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1. A $4\ \text{kg}$ object moving to the left collides with and sticks to a $3\ \text{kg}$ object moving to the right. Which of the following is true of the motion of the combined objects immediately after the collision?

(A) They must be moving to the left.

(B) They must be moving to the right.

(C) They must be at rest.

(D) The motion cannot be determined without knowing the speeds of the objects before the collision.

2. A 1.0 kg lump of clay is sliding to the right on a frictionless surface with speed 2 m/s . It collides head-on and sticks to a 0.5 kg metal sphere that is sliding to the left with speed 4 m/s . What is the kinetic energy of the combined objects after the collision?

(A) 6J

(B) 4J

(C) 2J

(D) 0J

3. A 2 kg object traveling at 5 m/s on a frictionless horizontal surface collides head-on with and sticks to a 3 kg object initially at rest. Which of the following correctly identifies the change in total kinetic energy and the resulting speed of the objects after the collision?

(A)

Kinetic Energy	Speed
Increases	2 m/s

(B)

Kinetic Energy	Speed
Increases	3.2 m/s

(C)

Kinetic Energy	Speed
Decreases	2 m/s

(D)

Kinetic Energy	Speed
Decreases	3.2 m/s

CHAPTER5PARTB

4. A ball of mass *m* and momentum *p* has kinetic energy equal to which of the following?

(A) $\frac{1}{2}\ \frac{p^2}{m}$

(B) $\frac{p^2}{m}$

(C) $2\ \frac{p^2}{m}$

(D) $\frac{1}{2}\ \frac{m}{p^2}$

(E) $2\ \frac{m}{p^2}$

5. A cart of mass m is moving with negligible friction along a track with known speed v_1 to the right. It collides with and sticks to a cart of mass 4*m* moving with known speed v_2 to the right. Which of the two principles, conservation of momentum and conservation of mechanical energy, must be applied to determine the final speed of the carts, and why?

(A) Only conservation of momentum, because the momentum lost by one cart is gained by the other and there is only one unknown quantity.

(B) Both conservation of mechanical energy and conservation of momentum, because both principles apply in any collision.

(C) Both conservation of mechanical energy and conservation of momentum, because neither cart changes direction.

(D) Either conservation of momentum or conservation of mechanical energy, because only one equation is required to solve for the one unknown variable.

6. A dog of mass 10 kg sits on a skateboard of mass 2 kg that is initially traveling south at 2 m/s. The dog jumps off with a velocity of 1 m/s north rela-tive to the ground. Which of the following is the best estimate of the velocity of the skateboard immediately after the dog has jumped?

(A) 1 m/s north

(B) 1 m/s south

(C) 3 m/s south

(D) 7 m/s south

(E) 17 m/s south

7. A projectile fired into the air explodes and splits into two halves of equal mass that hit the ground at the same time. If the projectile had not exploded, it would have landed at point *X*, which is a distance *R* to the right of the launch point. After the explosion, one of the halves lands at point *Y*, which is a distance 2*R* to the right of the launch point. If air resistance is negligible, where did the other half land?

(A) To the left of the launch point

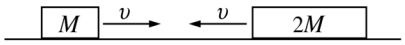
(B) At the launch point

(C) Between the launch point and point *X*

(D) Between points *X* and *Y*

CHAPTER5PARTB

8.



The two blocks of masses *M* and 2*M* shown above initially travel at the same speed *v* but in opposite directions. They collide and stick together. How much mechanical energy is lost to other forms of energy during the collision?

(A) Zero

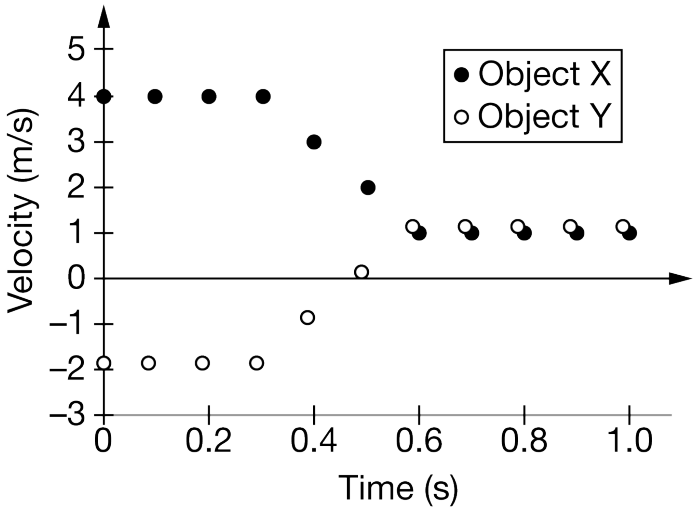
(B) $\frac{1}{2}Mv^2$

(C) $\frac{3}{4}Mv^2$

(D) $\frac{4}{3}Mv^2$

(E) $\frac{3}{2}Mv^2$

9.



Object X travels across a horizontal surface and collides with object Y. The velocity as a function of time for object X and object Y before, during, and after the collision is shown in the graph. Both objects have a mass of $2\ \mathrm{kg}$. Which of the following correctly describes the momentum $\vec{p}$ of the system and the kinetic energy K of the system?

CHAPTER5PARTB

(A)

$\vec{p}$	K
Conserved	Conserved

(B)

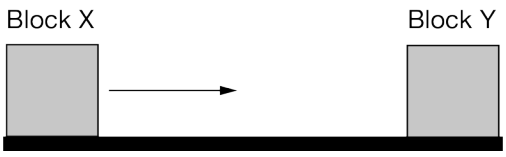
$\vec{p}$	K
Conserved	Not conserved

(C)

$\vec{p}$	K
Not conserved	Conserved

(D)

$\vec{p}$	K
Not conserved	Not conserved



A student plans to conduct an experiment in which the momentum of a two-object system can be determined immediately before and after a collision takes place. The student slides block X at an unknown constant speed toward an identical block, block Y, that is initially at rest, as shown in the figure. There is negligible friction between the blocks and the surface.

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10.

Trial Number	Momentum of Block X Before Collision $\left(\frac{\text{kg·m}}{\text{s}}\right)$	Momentum of Block Y Before Collision $\left(\frac{\text{kg·m}}{\text{s}}\right)$	Momentum of Block X After Collision $\left(\frac{\text{kg·m}}{\text{s}}\right)$	Momentum of Block Y After Collision $\left(\frac{\text{kg·m}}{\text{s}}\right)$
1	6.1	0.0	0.1	5.2
2	5.9	0.1	−0.1	5.3
3	6.0	0.1	0.0	5.2

The student uses the data collected from the experiment to create the data table. Which of the following statements is true regarding the data?

(A) The momentum of the two-block system is conserved because the initial momentum of block X is experimentally consistent for all trials.

(B) The momentum of the two-block system is conserved because the final momentum of block Y is experimentally consistent for all trials.

(C) The momentum of the two-block system is not conserved because the initial momentum of the system is not equal to the final momentum of the system.

(D) The level of error associated with the data is too high to make a conclusion regarding the momentum of the individual blocks and the system.

11. Which of the following choices lists the measuring tools necessary to determine the initial momentum of the system before the collision takes place?

(A) Mass balance

(B) Mass balance and meterstick

(C) Mass balance, meterstick, and stopwatch

(D) Mass balance, meterstick, stopwatch, and force probe

---

12. An empty sled of mass M moves without friction across a frozen pond at speed v_0. Two objects are dropped vertically into the sled one at a time: first an object of mass m and then an object of mass $2m$. Afterward the sled moves with speed v_f. What would be the final speed of the sled if the objects were dropped into it in reverse order?

(A) $v_f / 3$

(B) $v_f / 2$

(C) v_f

(D) $2v_f$

(E) $3v_f$

13. An ice-skater is moving at a constant velocity across an icy pond. The skater throws a snowball directly ahead. Which of the following correctly describes the velocity of the center of mass of the skater-snowball system immediately after the snowball is thrown? Assume friction and air resistance are negligible.

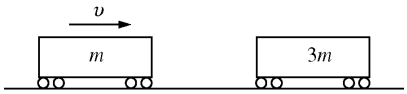
CHAPTER5PARTB

(A) It is equal to the velocity of the snowball.
(B) It is equal to the new velocity of the skater.
(C) It is equal to half the original velocity of the skater.
(D) It is equal to the original velocity of the skater.

14. A person of mass 60 kg sliding along level ice at a speed of 3.0 m/s collides with a second person who is initially at rest. Assume that friction is negli-gible. If the two people hold onto each other and their common final speed after colliding is 2.0 m/s, the mass of the second person is

(A) 10 kg
(B) 30 kg
(C) 40 kg
(D) 80 kg
(E) 90 kg

15.



A railroad car of mass *m* is moving with speed *u* when it collides with and connects to a second railroad car of mass 3*m*, initially at rest, as shown above. How do the speed and kinetic energy of the connected cars compare to those of the single car of mass *m* before the collision?

CHAPTER5PARTB

(A)

Speed	Kinetic Energy
Less	Less

(B)

Speed	Kinetic Energy
Less	The same

(C)

Speed	Kinetic Energy
The same	Less

(D)

Speed	Kinetic Energy
The same	The same

(E)

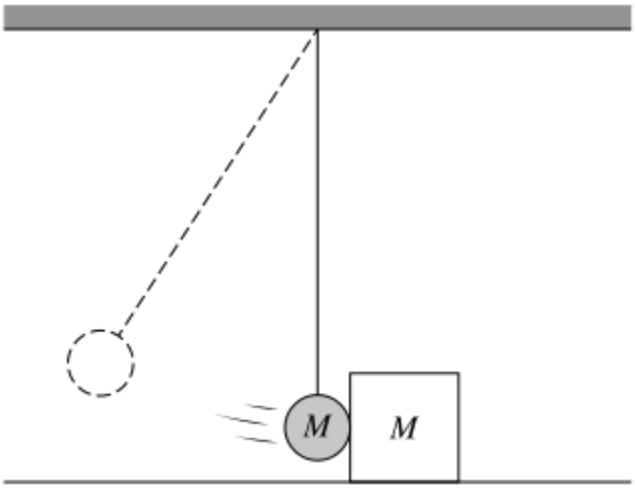
Speed	Kinetic Energy
Greater	The same

16. A toy cannon of mass 1.0 kg is initially at rest on a horizontal surface when it launches a 0.05 kg projectile with a velocity of 10 m/s at an angle of 60° above the horizontal. What is the speed of the 1.0 kg cannon immediately after the projectile is released, assuming that friction is negligible?

(A) 0.25 m/s
(B) 0.35 m/s
(C) 0.43 m/s
(D) 0.50 m/s
(E) 0.87 m/s

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17.



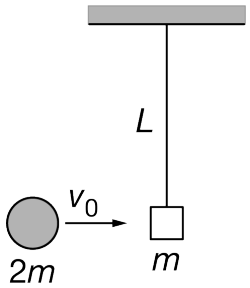
A ball of mass M is suspended from the ceiling by a lightweight string, displaced by a small angle from the vertical, and released from rest, as shown. The ball collides with a box, also of mass M, that sits at rest on a horizontal surface, causing the box to move to the right. Frictional forces are negligible. Which of the following describe possible observations of the ball's motion following the collision? Select two answers.

A The ball stops completely.

B The ball continues to the right but at a slower speed than the box does.

C The ball changes direction and moves to the left at a slower speed than the box does.

D The ball changes direction and moves to the left with a faster speed than the box does.



A clay ball of mass $2m$ is moving horizontally with speed v_0 just before colliding with a block of mass m, as shown above. The block is suspended from a light string with length L. The clay sticks to the block, and the block swings up to a maximum height h_0 above the block's initial position (where $h_0 << L$). The block then oscillates about its lowest position with period T_0.

18. Which of the following quantities is the same immediately after the collision and at the instant the block reaches height h_0 ?

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(A) Linear momentum of the clay-block system

(B) Angular momentum of the clay-block system about the top of the string

(C) Total mechanical energy of the clay-block system

(D) Total mechanical energy of the clay-block-Earth system

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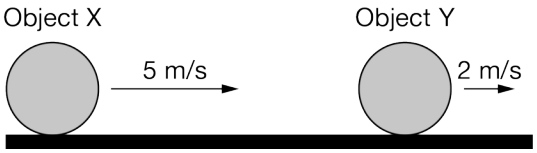
19. A brother and sister are standing next to each other at rest on a surface of frictionless ice. The brother's mass is exactly twice that of his sister's. The sister suddenly pushes her brother. As a result, the sister moves with kinetic energy K. What is the resulting kinetic energy of the brother?

(A) $4K$

(B) $2K$

(C) $\frac{K}{2}$

(D) $\frac{K}{4}$



Two objects of the same mass travel in the same direction along a horizontal surface. Object X has a speed of $5\ \frac{\mathrm{m}}{\mathrm{s}}$ and object Y has a speed of $2\ \frac{\mathrm{m}}{\mathrm{s}}$, as shown in the figure. After a period of time, object X collides with object Y.

20. Consider the situation in which the objects collide but do not stick together. Which of the following predictions is true about the center of mass of the two-object system immediately after the collision?

(A) The center of mass does not move.

(B) The velocity of the center of mass does not change.

(C) The velocity of the center of mass decreases in speed.

(D) The velocity of the center of mass increases in speed.

21. Consider the situation in which the objects collide and stick together. Which of the following predictions is true about the center of mass of the two-object system immediately after the collision?

(A) The center of mass does not move.

(B) The velocity of the center of mass does not change.

(C) The velocity of the center of mass decreases in speed.

(D) The velocity of the center of mass increases in speed.

22. Consider the situation in which object X has a speed of $2\ \mathrm{m/s}$ and object Y has a speed of $5\ \mathrm{m/s}$ after the collision takes place. After the collision, both objects travel in the same direction. Which of the following predictions must be true about how the momentum $\vec{p}$ of the two-object system and the kinetic energy K of the two-object system change from before the collision to after the collision?

CHAPTER5PARTB

(A)

$\overrightarrow{p}$	K
Remains constant	Remains constant

(B)

$\overrightarrow{p}$	K
Remains constant	Decreases

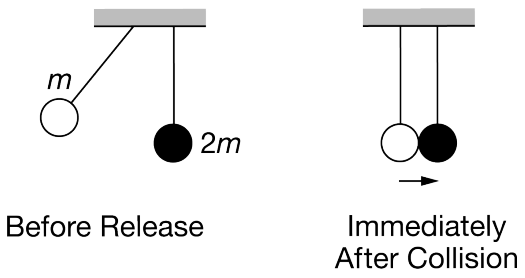
(C)

$\overrightarrow{p}$	K
Decreases	Remains constant

(D)

$\overrightarrow{p}$	K
Decreases	Decreases

23.



Sphere 1 of mass m and sphere 2 of mass $2m$ hang from light strings. Sphere 1 is pulled back, as shown above, and released from rest. Sphere 1 has kinetic energy K_i immediately before colliding with sphere 2. The two spheres stick together and move horizontally for an instant after the collision. During the collision, what is the change in the kinetic energy ΔK of the two-sphere system?

(A) 0

(B) $-\frac{K_i}{3}$

(C) $-\frac{K_i}{2}$

(D) $-\frac{2K_i}{3}$

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24. Two particles collide and stick together. If no external forces act on the two particles, which of the following is correct for the change in total momentum Δp and the change in total kinetic energy ΔK of the two particles?

(A) $\Delta p < 0$; $\Delta K < 0$

(B) $\Delta p < 0$; $\Delta K = 0$

(C) $\Delta p = 0$; $\Delta K < 0$

(D) $\Delta p = 0$; $\Delta K = 0$

(E) $\Delta p = 0$; $\Delta K > 0$

25.

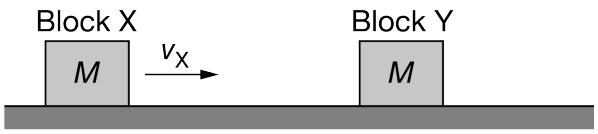


Figure 1. Before the collision

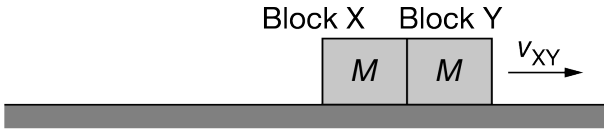


Figure 2. After the collision

Block X slides along a horizontal surface with a speed v_{X} toward block Y that is initially at rest, as shown in Figure 1. After block X collides with block Y, the two blocks remain stuck together and travel at a velocity of v_{XY}, as shown in Figure 2. Frictional forces are considered to be negligible. Which of the following claims is correct regarding the momentum of the system containing only block X and the system that contains block X and block Y?

(A) The system containing block X is an open system, and the system of both blocks is an open system.

(B) The system containing block X is an open system, and the system of both blocks is a closed system.

(C) The system containing block X is a closed system, and the system of both blocks is an open system.

(D) The system containing block X is a closed system, and the system of both blocks is a closed system.

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26.

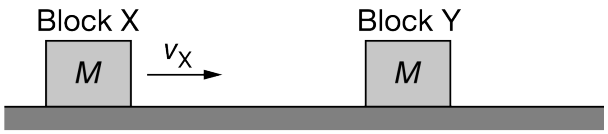


Figure 1. Before the collision

Figure 1. Before the Collision

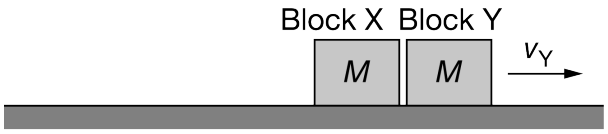


Figure 2. After the collision

Figure 2. After the Collision

Block X of mass M travels in the positive direction with a speed v_{X} toward block Y of mass M that is at rest, as shown in Figure 1. After the collision, block Y travels with a speed of v_{Y} in the positive direction while block X remains at rest. The horizontal surface that the blocks slide across is considered to be smooth. How can a student determine whether the collision is elastic or inelastic?

(A) The student only needs to observe that the blocks do not stick together after the collision, which means that the collision is elastic.

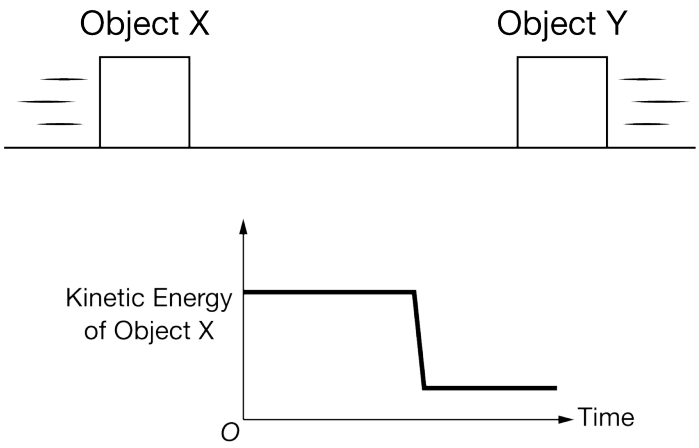
(B) The masses of both blocks are known, and the initial and final velocities are both blocks are known. Therefore, the student must compare the initial momentum of the two-block system before the collision and after the collision using $\Sigma \overrightarrow{p}_0 = \Sigma \overrightarrow{p}_f$.

(C) The masses of both blocks are known, and the initial and final velocities are both blocks are known. The student should use $\Delta \overrightarrow{p} = m\Delta \overrightarrow{v}$ for either block X or block Y to determine how much the block's momentum has changed.

(D) The masses of both blocks are known, and the initial and final velocities are both blocks are known. Therefore, the student must compare the initial kinetic energy of the two-block system before the collision and after the collision using $\Delta K = \frac{1}{2}m\Delta v^2$.

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27.



Two identical objects, X and Y, move toward each other at different speeds on a horizontal surface with negligible friction, as shown in the top figure. The objects then collide elastically and move away from each other. The kinetic energy of object X as a function of time is shown in the graph. Which of the following is true of the speed v_Y of object Y?

(A) v_Y after the collision is greater than it was before the collision.

(B) v_Y after the collision is equal to what it was before the collision.

(C) v_Y after the collision is less than it was before the collision.

(D) v_Y after the collision cannot be compared to what it was before the collision without knowing the mass of the objects.

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28.

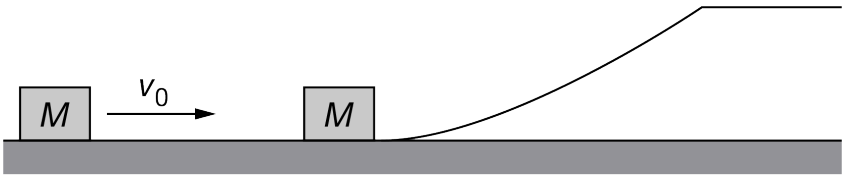


Figure 1. Before the collision

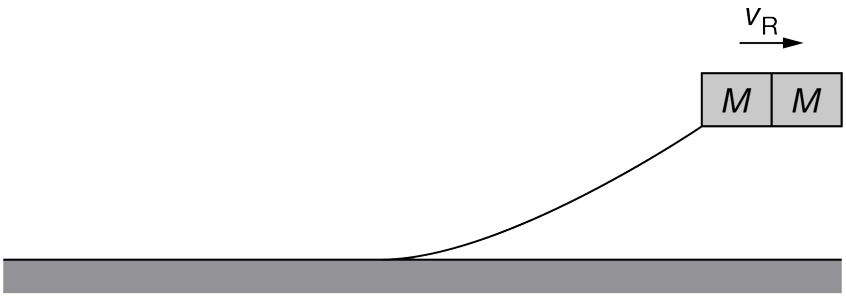


Figure 2. After the collision

A block of known mass M is at rest at the base of a ramp. A second identical block of mass M travels at a known, constant velocity v_0, as shown in Figure 1. The block that travels at a constant speed collides with and sticks to the first block. Both blocks slide up the ramp and travel with an unknown velocity v_R at the top of the ramp, as shown in Figure 2. All frictional forces are considered to be negligible. Which quantity should the student measure, if any, to determine whether the conservation of momentum applies to the two-block system from immediately before the collision to immediately after the blocks have reached the top of the ramp while stuck together? Justify your selection.

(A) The force due to gravity exerted on both blocks as they travel up the ramp, because the force due to gravity does work on the system as it travels up the ramp.

(B) The time in which the blocks travel up the ramp, because this can be used to determine the change in momentum of the system from before the collision to after the collision.

(C) The acceleration of both blocks as they travel up the ramp, because this can be used to determine the average net force exerted on the blocks.

(D) The velocity v_R of the two-block system at the top of the ramp, because this can be used to determine the final momentum of the system.

29. In trial 1 of an experiment, a cart moves with speed v_0 on a frictionless, horizontal track and collides elastically with another cart that is initially at rest. In trial 2, the setup is identical except that the carts stick together during the collision. How does the speed of the two-cart system's center of mass change, if at all, during the collision in each trial?

CHAPTER5PARTB

(A)

Trial 1	Trial 2
Does not change	Does not change

(B)

Trial 1	Trial 2
Does not change	Decreases

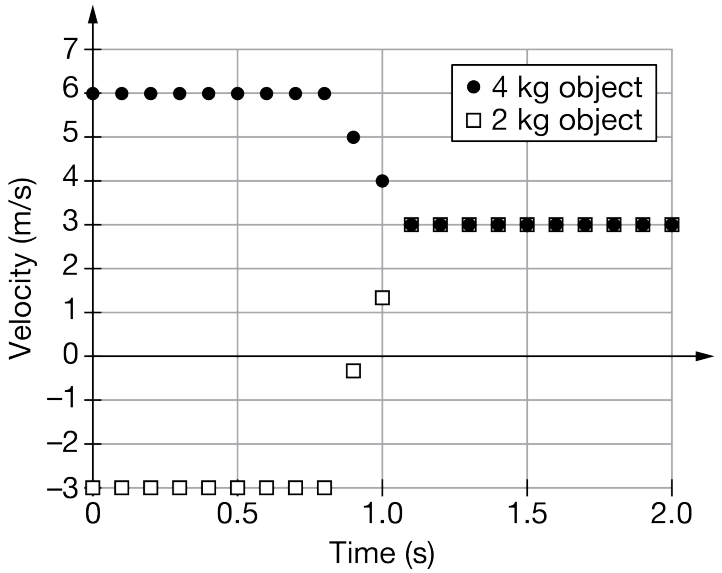
(C)

Trial 1	Trial 2
Decreases	Does not change

(D)

Trial 1	Trial 2
Decreases	Decreases

30.



A student performs an experiment in which a $4\ \text{kg}$ object travels across a horizontal surface with an initial speed velocity of $6\ \text{m/s}$ and a $2\ \text{kg}$ object travels across a horizontal surface with an initial speed velocity of $-3\ \text{m/s}$. The objects travel toward each other and collide. Data collected from the experiment were used to create the velocity versus time graph shown that contains information about both objects before and after the collision. The positive direction is considered to be to the right. Which of the following statements are true regarding the data from the experiment?

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(A) Both objects always travel in the positive direction during the experiment.

(B) Kinetic energy is conserved during the experiment.

(C) The position of the center of mass of the system remains constant during the experiment.

(D) The velocity of the center of mass of the two-object system remains constant during the experiment.

31. Which of the following is true of the conservation of momentum and kinetic energy?

(A) Momentum is conserved only in elastic collisions.

(B) Momentum is conserved only in inelastic collisions.

(C) Kinetic energy is conserved only in elastic collisions.

(D) Kinetic energy is conserved only in inelastic collisions.

(E) Both require the same conditions in order to be conserved.

32.

Trial Number	Mass of Object X (kg)	Mass of Object Y (kg)	Velocity of Object X Before Collision (m/s)	Velocity of Object Y Before Collision (m/s)	Average Force Exerted on Object X by Object Y (N)	Average Force Exerted on Object Y by Object X (N)	Time of Collision (s)
1	2.1	1.1	2.2	−1.1	101	101	0.2
2	2.0	1.1	1.9	−1.0	105	105	0.2
3	1.9	1.0	2.0	−1.0	99	99	0.2

In an experiment, two objects, object X and object Y, travel toward each other and collide. Data are collected about each object before, during, and after the collision, as shown in the table. Which of the following pairs of data, when used together to create two graphs, could verify the conservation of momentum? Select two answers.

A Average force exerted on object X by object Y and time of collision, because these measurements can be used to determine the change in momentum of object X.

B Average force exerted on object Y by object X and time of collision, because these measurements can be used to determine the change in momentum of object Y.

C Mass of object X and velocity of object X before collision, because these measurements can be used to determine the initial momentum of object X.

D Mass of object Y and velocity of object Y before collision, because these measurements can be used to determine the initial momentum of object X.

33.

Cart 1 Mass (kg)	Cart 2 Mass (kg)	Velocity of Cart 1 Immediately Before Collision (m/s)	Velocity of Cart 2 Immediately Before Collision (m/s)	Velocity of Cart 1 Immediately After Collision (m/s)	Velocity of Cart 2 Immediately After Collision (m/s)
1	2	4	0	1	1

A group of students conducts an experiment in which two carts collide with each other as they travel across a horizontal surface with negligible friction. Using motion detectors and a mass balance, the students collect data about the carts immediately before and immediately after the collision, as shown in the table. Which of the following claims is true regarding the momentum and the kinetic energy of the two-cart system for the experiment? Does the data indicate that a net external force acts on the system?

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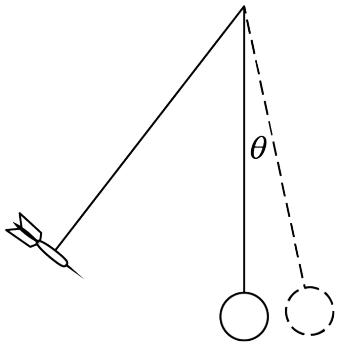
(A) The momentum is the same and the total kinetic energy of the system is the same immediately before the collision and immediately after the collision. This indicates that a net external force is not exerted on the system.

(B) The momentum is different and the total kinetic energy of the system is the same immediately before the collision and immediately after the collision. This indicates that a net external force is exerted on the system.

(C) The momentum is the same and the total kinetic energy of the system is different immediately before the collision and immediately after the collision. This indicates that a net external force is not exerted on the system.

(D) The momentum is different and the total kinetic energy of the system is different immediately before the collision and immediately after the collision. This indicates that a net external force is exerted on the system.

34.



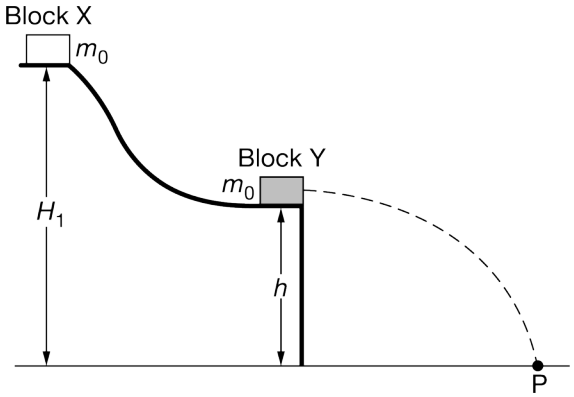
A dart and a rubber sphere are suspended from the same point by light strings. When the dart is released from the position shown above, it swings downward until its tip strikes the sphere. The dart can have different tips attached. Tip A will stick into the rubber sphere upon impact. Tip B will bounce inelastically off the sphere. Tip C will bounce elastically off the sphere. For which tip, if any, will the sphere swing to the greatest maximum angle θ?

(A) Tip A

(B) Tip B

(C) Tip C

(D) None of the tips; the angle will be the same for each.



Block X of mass m_0 is at rest at the top of a ramp, and the block's center of mass is at a height H_1 above the ground. Block X is then released from rest, and it slides down the ramp and collides with block Y of mass m_0, which is initially at rest and has its center of mass at a height h above the ground. At the moment before the collision, block X has a speed of v_0. After the collision, block Y travels such that it lands at point P.

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35. Consider the block X-block Y system from the moment in time that block X is released from rest to the moment immediately after block X collides with block Y. Which of the following claims best describes the system?

(A) Because the total momentum of the system does not remain constant, the system is open.

(B) Because the total kinetic energy of the system does not remain constant, the system is open.

(C) Because the total momentum of the system remains constant, the system is closed.

(D) Because the total kinetic energy of the system remains constant, the system is closed.

36. Consider the scenario in which block X is released from rest at a height H_2, which is lower than H_1 but higher than h. Which of the following statements is true about the horizontal distance traveled by block Y as a projectile in the two scenarios? Assume the collision in both scenarios is elastic.

(A) The horizontal distance will be greater for block Y when block X is released from height H_2.

(B) The horizontal distance will be greater for block Y when block X is released from height H_1.

(C) The horizontal distance will be the same for block Y in both scenarios.

(D) The answer cannot be determined without knowing the exact height of H_1 and H_2.

37.



Two blocks are on a horizontal, frictionless surface. Block A is moving with an initial velocity of v_0 toward block B, which is stationary, as shown above. The two blocks collide, stick together, and move off with a velocity of $v_0/3$. Which block, if either, has the greater mass?

(A) Block A

(B) Block B

(C) Neither; their masses are the same.

(D) The answer cannot be determined without knowing the mass of one of the blocks.

38. A student must analyze data collected from an experiment in which a block of mass $2M$ traveling with a speed v_0 collides with a block of mass M that is initially at rest. After the collision, the two blocks stick together. Which of the following applications of the equation for the conservation of momentum represent the initial and final momentum of the system for a completely inelastic collision between the blocks? Justify your selection. Select two answers.

A $2Mv_0 = 3Mv_f$, because the blocks stick together after the collision.

B $3Mv_0 = 3Mv_f$, because the blocks stick together after the collision.

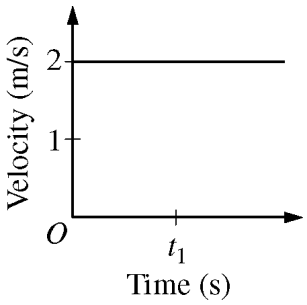
C $2Mv_0 = 2Mv_f + Mv_f$, because the blocks stick together after the collision.

D $2Mv_0 = Mv_0 + 3Mv_f$, because the blocks do not stick together after the collision.

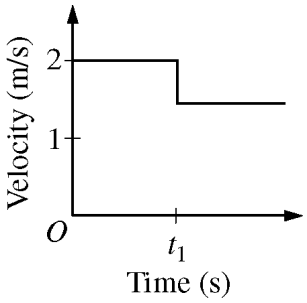
CHAPTER5PARTB

39. Two identical carts are free to move along a straight frictionless track. At time $t1$, cart X is moving at 2.0 m/s when it collides with and sticks to cart Y, which is initially at rest. Which of the following graphs best shows the velocity of cart X before and after the collision?

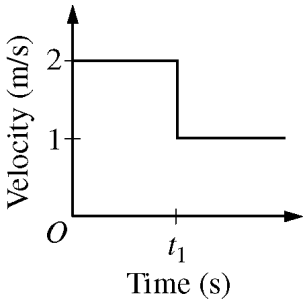
(A)



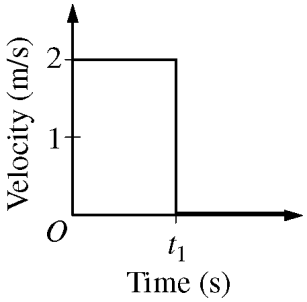
(B)



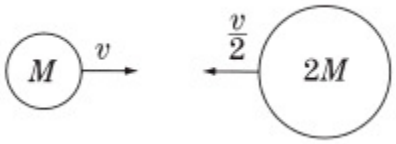
(C)



(D)



40.



A ball of mass M and speed v collides head-on with a ball of mass $2M$ and speed $\frac{v}{2}$, as shown above. If the two balls stick together, their speed after the collision is

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(A) 0

(B) $\frac{v}{2}$

(C) $\frac{\sqrt{2}v}{2}$

(D) $\frac{\sqrt{3}v}{2}$

(E) $\frac{3v}{2}$

A ball is dropped and bounces off the floor. Its speed is the same immediately before and immediately after the collision.

41. How does the height to which the ball bounces compare to the height from which it was dropped?

(A) It is less.

(B) It is the same.

(C) It is greater.

(D) It cannot be determined without knowing the value of the height from which the ball was dropped.

(E) It cannot be determined without knowing the value of the ball's speed as it hits the floor.

42. Which of the following is true about the collision between the ball and the floor?

(A) The ball's momentum is conserved.

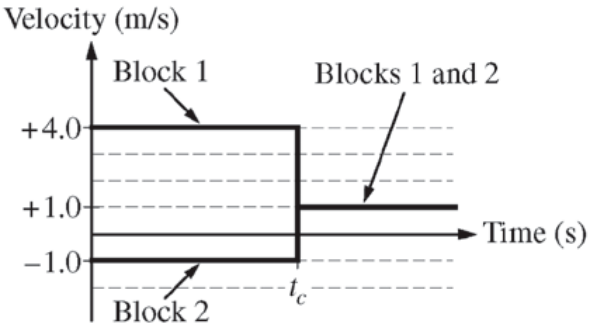
(B) The ball's momentum changes direction but not magnitude.

(C) The ball's momentum changes magnitude but not direction.

(D) The impulse delivered to the ball by the floor is zero.

(E) The impulse delivered to the floor by the ball is zero.

Refer to the following material for answering the questions.



Block 1 of mass m_1 and block 2 of mass m_2 are sliding along the same line on a horizontal frictionless surface when they collide at time t_c. The graph above shows the velocities of the blocks as a function of time.

43. How does the kinetic energy of the two-block system after the collision compare with its kinetic energy before the collision, and why?

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(A) It is less, because the blocks have the same velocity after the collision, so some of their kinetic energy was transformed into internal energy.

(B) It is less, because the blocks have velocities in opposite directions before the collision, so some of their kinetic energy cancels.

(C) It is the same, because the collision was instantaneous, so the effect of external forces during the collision is negligible.

(D) It is the same, because the blocks have the same velocity after the collision, and there is no friction acting on them.

44. Which block has the greater mass, and what information indicates this?

(A) Block 1, because it had a greater speed before the collision.

(B) Block 1, because the velocity after the collision is in the same direction as its velocity before the collision.

(C) Block 2, because it had a smaller speed before the collision.

(D) Block 2, because the final velocity is closer to the initial velocity of block 2 than it is to the initial velocity of block 1.

45. Which of the following is true of the motion of the center of mass of the two-block system during the time shown?

(A) The center of mass does not move because the blocks are moving in opposite directions before the collision.

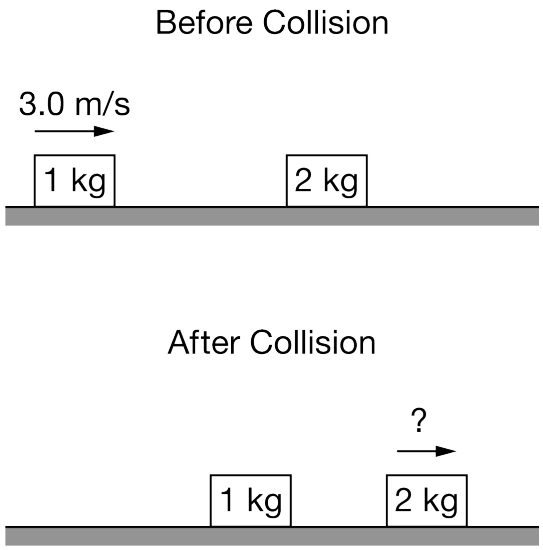
(B) The center of mass moves at a constant velocity of +1.0 m/s because there is no friction acting on the system.

(C) The center-of-mass velocity starts out greater than +1.0 m/s but decreases to +1.0 m/s during the collision because the collision is inelastic.

(D) The center-of-mass velocity increases as the blocks get closer together, and then becomes constant after the collision.

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46.



A block of mass $1\ \text{kg}$ slides on a frictionless, horizontal surface with a velocity of $3.0\ \text{m/s}$ to the right, as shown above, and collides with a block of mass $2\ \text{kg}$ that is at rest. As a result of the collision, the $1\ \text{kg}$ block comes to rest. Which of the following correctly states whether the collision is elastic or inelastic and provides a valid justification?

(A) Elastic, because the total momentum before the collision equals the total momentum after.

(B) Elastic, because some of the initial kinetic energy is converted to other forms of energy but the total energy is conserved.

(C) Inelastic, because the total momentum before the collision does not equal the total momentum after.

(D) Inelastic, because some of the initial kinetic energy is converted into nonmechanical energy.

47. In a one-dimensional perfectly elastic collision, an object of mass m is traveling with speed v_0 in the $+x$-direction when it strikes an object with mass $3m$ that is at rest. What are the objects' velocities following the collision?

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(A)

Object of Mass *m*	Object of Mass 3*m*
Zero	$v_0/3$, +*x*-direction

(B)

Object of Mass *m*	Object of Mass 3*m*
$v_0/4$, +*x*-direction	$v_0/2$, +*x*-direction

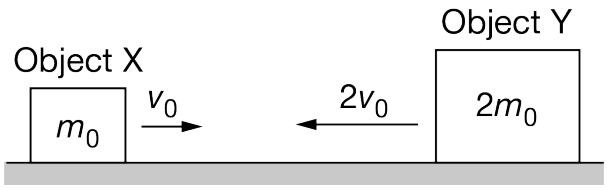
(C)

Object of Mass *m*	Object of Mass 3*m*
$v_0/2$, +*x*-direction	$v_0/2$, +*x*-direction

(D)

Object of Mass *m*	Object of Mass 3*m*
$v_0/2$, -*x*-direction	$v_0/2$, +*x*-direction

48.



Object X of mass m_0 travels to the right with a velocity v_0. Object Y of mass $2m_0$ moves to the left at $2v_0$, as shown in the figure. The objects collide and then stick together. What is the change in kinetic energy of the two-object system from immediately before the collision to immediately after the collision?

(A) The kinetic energy increases by $6m_0v_0^2$.

(B) The kinetic energy increases by $3m_0v_0^2$.

(C) The kinetic energy decreases by $6m_0v_0^2$.

(D) The kinetic energy decreases by $3m_0v_0^2$.

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Scenario Number	Final Velocity of Cart X	Final Velocity of Cart Y
1	0	v_{Y1}
2	v_{X2}	v_{Y2}
3	$-v_{X3}$	v_{Y3}

Cart X of mass m_0 travels along a horizontal surface with a constant speed in the positive horizontal direction. Cart X then collides with cart Y of mass M_0, which was initially at rest. After the collision, cart Y has a positive velocity. Immediately after the collision, cart X and cart Y could have one of three final velocities that are indicated in the table. In all scenarios, the total momentum of the two-cart system is the same before and after the collision.

49. Assume that the collision in each scenario is elastic. How does the magnitude of the change in the momentum Δp of Object Y compare for each scenario?

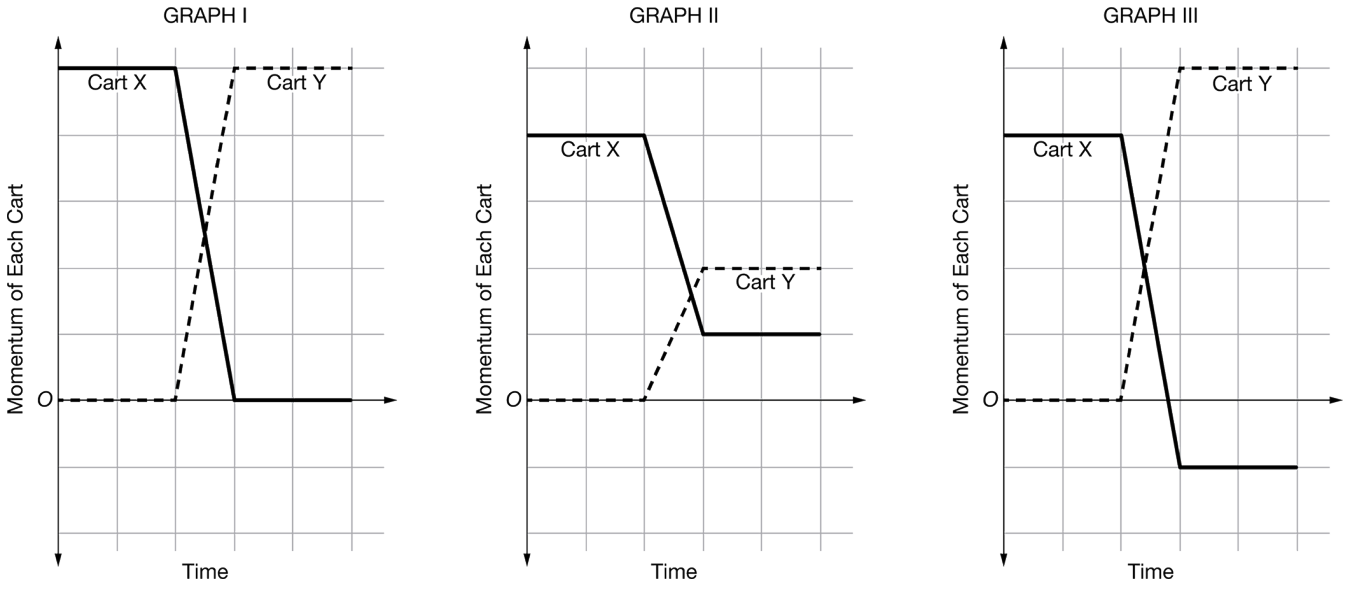
(A) $\Delta p_1 > \Delta p_2 > \Delta p_3$

(B) $\Delta p_1 > \Delta p_3 > \Delta p_2$

(C) $\Delta p_3 > \Delta p_2 > \Delta p_1$

(D) $\Delta p_3 > \Delta p_1 > \Delta p_2$

50.



Graphs I , II , and III that are shown represent momentum versus time graphs for three possible cases in which a collision could occur between two carts. Which of the momentum versus time graphs are possible representations of one of the three scenarios if the system is closed?

(A) Graphs I and II only

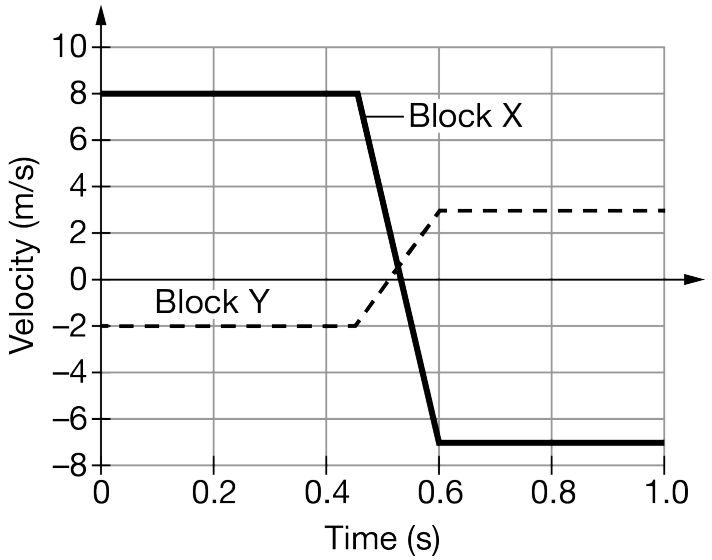
(B) Graphs I and III only

(C) Graphs II and III only

(D) Graphs I, II, and III

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51.



Block X of mass $2\ \mathrm{kg}$ and block Y of unknown mass travel toward each other. An elastic collision occurs in which momentum is conserved. The graph shows the velocity of block X and of velocity of block Y as a function of time before, during, and after the collision. What is the mass of block Y?

(A) $0.4\ \mathrm{kg}$
(B) $2\ \mathrm{kg}$
(C) $6\ \mathrm{kg}$
(D) $30\ \mathrm{kg}$

52.



Trial Number	Initial Velocity of Cart X $(\mathrm{m/s})$	Initial Velocity of Cart Y $(\mathrm{m/s})$	Final Velocity of Cart X $(\mathrm{m/s})$	Final Velocity of Cart Y $(\mathrm{m/s})$
1	3	-1	0.7	4.7
2	2	-2	-2	2
3	3	2	1.8	2.8

A student must conduct an experiment to verify the conservation of momentum for a closed two-cart system. Cart X and cart Y travel toward each other and eventually collide, as shown in the figure. Data collected from the experiment are shown in the table. What additional measuring tool should the student have used in order to verify the conservation of momentum?

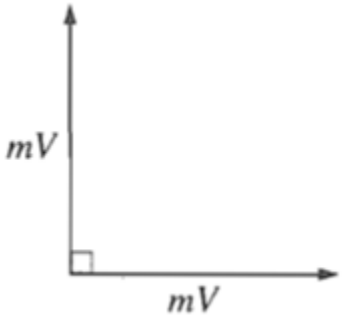
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(A) Force sensor
(B) Meterstick
(C) Stopwatch
(D) Balance

53. Two skaters are initially at rest next to each other on frictionless ice. Skater *A* pushes on skater *B*. If skater *A* has greater mass than skater *B*, which of the following correctly relates the magnitudes of their momentums *p* and their kinetic energies *K* after the push?

(A) $p_A = p_B$ and $K_A < K_B$
(B) $p_A = p_B$ and $K_A = K_B$
(C) $p_A = p_B$ and $K_A > K_B$
(D) $p_A < p_B$ and $K_A < K_B$
(E) $p_A < p_B$ and $K_A = K_B$

54.



A stationary object explodes, breaking into three pieces of masses *m, m,* and 3*m*. The two pieces of mass *m* move off at right angles to each other with the same magnitude of momentum *mV,* as shown in the diagram above. What are the magnitude and direction of the velocity of the piece having mass 3*m* ?

CHAPTER5PARTB

(A)

Magnitude	Direction
$\frac{V}{\sqrt{3}}$	↗

(B)

Magnitude	Direction
$\frac{V}{\sqrt{3}}$	↙

(C)

Magnitude	Direction
$\frac{\sqrt{2}V}{3}$	↗

(D)

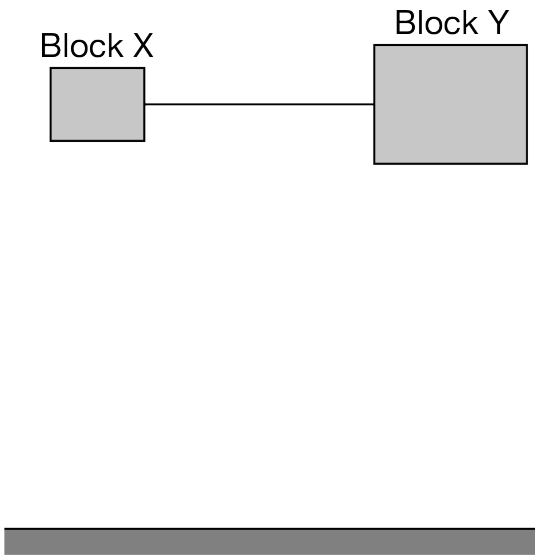
Magnitude	Direction
$\frac{\sqrt{2}V}{3}$	↙

(E)

Magnitude	Direction
$\sqrt{2}V$	↙

CHAPTER5PARTB

55.



Block X and Block Y are tied together by a rope. The system containing Block X and Block Y is dropped above Earth's surface in the orientation shown in the figure. Block Y has a larger mass than Block X. Which of the following claims is correct regarding the momentum of the system containing only Block X and the system that contains Block X and Block Y?

(A) The system containing Block X is an open system, and the system of both blocks is an open system.

(B) The system containing Block X is an open system, and the system of both blocks is a closed system.

(C) The system containing Block X is a closed system, and the system of both blocks is an open system.

(D) The system containing Block X is a closed system, and the system of both blocks is a closed system.

56. A block of mass m slides along a frictionless surface with kinetic energy K_i. It collides with a block of mass $3m$ that is initially at rest, and the two blocks stick together and slide with total kinetic energy K_f. What is the ratio $K_f : K_i$?

(A) $1:1$

(B) $1:2$

(C) $1:3$

(D) $1:4$

57. Two objects, *A* and *B*, initially at rest, are "exploded" apart by the release of a coiled spring that was compressed between them.

As they move apart, the velocity of object *A* is 5 m/s and the velocity of object *B* is -2 m/s. The ratio of the mass of object *A* to the mass of object *B*, m_A/m_B, is

(A) 4/25

(B) 2/5

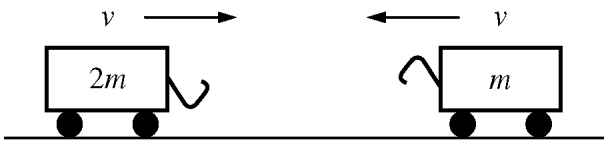
(C) 1/1

(D) 5/2

(E) 25/4

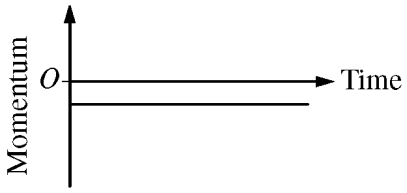
CHAPTER5PARTB

58.

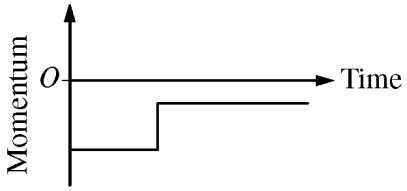


Two carts, of mass $2m$ and m, approach each other head-on with the same speed v, as shown in the figure above. When the carts collide, they hook together. Assuming positive momentum is to the right, which of the following best represents the momentum of the cart of mass m as a function of time before and after the collision?

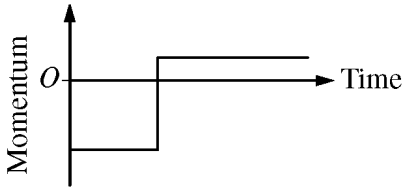
(A)



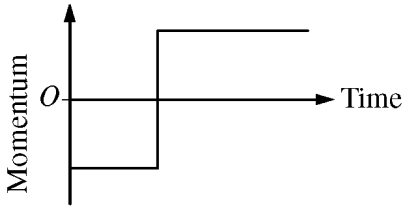
(B)



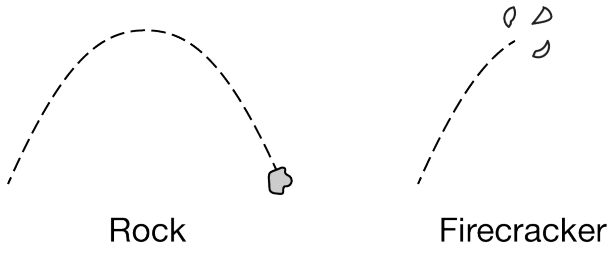
(C)



(D)



59.



A rock and a firecracker are each thrown into the air at the same angle and with the same initial speed. The rock follows the trajectory shown above on the left. The firecracker initially follows the same trajectory as the rock but explodes into three pieces at the point indicated above on the right. Which of the following describes the motion of the center of mass of the firecracker pieces after the explosion?

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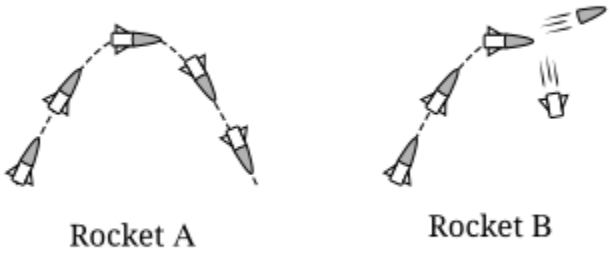
(A) It follows a path identical to the path of the rock.

(B) It remains at rest as the firecracker pieces move away.

(C) It falls vertically downward.

(D) It continues to move in a straight line with the same velocity that the firecracker had just before the explosion.

60.



Two identical rockets, A and B, are launched into the air at the same angle with the same initial speed. Rocket A remains intact throughout its trajectory, as shown on the left. Rocket B separates into two pieces at the top of its trajectory, as shown on the right. Which of the following best explains why the trajectory of the center of mass of Rocket B follows the same trajectory as that of the center of mass of Rocket A?

(A) No external force is exerted on the center of mass of either rocket.

(B) The total mechanical energy of both rockets remains constant.

(C) Gravitational forces are the only external forces exerted on both rockets.

(D) The momentum of the center of mass of both rockets remains constant.

61. Block A of mass m_0 slides with constant velocity v_0 across a horizontal surface toward Block B of mass $\frac{1}{2}m_0$ that is initially at rest. The blocks collide and stick together. What is the kinetic energy of the two-block system after the collision?

(A) $\frac{1}{6}m_0{v_0}^2$

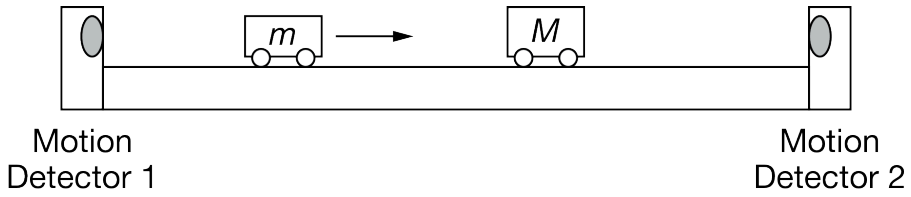
(B) $\frac{1}{3}m_0{v_0}^2$

(C) $\frac{1}{2}m_0{v_0}^2$

(D) $\frac{2}{3}m_0{v_0}^2$

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62.



In the setup shown above, a student uses motion detector 1 to measure the speed v_i of a cart with mass m before it collides with and sticks to a stationary cart with mass M. Motion detector 2 measures the speed v_f of the carts after the collision. The student repeats the experiment several times using different values of v_i and creates a graph of v_f as a function of v_i. The slope of this graph is most nearly equal to

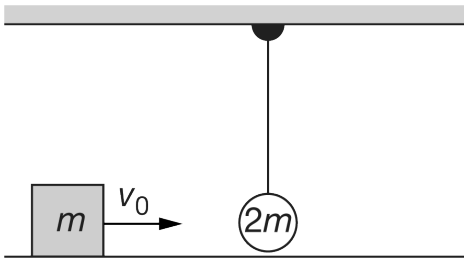
(A) $\frac{m}{M}$

(B) $\frac{m}{M+m}$

(C) $\frac{M-m}{M+m}$

(D) $\sqrt{\frac{m}{M+m}}$

63.



A block of mass m travels with speed v_0 to the right on a horizontal surface with negligible friction toward a sphere of mass $2m$ hanging at rest from a light cord, as shown above. The block collides elastically with the sphere. Which of the following correctly describes the speed and direction of the block and the speed of the sphere a short time after the collision?

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(A)

Speed and Direction of Block	Speed of Sphere
$\frac{v_0}{3}$ to the left	Slightly less than $\frac{2v_0}{3}$

(B)

Speed and Direction of Block	Speed of Sphere
$\frac{v_0}{3}$ to the right	Slightly less than $\frac{2v_0}{3}$

(C)

Speed and Direction of Block	Speed of Sphere
Zero	Slightly less than v_0

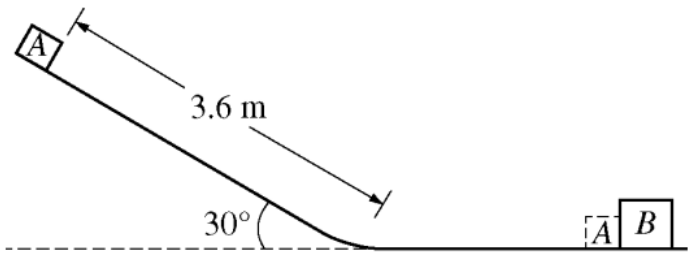
(D)

Speed and Direction of Block	Speed of Sphere
v_0 to the left	Zero

64. Block X of mass $4M$ travels at a speed $5v_0$ toward block Y of mass M, which is initially at rest. After block X elastically collides with block Y, block X has a speed of $3v_0$ in the same direction as before the collision. What is the speed of block Y immediately after the collision?

(A) $1.2v_0$
(B) $3v_0$
(C) $8v_0$
(D) $20v_0$

65.



Block A of mass 2.0 kg is released from rest at the top of a 3.6 m long plane inclined at an angle of 30º, as shown in the figure above. After sliding on the horizontal surface, block *A* hits and sticks to block *B*, which is at rest and has mass 3.0 kg. Assume friction is negligible. The speed of the blocks after the collision is most nearly

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(A) 2.4 m/s
(B) 3.2 m/s
(C) 3.8 m/s
(D) 6.0 m/s

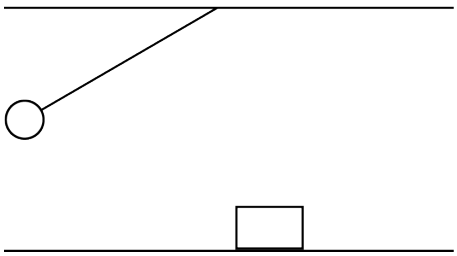
66. Two identical blocks with mass 5.0 kg each are connected to the opposite ends of a compressed spring. The blocks initially slide together on a frictionless surface with velocity 2 m/s to the right. The spring is then released by remote control. At some later instant, the left block is moving at 1 m/s to the left, and the other block is moving to the right. What is the speed of the center of mass of the system at that instant?

(A) 4 m/s
(B) 3 m/s
(C) 2 m/s
(D) 0 m/s

67. Two identical blocks are connected to the opposite ends of a compressed spring. The blocks initially slide together on a frictionless surface with velocity v to the right. The spring is then released by remote control. At some later instant, the left block is moving at $v/2$ to the left, and the other block is moving to the right. What is the speed of the center of mass of the system at that instant?

(A) $5v/2$
(B) $3v/2$
(C) v
(D) $v/2$

68.

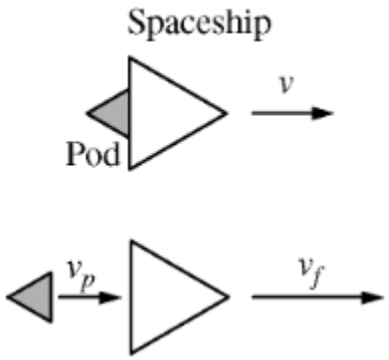


A sphere of mass 3 kg attached to a thin string is released from the position shown above. At its lowest point the sphere strikes a block of mass 1 kg that is initially at rest. Using measurements of the objects' speeds taken by two motion detectors immediately before and after the collision, a student calculates that the total kinetic energy of the sphere-block system after the collision is significantly less than it was before the collision. Which of the following most plausibly explains this result?

(A) The student made a mistake in obtaining data, because in a collision the kinetic energy must be conserved.
(B) In calculating kinetic energy after the collision, the student did not account for the energy lost when the block slid on the table.
(C) In calculating kinetic energy, the student did not consider the potential energy of the sphere-Earth system as the sphere was released.
(D) The sphere or the block was deformed during the collision and dissipated part of the sphere-block system's mechanical energy.

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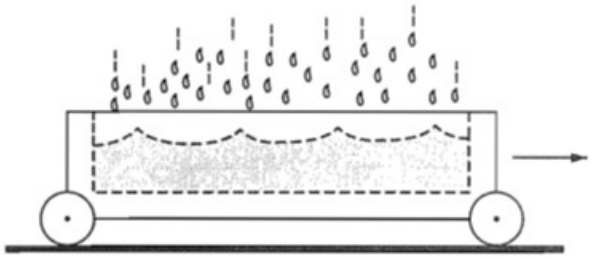
69.



A spaceship and its shuttle pod are traveling to the right in a straight line with speed v, as shown in the top figure above. The mass of the pod is m, and the mass of the spaceship is $6m$. The pod is launched, and afterward the pod is moving to the right with speed v_p and the spaceship is moving to the right with speed where $v_f > v$, as shown in the bottom figure. Which of the following is true of the speed v_c of the center of mass of the system after the pod is launched?

(A) $v_c = v_f$
(B) $v < v_c < v_f$
(C) $v_c < v$
(D) $v_c = v$

70.



An open cart on a level surface is rolling without frictional loss through a vertical downpour of rain, as shown above. As the cart rolls, an appreciable amount of rainwater accumulates in the cart. The speed of the cart will

(A) increase because of conservation of momentum
(B) increase because of conservation of mechanical energy
(C) decrease because of conservation of momentum
(D) decrease because of conservation of mechanical energy
(E) remain the same because the raindrops are falling perpendicular to the direction of the cart's motion

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71.



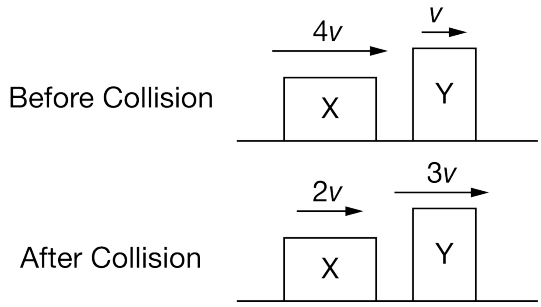
Two objects of mass 0.2 kg and 0.1 kg, respectively, move parallel to the *x*-axis, as shown above. The 0.2 kg object overtakes and collides with the 0.1 kg object. Immediately after the collision, the *y*-component of the velocity of the 0.2 kg object is 1 m/s upward. What is the y-component of the velocity of the 0.1 kg object immediately after the collision?

(A) 2 m/s downward
(B) 0.5 m/s downward
(C) 0 m/s
(D) 0.5 m/s upward
(E) 2 m/s upward

72. A heavy toy truck collides with a lightweight toy car that is initially at rest. Frictional forces are negligible. After the collision, the car and truck move together. During the collision, which of the following is true?

(A) The momentum lost by the truck equals the momentum gained by the car.
(B) The kinetic energy lost by the truck equals the kinetic energy gained by the car.
(C) The magnitude of the car's acceleration equals the magnitude of the truck's acceleration.
(D) The center-of-mass speed of the car-truck system decreases.

73.



The figure above shows the relative velocities of boxes X and Y before and after they collide on a surface with negligible friction. Which of the following correctly compares the masses of the two boxes and indicates whether the kinetic energy of the two-box system changes during the collision?

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(A)

Box Masses	Kinetic Energy
Equal	Changes

(B)

Box Masses	Kinetic Energy
Equal	Does not change

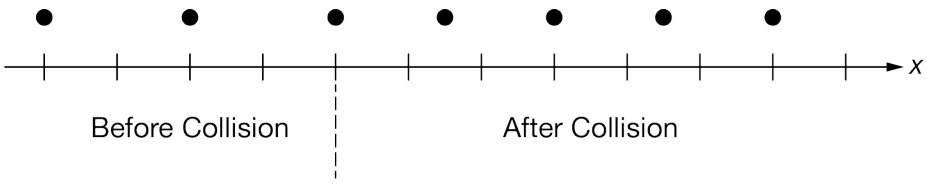
(C)

Box Masses	Kinetic Energy
Unequal	Changes

(D)

Box Masses	Kinetic Energy
Unequal	Does not change

74.



Cart A of mass m_A travels toward cart B of mass m_B, which is initially at rest. The two carts stick together after the collision. The position x of the center of mass of cart A is recorded at equal time intervals before and after the collision, as shown above. Based on the data, what can be concluded about the relative masses of carts A and B?

(A) $m_A > m_B$

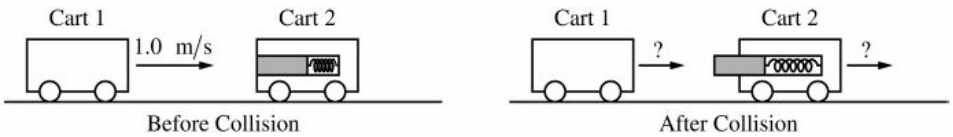
(B) $m_A < m_B$

(C) $m_A = m_B$

(D) The answer cannot be determined without knowing the initial speed of cart A.

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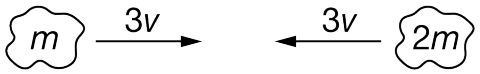
75. Directions: For the question or incomplete statement below, two of the suggested answers are correct. For this question, you must select both correct choices to earn credit. No partial credit will be earned if only one correct choice is selected. Select the two that are best in each case.



Two lab carts have the same mass and are free to move on a horizontal track. The carts' wheels have negligible mass. Cart 1 travels to the right at $1.0\ \text{m/s}$ and collides with cart 2, which is initially at rest, as shown at left above. Cart 2 has a compressed spring-loaded plunger with a nonnegligible amount of stored energy. During the collision, the spring-loaded plunger pops out, staying in contact with cart 1 for $0.10\ \text{s}$ as the spring decompresses. Negligible mechanical energy dissipates during the collision. Taking rightward as positive, the carts' velocities after the collision could be which of the following? Select two answers.

	Cart 1	Cart 2
A	0	$1.0\ \text{m/s}$
B	$0.5\ \text{m/s}$	$0.5\ \text{m/s}$
C	$-0.5\ \text{m/s}$	$1.5\ \text{m/s}$
D	$-1.0\ \text{m/s}$	$2.0\ \text{m/s}$

76.



Two lumps of clay with masses m and $2m$ are traveling in opposite directions with speed $3v$, as shown above. The lumps of clay collide and stick together. What is the speed of the combined lump of clay after the collision?

(A) Zero

(B) v

(C) $2v$

(D) $3v$

77. Two people of unequal mass are initially standing still on ice with negligible friction. They then simultaneously push each other horizontally. Afterward, which of the following is true?

(A) The kinetic energies of the two people are equal.

(B) The speeds of the two people are equal.

(C) The momenta of the two people are of equal magnitude.

(D) The center of mass of the two-person system moves in the direction of the less massive person.

(E) The less massive person has a smaller initial acceleration than the more massive person.

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78.

Trial Number	Mass of Cart X (kg)	Mass of Cart Y (kg)	Initial Velocity of Cart X (m/s)	Initial Velocity of Cart Y (m/s)	Final Velocity of Cart X (m/s)	Final Velocity of Cart X (m/s)
1	5	2	3	−1	0.7	4.7
2	3	2	2	−2	0.4	0.4
3	2	2	4	0	0	4

An experiment is performed in which a collision occurs between cart X and cart Y. Data are collected about each cart before and after a collision takes place. Which data from the table should the student use to verify the conservation of momentum for each trial, and what is a justification for using those data?

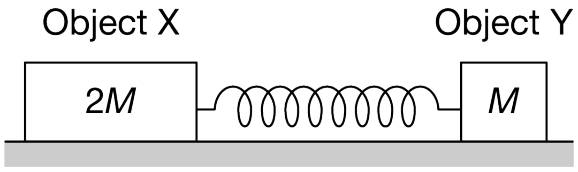
(A) The initial and final velocity of cart X and the initial and final velocity of cart Y, because the speeds should be compared before and after the collision.

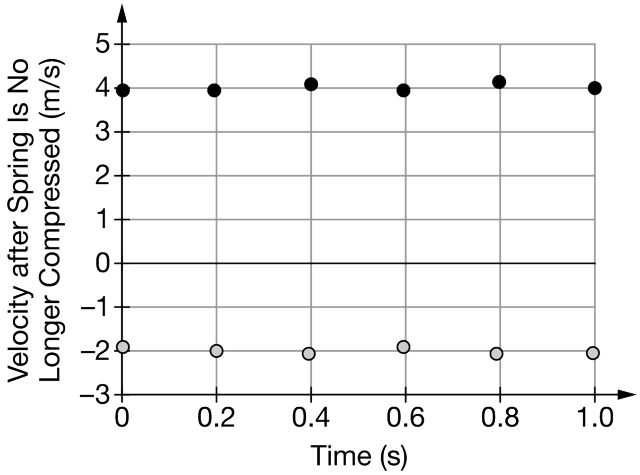
(B) The mass of cart X, the initial velocity of cart X, and the final velocity of cart X, because the momentum of cart X should be determined before and after the collision.

(C) The mass of cart Y, the initial velocity of cart Y, and the final velocity of cart Y, because the momentum of cart Y should be determined before and after the collision.

(D) All data are necessary to verify the conservation of momentum, because all information for each cart should be known.

79.





In an experiment, a spring is placed between object X and object Y. Object X has twice the mass of object Y, which has mass M. The two objects are pushed together until the spring is at its maximum compression, as shown in the figure. The objects are released from rest, and data are collected for the speed of each object immediately after the spring is no longer compressed. However, the graph does not indicate which object corresponds to a given velocity, and the positive direction is not indicated. Which of the following correctly describes the velocities of object X and object Y after the collision?

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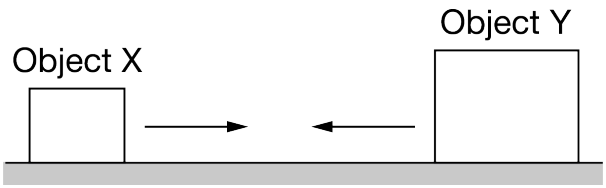
(A) Object X travels at $4\ \frac{\mathrm{m}}{\mathrm{s}}$ and object Y travels at $-2\ \frac{\mathrm{m}}{\mathrm{s}}$ after the spring is no longer compressed.

(B) Object X travels at $-2\ \frac{\mathrm{m}}{\mathrm{s}}$ and object Y travels at $4\ \frac{\mathrm{m}}{\mathrm{s}}$ after the spring is no longer compressed.

(C) Either object can have either speed because the conservation of momentum will still be maintained.

(D) Not enough information is given to match the objects to a specific speed after the spring is no longer compressed.

80.



A student conducts an experiment to verify that a collision is elastic. The two objects, object X and object Y, travel toward each other, as shown in the figure. The mass and the initial speed of both objects are known. Which of the following equations should the student consider using to verify that the collision is elastic, and why?

Equation I: $\Delta\vec{p} = \vec{F}\,\Delta t$

Equation II: $\Sigma\vec{p}_{\,0} = \Sigma\vec{p}_{\,f}$

Equation III: $\Delta K = K_f - K_0$

(A) Equation I only, because the change in momentum of object X will be equal to the negative change of momentum for object Y.

(B) Equation II only, because the conservation of momentum must be verified for the system of object X and object Y.

(C) Equation I and equation III, because the change in momentum of object X will be equal to the negative change of momentum for object Y, and the difference in the kinetic energy of the system before and after the collision should be determined.

(D) Equation II and equation III, because the conservation of momentum must be verified for the system of object X and object Y, and the difference in the kinetic energy of the system before and after the collision should be determined.

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81.



A student must conduct an experiment to verify the conservation of momentum for a closed two-cart system. Cart X and cart Y travel toward each other and eventually collide, as shown in the figure. The student has determined the following procedure.

Step 1: Measure the mass of cart X and cart Y with a balance.

Step 2: Use a motion sensor to record data of the velocity of each cart before, during, and after the collision.

Step 3: Use the data and $\Sigma \vec{p}_0 = \Sigma \vec{p}_f$ to determine if the right-hand side of the equation is equal to the left-hand side of the equation.

Which of the following steps should the student add to the procedure so that the conservation of momentum can be experimentally verified?

(A) Conduct the experiment on a smooth, level surface.

(B) Attach adhesive strips to each cart so that they stick together after they collide.

(C) Ensure that the mass of each cart is the same.

(D) Ensure that the initial speed of each cart is the same.

82. Object X of mass $4\ \mathrm{kg}$ travels with a speed of $3\ \frac{\mathrm{m}}{\mathrm{s}}$ toward object Y of mass $2\ \mathrm{kg}$ that is initially at rest. Object X then collides with and sticks to object Y. After the collision, object X and object Y remain stuck together. How much mechanical energy is converted into nonmechanical energy during the collision?

(A) $0\ \mathrm{J}$

(B) $6\ \mathrm{J}$

(C) $9\ \mathrm{J}$

(D) $10\ \mathrm{J}$