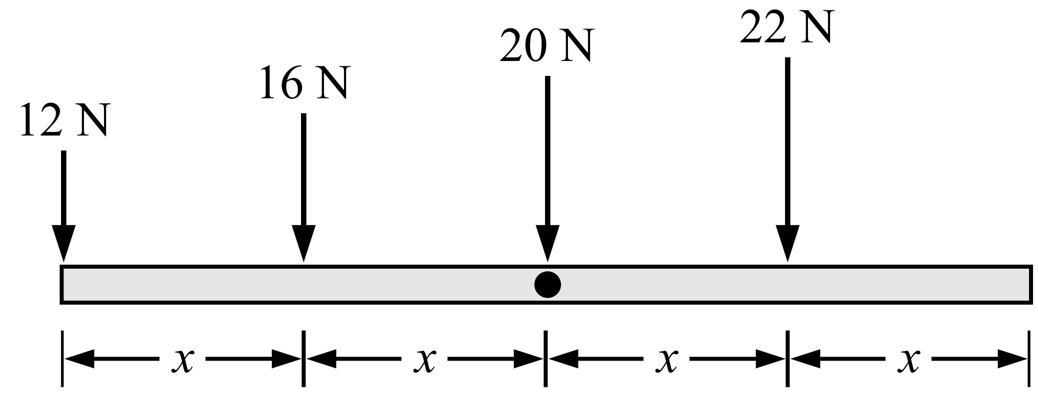
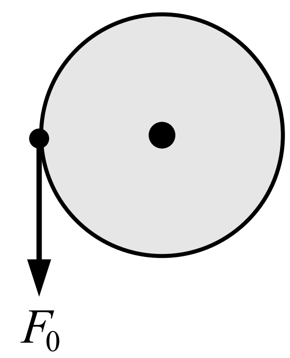
ROTATIONAL DYNAMICS



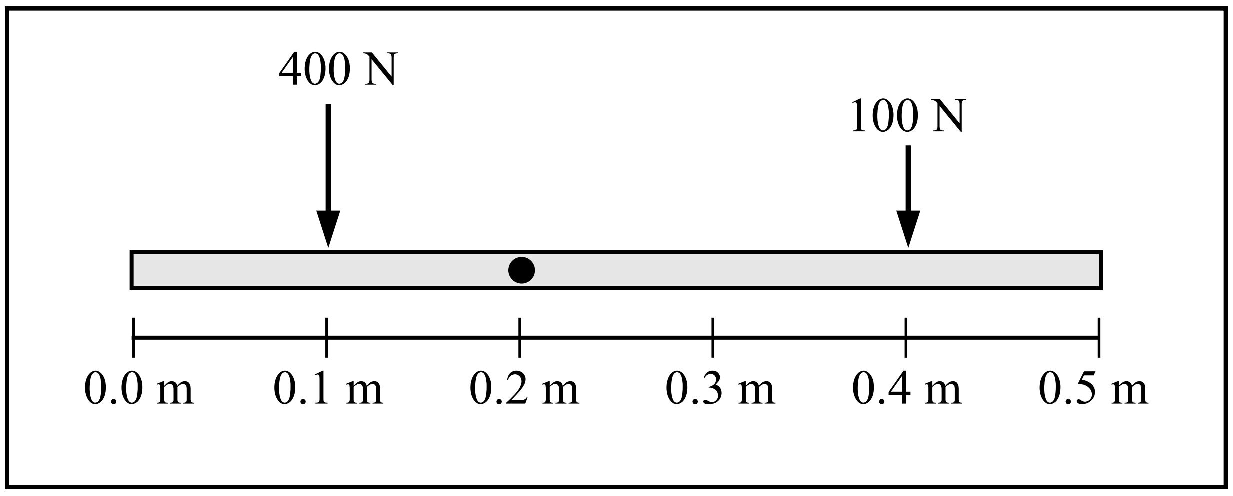
1. Four forces are exerted on a rod which is free to rotate about its center. The forces are applied at evenly spaced distances as shown in the figure above. Which single force, if applied on its own, would cause the rod to rotate with the greatest angular acceleration (magnitude)?

(A) The 22 N force
(B) The 12 N force
(C) The 20 N force
(D) The 16 N force



2. A wheel is initially spinning freely about its center in the clockwise direction with a constant angular speed. A force is then applied to the wheel as shown in the figure above. At the moment the force is applied, which of the following is true about the angular acceleration of the wheel?

(A) The angular acceleration is in the clockwise direction
(B) The angular acceleration is in the counterclockwise direction
(C) The angular acceleration is zero
(D) None of the above can be determined



Top view

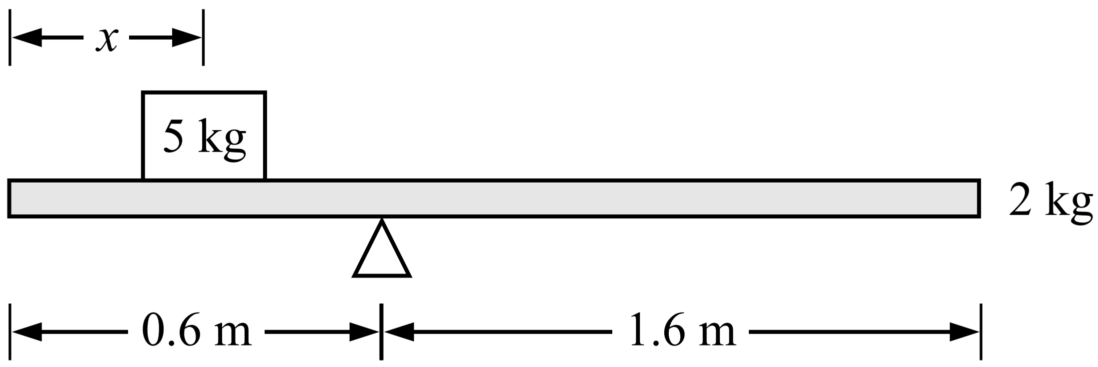
3. A rod is resting on a table with negligible friction and is pinned so it is free to rotate about a point 0.2 m from the left end of the rod. Two horizontal forces are applied to the beam as shown in the figure above, which is a top-down view of the rod on the table. The rotational inertia of the beam is 20 kg·m². At the moment the two forces are applied, the magnitude of the angular acceleration of the beam is

(A) 0 rad/s²

(B) 3 rad/s²

(C) 1 rad/s²

(D) 20 rad/s²



Note: Figure not drawn to scale.

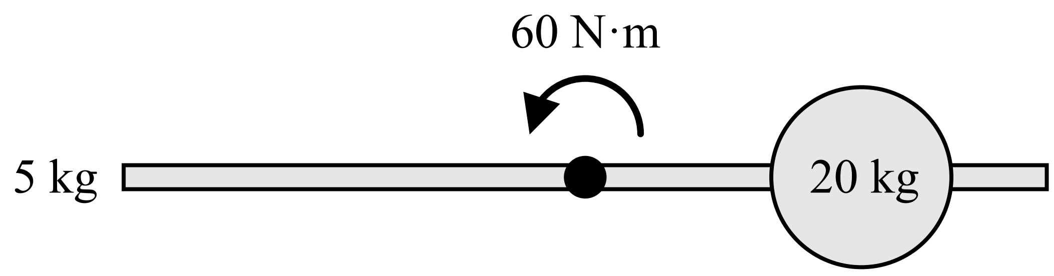
4. A 2 kg beam is resting on a pivot point and a 5 kg block is resting on the beam as shown in the figure above. If the beam and the block remain at rest, what is the distance between the center of the block and the left end of the beam?

(A) 0.8 m

(B) 0.2 m

(C) 0.6 m

(D) 0.4 m



Top view

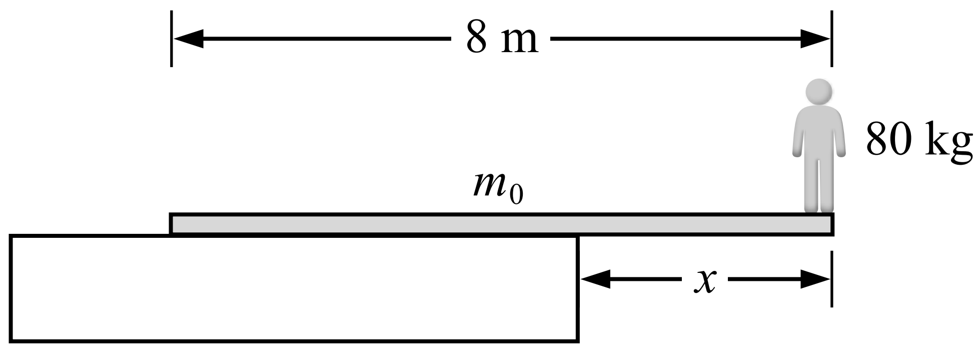
5. A 20 kg sphere is attached to a 5 kg rod which is free to rotate about its center as shown in the figure above. A 60 N·m torque is applied to the rod by a force which is not shown, and the rod and sphere rotate with an angular acceleration. Which of the following changes would increase the angular acceleration of the rod and sphere?

(A) Decrease the mass of the rod

(B) Move the sphere farther from the center of the rod

(C) Increase the mass of the sphere

(D) Increase the total length of the rod so the total mass of the rod remains the same and it rotates about its center



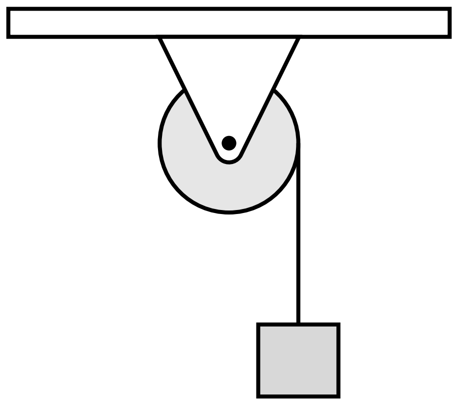
6. An 80 kg person stands at the end of an 8 m long beam with a mass of m_0. The beam remains at rest on top of a large block as shown in the figure above. What is the maximum distance x that the beam can extend from the block without the beam rotating?

(A) 0 m

(B) 1 m

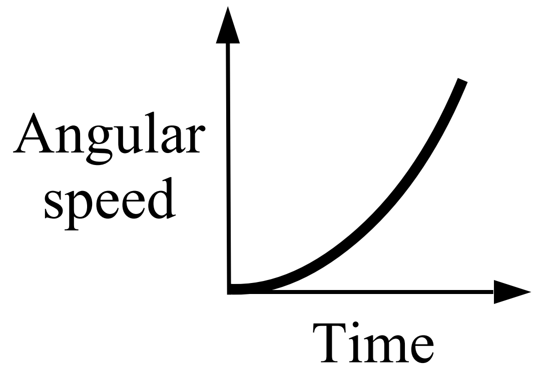
(C) 4 m

(D) Cannot be determined

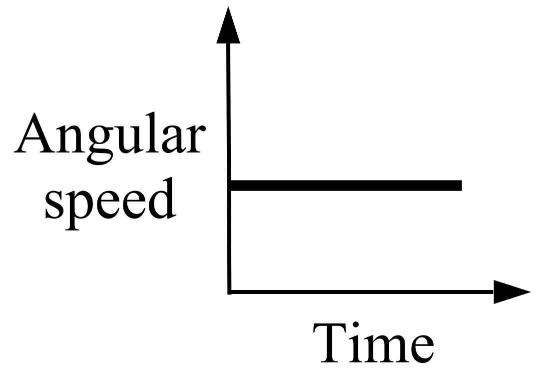


7. A block is hanging from a string which is wrapped around the outside of a pulley as shown in the figure above. The mass of the pulley and the block is not negligible, but the friction on the pulley's axle is negligible. The pulley and block are released from rest. Which of the following graphs shows the motion of the pulley?

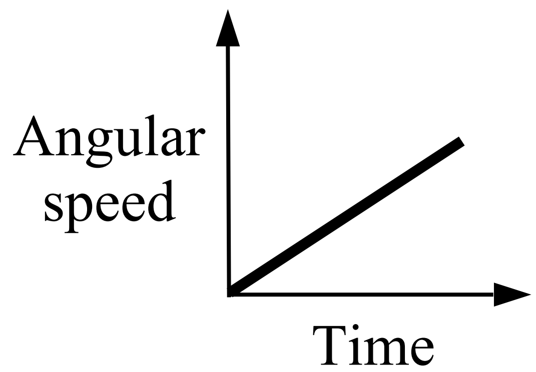
(A)



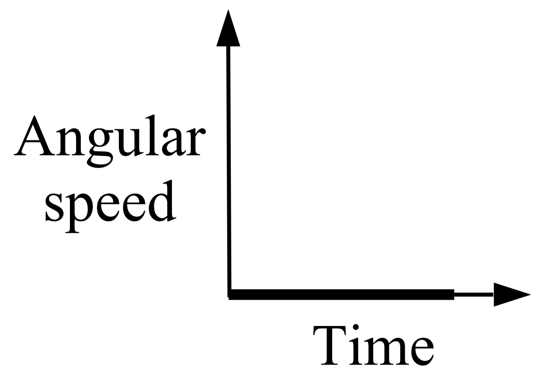
(B)

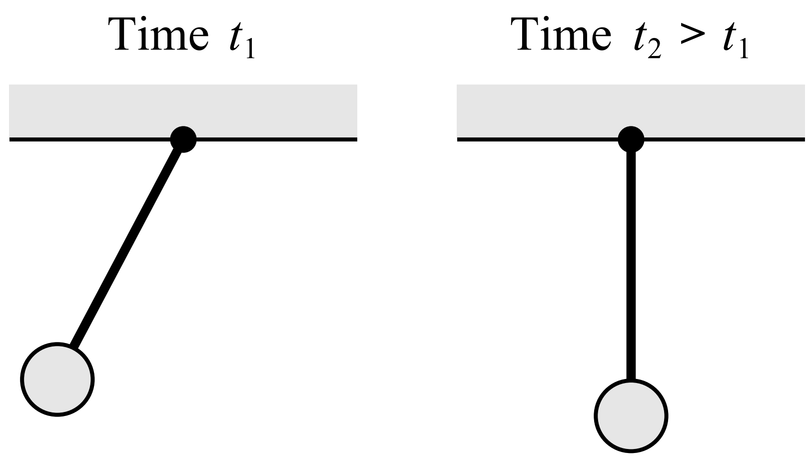


(C)



(D)





8. A pendulum consisting of a rod and a sphere is free to pivot about the point where the rod is attached to the ceiling as shown in the figure above. The pendulum is released from rest at the position shown at time t_1. The pendulum swings back and forth and is momentarily vertical at a later time t_2. Which of the following correctly describes how the angular speed of the pendulum is changing at time t_1 and time t_2?

(A)

Angular speed at t_1	Angular speed at t_2
Not changing	Not changing

(B)

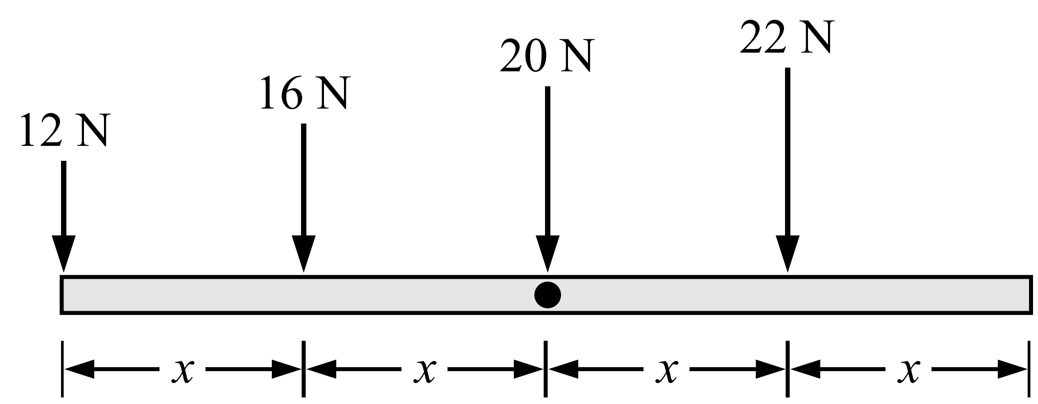
Angular speed at t_1	Angular speed at t_2
Increasing	Increasing

(C)

Angular speed at t_1	Angular speed at t_2
Decreasing	Increasing

(D)

Angular speed at t_1	Angular speed at t_2
Increasing	Not changing



1. Four forces are exerted on a rod which is free to rotate about its center. The forces are applied at evenly spaced distances as shown in the figure above. Which single force, if applied on its own, would cause the rod to rotate with the greatest angular acceleration (magnitude)?

(A) The 22 N force

(B) The 12 N force

(C) The 20 N force

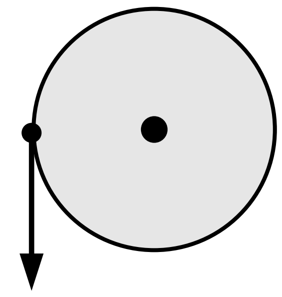
(D) The 16 N force

A Incorrect
The torque produced by the 22 N force is: $\tau = rF_{\perp} = (x)(22 \text{ N}) = 22x$

B Correct
The angular acceleration of the rod is equal to the net torque acting on the rod divided by the rotational inertia of the rod about the point of rotation. The force which produces the greatest torque about the point of rotation (the center) will result in the greatest angular acceleration. The torque produced by a force is equal to the distance between the point of rotation and the point where the force is applied, multiplied by the component of the force which is perpendicular to the rod (all of the forces are perpendicular to the rod).
12 N force: $\tau = rF_{\perp} = (2x)(12 \text{ N}) = 24x$

C Incorrect
The torque produced by the 20 N force is: $\tau = rF_{\perp} = (x)(20 \text{ N}) = 0$

D Incorrect
The torque produced by the 16 N force is: $\tau = rF_{\perp} = (x)(16 \text{ N}) = 16x$



2. A wheel is initially spinning freely about its center in the clockwise direction with a constant angular speed. A force is then applied to the wheel as shown in the figure above. At the moment the force is applied, which of the following is true about the angular acceleration of the wheel?

(A) The angular acceleration is in the clockwise direction

(B) The angular acceleration is in the counterclockwise direction

(C) The angular acceleration is zero

(D) None of the above can be determined

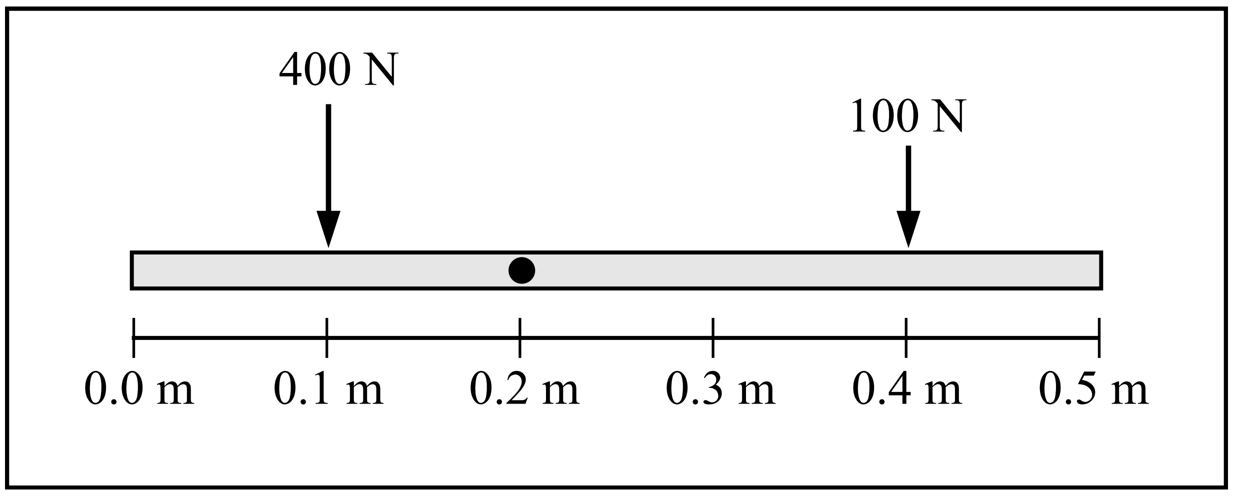
A Incorrect

B **Correct**

The angular acceleration of an object is in the same direction as the net torque acting on the object, regardless of the direction of the angular velocity: $\Sigma\tau = I\alpha$. The applied force produces a torque in the counterclockwise direction so the angular acceleration of the wheel is counterclockwise and the angular speed decreases.

C Incorrect

D Incorrect



Top view

3. A rod is resting on a table with negligible friction and is pinned so it is free to rotate about a point 0.2 m from the left end of the rod. Two horizontal forces are applied to the beam as shown in the figure above, which is a top-down view of the rod on the table. The rotational inertia of the beam is 20 kg·m². At the moment the two forces are applied, the magnitude of the angular acceleration of the beam is

(A) 0 rad/s²

(B) 3 rad/s²

(C) 1 rad/s²

(D) 20 rad/s²

A **Incorrect**

This answer incorrectly uses 0.4 m as the distance between the 100 N force and the point of rotation.

B **Incorrect**

This answer incorrectly adds the torques produced by each force. The torques are in opposite directions so one torque must be negative.

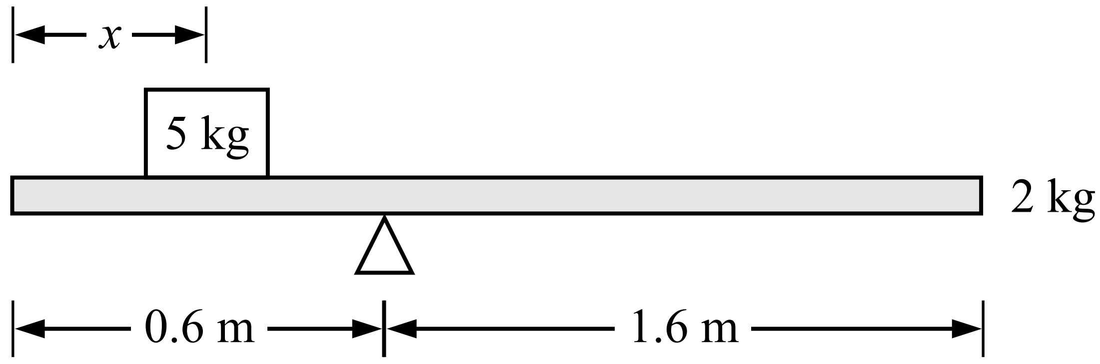
C **Correct**

The net torque acting on the beam about the point of rotation is equal to the rotational inertia of the beam multiplied by the angular acceleration of the beam. The torques act in opposite directions.

$\Sigma\tau = \tau_{400\text{ N}} - \tau_{100\text{ N}} = I\alpha$ $\quad (0.1\text{ m})(400\text{ N}) - (0.2\text{ m})(100\text{ N}) = (20\text{ kg}\cdot\text{m}^2)\alpha$ $\quad \alpha = 1\text{ rad/s}^2$

D **Incorrect**

This answer is the value of the net torque (20 N·m) with the units for angular acceleration.



Note: Figure not drawn to scale.

4. A 2 kg beam is resting on a pivot point and a 5 kg block is resting on the beam as shown in the figure above. If the beam and the block remain at rest, what is the distance between the center of the block and the left end of the beam?

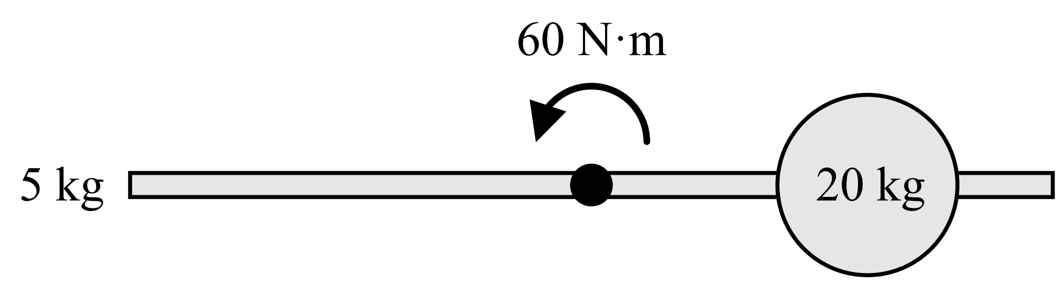
(A) 0.8 m
(B) 0.2 m
(C) 0.6 m
(D) 0.4 m

A Incorrect
This answer incorrectly adds the torques from the block and the beam. The torques act in opposite directions so one torque must be negative.

B Incorrect
This answer incorrectly uses x as the distance between the block and the point of rotation.

C Incorrect
This answer only inludes the torque produced by the block and excludes the torque produced by the beam.

D **Correct**
The beam remains at rest so the angular acceleration of the beam is zero and the net torque acting on the beam about the point of rotation is zero. The weight force of the 5 kg block acts at the center of the block and produces a torque about the pivot point. The weight force of the beam acts at the center of the beam and also produces a torque about the pivot point. The beam is 2.2 m long so the center of the beam is 1.1 m from the left end or 0.5 m to the right of the pivot point. The torques act in opposite directions.
$\Sigma\tau = \tau_{\text{block}} - \tau_{\text{beam}} = I(0\ \text{rad/s}^2)$ $\quad rF_{\text{block}} - rF_{\text{beam}} = 0$ $\quad (0.6\ \text{m} - x)(5\ \text{kg})g - (0.5\ \text{m})(2\ \text{kg})g = 0$
$x = 0.4\ \text{m}$



Top view

5. A 20 kg sphere is attached to a 5 kg rod which is free to rotate about its center as shown in the figure above. A 60 N·m torque is applied to the rod by a force which is not shown, and the rod and sphere rotate with an angular acceleration. Which of the following changes would increase the angular acceleration of the rod and sphere?

(A) Decrease the mass of the rod

(B) Move the sphere farther from the center of the rod

(C) Increase the mass of the sphere

(D) Increase the total length of the rod so the total mass of the rod remains the same and it rotates about its center

A **Correct**

The net torque acting on the system is equal to the rotational inertia of the system multiplied by the angular acceleration: $\Sigma\tau = I\alpha$. Decreasing the rotational inertia would increase the angular acceleration. The rotational inertia of the system depends on the distribution of mass relative to the point of rotation. Decreasing the mass of the rod would decrease the rotational inertia and increase the angular acceleration.

B Incorrect

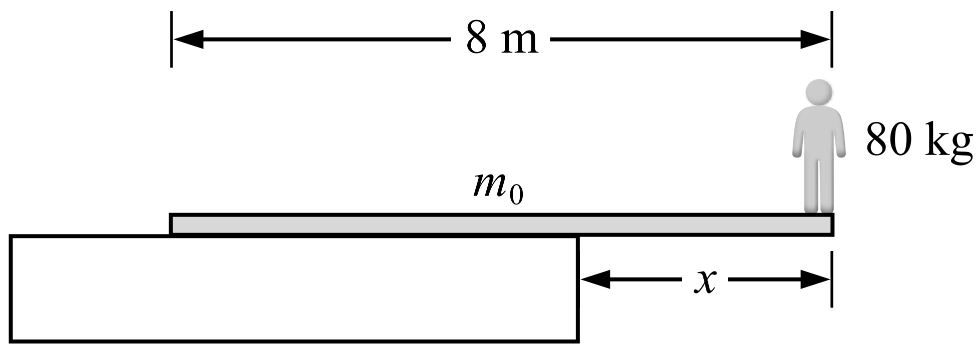
Moving the sphere farther from the center of the rod would increase the system's rotational inertia and decrease the angular acceleration.

C Incorrect

Increasing the mass of the sphere would increase the system's rotational inertia and decrease the angular acceleration.

D Incorrect

Increasing the length of the rod would move mass away from the point of rotation which would increase the system's rotational inertia and decrease the angular acceleration.



6. An 80 kg person stands at the end of an 8 m long beam with a mass of m_0. The beam remains at rest on top of a large block as shown in the figure above. What is the maximum distance x that the beam can extend from the block without the beam rotating?

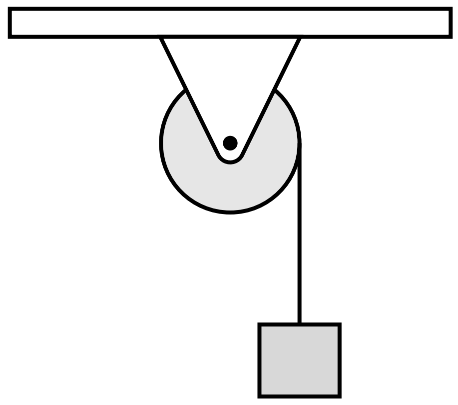
(A) 0 m
(B) 1 m
(C) 4 m
(D) Cannot be determined

A Incorrect

B Incorrect

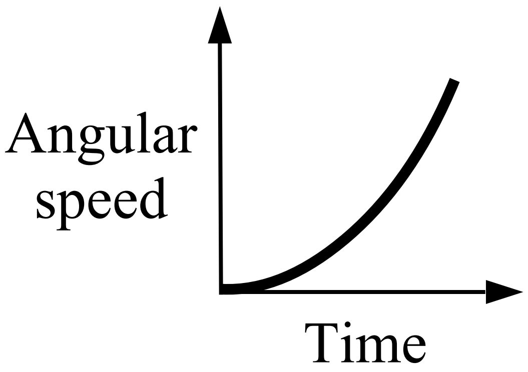
C Incorrect

D Correct
The maximum length that the beam can extend from the block is when the net torque on the beam about the pivot point (the right end of the block) is zero. The net torque is the sum of the counterclockwise torque produced by the weight force acting on the center of the beam minus the clockwise torque produced by the weight force acting on the person. The mass of the beam must be given in order to find the torque produced by the weight force on the beam.

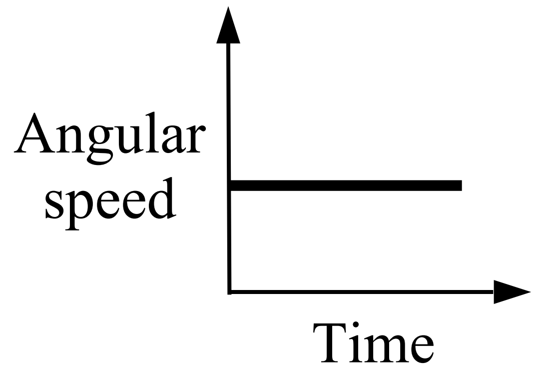


7. A block is hanging from a string which is wrapped around the outside of a pulley as shown in the figure above. The mass of the pulley and the block is not negligible, but the friction on the pulley's axle is negligible. The pulley and block are released from rest. Which of the following graphs shows the motion of the pulley?

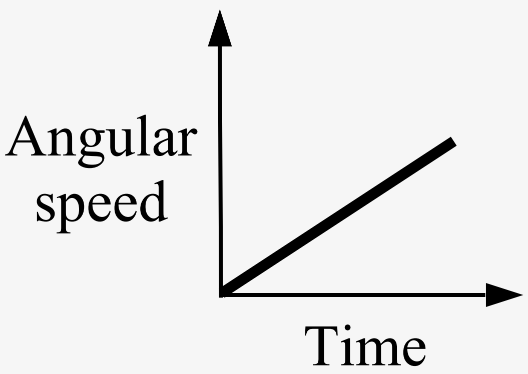
(A)



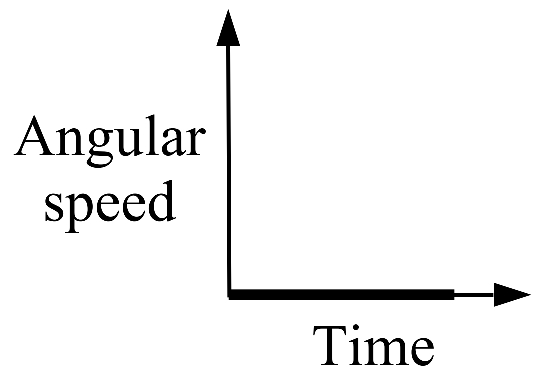
(B)



(C)



(D)

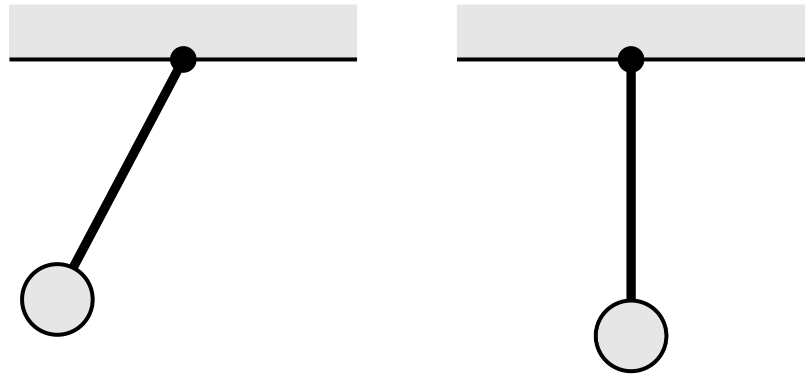


A Incorrect
This would be a graph of the angular position or displacement of the wheel vs time.

B Incorrect

C Correct
The tension in the string from the weight of the block produces a constant torque on the pulley about its center. A net torque causes an object to rotate with a constant angular acceleration, $\tau_{net} = I\alpha$. Angular acceleration is the change in angular velocity divided by time, $\alpha = \Delta\omega/\Delta t$, so a graph of the angular speed is a straight line with a constant positive slope (which is the angular acceleration).

D Incorrect



8. A pendulum consisting of a rod and a sphere is free to pivot about the point where the rod is attached to the ceiling as shown in the figure above. The pendulum is released from rest at the position shown at time t_1. The pendulum swings back and forth and is momentarily vertical at a later time t_2. Which of the following correctly describes how the angular speed of the pendulum is changing at time t_1 and time t_2?

(A)

Angular speed at t_1	Angular speed at t_2
Not changing	Not changing

(B)

Angular speed at t_1	Angular speed at t_2
Increasing	Increasing

(C)

Angular speed at t_1	Angular speed at t_2
Decreasing	Increasing

(D)

Angular speed at t_1	Angular speed at t_2
Increasing	Not changing

A Incorrect

B Incorrect

C Incorrect

D **Correct**

The weight forces acting on the rod and the sphere can produce a net torque on the pendulum about the point of rotation (the top of the rod). A net torque causes the pendulum to rotate with an angular acceleration, $\Sigma\tau = I\alpha$, and an angular acceleration is a change in the angular velocity (or speed). A torque is produced at time t_1 because the weight forces have a component that is perpendicular to the rod (the weight forces are at an angle to the rod and not parallel to it), so there is an angular acceleration which causes the angular speed to increase (the pendulum starts at rest). There is no torque on the pendulum at time t_2 because the weight forces are parallel to the rod and the line of force passes through the point of rotation, so there is no angular acceleration and the angular speed does not change at that moment.