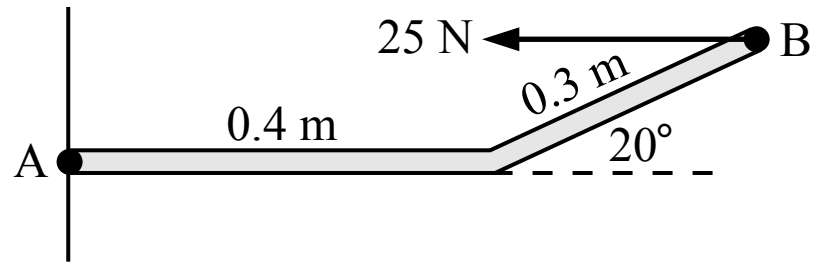
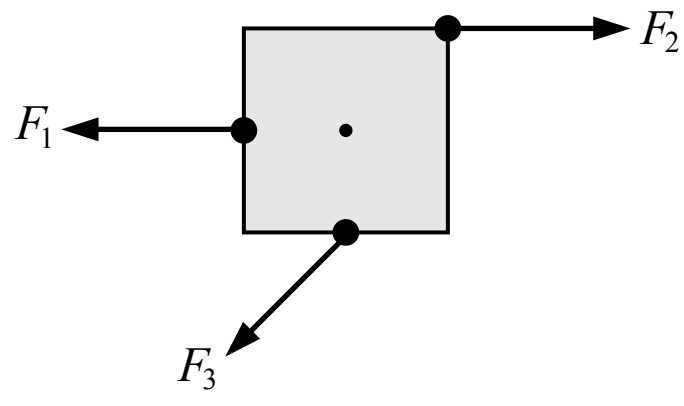
TORQUE



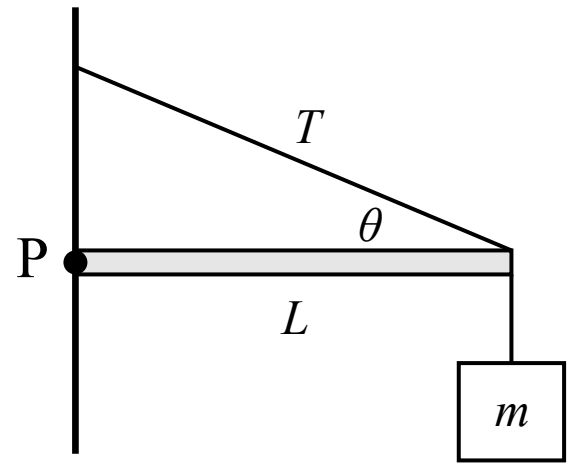
1. A rod consisting of a 0.4 m long segment and a 0.3 m long segment is attached to a wall at point A as shown in the figure above. A 25 N force acts horizontally at point B on the rod. The magnitude of the torque produced by the 25 N force about point A is

   (A) 10 N·m
   (B) 2.6 N·m
   (C) 6.0 N·m
   (D) 3.4 N·m



2. Three forces with equal magnitude are exerted on a square which is free to rotate about the point at its center as shown in the figure above. How do the magnitudes of the torques produced by the three forces about the center compare?

   (A) $\tau_1 = \tau_2 = \tau_3$
   (B) $\tau_1 < \tau_2 < \tau_3$
   (C) $\tau_3 < \tau_1 = \tau_2$
   (D) $\tau_1 < \tau_3 < \tau_2$



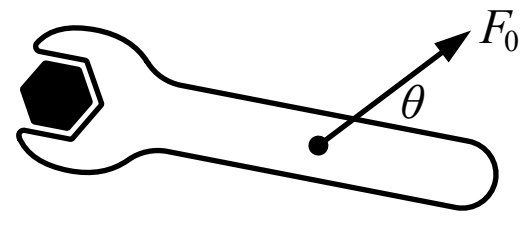
3. A horizontal pole with a length of L and negligible mass is attached to a wall at point P where it is free to rotate. At the other end of the pole, a block of mass m is suspended by a string with negligible mass and a rope with a tension of T and negligible mass connects the pole and the wall at an angle as shown in the figure above. The magnitude of the net torque acting on the pole about point P is

(A) $LT\sin(\theta) + Lmg$

(B) $LT\cos(\theta) - Lmg$

(C) $LT\sin(\theta) - Lmg$

(D) $T\sin(\theta) - mg$



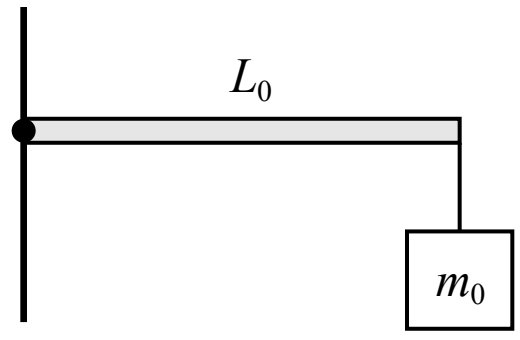
4. A force is exerted on a wrench in order to turn the bolt at the left end of the wrench as shown in the figure above. Which of the following changes would <u>not</u> increase the torque produced by the force about the center of the bolt?

(A) Increase θ to 90°

(B) Move the force closer to the bolt

(C) Double the magnitude of the force

(D) All of the above would increase the torque



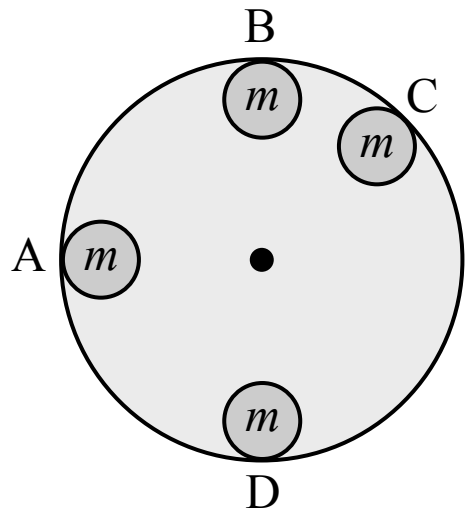
5. A beam with negligible mass and a length of L_0 is attached to a wall at its left end. A block with a mass of m_0 is suspended from the right end of the beam by a string with negligible mass, producing a torque of τ_0 about the left end of the beam. If the length of the beam was changed to $L_0/3$ and the mass was changed to $2\,m_0$, the torque produced about the left end of the beam would be

(A) $2\tau_0/3$

(B) $6\tau_0$

(C) $3\tau_0/2$

(D) $\tau_0/3$



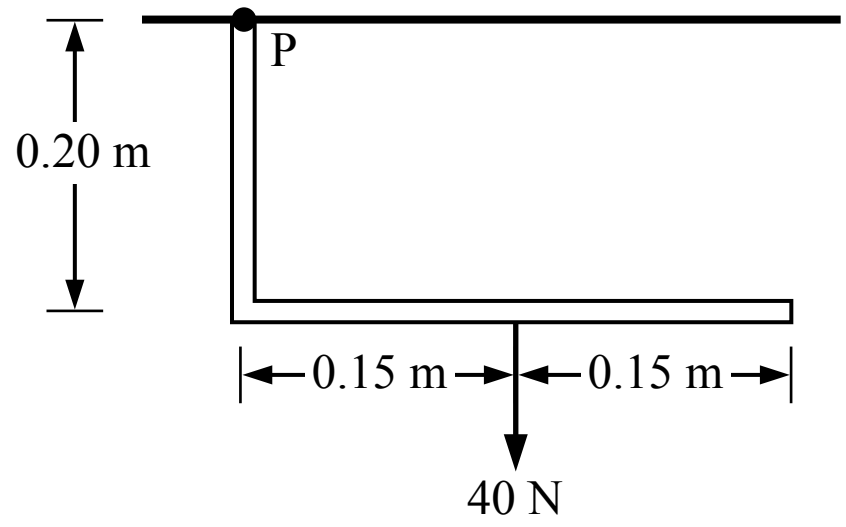
6. A large vertical disk is free to rotate about a horizontal axle passing through its center. A small disk of mass m is attached to the outer edge of the large disk. At which of the locations shown should the small disk be attached so that the torque produced by the small disk about the axle at the center of the large disk is greatest?

(A) Location A

(B) Location B

(C) Location C

(D) Location D



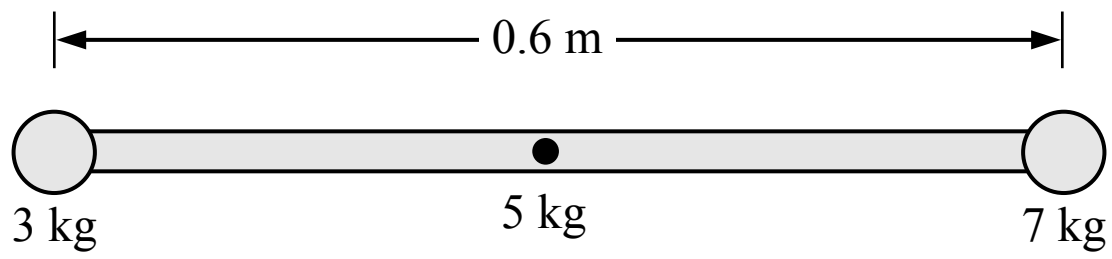
7. A thin pipe with negligible mass is attached to the ceiling at point P as shown in the figure above. The torque generated at point P by the 40 N force is

   (A) 14 N·m

   (B) 12 N·m

   (C) 8 N·m

   (D) 6 N·m



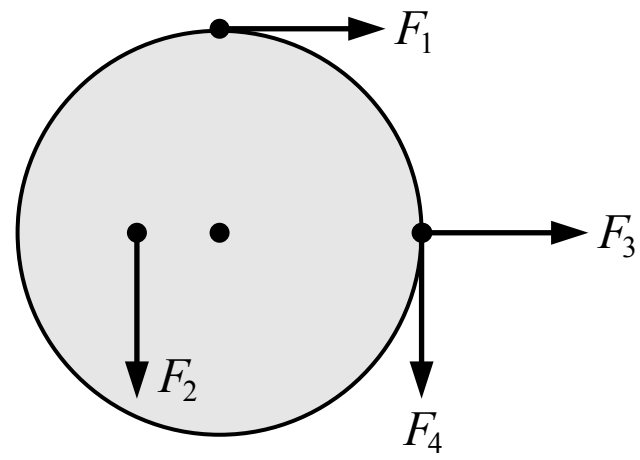
8. A 3 kg sphere and a 7 kg sphere are attached to the ends of a 5 kg rod which is free to rotate about an axle passing through its center. When the rod is horizontal as shown in the figure above, the magnitude of the net torque on the rod about the axle is most nearly

   (A) 60 N·m

   (B) 12 N·m

   (C) 30 N·m

   (D) 90 N·m



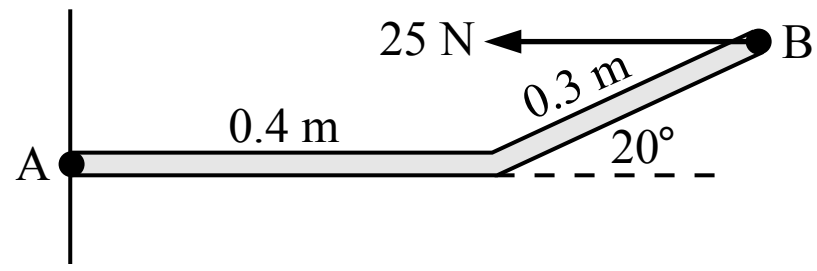
9. Four forces with equal magnitudes are exerted on a wheel as shown in the figure above. Which of the following correctly ranks the forces by the magnitude of the torque produced by each force about the center of the wheel?

(A) $F_2 < (F_1 = F_3 = F_4)$

(B) $F_3 < F_4 < F_1 < F_2$

(C) $F_3 < F_2 < (F_1 = F_4)$

(D) $F_2 < F_4 < (F_1 = F_3)$



1. A rod consisting of a 0.4 m long segment and a 0.3 m long segment is attached to a wall at point A as shown in the figure above. A 25 N force acts horizontally at point B on the rod. The magnitude of the torque produced by the 25 N force about point A is

(A) 10 N·m

(B) 2.6 N·m

(C) 6.0 N·m

(D) 3.4 N·m

A Incorrect

This answer incorrectly calculates the torque as $\tau = (0.4\ \text{m})(25\ \text{N})$.

B Correct

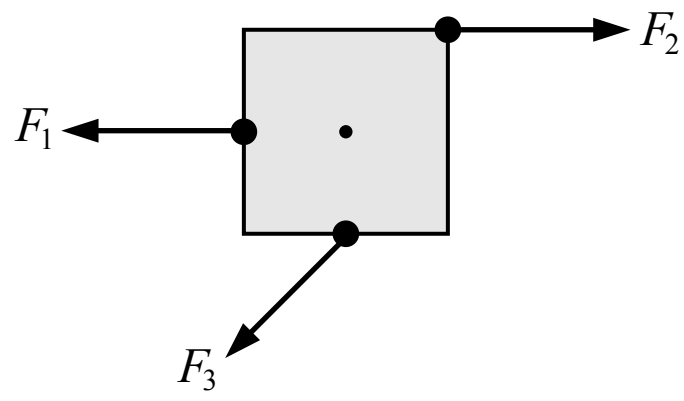
The magnitude of the torque produced by a force can be calculated in two ways. First, $\tau = rF_\perp$ where r is the straight-line distance between the point of rotation and the point where the force is applied (the straight-line distance between points A and B which is not 0.7 m) and $F_\perp$ is the component of the force that is perpendicular to the radial line (a straight line betwen points A and B). Those values could be found using geometry. The second method would be easier: $\tau = r_\perp F$ where $r_\perp$ is the distance between the point of rotation and the line of force (a line that extends from the force vector), and F is the magnitude of the force.
$\tau = r_\perp F = (0.3\ \text{m})\sin(20°)(25\ \text{N}) = 2.6\ \text{N·m}$

C Incorrect

This answer incorrectly calculates the torque as $\tau = (0.7\ \text{m})(25\ \text{N})\sin(20°)$.

D Incorrect

This answer incorrectly calculates the torque as $\tau = (0.4\ \text{m})(25\ \text{N})\sin(20°)$.



2. Three forces with equal magnitude are exerted on a square which is free to rotate about the point at its center as shown in the figure above. How do the magnitudes of the torques produced by the three forces about the center compare?

(A) $\tau_1 = \tau_2 = \tau_3$

(B) $\tau_1 < \tau_2 < \tau_3$

(C) $\tau_3 < \tau_1 = \tau_2$

(D) $\tau_1 < \tau_3 < \tau_2$

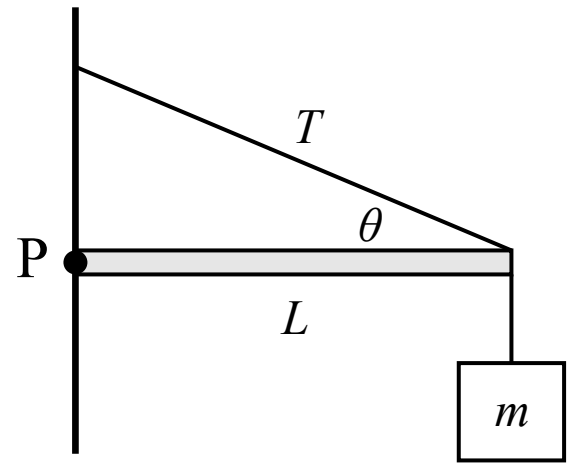
A Incorrect

B Incorrect

C Incorrect

D Correct

The magnitude of the torque produced about a point of rotation by a force can be calculated in two ways: $\tau = rF_\perp = r_\perp F$. F_1 acts along a line that passes through the point of rotation so no torque is produced by F_1. F_3 acts at a point that is a distance from the point of rotation equal to half of the square's width, and it acts at an angle to that radial line (not perpendicular). F_2 acts along a line of force that is a distance from the point of rotation that is equal to half of the square's width, and it acts perpendicular to that radial line so it produces a greater torque than F_3. This is equivalent to F_2 acting at the same point as F_3.



3. A horizontal pole with a length of L and negligible mass is attached to a wall at point P where it is free to rotate. At the other end of the pole, a block of mass m is suspended by a string with negligible mass and a rope with a tension of T and negligible mass connects the pole and the wall at an angle as shown in the figure above. The magnitude of the net torque acting on the pole about point P is

(A) $LT\sin(\theta) + Lmg$

(B) $LT\cos(\theta) - Lmg$

(C) $LT\sin(\theta) - Lmg$

(D) $T\sin(\theta) - mg$

A Incorrect

This answer incorrectly adds the two torques, but they are in opposite directions so one must be negative.

B Incorrect

This answer incorrectly uses the horizontal component of the tension force and switches $\sin(\theta)$ and $\cos(\theta)$.

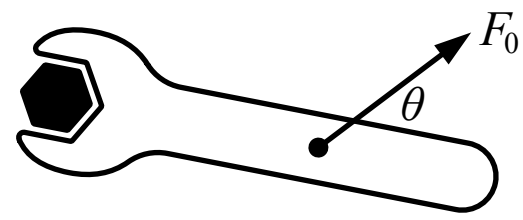
C Correct

There is a torque produced by the tension force from the upper rope and a torque produced by the weight force from the suspended block. The net torque about point P is the sum of those two torques which are in opposite directions, so one torque must be positive and the other must be negative (conventionally counterclockwise torques are positive).

$\Sigma\tau = \tau_{\text{rope}} - \tau_{\text{block}} = rF_{\text{rope}\perp} - rF_{\text{block}\perp} = LT\sin(\theta) - Lmg$

D Incorrect

This answer includes the forces but not the torques, which must be multiplied by the distance between the point of rotation and the point where the force is applied (L).



4. A force is exerted on a wrench in order to turn the bolt at the left end of the wrench as shown in the figure above. Which of the following changes would not increase the torque produced by the force about the center of the bolt?

(A) Increase θ to 90°

(B) Move the force closer to the bolt

(C) Double the magnitude of the force

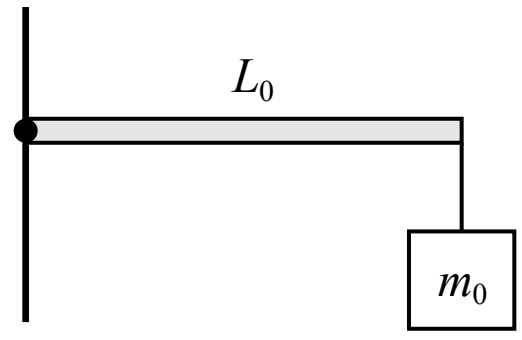
(D) All of the above would increase the torque

A Incorrect
This answer is a change that would increase the torque produced by the force about the center of the bolt.

B **Correct**
The magnitude of the torque produced by the force about the center of the bolt is equal to the distance between the center of the bolt and the point where the force is applied multiplied by the component of the force which is perpendicular to the wrench handle (the radial line). Moving the force closer to the bolt would decrease the torque produced by the force about the center of the bolt.

C Incorrect
This answer is a change that would increase the torque produced by the force about the center of the bolt.

D Incorrect



5. A beam with negligible mass and a length of L_0 is attached to a wall at its left end. A block with a mass of m_0 is suspended from the right end of the beam by a string with negligible mass, producing a torque of τ_0 about the left end of the beam. If the length of the beam was changed to $L_0/3$ and the mass was changed to $2\,m_0$, the torque produced about the left end of the beam would be

(A) $2\tau_0/3$

(B) $6\tau_0$

(C) $3\tau_0/2$

(D) $\tau_0/3$

A **Correct**

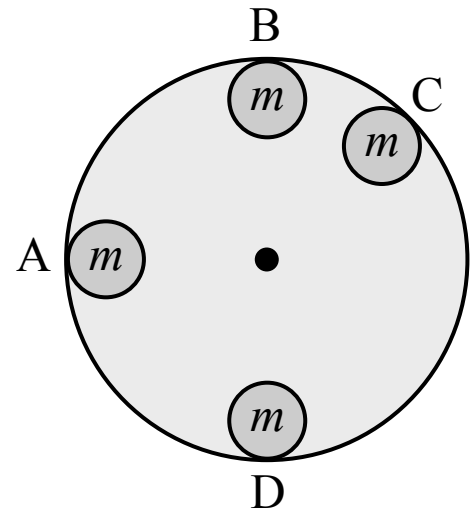
The weight force on the block produces a torque about the left end of the beam which is equal to the length of the beam multiplied by the weight force of the block (which acts perpendicular to the beam). If the length of the beam is divided by 3 and the mass of the block is multiplied by 2 then the torque is multiplied by 2/3.

$\tau_0 = rF_\perp = L_0 m_0 g \qquad \tau = (L_0/3)(2\,m_0)g = 2\tau_0/3$

B Incorrect

C Incorrect

D Incorrect



6. A large vertical disk is free to rotate about a horizontal axle passing through its center. A small disk of mass m is attached to the outer edge of the large disk. At which of the locations shown should the small disk be attached so that the torque produced by the small disk about the axle at the center of the large disk is greatest?

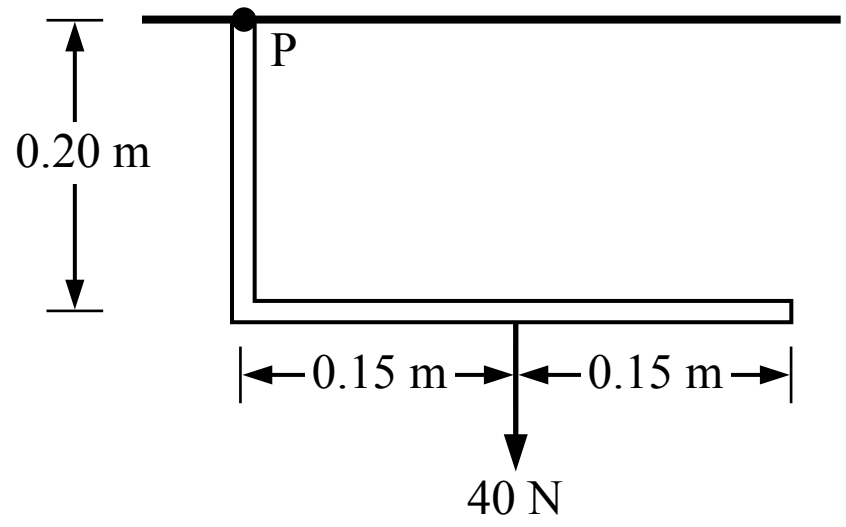
(A) Location A
(B) Location B
(C) Location C
(D) Location D

A **Correct**
The torque is equal to the distance r between the point of rotation (the axle) and the point where the force is applied (the weight force is acting at the center of the small disk), multiplied by the component of that force which is perpendicular to r (a line connecting the point of rotation and the point where the force is applied): $\tau = rF_{\perp}$. The weight force on the small disk always acts vertically downwards. When the small disk is in location A, the weight force is perpendicular to r so the torque produced by the weight force is greatest.

B Incorrect
No torque is produced by the weight of the small disk at location B because the weight force is parallel to r.

C Incorrect
The torque produced by the weight of the small disk at location C is less than at location A because the weight force is not perpendicular to r.

D Incorrect
No torque is produced by the weight of the small disk at location D because the weight force is parallel to r.



7. A thin pipe with negligible mass is attached to the ceiling at point P as shown in the figure above. The torque generated at point P by the 40 N force is

(A) 14 N·m

(B) 12 N·m

(C) 8 N·m

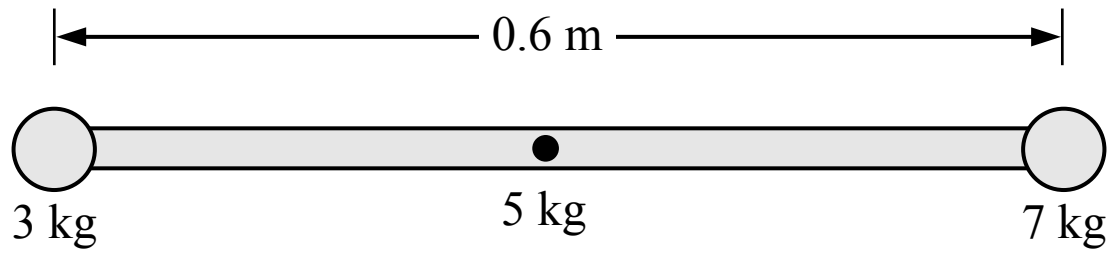
(D) 6 N·m

A Incorrect
This answer incorrectly calculates the torque as $\tau = (0.35\ \text{m})(40\ \text{N})$

B Incorrect
This answer incorrectly calculates the torque as $\tau = (0.30\ \text{m})(40\ \text{N})$

C Incorrect
This answer incorrectly calculates the torque as $\tau = (0.20\ \text{m})(40\ \text{N})$

D Correct
The torque generated by the 40 N force about point P can be calculated as $\tau = rF_{\perp}$, the straight-line distance between point P and the point where the 40 N force acts (which would have to be found using geometry) multiplied by the component of the 40 N force that is perpendicular to that distance line (the angle between them would have to be found using geometry). The torque can also be calculated as $\tau = r_{\perp}F$, the distance between point P and a line passing through the 40 N force vector (which is 0.15 m) multiplied by the full 40 N force: $\tau = r_{\perp}F = (0.15\ \text{m})(40\ \text{N}) = 6\ \text{N·m}$



8. A 3 kg sphere and a 7 kg sphere are attached to the ends of a 5 kg rod which is free to rotate about an axle passing through its center. When the rod is horizontal as shown in the figure above, the magnitude of the net torque on the rod about the axle is most nearly

(A) 60 N·m

(B) 12 N·m

(C) 30 N·m

(D) 90 N·m

A Incorrect

This answer incorrectly adds each torque and includes a torque from the rod as $\tau = (0.6\ \text{m})(5\ \text{kg})g$.

B Correct

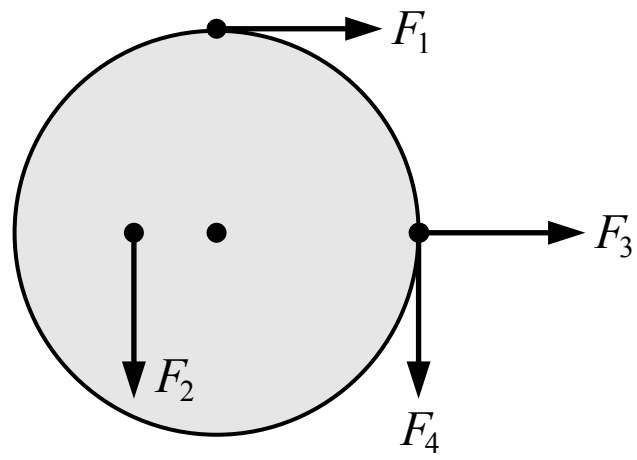
The net torque acting on the rod about the axle is the sum of the torques produced by the weight forces on the spheres and the rod. Each weight force acts vertically downwards at the center of mass of each object. The torque produced by the rod's weight force is zero because the force acts directly at the point of rotation. The torques produced by each sphere act in opposite directions. Using counterclockwise as positive:
$\Sigma\tau = \tau_3 + \tau_5 - \tau_7 = (0.3\ \text{m})(3\ \text{kg})g + (0\ \text{m})(5\ \text{kg})g - (0.3\ \text{m})(7\ \text{kg})g = \text{-}12\ \text{N·m}$ (magnitude is positive)

C Incorrect

This answer incorrectly adds the torques from each sphere. The torques act in opposite directions so one must be negative.

D Incorrect

This answer incorrectly adds the torques as $\Sigma\tau = (0.6\ \text{m})(3\ \text{kg} + 5\ \text{kg} + 7\ \text{kg})g$.



9. Four forces with equal magnitudes are exerted on a wheel as shown in the figure above. Which of the following correctly ranks the forces by the magnitude of the torque produced by each force about the center of the wheel?

(A) $F_2 < (F_1 = F_3 = F_4)$

(B) $F_3 < F_4 < F_1 < F_2$

(C) $F_3 < F_2 < (F_1 = F_4)$

(D) $F_2 < F_4 < (F_1 = F_3)$

A Incorrect

B Incorrect

C Correct

The torque produced by a force about the center of the wheel is $\tau = rF_\perp$, the distance between the center of the wheel and the point where the force is applied multiplied by the component of the force that is perpendicular to the radius. F_3 does not produce a torque about the center because it is in line with the radius. F_2 is perpendicular to the radius but it acts at a smaller radius (a shorter distance from the center) than F_1 and F_4, which are both perpendicular to the radius and act at the same a larger radius.

D Incorrect