EOT – Grade 11 Adv
Plan C

Ms. Asmaa Alhameed

MCQ

Question 1-15

as per the EOT

(1) Define the center of mass as the point at which all the mass of an object appears to be concentrated. (2) Recall that center of gravity is equivalent to center of mass in situations where the gravitational force is constant everywhere throughout the object.	Student Book (S.B)	226

Definition

The **center of mass** is the point at which we can imagine all the mass of an object to be concentrated.

Thus, the center of mass is also the point at which we can imagine the force of gravity acting on the entire object to be concentrated. If we can imagine all of the mass to be concentrated at this point when calculating the force due to gravity, it is legitimate to call this point the *center of gravity*, a term that can often be used interchangeably with *center of mass*. (To be precise, we should note that these two terms are only equivalent in situations where the gravitational force is constant everywhere throughout the object. In Chapter 12, we will see that this is not the case for very large objects.)

2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure **8.2** Concept Check **8.1**	**227**

$$\vec{R} = \frac{\vec{r}_1 m_1 + \vec{r}_2 m_2}{m_1 + m_2}.$$

$$X = \frac{x_1 m_1 + x_2 m_2}{m_1 + m_2}, \quad Y = \frac{y_1 m_1 + y_2 m_2}{m_1 + m_2}, \quad Z = \frac{z_1 m_1 + z_2 m_2}{m_1 + m_2}.$$

2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure **8.2** Concept Check **8.1**	**227**

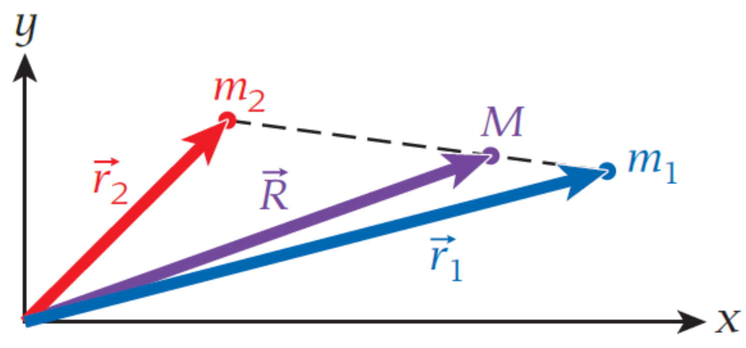


FIGURE 8.2 Location of the center of mass for a system of two masses m_1 and m_2, where $M = m_1 + m_2$.

Concept Check 8.1

In the case shown in Figure 8.2, what are the relative magnitudes of the two masses m_1 and m_2?

a) $m_1 < m_2$

b) $m_1 > m_2$

c) $m_1 = m_2$

d) Based solely on the information given in the figure, it is not possible to decide which of the two masses is larger.

2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure 8.2 Concept Check 8.1	227

سؤال وزاري سابق

"A Point where all weight of object acts", what is this point called?

"نقطة على الجسم ترتكز فيها كتلة هذا الجسم كلها"، ماذا تسمى هذه النقطة؟

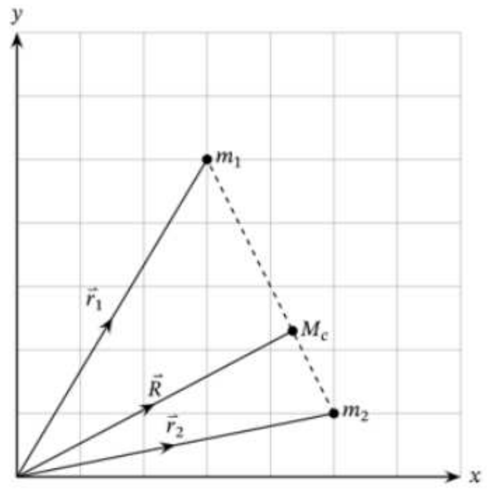
- center of mass
  مركز الكتلة
- center of field
  مركز المجال
- central point
  النقطة المركزية
- equivalence point
  نقطة التعادل

2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure 8.2 Concept Check 8.1	227

سؤال وزاري سابق

Based on the graph below that shows the center of mass of two masses m_1 and m_2, what are the relative magnitudes of the two masses m_1 and m_2?

بناء على الرسم البياني الذي يوضح موقع مركز الكتلة لنظام مكون من كتلتين m_1 و m_2، ما المقادير النسبية للكتلتين m_1 و m_2؟



$m_1 < m_2$

$m_1 > m_2$

$m_1 = m_2$

it is not possible to decide which of the two masses is larger.
لا يمكن تحديد أي الكتلتين أكبر

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

During an object's **circular motion,** its *x*- and *y*-coordinates change continuously, but the distance from the object to the center of the circular path stays the same. We can take advantage of this fact by using **polar coordinates** to study circular motion. Shown in Figure 9.3 is the position vector, $\vec{r}$, of an object in circular motion. This vector changes as a function of time, but its tip always moves on the circumference of a circle. We can specify $\vec{r}$ by giving its *x*- and *y*-components. However, we can specify the same vector by giving two other numbers: the angle of $\vec{r}$ relative to the *x*-axis, θ, and the length of $\vec{r}$, $r = |\vec{r}|$ (Figure 9.3).

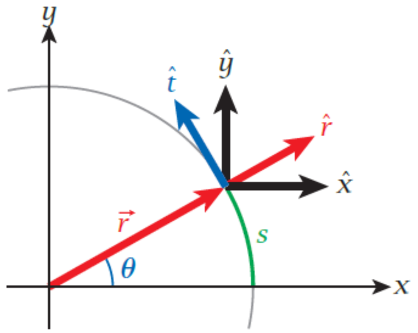


FIGURE 9.3 Polar coordinate system for circular motion.

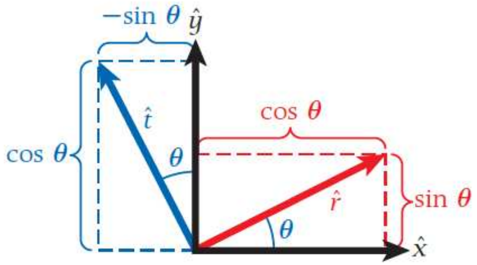


FIGURE 9.4 Relationship between the radial and tangential unit vectors shown in Figure 9.3, the Cartesian unit vectors, and the sine and cosine of the angle.

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

Trigonometry provides the relationship between the Cartesian coordinates x and y and the polar coordinates θ and r:

$$r = \sqrt{x^2 + y^2} \tag{9.1}$$

$$\theta = \tan^{-1}(y/x). \tag{9.2}$$

The inverse transformation from polar to Cartesian coordinates is given by

$$x = r\cos\theta \tag{9.3}$$

$$y = r\sin\theta. \tag{9.4}$$

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

EXAMPLE 9.1 Locating a Point with Cartesian and Polar Coordinates

A point has a location given in Cartesian coordinates as (4,3), as shown in Figure 9.5.

PROBLEM

How do we represent the position of this point in polar coordinates?

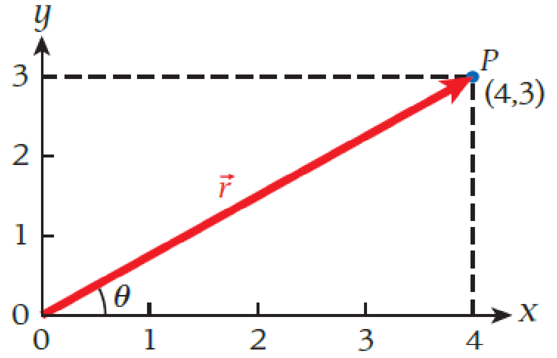


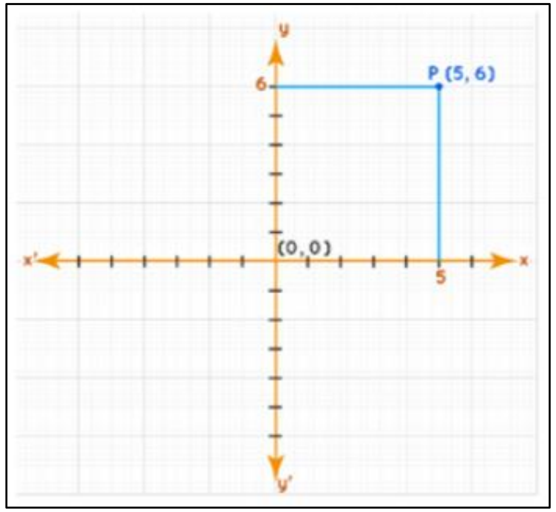
FIGURE 9.5 A point located at (4,3) in a Cartesian coordinate system.

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

سؤال وزاري سابق

A point P has a location given in Cartesian coordinates as shown in the graph below, how to represent point P in polar coordinates?

يحدد موقع النقطة P بالإحداثيات الديكارتية كما هو موضح بالرسم البياني أدناه، كيف يمكن تمثيل موقع P بالإحداثيات القطبية؟



(7.8, 0.88 rad)

(7.8, 50.2 rad)

(7.8, 0.7 rad)

(7.8, 40 rad)

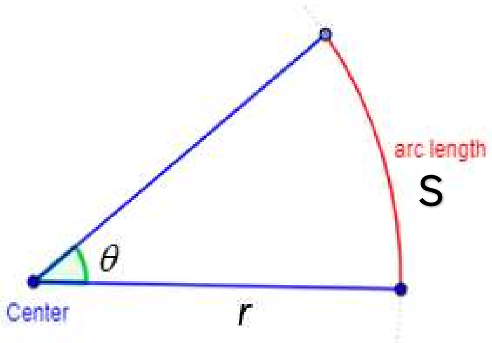
4.	Relate the arc length (s), to the radius (r) of the circular path and the angle (θ), measured in radians.	S.B/Figure 9.3 Student Book (S.B)	255 257

Arc Length

Figure 9.3 also shows (in green) the path on the circumference of the circle traveled by the tip of the vector $\vec{r}$ in going from an angle of zero to θ. This path is called the *arc length*, *s*. It is related to the radius and angle via

$$s = r\theta. \quad (9.7)$$

For this relationship to work out numerically, the angle has to be measured in radians. The fact that the circumference of a circle is $2\pi r$ is a special case of equation 9.7 with $\theta = 2\pi$ rad, corresponding to one full turn around the circle. The arc length has the same unit as the radius.



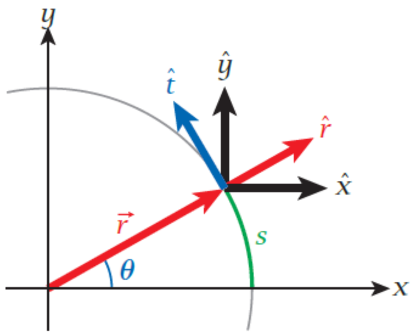
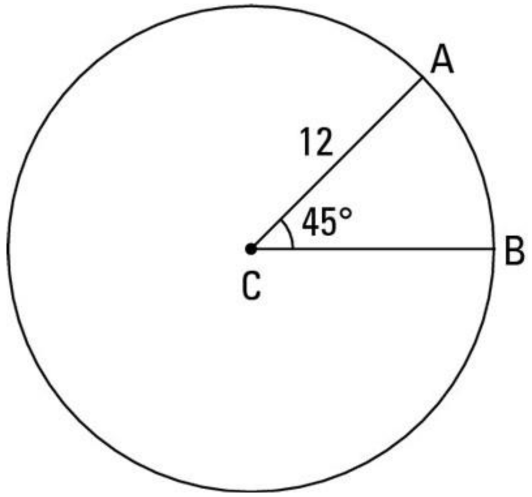


FIGURE 9.3 Polar coordinate system for circular motion.

4.	Relate the arc length (s), to the radius (r) of the circular path and the angle (θ), measured in radians.	S.B/Figure 9.3 Student Book (S.B)	255 257

Practice: Find the arc length of the following circle with a radius of 12 cm.



4.	Relate the arc length (s), to the radius (r) of the circular path and the angle (θ), measured in radians.	S.B/Figure **9.3** Student Book (S.B)	**255** **257**

What is the angle of rotation (in degrees) between two hands of a clock, if the radius of the clock is $0.70\ \mathrm{m}$ and the arc length separating the two hands is $1.0\ \mathrm{m}$?

a. 40°
b. 80°
c. 81°
d. 163°

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises/Q. 9.61.(*a*)	260 282

We have seen that the change of an object's linear coordinates in time is its velocity. Similarly, the change of an object's angular coordinate in time is its **angular velocity.** The average magnitude of the angular velocity is defined as

$$\bar{\omega} = \frac{\theta_2 - \theta_1}{t_2 - t_1} = \frac{\Delta\theta}{\Delta t}.$$

Angular velocity measures how fast the angle θ changes in time. Another quantity also specifies how fast this angle changes in time–the **frequency,** f. For example, the rpm number on the tachometer in your car indicates how many times per minute the engine cycles and thus specifies the frequency of engine revolution. Figure 9.9 shows a tachometer, with the units specified as "1/min × 1000"; the engine hits the red line at 6000 revolutions per minute. Thus, the frequency, f, measures cycles per unit time, instead of radians per unit time as the angular velocity does. The frequency is related to the magnitude of the angular velocity, ω, by

$$f = \frac{\omega}{2\pi} \Leftrightarrow \omega = 2\pi f. \qquad (9.9)$$

This relationship makes sense because one complete turn around a circle requires an angle change of 2π rad. (Be careful–both frequency and angular velocity have the same unit of inverse seconds and can be easily confused.)

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises/Q. 9.61.(*a*)	260 282

Because the unit inverse second is used so widely, it was given its own name, the **hertz** (Hz), for the German physicist Heinrich Rudolf Hertz (1857–1894): 1 Hz = 1 s^{-1}. The **period of rotation,** T, is defined as the inverse of the frequency:

$$T = \frac{1}{f}. \quad (9.10)$$

The period measures the time interval between two successive instances where the angle has the same value; that is, the time it takes to pass once around the circle. The unit of the period is the same as that of time, the second (s). Given the relationships between period and frequency and between frequency and angular velocity, we also obtain

$$\omega = 2\pi f = \frac{2\pi}{T}. \quad (9.11)$$

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises/Q. 9.61.(a)	260 282

EXAMPLE 9.3 Revolution and Rotation of the Earth

PROBLEM

The Earth orbits around the Sun and also rotates on its pole-to-pole axis. What are the angular velocities, frequencies, and linear speeds of these motions?

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises/Q. 9.61.(a)	260 282

9.61 A boy is on a Ferris wheel, which takes him in a vertical circle of radius 9.00 m once every 12.0 s.

a) What is the angular speed of the Ferris wheel?

6.	Relate the magnitudes of linear (tangential) and angular velocities for circular motion as, and explain that this relation does not hold for tangential and angular velocity vectors which point in different directions.	Exercises/Q. 9.44	281

$$\vec{v} = r\omega\hat{t}. \quad (9.12)$$

(Again, $\hat{t}$ is the symbol for the tangential unit vector and has no connection with the time, t!)

If we take the absolute values of the left- and right-hand sides of equation 9.12, we obtain an important relationship between the magnitudes of the linear and angular speeds for circular motion:

$$v = r\omega. \quad (9.13)$$

Remember that this relationship holds only for the *magnitudes* of the linear and angular velocities. Their vectors point in different directions and, for uniform circular motion, are perpendicular to each other, with $\vec{\omega}$ pointing in the direction of the rotation axis and $\vec{v}$ tangential to the circle.

6.	Relate the magnitudes of linear (tangential) and angular velocities for circular motion as, and explain that this relation does not hold for tangential and angular velocity vectors which point in different directions.	Exercises/Q. **9.44**	**281**

9.44 A discus thrower (with arm length of 1.20 m) starts from rest and begins to rotate counterclockwise with an angular acceleration of 2.50 rad/s^2.

a) How long does it take the discus thrower's speed to get to 4.70 rad/s?

b) How many revolutions does the thrower make to reach the speed of 4.70 rad/s?

c) What is the linear speed of the discus at 4.70 rad/s?

d) What is the linear acceleration of the discus thrower at this point?

e) What is the magnitude of the centripetal acceleration of the discus thrown?

f) What is the magnitude of the discus's total acceleration?

7.	Relate the magnitude of the net acceleration in circular motion to the tangential acceleration and centripetal acceleration	Exercises/Q. 9.44 (f) Exercises/Q. 9.46 Additional Exercises/Q. 9.63	281 282

13.	Express the linear acceleration vector for an object in circular motion as $\vec{a}(t)=a_t\hat{t}-a_c\hat{r}$	Student Book (S.B) Exercises/Q. 9.46	262 281

14.	Distinguish between tangential acceleration and radial acceleration, specifying the cause and direction of each.	Student Book (S.B) Exercises/Q. 9.46/9.43	261 281

The rate of change of an object's angular velocity is its **angular acceleration,** denoted by the Greek letter α. The definition of the magnitude of the angular acceleration is analogous to that for the linear acceleration. Its time average is defined as

$$\bar{\alpha} = \frac{\Delta\omega}{\Delta t}.$$

Tangential acceleration:

$$a_t = \frac{dv}{dt}\hat{t} = r\alpha\hat{t}$$

Radial acceleration:

$$a_r = v\frac{d\hat{t}}{dt} = -v\omega\hat{r}$$

$$\vec{a}(t) = r\alpha\hat{t} - v\omega\hat{r}$$

a_t

$a_r = a_c$

$$a = r\sqrt{\alpha^2 + \omega^4}$$

سؤال وزاري سابق

A centrifuge rotor is accelerated for 30 s from rest to 20,000 rpm. What is its average angular acceleration?

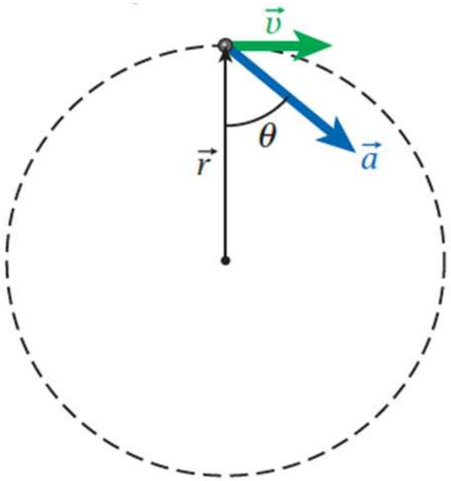
يتم تسريع دوار جهاز الطرد المركزي لمدة 30 s من السكون إلى 20,000 دورة في الدقيقة. ما متوسط تسارعها الزاوي؟

- 70 rad/s^2
- 2100 rad/s^2
- 11.1 rad/s^2
- 333 rad/s^2

9.44 A discus thrower (with arm length of 1.20 m) starts from rest and begins to rotate counterclockwise with an angular acceleration of 2.50 rad/s^2.

f) What is the magnitude of the discus's total acceleration?

•9.46 A particle is moving clockwise in a circle of radius 1.00 m. At a certain instant, the magnitude of its acceleration is $a = |\vec{a}| = 25.0\ \text{m/s}^2$, and the acceleration vector has an angle of $\theta = 50.0°$ with the position vector, as shown in the figure. At this instant, find the speed, $v = |\vec{v}|$, of this particle.



9.63 A car accelerates uniformly from rest and reaches a speed of 22.0 m/s in 9.00 s. The diameter of a tire on this car is 58.0 cm.

a) Find the number of revolutions the tire makes during the car's motion, assuming that no slipping occurs.

b) What is the final angular speed of a tire in revolutions per second?

9.43 A centrifuge in a medical laboratory rotates at an angular speed of 3600. rpm (revolutions per minute). When switched off, it rotates 60.0 times before coming to rest. Find the constant angular acceleration of the centrifuge.

8.	Identify that the centripetal force, necessary for circular motion, can be provided by different forces such as the force of friction, tension, gravitational force, Coulomb force, or the normal force..	Student Book (S.B) Exercises/Q. 9.50	264 281

$$F_c = ma_c = mv\omega = m\frac{v^2}{r} = m\omega^2 r$$

As you can see from this discussion, practically any force can act as the centripetal force. It was the force of static friction for the markers on the rotating table and the horizontal component of the tension in the string for the conical pendulum. But it can also be the gravitational force, which forces planets into (almost) circular orbits around the Sun, the Coulomb force acting on the electrons in atoms, or the normal force from a wall (see the following solved problem).

8.	Identify that the centripetal force, necessary for circular motion, can be provided by different forces such as the force of friction, tension, gravitational force, Coulomb force, or the normal force..	Student Book (S.B) Exercises/Q. 9.50	264 281

9.50 Calculate the centripetal force exerted on a vehicle of mass $m = 1500.$ kg that is moving at a speed of 15.0 m/s around a curve of radius $R = 400.$ m. Which force plays the role of the centripetal force in this case?

9.	Apply the kinematic relationships for circular motion with constant angular acceleration to calculate angular position, angular displacement, angular velocity, angular acceleration, or time.	Example 9.6 Example 9.7 Exercises/Q. 9.35	264 271 280

Table 9.1 Comparison of Kinematical Variables for Circular Motion

Quantity	Linear	Angular	Relationship
Displacement	s	θ	$s = r\theta$
Velocity	v	ω	$v = r\omega$
Acceleration	a	α	$a_t = r\alpha$
			$a_c = r\omega^2$
			$\vec{a} = r\alpha\hat{t} - r\omega^2\hat{r}$

$$\theta = \theta_0 + \omega_0 t + \tfrac{1}{2}\alpha t^2$$

$$\theta = \theta_0 + \bar{\omega} t$$

$$\omega = \omega_0 + \alpha t$$

$$\bar{\omega} = \tfrac{1}{2}(\omega + \omega_0)$$

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0).$$

9.	Apply the kinematic relationships for circular motion with constant angular acceleration to calculate angular position, angular displacement, angular velocity, angular acceleration, or time.	Example 9.6 Example 9.7 Exercises/Q. 9.35	264 271 280

سؤال وزاري سابق

A merry-go-round has an angular acceleration of 0.30 rad/s^2. After accelerating from rest for 2.8 s, through what angle in radians does the merry-go-round rotate?

تتحرك لعبة دوارة في مدينة الملاهي بتسارع زاوي يساوي (0.30 rad/s^2) من السكون لمدة 2.8 s، ما الزاوية التي تدور فيها اللعبة بالتقدير الدائري ؟

1.2 rad

2.4 rad

2.0 rad

8.0 rad

9.	Apply the kinematic relationships for circular motion with constant angular acceleration to calculate angular position, angular displacement, angular velocity, angular acceleration, or time.	Example 9.6 Example 9.7 Exercises/Q. 9.35	264 271 280

EXAMPLE 9.6 CD Player

PROBLEM

In Example 9.2, we established that a CD track is 5.4 km long. A music CD can store 74 min of music. What are the angular velocity and the tangential acceleration of the disc as it spins inside a CD player, assuming a constant linear velocity?

9.	Apply the kinematic relationships for circular motion with constant angular acceleration to calculate angular position, angular displacement, angular velocity, angular acceleration, or time.	Example 9.6 Example 9.7 Exercises/Q. 9.35	264 271 280

EXAMPLE 9.7 Hammer Throw

One of the most interesting events in track-and-field competitions is the hammer throw. The task is to throw the "hammer," a 12 cm-diameter iron ball attached to a grip by a steel cable, a maximum distance. The hammer's total length is 121.5 cm, and its total mass is 7.26 kg. The athlete has to accomplish the throw from within a circle of radius 2.13 m (7 ft), and the best way to throw the hammer is for the athlete to spin, allowing the hammer to move in a circle around him, before releasing it. At the 1988 Olympic Games in Seoul, the Russian thrower Sergey Litvinov won the gold medal with an Olympic record distance of 84.80 m. He took seven turns before releasing the hammer, and the period to complete each turn was obtained from examining the video recording frame by frame: 1.52 s, 1.08 s, 0.72 s, 0.56 s, 0.44 s, 0.40 s, and 0.36 s.

PROBLEM 1

What was the average angular acceleration during the seven turns? Assume constant angular acceleration for the solution, and then check whether this assumption is justified.

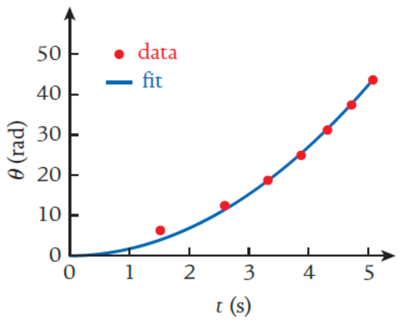


FIGURE 9.21 Angle as a function of time for Sergey Litvinov's 1988 gold-medal–winning hammer throw.

9.	Apply the kinematic relationships for circular motion with constant angular acceleration to calculate angular position, angular displacement, angular velocity, angular acceleration, or time.	Example 9.6 Example 9.7 Exercises/Q. 9.35	264 271 280

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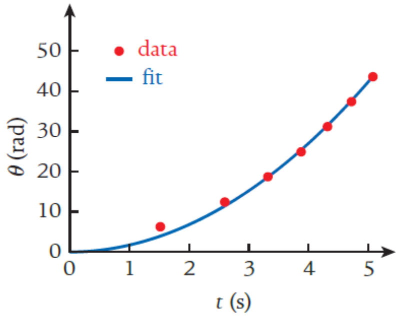
PROBLEM 2

Assuming that the radius of the circle on which the hammer moves is 1.67 m (the length of the hammer plus the arms of the athlete), what is the linear speed with which the hammer is released?



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9.	Apply the kinematic relationships for circular motion with constant angular acceleration to calculate angular position, angular displacement, angular velocity, angular acceleration, or time.	Example 9.6 Example 9.7 Exercises/Q. 9.35	264 271 280

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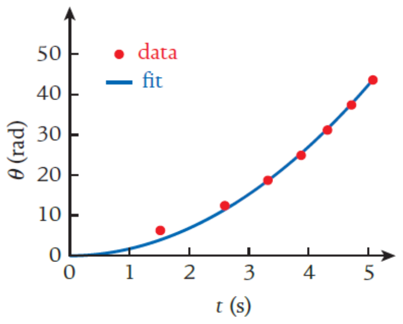
PROBLEM 3

What is the centripetal force that the hammer thrower has to exert on the hammer right before he releases it?



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9.	Apply the kinematic relationships for circular motion with constant angular acceleration to calculate angular position, angular displacement, angular velocity, angular acceleration, or time.	Example 9.6 Example 9.7 Exercises/Q. 9.35	264 271 280

9.35 A vinyl record plays at 33.3 rpm. Assume it takes 5.00 s for it to reach this full speed, starting from rest.

a) What is its angular acceleration during the 5.00 s?

b) How many revolutions does the record make before reaching its final angular speed?

10.	Convert angle measurements between degrees and radians.	Student Book (S.B)	256

The two most commonly used units for angles are degrees (°) and radians (rad). These units are defined such that the angle measured by one complete circle is 360°, which corresponds to 2π rad. Thus, the unit conversion between the two angular measures is

$$\theta\ (\text{degrees})\frac{\pi}{180} = \theta\ (\text{radians}) \Leftrightarrow \theta\ (\text{radians})\frac{180}{\pi} = \theta\ (\text{degrees})$$

$$1\ \text{rad} = \frac{180^\circ}{\pi} \approx 57.3^\circ.$$

10.	Convert angle measurements between degrees and radians.	Student Book (S.B)	256

9.31 What is the angle in radians that the Earth sweeps out in its orbit during winter?

What is 30° in radians?

a. $\frac{\pi}{12}$

b. $\frac{\pi}{9}$

c. $\frac{\pi}{6}$

d. $\frac{\pi}{3}$

10.	Convert angle measurements between degrees and radians.	Student Book (S.B)	256

1- convert the degree of the angle to radian measure:

A) $60°$ *B*) $240°$

2- convert the radian measure to degree:

A) $\frac{2\pi}{3}$ *B*) $\frac{11\pi}{6}$

10.	Convert angle measurements between degrees and radians.	Student Book (S.B)	256

سؤال وزاري سابق

A bike wheel rotates 4.50 revolutions. How many radians has it rotated?

يدور إطار الدراجة 4.50 دورة. كم يدور نفس الإطار بوحدة الراديان؟

28.3 rad
0.08 rad
7.0 rad
4.5 rad

11.	Sketch the path taken in circular motion (uniform and non-uniform) and explain the velocity and acceleration vectors (magnitudes and directions) during the motion	S.B/Figure 9.12 S.B/MCQ/Q.9.4	262 278

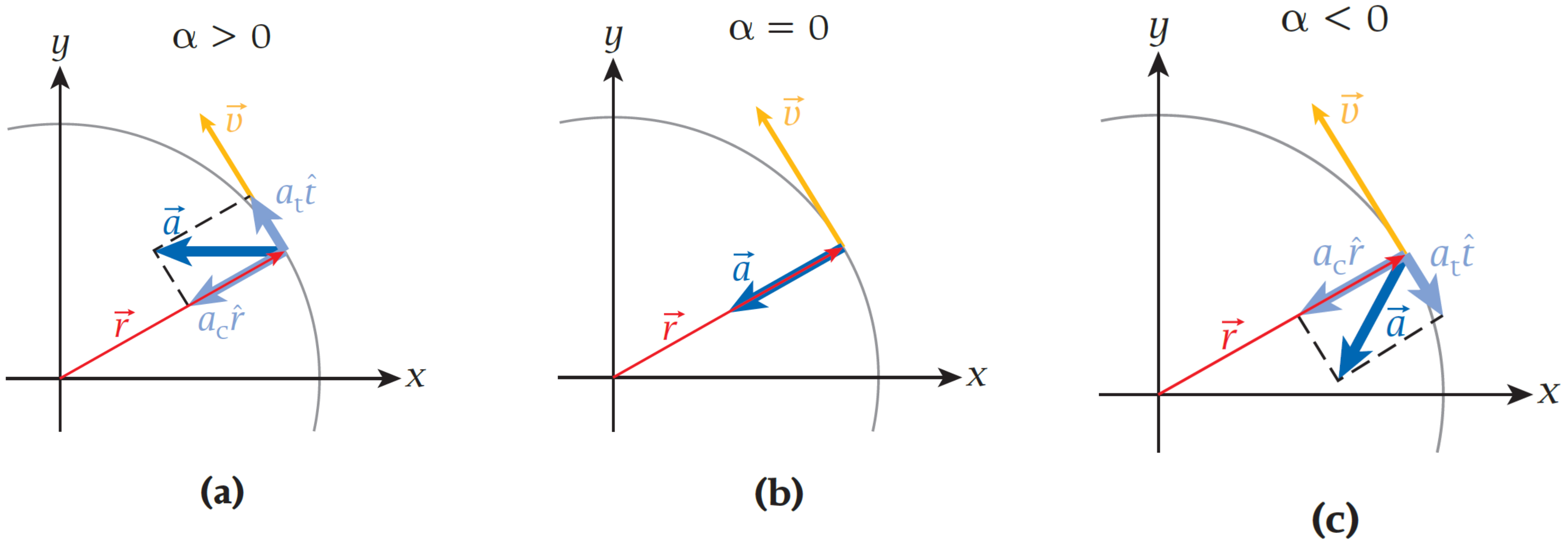
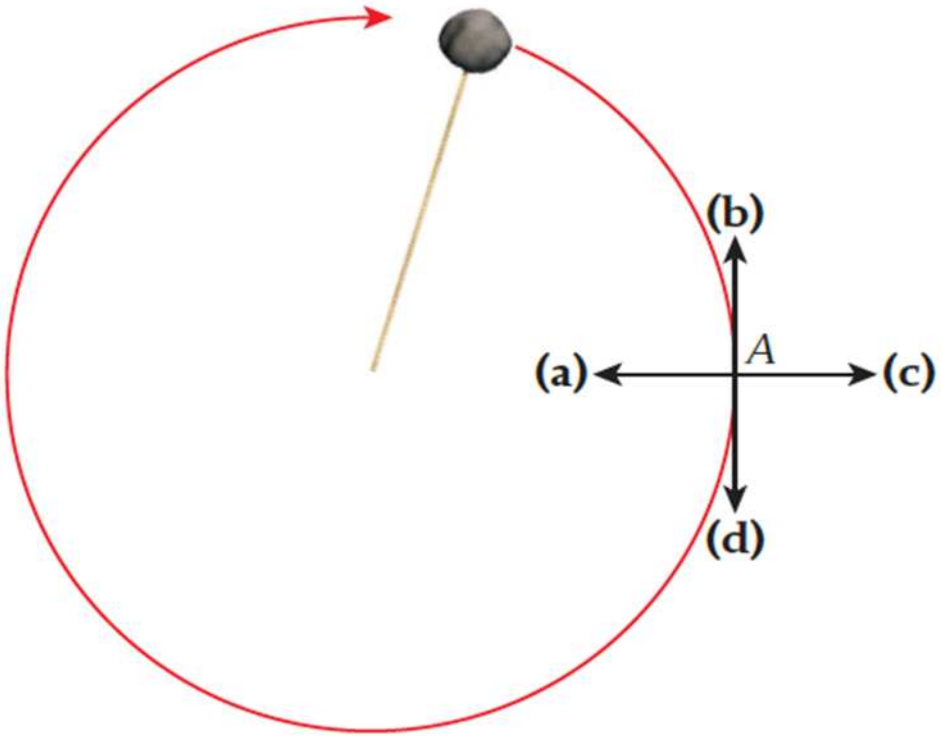


FIGURE 9.12 Relationships among linear acceleration, centripetal acceleration, and angular acceleration for (a) increasing speed; (b) constant speed; and (c) decreasing speed.

11.	Sketch the path taken in circular motion (uniform and non-uniform) and explain the velocity and acceleration vectors (magnitudes and directions) during the motion	S.B/Figure 9.12 S.B/MCQ/Q.9.4	262 278

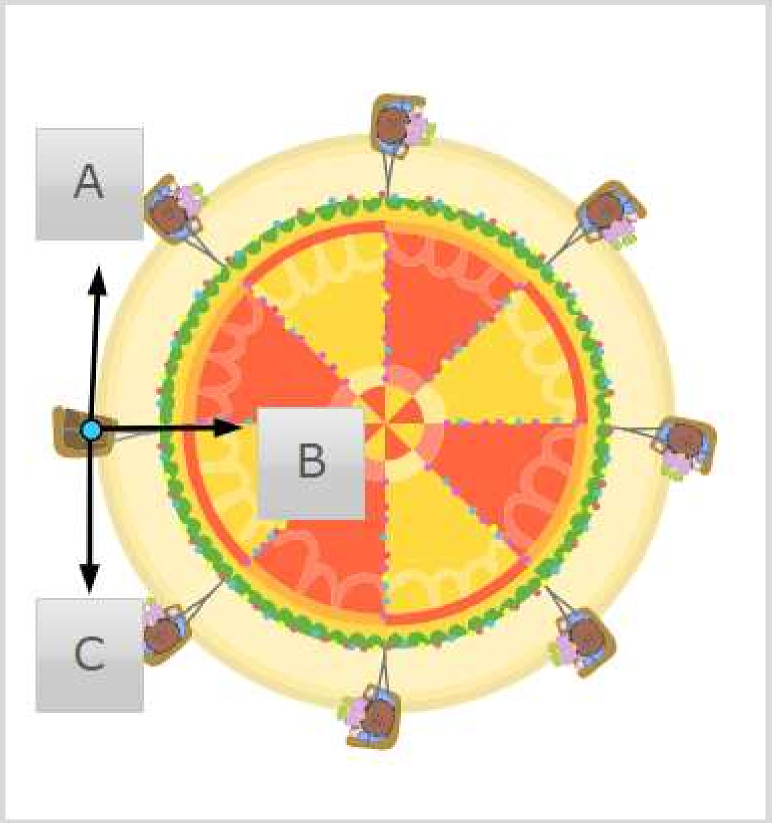
9.4 A rock attached to a string moves clockwise in uniform circular motion. In which direction from point *A* is the rock thrown off when the string is cut?



11.	Sketch the path taken in circular motion (uniform and non-uniform) and explain the velocity and acceleration vectors (magnitudes and directions) during the motion	S.B/Figure **9.12** S.B/MCQ/Q.**9.4**	**262** **278**

Activity: A merry-go-round has a radius of $3\ \mathrm{m}$. Determine the direction of the centripetal acceleration, which is affecting one of the seats, and calculate its magnitude knowing that the linear velocity of the seat is $3.77\ \frac{\mathrm{m}}{\mathrm{s}}$. Give the result to an accuracy of 0.01.

$a_{\mathrm{cp}} = \square\ \frac{\mathrm{m}}{\mathrm{s}^2}$



12.	Identify that for an object in circular motion with a given angular velocity, the centripetal force increases with the distance from the center	Student Book (S.B) Example 9.8	264 273

The three markers have the same angular velocity, ω, but are placed on different locations (different r). Their centripetal force is proportional to the distance, r, from the center of the disk.

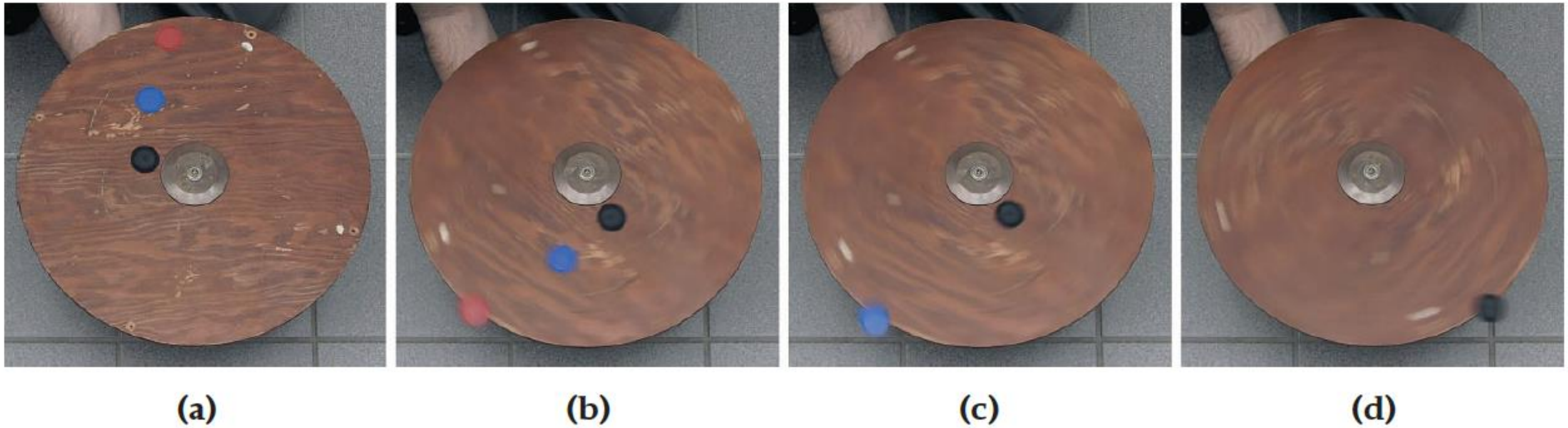


FIGURE 9.14 Markers on a spinning table. Shown from left to right are the initial positions of the markers and the moments when the three markers slide off during the process of circular motion.

12.	Identify that for an object in circular motion with a given angular velocity, the centripetal force increases with the distance from the center	Student Book (S.B) Example 9.8	264 273

EXAMPLE 9.8 Formula 1 Racing

If you watch a Formula 1 race, you can see that the race cars approach curves from the outside, cut through to the inside, and then drift again to the outside, as shown by the red path in Figure 9.24a. The blue path is shorter. Why don't the drivers follow the shortest path?

PROBLEM

Suppose that cars move through the U-turn shown in Figure 9.24a at constant speed and that the coefficient of static friction between the tires and the road is $\mu_s = 1.2$. (As was mentioned in Chapter 4, modern race car tires can have coefficients of friction that exceed 1 when they are heated to race temperature and thus are very sticky.) If the radius of the inner curve shown in the figure is $R_B = 10.3$ m and radius of the outer is $R_A = 32.2$ m and the cars move at their maximum speed, how much time will it take to move from point A to A' and from point B to B'?

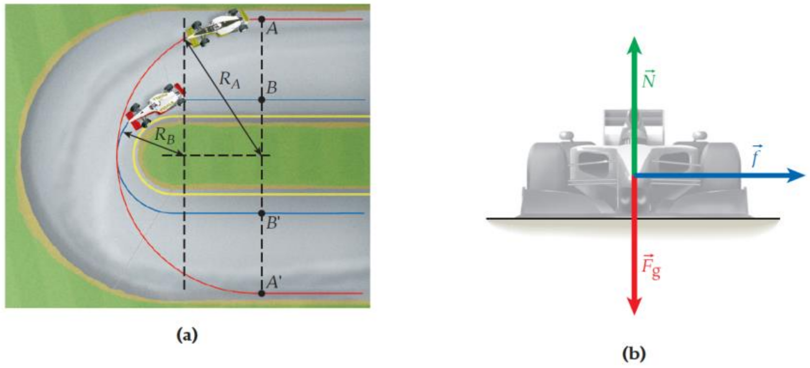


FIGURE 9.24 (a) Paths of race cars negotiating a turn on an oval track in two ways. (b) Free-body diagram for a race car in a curve.

15.	Apply Newton's laws of motion and/or energy conservation principles to analyze circular motion in a vertical or horizontal plane (motion in vertical loop of an amusement park ride, rotating cylinder, moving through a levelled or banked curve,...)	S.B/Figure 9.18/9.19 S.B/Figure 9.20 S.B/MCQ/Q.9.11	266 268 278

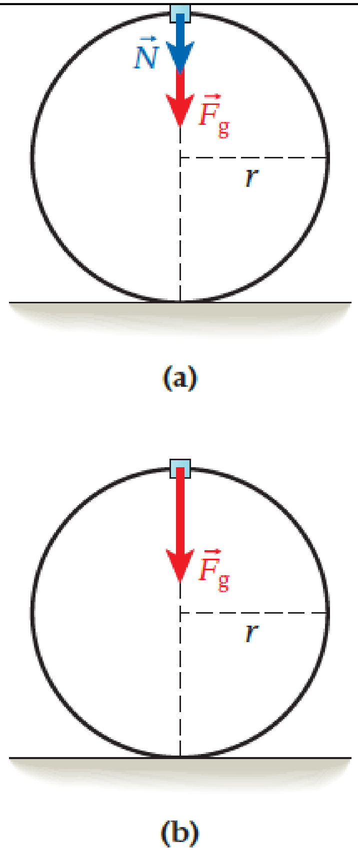


FIGURE 9.18 (a) Free-body diagram for a passenger at the top of the vertical loop of a roller coaster. (b) Condition for the feeling of weightlessness.

15.	Apply Newton's laws of motion and/or energy conservation principles to analyze circular motion in a vertical or horizontal plane (motion in vertical loop of an amusement park ride, rotating cylinder, moving through a levelled or banked curve,...)	S.B/Figure 9.18/9.19 S.B/Figure 9.20 S.B/MCQ/Q.9.11	266 268 278

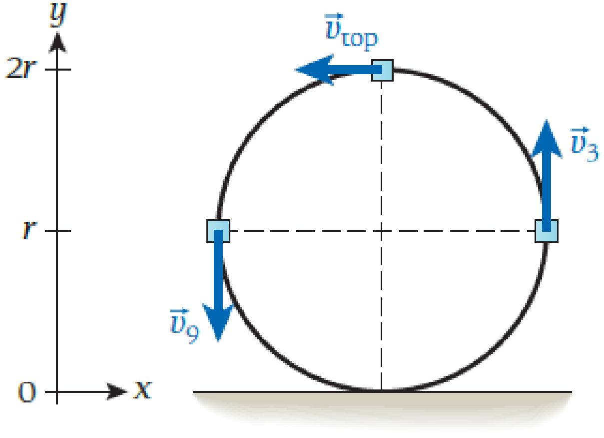


FIGURE 9.19 Directions of the velocity vectors at several points along the vertical roller coaster loop.

15.	Apply Newton's laws of motion and/or energy conservation principles to analyze circular motion in a vertical or horizontal plane (motion in vertical loop of an amusement park ride, rotating cylinder, moving through a levelled or banked curve,...)	S.B/Figure 9.18/9.19 S.B/Figure 9.20 S.B/MCQ/Q.9.11	266 268 278

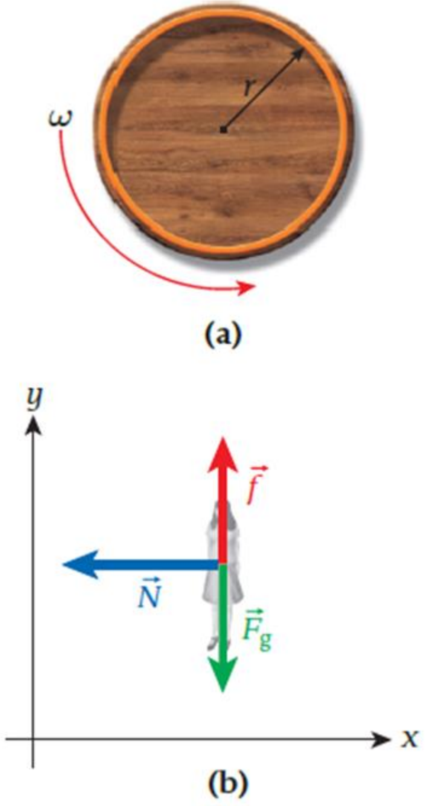
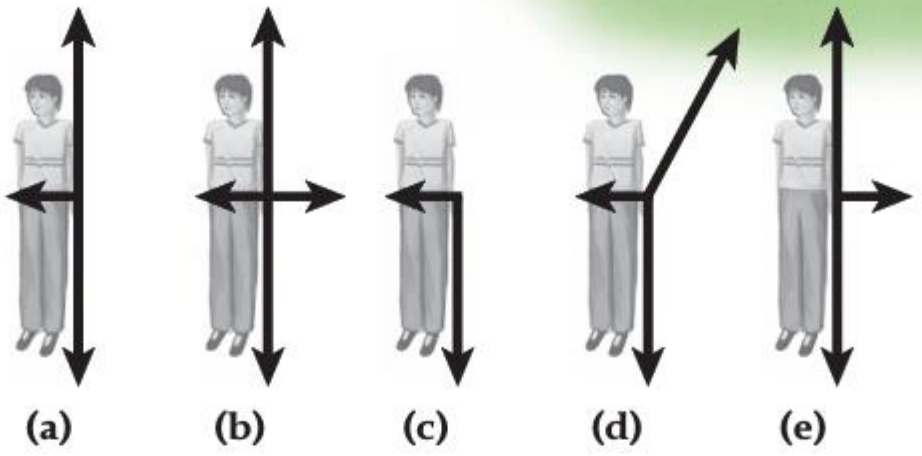


FIGURE 9.20 (a) Top view of the rotating cylinder of a carnival ride. (b) Free-body diagram for one of the riders.

15.	Apply Newton's laws of motion and/or energy conservation principles to analyze circular motion in a vertical or horizontal plane (motion in vertical loop of an amusement park ride, rotating cylinder, moving through a levelled or banked curve,...)	S.B/Figure **9.18/9.19** S.B/Figure **9.20** S.B/MCQ/Q.**9.11**	**266** **268** **278**

9.11 The figure shows a rider stuck to the wall without touching the floor in the Barrel of Fun at a carnival. Which diagram correctly shows the forces acting on the rider?



End of MCQ