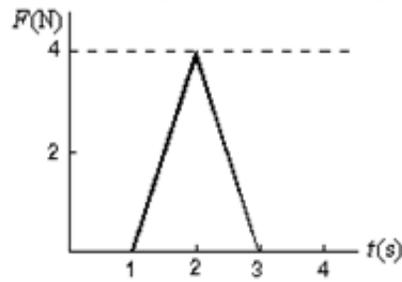


Question 1 (2 points)

A 5-kg object can move along the x axis. It is subjected to a force \vec{F} in the positive x direction; a graph of F as a function of time t is shown below. Over the time the force is applied, how would you find the change in the velocity of the object?



- a) Integrate to get impulse, and set that equal to the change in momentum.
- b) Integrate to get work, and set that equal to the change in momentum.
- c) Integrate to get work, and set that equal to the change in kinetic energy.
- d) Find slope to get work, and set that equal to the change in kinetic energy.
- e) Find slope to get impulse, and set that equal to the change in kinetic energy.
- f) Integrate to get impulse, and set that equal to the change in kinetic energy.
- g) Find slope to get impulse, and set that equal to the change in momentum.

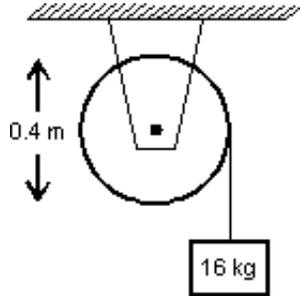
Question 2 (2 points)

If the angular velocity vector of a spinning body points out of the page then, when viewed from above the page, the body is spinning...

- a) clockwise about an axis that is perpendicular to the page
- b) counterclockwise about an axis that is perpendicular to the page
- c) about an axis that is parallel to the page
- d) about an axis that is changing orientation
- e) about an axis that is getting longer

Question 3 (2 points)

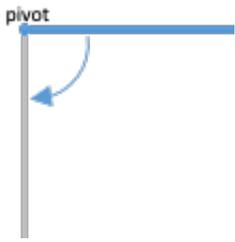
A block of mass m is attached to a cord that is wrapped around the rim of a flywheel of radius R and hangs vertically, as shown. The rotational inertia of the flywheel is I . When the block is released and the cord unwinds, what is the correct equation of motion for the flywheel?



- a) $T = I\alpha$
- b) $TR = I\alpha$
- c) $T - mg = ma$
- d) $mgR = I\alpha$
- e) $mgR - TR = I\alpha$
- f) More than one of the above is correct

Question 4 (2 points)

A uniform bar of mass m and length L is pivoted at one end and falls towards the vertical. You are asked to find the final angular speed when it had fallen from rest to the vertical. What concept could you use?



- a. Newton's 2nd Law combined with constant-acceleration kinematics
- b. Conservation of energy
- c. Conservation of angular momentum
- d. All three would work
- e. Two of the three would work

a) A only

b) B only

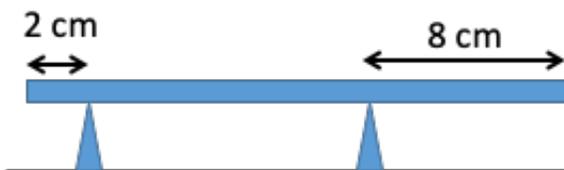
c) C only

d) D

e) E

Question 5 (2 points)

A 5 kg beam is 20 cm long and has a uniform density. It is balanced on two points as shown.



Take n_1 to be the normal force at the lefthand point, and n_2 as the normal force at the righthand point. Which is the correct Newton's 2nd Law for Rotation equation applied to the beam, **using the left-hand point as the pivot?**

- a) $(2 \text{ cm})(n_1) + (12 \text{ cm})(n_2) - (10 \text{ cm})(5 \text{ kg})(9.81 \text{ m/s}^2) = 0$
- b) $(2 \text{ cm})(n_1) + (8 \text{ cm})(n_2) - (10 \text{ cm})(5 \text{ kg})(9.81 \text{ m/s}^2) = 0$
- c) $(12 \text{ cm})(n_2) - (10 \text{ cm})(5 \text{ kg})(9.81 \text{ m/s}^2) = 0$
- d) $(10 \text{ cm})(n_2) - (10 \text{ cm})(5 \text{ kg})(9.81 \text{ m/s}^2) = 0$
- e) $(10 \text{ cm})(n_2) - (8 \text{ cm})(5 \text{ kg})(9.81 \text{ m/s}^2) = 0$
- f) $(8 \text{ cm})(n_1) + (2 \text{ cm})(n_2) = 0$
- g) $(18 \text{ cm})(n_2) - (10 \text{ cm})(5 \text{ kg})(9.81 \text{ m/s}^2) = 0$

Question 6 (2 points)

A bar is pivoted at one end and held horizontally in a gravitational field and released from rest. It swings downwards. Choose **all** of the correct statements below. Ignore any resistive forces.

- As it swings downwards, the angular acceleration is constant.
- As it swings downwards, total mechanical energy is conserved.
- As it swings downwards, the torque acting on it is constant.
- As it swings downwards, the angular speed decreases.
- Once it has reached the vertical position, the change in gravitational potential energy relative to the starting point is $\frac{mgL}{2}$.

Question 7 (2 points)

An ice cube slides down a ramp without friction. A solid sphere and a spherical shell roll down an identical ramp. All three started at the same height from rest. Select **all** of the true statements.

- The ice cube takes the shortest time to get down the ramp, regardless of its mass relative to the rolling objects.
- You would need to know the relative masses and radii of the solid sphere and spherical shell in order to decide which one takes the longest.
- The solid sphere will always take a shorter time on the ramp than the spherical shell.
- The spherical shell and the solid sphere will always have the same **angular** speed when they reach the bottom, regardless of their relative radii.
- All three have the same speed of their center of masses at the bottom, because of conservation of energy.

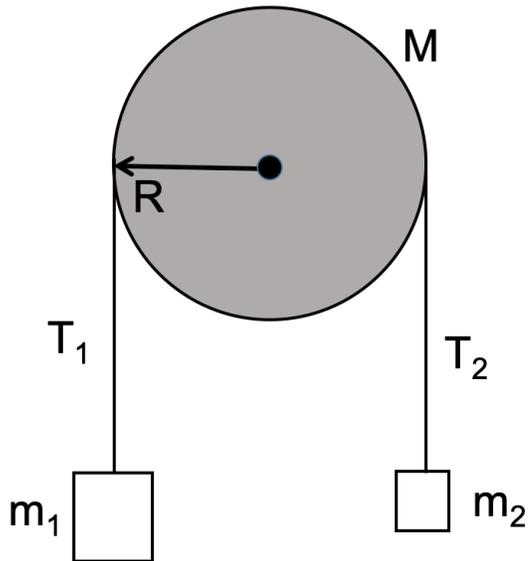
Question 8 (2 points)

A ball hits a wall perpendicularly. It initially travels in the positive x direction and it hits with a speed v_0 . It bounces off perpendicularly with half of its original speed, so the final speed is $v_0/2$. The ball was in contact with the wall for a time t . What is the average force exerted on the ball by the wall? Assume the mass of the ball is 1 kg.

- a)
$$-\frac{3v_0}{2t}\hat{i}$$
- b)
$$+\frac{3v_0}{2t}\hat{i}$$
- c)
$$-\frac{v_0}{2t}\hat{i}$$
- d)
$$+\frac{v_0}{2t}\hat{i}$$

Question 9 (2 points)

Consider the pulley in the set-up shown. Assume that mass m_1 accelerates downwards. The pulley has a total mass M and radius R and can be modeled as a solid uniform disk. What is the correct Newton's 2nd Law equation of motion for this pulley, where α is the magnitude of the angular acceleration, and all other variables shown also represent magnitudes?



a)

$$m_1 g R - m_2 g R = \frac{1}{2} M R^2 \alpha$$

b)

$$m_1 g R + m_2 g R = \frac{1}{2} M R^2 \alpha$$

c)

$$T_1 - T_2 = \frac{1}{2} M R^2 \alpha$$

d)

$$T_1 R - T_2 R = \frac{1}{2} M R^2 \alpha$$

e)

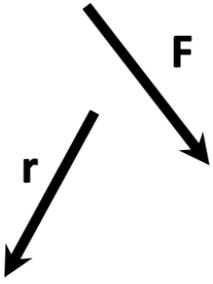
$$T_1 R + T_2 R = \frac{1}{2} M R^2 \alpha$$

f)

$$m_1 g - m_2 g = \frac{1}{2} M R^2 \alpha$$

Question 10 (2 points)

What is the direction of the torque vector that would be caused by the vectors \mathbf{r} and \mathbf{F} below?



- a) out of the page/screen
- b) into the page/screen
- c) towards the top of the page/screen
- d) parallel to \mathbf{r}
- e) parallel to \mathbf{F}
- f) $\mathbf{r} \times \mathbf{F} = 0$ so the torque is zero

Question 11 (2 points)

Consider the following integral:

$$\int_0^L (3x^2 + 4x^4) dx$$

Which of the following are possible correct interpretations of what this integral could represent? Make sure to read all options, and select **ALL** answers that could apply to the integral above.

- The total mass of a long rod that is pivoted at the end of the rod and that has a non-uniform mass density given by

$$\lambda = (3x^2 + 4x^4)$$

where $x = 0$ at the axis of rotation.

- The moment of inertia of a long rod that is pivoted at the end of the rod of the rod and that has a non-uniform mass density given by

$$\lambda = (3 + 4x^2)$$

where $x = 0$ at the axis of rotation.

- The moment of inertia of a long rod that is pivoted at the center of the rod and that has a non-uniform mass density given by

$$\lambda = (3 + 4x^2)$$

where $x = 0$ at the axis of rotation.

- The total mass of a long rod that is pivoted at the center of the rod that has a non-uniform mass density given by

$$\lambda = (3x^2 + 4x^4)$$

where $x = 0$ at the axis of rotation.

- The total mass of a long rod that is pivoted at the center of the rod that has a uniform mass density.

- The moment of inertia of a long rod that is pivoted at the center of the rod that has a non-uniform mass density given by

$$\lambda = (3x^2 + 4x^4)$$

where $x = 0$ at the axis of rotation.

Question 12 (2 points)

A wheel of radius R rotates around its center with an angular velocity given by

$$\omega = At^2 - Bt.$$

A and B are positive constants. What is the angular acceleration of the wheel at $t = 3$ seconds?

- a) $6A - 3B$
- b) $9A - 3B$
- c) $3A - B$
- d) $9A - 4.5B$
- e) $6A - B$

Question 13 (2 points)

A force that varies with time is given by $F = At^2$. It is applied to an object of mass m that is initially at rest. The force acts for 2 seconds, and then the object slides along a frictionless surface. It compresses a spring by a maximum distance d before coming to rest. What is the spring constant of the spring?

a)

$$k = \frac{64A^2}{9md^2}$$

b)

$$k = \frac{64A^2}{md^2}$$

c)

$$k = \frac{8A^2}{md^2}$$

d)

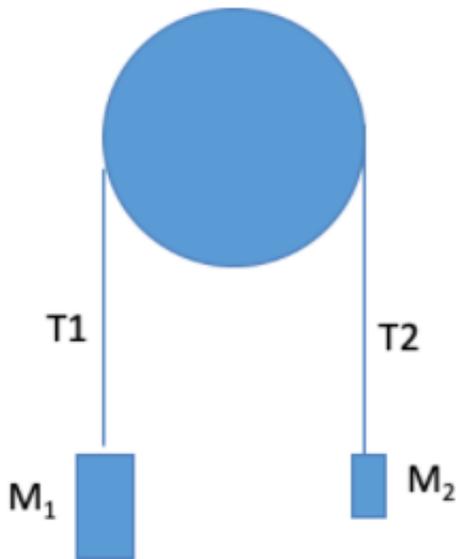
$$k = \frac{16A}{3md^2}$$

e)

$$k = \frac{16A^2}{3md^2}$$

Question 14 (2 points)

Say that $M_1 > M_2$ and the pulley is a solid disk of mass M_p and radius R . The system moves so that M_1 accelerates downwards with acceleration a . Draw a free body diagram for each object. Which of the following statements must be true?

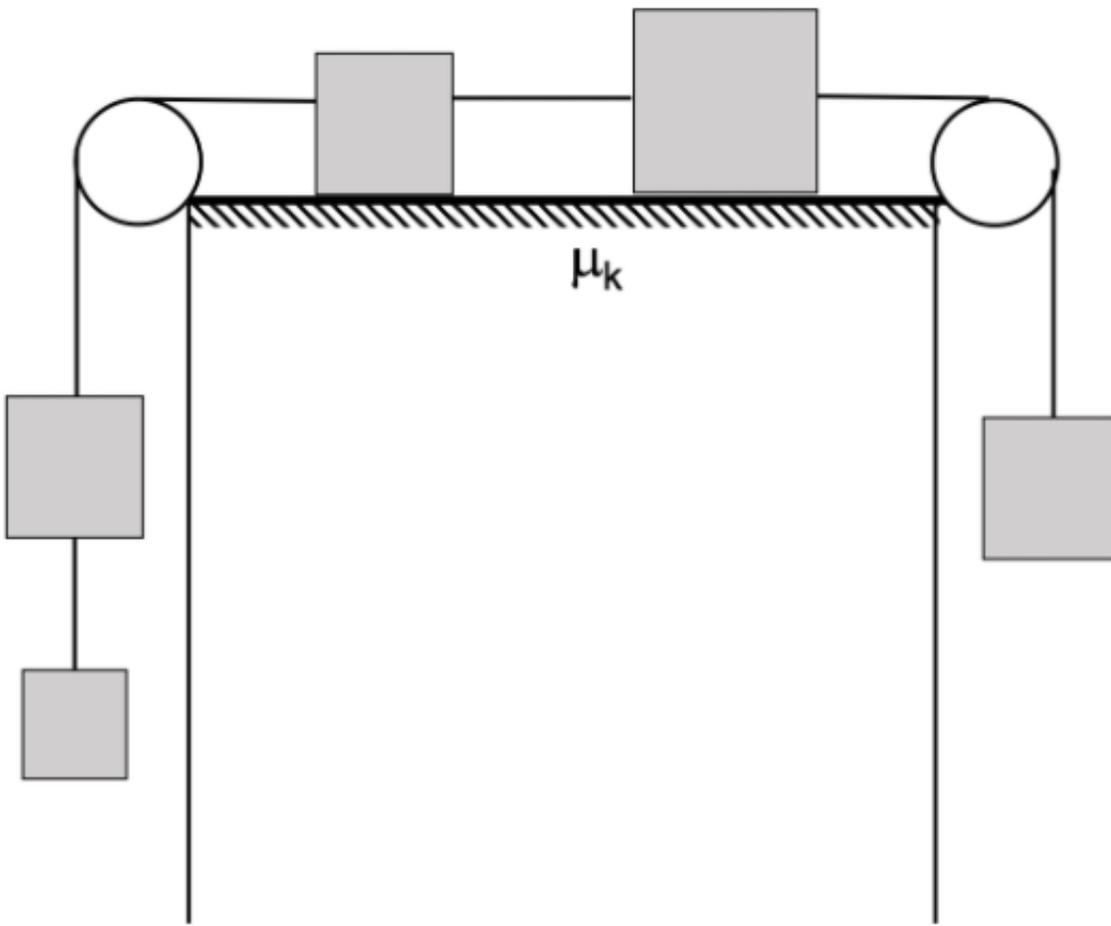


- I. $T_1 = T_2$
- II. $T_1 > T_2$
- III. $T_1 < T_2$
- IV. $T_1 = M_1g$
- V. $T_1 < M_1g$

- I and IV only.
- I and V only.
- II only.
- II and IV only.
- II and V only.

Question 15 (2 points)

For the system shown below, how many equations of motion would you write down to solve for the acceleration of the system and the tensions in each portion of the ropes? Assume all pulleys and blocks have finite nonzero mass.



- 1
- 2
- 5
- 7

Question 16 (2 points)

A wheel rotates with an angular velocity given by

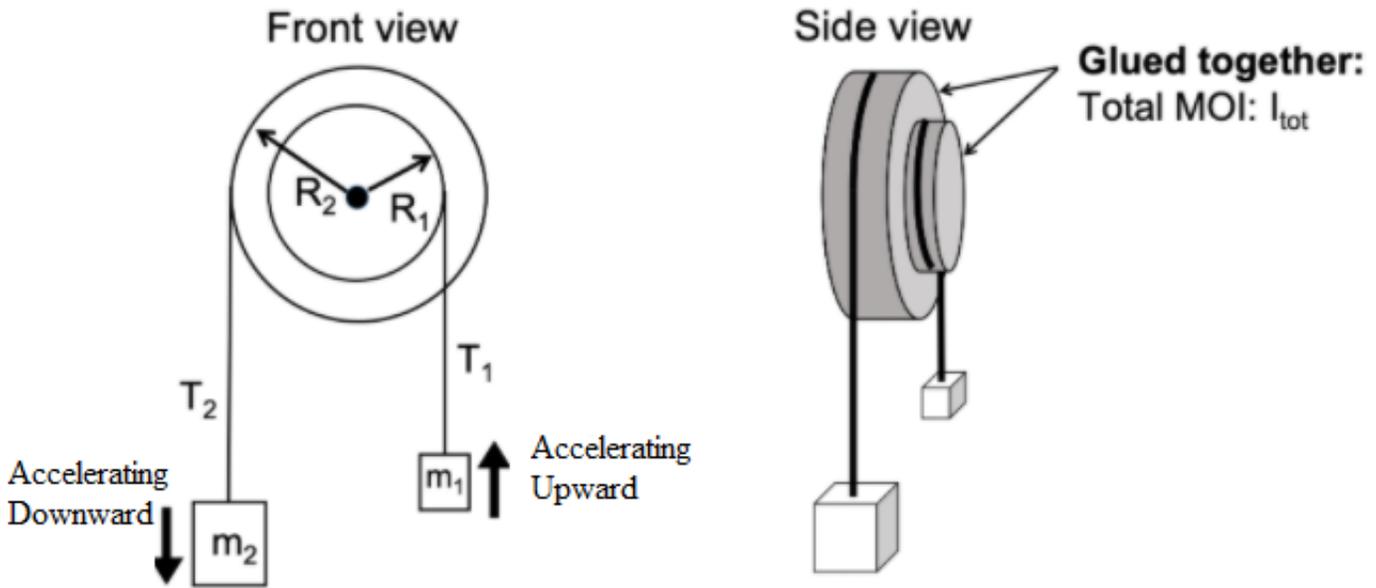
$$\omega(t) = At^3 + B.$$

What is the angular acceleration at $t = 1$ second?

- 3A
- A + B
- A/4 + B
- (A + B)/2
- None of the above.

Question 17 (2 points)

Consider the system shown below, where a pulley has two different radii, each with ropes wrapped around them attached to hanging masses. The two parts of the pulley are rigidly attached so that the whole pulley rotates as one. The ropes do not stretch or compress.

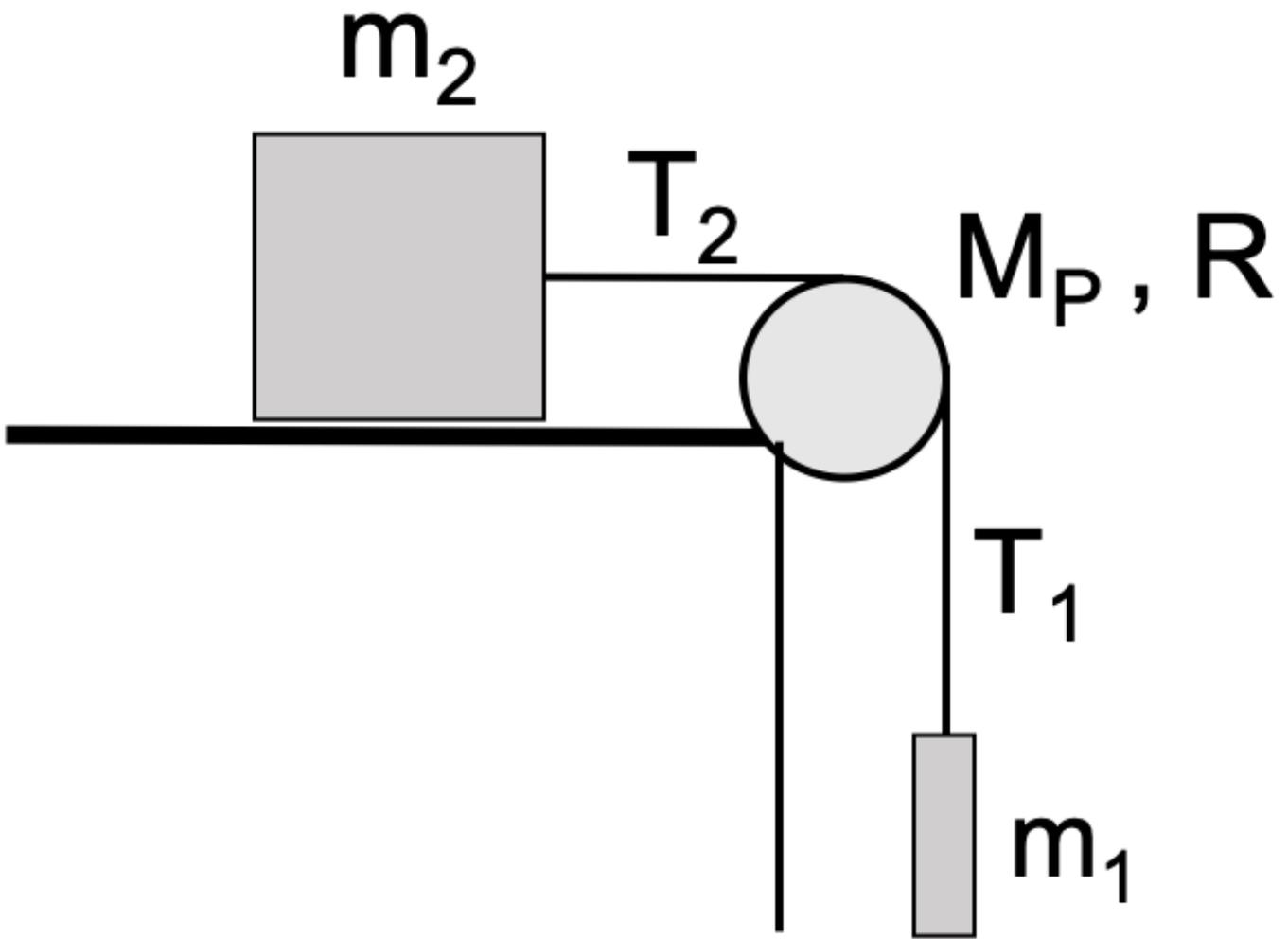


Which statement is the only true statement below?

- The angular acceleration of the the two pulleys is the same.
- The linear accelerations of each mass are same magnitude.
- The mass attached to the larger radii has a smaller linear acceleration than the other mass.
- The larger radii pulley has a larger angular acceleration.
- The tension in the two ropes must be the same.

Question 18 (2 points)

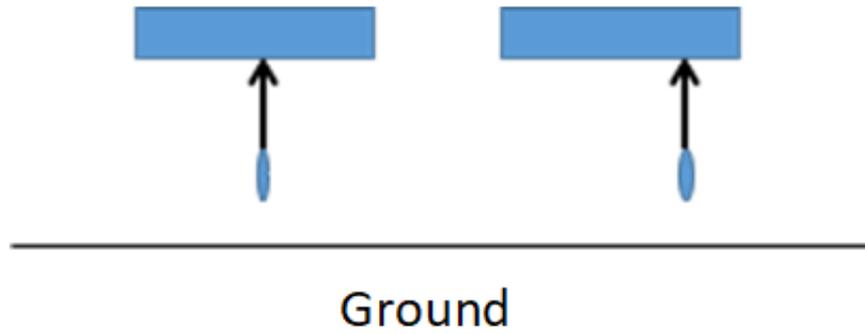
For the modified Atwood's machine shown below, what does the linear acceleration of the system approach as the pulley's mass becomes very large?



- Infinity
- g
- Zero
- $g \frac{(M_1 - M_2)}{(M_1 + M_2)}$

Question 19 (2 points)

Two identical blocks are shot with identical bullets. Each block is initially suspended at rest and the bullet is travelling vertically and hits it from below. One block is shot at its center while the other is shot off center. What is conserved in this collision?



- a. mechanical energy
- b. linear momentum
- c. angular momentum
- d. All three
- e. Just linear momentum and angular momentum

a) A only

b) B only

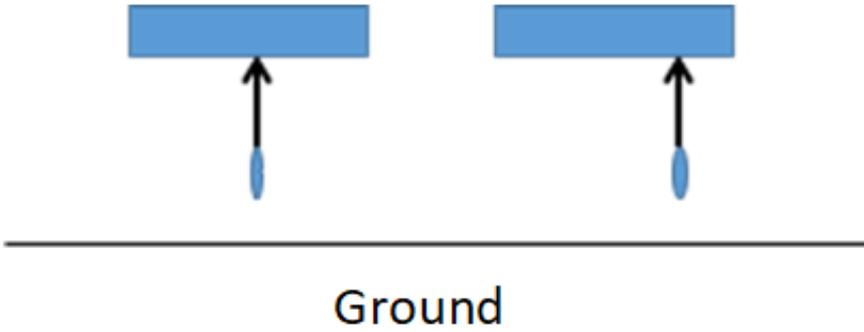
c) C only

d) D

e) E

Question 20 (2 points)

Two identical blocks are shot with identical bullets. Each block is initially suspended at rest and the bullet is travelling vertically and hits it from below. One block is shot at its center while the other is shot off center. If we apply conservation of angular momentum to these blocks, relative to the center of each block (the axis of rotation), which system has the larger angular momentum?



- A) The one shot off center.
- B) The one shot in the center.
- C) They both have the same.

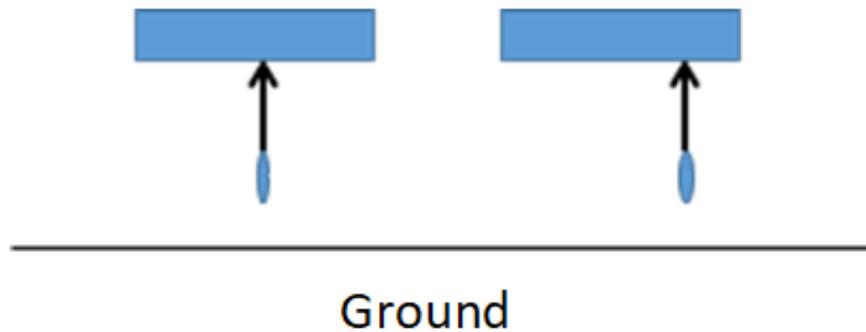
a) A

b) B

c) C

Question 21 (2 points)

Two identical blocks are shot with identical bullets. Each block is initially suspended at rest and the bullet is travelling vertically and hits it from below. One block is shot at its center while the other is shot off center. If we apply conservation of linear momentum to these blocks, which block will have the larger translational speed (of its center of mass) right after the collision?



- A) The one shot off center.
- B) The one shot in the center.
- C) They both have the same.

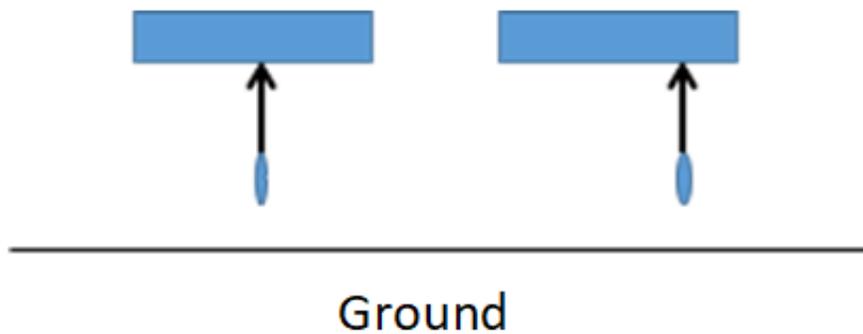
a) A

b) B

c) C

Question 22 (2 points)

Two identical blocks are shot with identical bullets. Each block is initially suspended at rest and the bullet is travelling vertically and hits it from below. One block is shot at its center while the other is shot off center. Which block will have its center of mass go highest?



A) The one shot off center.

B) The one shot in the center.

C) They both go to the same maximum height because they have the same linear speed after the collision

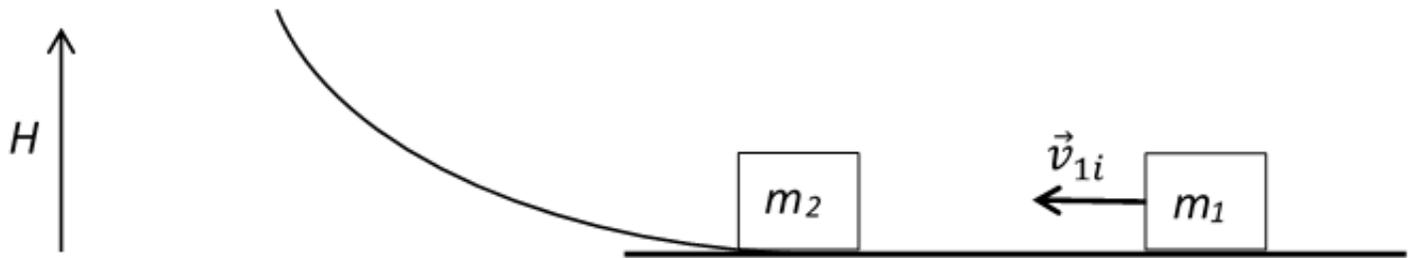
a) A

b) B

c) C

Question 23 (2 points)

A chunk of ice of mass m_1 is sliding with a horizontal velocity of magnitude v_{1i} on the floor of an ice-covered valley when it collides with and sticks to another chunk of ice of mass m_2 that is initially at rest at the base of a hill. The two blocks stick together and move up the hill together. Since the valley and hill are icy, there is no friction between the chunks and the ground.



What is the numerical value of the maximum vertical distance H that the combined ice chunks will go up the hill after the collision if $m_1 = 5.00$ kg, $m_2 = 7.50$ kg, and $v_{1i} = 12.0$ m/s?

- a) 1.17 m
- b) 2.00 m
- c) 4.66 m
- d) 1.94 m
- e) None of the above