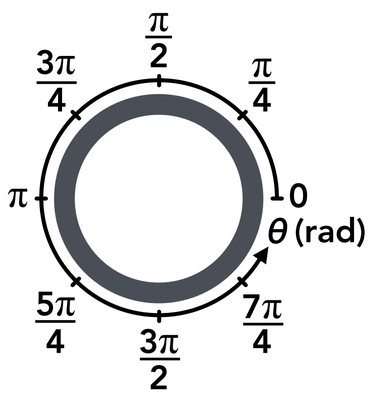
A



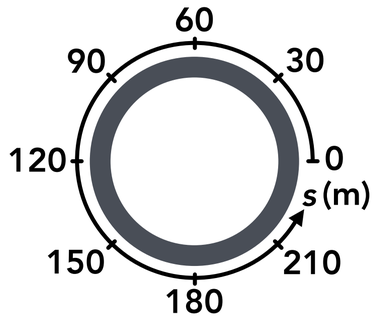

B



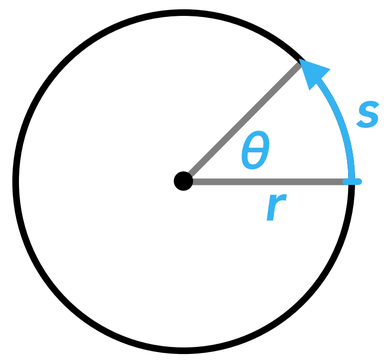

C




D




5. In the circle shown to the right:
   What would be the arc length $s$, given $\theta = \pi/4$ rad and $r = 5$ m?
   What would be the angle $\theta$, given $s = 2$ m and $r = 2.5$ m?
   What would be the radius $r$, given $\theta = \pi/3$ rad and $s = 12$ m?




## Level 1

6. On a circular race track with a diameter of 20 m, what is the angular position (in rad) associated with the a tangential position of 16 m?

7. On a circular race track, a tangential position of 30 m corresponds to an angular position of 120°. What is the radius of the track?

8. The handle on a door is 0.7 m from the door hinge. When the door is opened, if the handle moves an arc length of 0.9 m, what is the angular displacement of the door in deg?

9. A fly is sitting on a ceiling fan blade, 0.4 m from the center of rotation of the fan. If the tangential velocity of the fly is -8 m/s, what is the angular velocity of the fan in rad/s?

10. A small rock gets stuck in the outer edge of a car's tire, which is 0.6 m in diameter. If the angular velocity of the wheel is 6 rad/s, what is the tangential velocity of the rock (from the tire's rotation, ignoring the car's motion)?

11. A car is driving on a circular track with a tangential velocity of 18 m/s. If the angular velocity swept out by the car is 1.5 rad/s, what is the radius of the track?

12. A fly is sitting on a vinyl record when the "Start" button is pushed and the record accelerates at 2 rad/s². If the fly experiences a tangential acceleration of 0.2 m/s², how far is the fly from the center of the record?

13. An athlete performs a hammer throw by spinning around while holding a wire with a metal ball at the end, speeding up and eventually releasing the ball. If the ball is 1.5 m from the athlete's center of rotation and their angular acceleration is 4 rad/s², what is the tangential acceleration of the ball?

14. A person riding 3.5 m from the center of a carousel experiences a tangential acceleration of 2 m/s², what is the carousel's angular acceleration in rad/s² ?

## Level 2

15. A person is on an amusement park ride that rotates so that the riders follow a circular path with a diameter of 6 m. The ride begins and turns 12 revolutions clockwise, then stops and turns 7 revolutions counterclockwise, then stops and turns 4 revolutions clockwise. What is the tangential displacement of a person from the beginning to the end of the ride, in m?

16. While a 30 cm diameter record is playing, a fly sitting on the outer edge of the record covers a tangential displacement of -35.7 m during a song. How many revolutions did the record turn during the song?

17. While tightening a bolt, a wrench rotates from an angular position of $2\pi/3$ rad to $\pi/3$ rad. What was the tangential displacement, in cm, of a point on the wrench that is 15 cm away from the bolt?

18. A figure skater spins around with their arms stretched out and their hands 0.8 m from their center of rotation. If the tangential velocity of their hands is 17 m/s, what is the angular velocity of the skater in rpm?

19. If the hands on a clock (a 12-hour clock) are all 12 cm long, what is the tangential speed of a point on the tip of the hour, minute, and second hands in mm/s?

20. Two flies are sitting on a spinning record at different spots but the same distance from the edge of the record. Which of the following is true about the motion of the flies?

    A They have the same tangential speed and the same angular speed
    B They have the same tangential speed but different angular speeds
    C They have different tangential speeds but the same angular speed
    D They have different tangential speeds and different angular speeds

21. If a 22 m diameter Ferris wheel is spinning at 5 rpm, what is the tangential displacement of a rider over 30 s?

22. Two cars are driving around the same, large circular track that only has one lane. If Car A has a higher tangential velocity than Car B, how are their angular velocities related?

    A Car A > Car B
    B Car A = Car B
    C Car A < Car B

23. A rider on a roller coaster travels through a circular loop with a radius of 9 m, slowing down as they move higher in the loop. If the tangential acceleration of the rider is -7 m/s², what is their angular acceleration in rad/s² ?

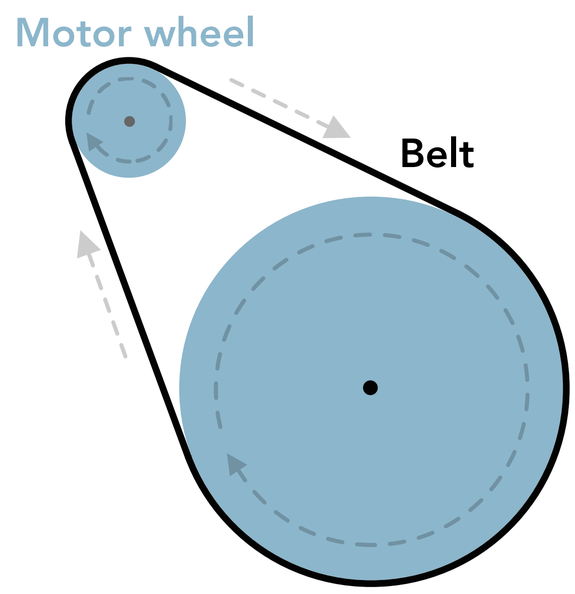
24. A pole vaulter runs and plants the end of the 5 m long pole in the ground, propelling them upwards along a circular path with an initial tangential velocity of 8 m/s. When the pole vaulter reaches the peak 1.8 s later, their tangential velocity is 5 m/s. What was the angular acceleration of the pole, in rad/s² (assuming it was constant)?

## Level 3

25. Two people are riding on a large carousel. Person A is 6 m from the center and person B is 8 m from the center. If person A experiences a tangential displacement of 50 m during a period of time, what is the tangential displacement of person B during that time?

26. Car A is on a circular track with a radius of 0.6 km, and car B is on a circular track with a different radius. During a period of time, car A and car B both drive the same angular displacement. If car A travelled a tangential displacement of 1.4 km, and car B travelled a displacement of 1.8 km, what is the radius of car B's track in km?

27. A belt-driven record player like the one shown to the right (not drawn to scale) has a rubber belt wrapped around the outside of a motor wheel and the outside of the platter (a spinning plate that the record sits on while playing). As the motor wheel spins it drives the belt which turns the platter and record. If the diameter of the motor wheel is 22 mm and the diameter of the platter is 330 mm, how many times does the motor wheel have to turn to get the platter to rotate once? (Consider the way in which the belt relates the motion of the motor wheel and platter, without slipping).




28. Many belt-driven record players like the one shown above allow you to play records at two different speeds: 33 1/3 rpm and 45 rpm. Two motor wheels, which have different diameters, are stacked on top of each other and are connected to the same motor shaft. The motor always spins at the same speed, but wrapping the belt around one motor wheel or the other changes the speed of the belt and the platter. On this record player, the platter has a diameter of 330 mm, and the motor wheel used to spin the platter at 33 1/3 rpm has a diameter of 22 mm. What is the diameter of the motor wheel used to spin the platter at 45 rpm?

29. The International Space Station (ISS) is in a circular orbit around the Earth. It takes 92.5 minutes for the ISS to circle the Earth and complete 1 orbit. If the diameter of the Earth is 12,742 km (assuming it's a sphere) and the tangential speed of the ISS is 7.66 km/s, how high is the ISS above the ground, in km?

30. Two flies are sitting on the same spinning record. Fly A is 6 cm from the center and fly B is 14 cm from the center. If fly A travels a tangential displacement of 44 cm in 2.1 s, how many cm does fly B travel in 3.6 s?

31. While a bike (or anything with wheels) is moving, the tangential speed of the very outer edge of the tire matches the speed of the ground passing under the tire, assuming the tire is contacting the ground without slipping. That is also the same speed that the bike itself is moving forwards. If a bike with 66 cm diameter tires is traveling at 20 km/h, what is the angular speed of the wheels in rpm?

32. Two cars are on a circular track with 2 lanes. Car A follows the outside lane, a circular path with a radius of 100 m and car B follows the inside lane, a circular path with a radius of 95 m. The cars remain side by side as they drive around the track. If car A is travelling at a tangential speed of 65 km/h, what is car B's tangential speed in km/h?

33. You're using a medieval slingshot, which involves swinging around a length of string with a rock in a pouch at the end. At first you swing the rock around in a circle with a tangential speed of 25 m/s, but then decide it's a little too fast and slow it down to a tangential speed of 16 m/s over the course of 3 s. If the angular acceleration of the rock and string was -1.5 rad/s² during that time, what is the total length of the string and your arm (how far is the rock from the center of rotation)?

34. A car gets a small rock stuck in a tire while driving, which is 21 cm from the center of the wheel. The car is stopped at an intersection, and when the light turns green the car accelerates and the wheels speed up to 450 rpm in 4 s. What is the tangential acceleration of the rock during that period in cm/s² ?

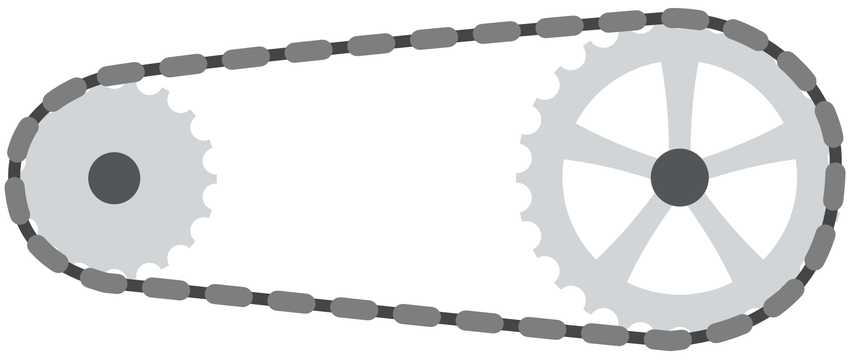
35. A bolt on a wind turbine blade (bolt A) is some distance from the center of rotation, and another bolt (bolt B) is twice as far from the center as bolt A. The wind suddenly increases and the wind turbine experiences an angular acceleration. If bolt B experiences a tangential acceleration of 12 m/s², what is the tangential acceleration of bolt A?

36. A race car on a 0.6 km diameter circular track is going 50 km/h. When the car is 80 m from the finish line, the driver speeds up such that the car's angular acceleration around the track is a constant 0.01 rad/s². From the moment the car began accelerating, how long did it take to cross the finish line?

37. A vial spinning in a lab centrifuge is 12 cm from the center of rotation. The technician sets the centrifuge to a higher speed, and the vial experiences a tangential acceleration of 2 m/s². During the 4 s it takes to go from one speed to the next, the centrifuge rotates 40 times. What was the original, slower angular speed of the centrifuge in rpm?

38. On a hot summer day, you walk over and turn up the speed of your ceiling fan from 200 rpm to 300 rpm. During the period of time that the fan is increasing in speed, a fly sitting 75 cm from the fan's center of rotation travels a tangential displacement of 15 m. What was the angular acceleration of the fan during that time?

39. As shown below, the chain on a bicycle wraps around the outside of a 18 cm diameter pedal sprocket (a circular metal plate with teeth that mesh with the chain) which is connected to the same shaft as the pedals. The chain also wraps around a 10 cm diameter rear wheel sprocket which is connected to the same axle as the rear wheel. When the cyclist begins pedaling, the sprockets and chain turn the rear wheel, moving the bike. The cyclist starts from rest and then accelerates for 6 s, after which the pedal sprocket is turning at 40 rpm. How many rotations does the rear wheel sprocket complete during those 6 s?



## Answers

1. A, C, D
2. 3.2 m
3. A, C
4. B, C
5. $s$ = 3.9 m $\theta$ = 0.8 m $r$ = 11.5 m
6. 1.6 rad
7. 14.3 m
8. 73.7°
9. -20 rad/s
10. 1.8 m/s
11. 12 m
12. 0.1 m
13. 6 m/s²
14. 0.6 rad/s²
15. -169.6 m
16. -37.9 rev
17. -15.7 cm
18. 202.9 rpm
19. Hour hand: 0.017 mm/s minute hand: 0.21 mm/s second hand: 12.6 mm/s
20. A
21. 172.8 m
22. A
23. -0.8 rad/s²
24. -0.3 rad/s²
25. 66.7 m
26. 0.8 km
27. 15 rev
28. 29.7 mm
29. 395 km
30. 175.9 cm
31. 160.8 rpm
32. 61.8 km/h
33. 2 m
34. 247.4 cm/s²
35. 6 m/s²
36. 4.0 s
37. 281.7 rpm
38. 13.7 rad/s²
39. 3.6 rev