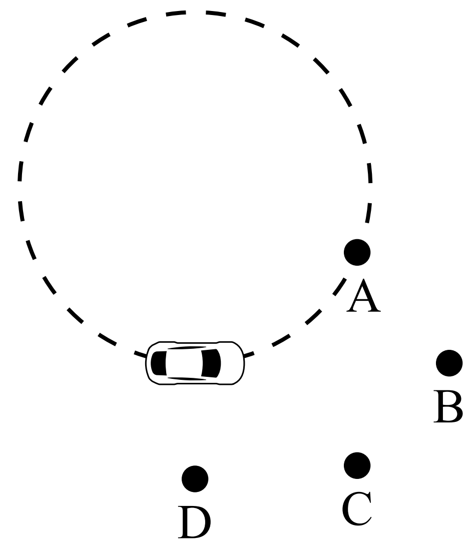
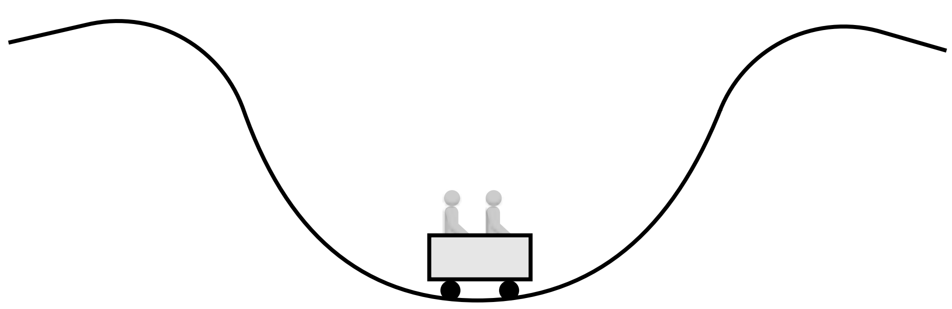
CENTRIPETAL ACCELERATION AND FORCE



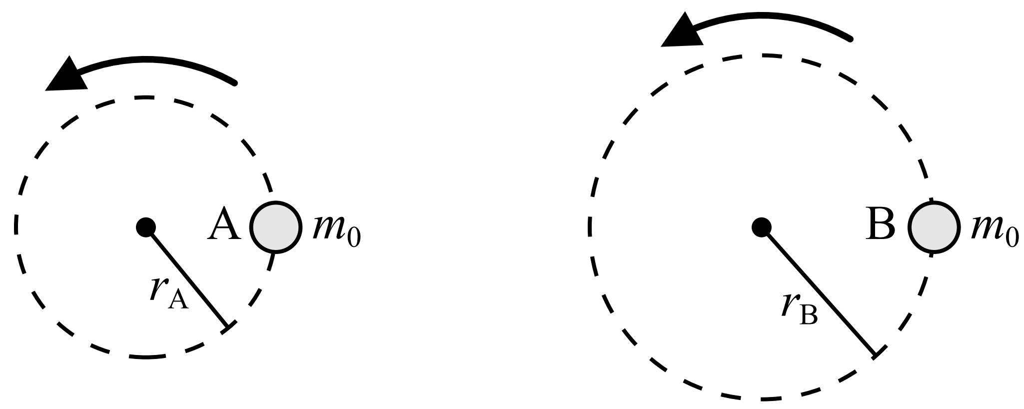
1. A car is driving around in a counterclockwise circle at a constant speed as shown in the figure above. The car is driving on ice but the friction between the tires and the ice is great enough for the car to drive in the circle. When the car is in the position shown the tires slip. If the friction force on the tires is assumed to be zero after that moment, which of the points shows the position of the car a period of time later?

   (A) Point A
   (B) Point B
   (C) Point C
   (D) Point D



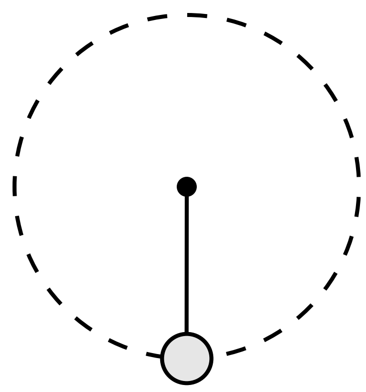
2. Two people are riding a roller coaster and the car enters a dip with a circular arc as shown in the figure above. When the car is at the position shown, the apparent weight of a rider is

   (A) equal to their true weight
   (B) less than their true weight
   (C) greater than their true weight
   (D) a comparison between their apparent weight and true weight cannot be determined



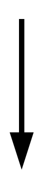
3. Two objects with the same mass are in uniform circular motion. Object A follows a circular path with radius r_A and object B follows a circular path with a radius of $r_B > r_A$. If the period of each object's circular motion is the same, the magnitude of the net force acting on object A is

   (A) equal to the net force acting on object B
   (B) less than the net force acting on object B
   (C) greater than the net force acting on object B
   (D) a comparison between the net force on object A and object B cannot be determined

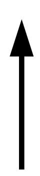


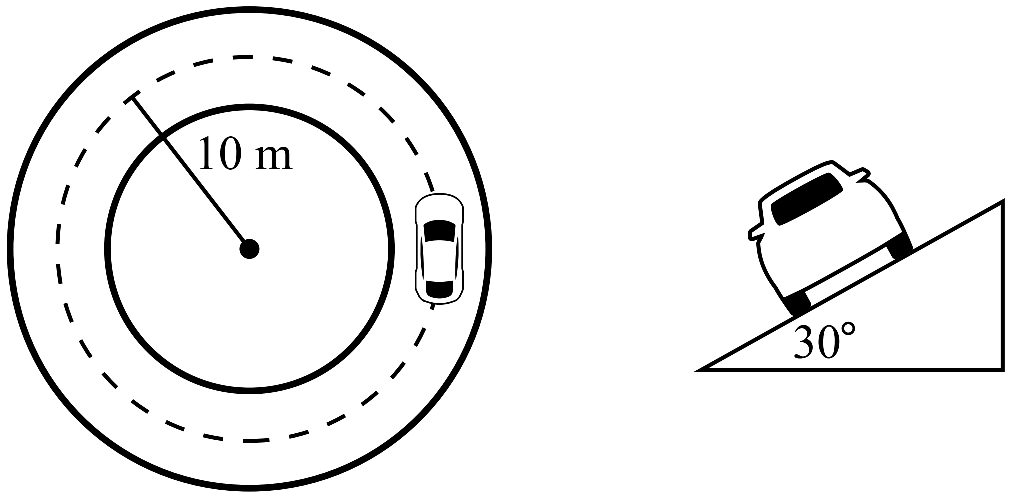
4. A sphere is attached to a string and swings around in a vertical circle at a constant speed. Which of the following shows the direction of the net force acting on the sphere when it is at the position shown in the figure above?

   (A) 

   (B) 

   (C) 

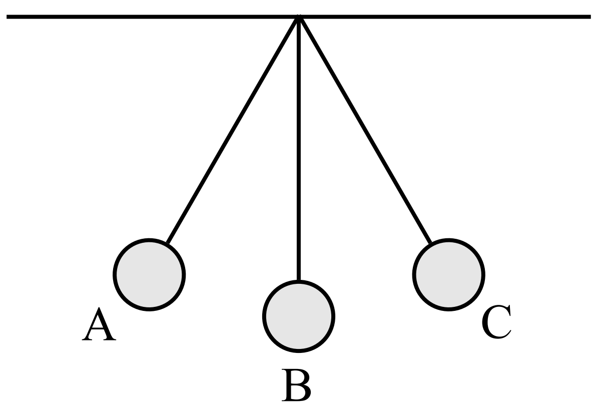
   (D) 



Top view Side view

5. A car is driving around a banked circular track at a constant speed as shown in the figure above. The track is inclined at an angle of 30° with the ground and the radius of the circular path of the car is 10 m. The track is covered in ice and the friction between the tires and the inclined track is negligible, but the car does not slide up or down the incline. The speed of the car is most nearly

(A) 10.0 m/s
(B) 13.2 m/s
(C) 7.6 m/s
(D) 7.1 m/s



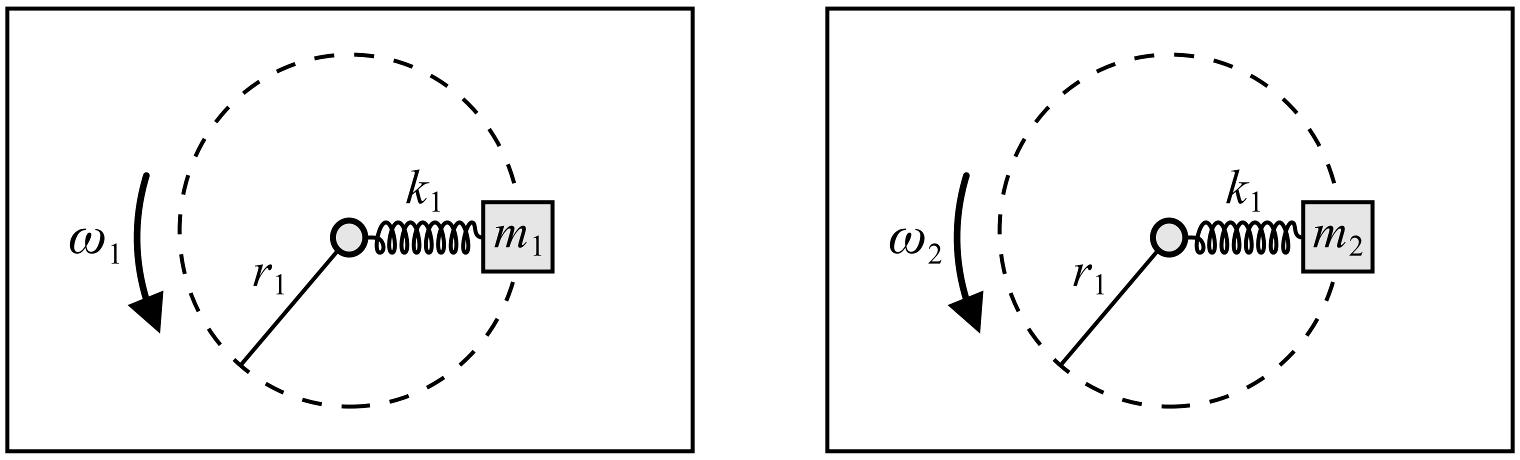
6. A pendulum consists of a sphere attached to a string suspended from the ceiling. As the sphere swings across from position A to position C, what is the direction of the acceleration of the sphere at position B?

(A) 

(B) 

(C) 

(D) The acceleration is zero



Top view

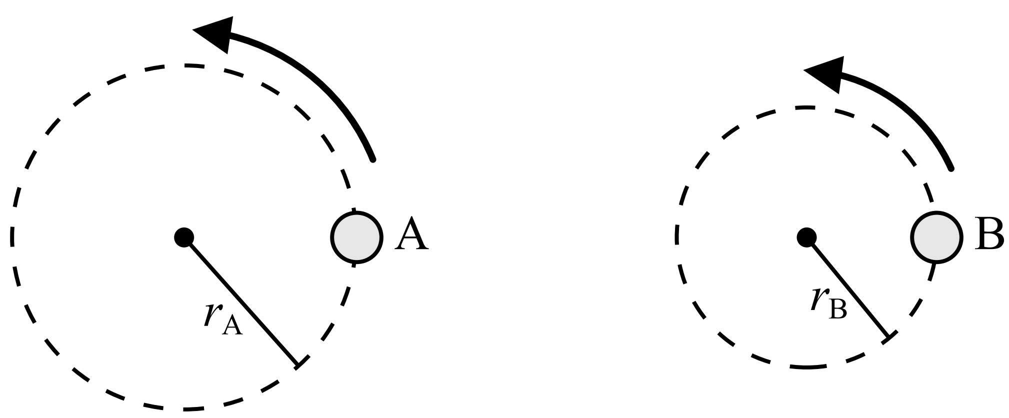
Figure 1

Top view

Figure 2

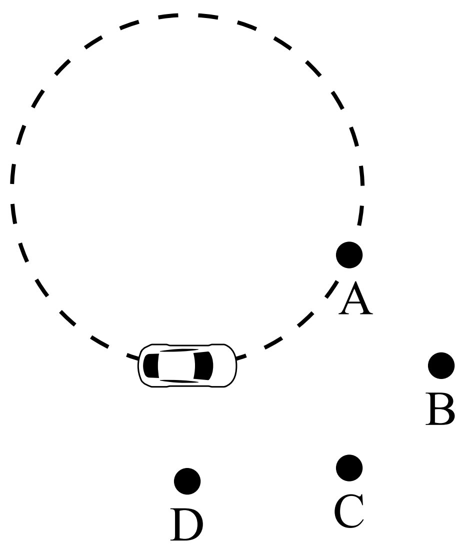
7. In Figure 1 above a small block of mass m_1 is attached to one end of a spring with a spring constant of k_1 and the other end of the spring is attached to an axle which passes through a hole in the table. A motor below the table causes the axle to rotate with a constant angular speed of ω_1 and the block travels in a horizontal circle with a radius of r_1 on the surface of the table which has negligible friction. In Figure 2 the block is replaced with a different block that has the same dimensions but a mass of m_2 where $m_2 > m_1$. The motor now rotates the axle with a constant angular speed of ω_2 so that the radius of the circular path is still r_1. How does ω_2 compare to ω_1?

(A) $\omega_1 < \omega_2$
(B) $\omega_1 = \omega_2$
(C) $\omega_1 > \omega_2$
(D) Cannot be determined



8. Two objects are in uniform circular motion. Object A follows a circular path with radius r_A and object B follows a circular path with a radius of $r_B < r_A$. If the period of each object's circular motion is the same, the magnitude of the acceleration of object B is

(A) less than the magnitude of the acceleration of object A
(B) greater than the magnitude of the acceleration of object A
(C) equal to the magnitude of the acceleration of object A
(D) a comparison between the acceleration of object A and object B cannot be determined



1. A car is driving around in a counterclockwise circle at a constant speed as shown in the figure above. The car is driving on ice but the friction between the tires and the ice is great enough for the car to drive in the circle. When the car is in the position shown the tires slip. If the friction force on the tires is assumed to be zero after that moment, which of the points shows the position of the car a period of time later?

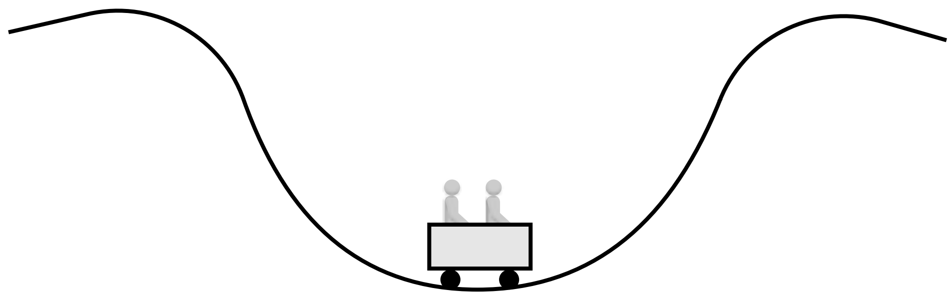
   (A) Point A
   (B) Point B
   (C) Point C
   (D) Point D

A Incorrect

B **Correct**
The car is in uniform circular motion and the velocity of the car is always tangent to the circular path. When the friction force is removed, there are no horizontal forces acting on the car (parallel to the ground) so the car will move with a constant velocity (Newton’s 1st law of motion). At the position shown, the velocity of the car is tangent to the circle and points directly to the right, so the car will move in a straight line that passes through point B.

C Incorrect

D Incorrect



2. Two people are riding a roller coaster and the car enters a dip with a circular arc as shown in the figure above. When the car is at the position shown, the apparent weight of a rider is

(A) equal to their true weight

(B) less than their true weight

(C) greater than their true weight

(D) a comparison between their apparent weight and true weight cannot be determined

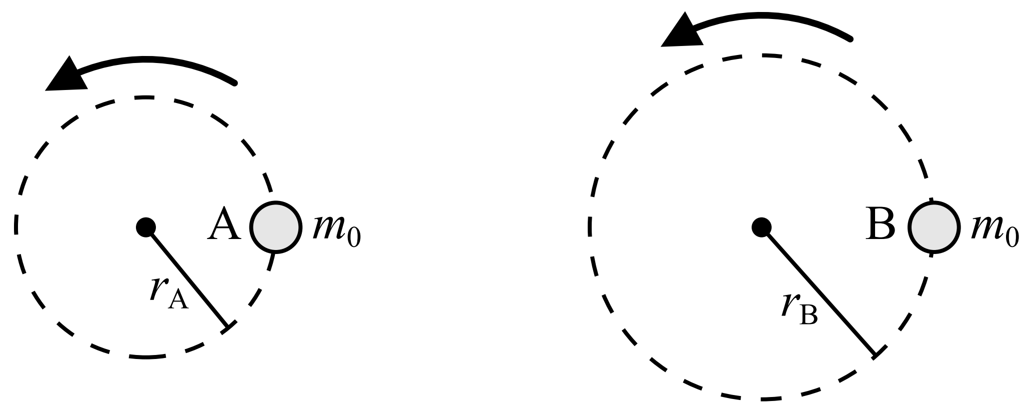
A Incorrect

B Incorrect

C **Correct**

There is a downwards weight force and an upwards normal force acting on each person (from the seat or floor of the car). When the car is at the bottom of the circular arc the net force on each person is upwards because they are moving in circular motion and they are accelerating upwards at that moment. The upwards normal force, which is the apparent weight, is greater than the downwards weight force on each person.

D Incorrect



3. Two objects with the same mass are in uniform circular motion. Object A follows a circular path with radius r_A and object B follows a circular path with a radius of $r_B > r_A$. If the period of each object's circular motion is the same, the magnitude of the net force acting on object A is

(A) equal to the net force acting on object B
(B) less than the net force acting on object B
(C) greater than the net force acting on object B
(D) a comparison between the net force on object A and object B cannot be determined

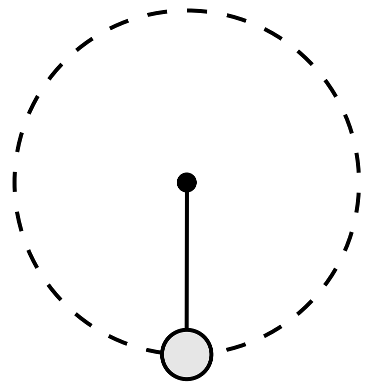
A Incorrect

B **Correct**
The objects are in uniform circular motion so the net force acting on each object is a centripetal force which is related to the mass, speed and radius of the circular motion in the equation below. The variable for speed can be replaced with the circumference of the circle divided by the period of the motion to get a relationship between the net force (the centripetal force), the radius, the mass and the period. If object B is moving around a circle with a greater radius and the mass and period are the same for both objects, the net force on object B is greater.

$$\Sigma F = F_c = \frac{mv^2}{r} = \frac{m}{r}\left(\frac{2\pi r}{T}\right)^2 = \frac{4\pi^2 m r^2}{rT^2} \qquad \Sigma F = \frac{4\pi^2 m r}{T^2}$$

C Incorrect

D Incorrect



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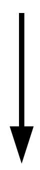
(A) 

(B) 

(C) 

(D) 

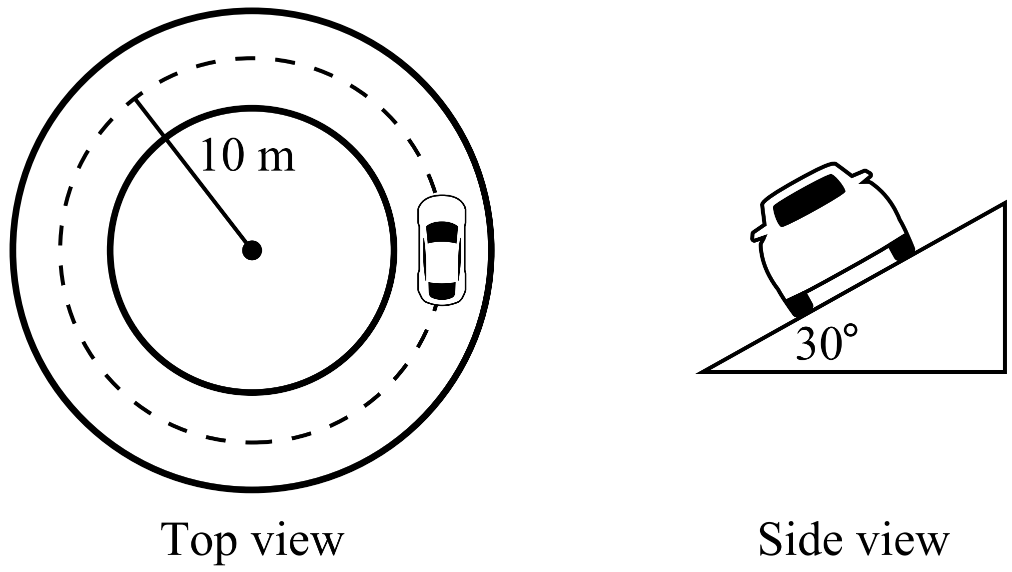
A Incorrect

B Incorrect

C Incorrect

D Correct

There is an upwards tension force and a downwards weight force acting on the sphere when it's at the bottom of the circular path. The sphere is in uniform circular motion so the net force acting on the sphere always points towards the center of the circle, which is upwards at that position.



5. A car is driving around a banked circular track at a constant speed as shown in the figure above. The track is inclined at an angle of 30° with the ground and the radius of the circular path of the car is 10 m. The track is covered in ice and the friction between the tires and the inclined track is negligible, but the car does not slide up or down the incline. The speed of the car is most nearly

(A) 10.0 m/s

(B) 13.2 m/s

(C) 7.6 m/s

(D) 7.1 m/s

A Incorrect

This answer incorrectly uses $\sin(30°)$ or $\cos(30°)$ for both components of the normal force.

B Incorrect

This answer incorrectly uses $\sin(30°)$ for the vertical component of the normal force and $\cos(30°)$ for the horizontal component of the normal force.

C **Correct**

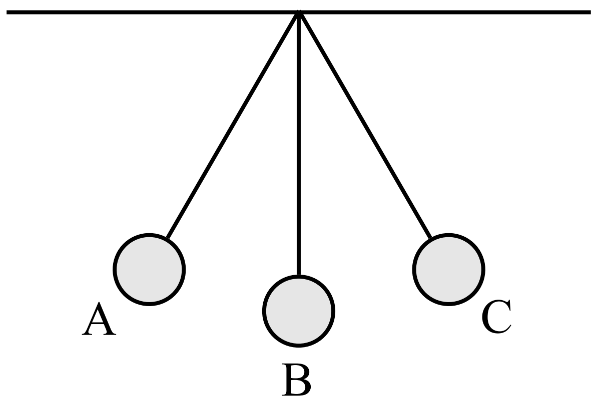
There is a weight force on the car which acts vertically downwards and a normal force on the car which acts perpendicular to the surface of the incline. The car is moving in uniform circular motion so the net force acting on the car (the centripetal force) always points towards the center of the circle. From the side view, this centripetal force acts horizontally to the left. The weight force only acts in the vertical direction, so the centripetal force is the horizontal component of the normal force on the car. The car does not move or accelerate vertically so the net force in the vertical direction is zero.

$$\Sigma F_y = F_n \cos(30°) - mg = m(0\ \text{m/s}^2) \qquad F_n = \frac{mg}{\cos(30°)}$$

$$\Sigma F_x = F_n \sin(30°) = \frac{mv^2}{r} \qquad \frac{mg}{\cos(30°)}\sin(30°) = \frac{mv^2}{r} \qquad \frac{g\ \sin(30°)}{\cos(30°)} = \frac{v^2}{(10\ \text{m})} \qquad v = 7.6\ \text{m/s}$$

D Incorrect

This answer incorrectly assumes the centripetal force is equal to the component of the weight force which acts parallel to the incline, $mg\sin(30°)$.



6. A pendulum consists of a sphere attached to a string suspended from the ceiling. As the sphere swings across from position A to position C, what is the direction of the acceleration of the sphere at position B?

(A) 

(B) 

(C) 

(D) The acceleration is zero

A Incorrect

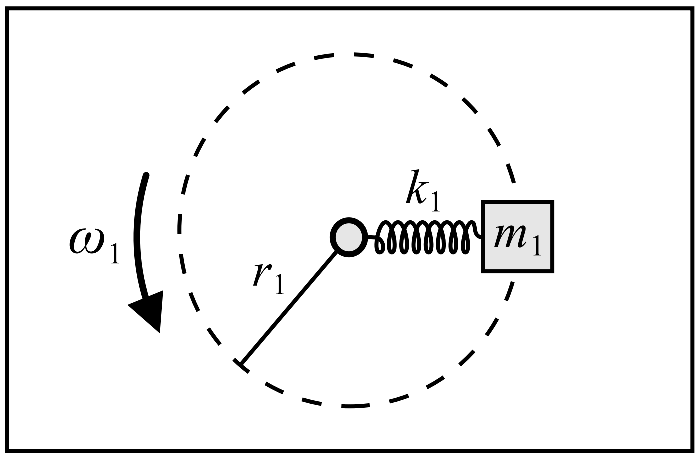
B Correct

There are no horizontal forces acting on the sphere at position B so there is no acceleration in the horizontal direction. The sphere is following a circular path and the velocity of the sphere is constantly changing direction so the sphere is accelerating at position B (acceleration is the change in the velocity vector over time, which can be a change in the magnitude or direction of the velocity). The acceleration of the sphere at position B is the centripetal acceleration caused by the tension force in the string which keeps the sphere moving in a circular path. The acceleration points upwards at position B towards the center of the circular path.

$\Sigma F_y = T - F_g = m a_y$ and $a = \frac{v^2}{r}$

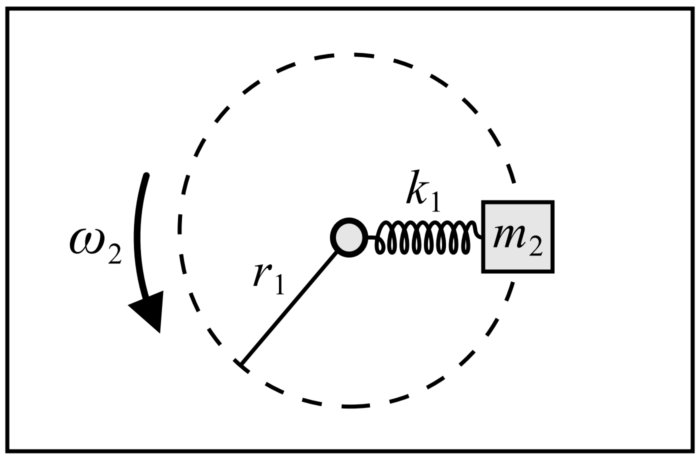
C Incorrect

D Incorrect



Top view

Figure 1



Top view

Figure 2

7. In Figure 1 above a small block of mass m_1 is attached to one end of a spring with a spring constant of k_1 and the other end of the spring is attached to an axle which passes through a hole in the table. A motor below the table causes the axle to rotate with a constant angular speed of ω_1 and the block travels in a horizontal circle with a radius of r_1 on the surface of the table which has negligible friction. In Figure 2 the block is replaced with a different block that has the same dimensions but a mass of m_2 where $m_2 > m_1$. The motor now rotates the axle with a constant angular speed of ω_2 so that the radius of the circular path is still r_1. How does ω_2 compare to ω_1?

(A) $\omega_1 < \omega_2$

(B) $\omega_1 = \omega_2$

(C) $\omega_1 > \omega_2$

(D) Cannot be determined

A Incorrect

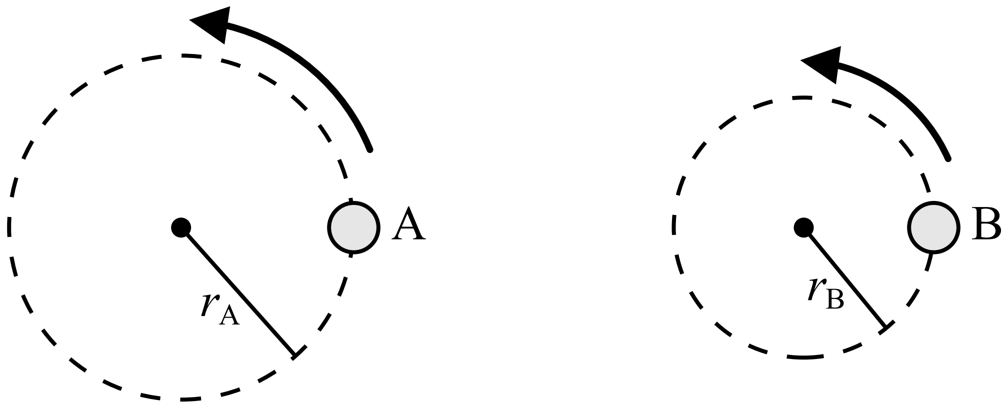
B Incorrect

C **Correct**

The spring force acting on the block is providing the centripetal force that is required to keep the block moving in circular motion (and not moving out away from the circle in a tangent line due to its inertia). The spring force is equal to the centripetal force and the variables are related as shown below. The radius r is the same so the change in length of the spring Δx is also the same. The spring constant k is the same. If the mass m is increased then the angular speed ω must decrease.

$$\Sigma F = ma \qquad F_{sp} = \frac{mv^2}{r} = \frac{m(r\omega)^2}{r} = mr\omega^2 \qquad k\Delta x = mr\omega^2 \qquad \frac{k\Delta x}{mr} = \omega^2$$

D Incorrect



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(A) less than the magnitude of the acceleration of object A
(B) greater than the magnitude of the acceleration of object A
(C) equal to the magnitude of the acceleration of object A
(D) a comparison between the acceleration of object A and object B cannot be determined

A **Correct**

The objects are in uniform circular motion so they move with a constant speed. The acceleration of each object is the centripetal acceleration which points towards the center of the circle. The centripetal acceleration is related to the radius, speed and period using the equations below (the variable for speed can be replaced with a term that includes the period). The objects have the same period and object B moves in a circle with a smaller radius so object B has a smaller centripetal acceleration than object A.

$$a_c = \frac{v^2}{r} = \left(\frac{2\pi}{T}\right)^2 r$$

B Incorrect

C Incorrect

D Incorrect