Name: _____

AP Physics 1

Unit 4 Complete Review

Linear Momentum

Momentum

1. An object of mass m moves with momentum p. Which of the following expressions gives the kinetic energy of the object?

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

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

   (C) pm

   (D) $\frac{pm}{2}$

2. A moving object has velocity v. The object's velocity is increased so that its new speed is $4v$. Which of the following quantities is also increased by a factor of 4?

   (A) Kinetic energy

   (B) Momentum

   (C) Gravitational potential energy

   (D) Impulse delivered during the motion

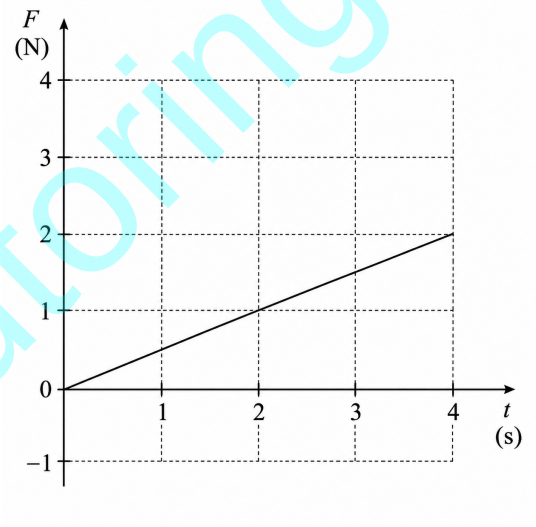
Impulse

3. A 3 kg hockey puck slides across the ice and collides head-on with a rigid barrier. Just before the collision, the puck has a speed of 7 m/s. After the collision, it rebounds in the opposite direction with a speed of 3 m/s.

   Which of the following gives the magnitude of the change in momentum of the puck during the collision?

   (A) $10\ \text{kg} \cdot \text{m/s}$
   (B) $12\ \text{kg} \cdot \text{m/s}$
   (C) $30\ \text{kg} \cdot \text{m/s}$
   (D) $60\ \text{kg} \cdot \text{m/s}$

4. A 2.0 kg robotic delivery cart is moving along a straight path with an initial speed of 2.0 m/s. The graph shows the magnitude of the net force acting on the cart as a function of time. Assume the net force acts in the same direction as the velocity.



   At $t = 4.0$ s, the cart's speed is closest to which of the following?

   (A) 2.0 m/s
   (B) 4.0 m/s
   (C) 10 m/s
   (D) 13 m/s

5. A 0.50 kg practice ball is launched by a training machine and travels toward a vertical rebound wall. The ball moves in a straight line and remains in contact with the wall for $t = 0.050$ s. Just before striking the wall, the ball has a velocity of 6.4 m/s, and immediately after the collision it has a velocity of -3.6 m/s.

(i) What is the magnitude of the change in momentum of the ball?

(A) 2 kg · m/s

(B) 3 kg · m/s

(C) 5 kg · m/s

(D) 10 kg · m/s

(ii) What is the magnitude of the average force exerted on the ball during the collision?

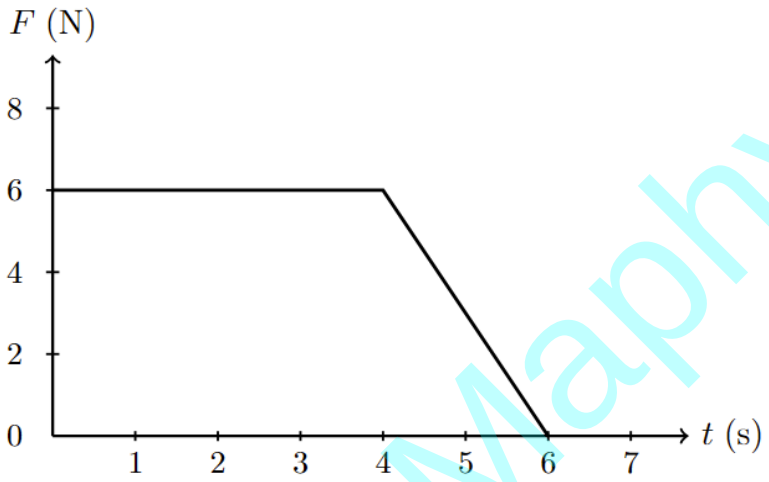
(A) 100 N

(B) 150 N

(C) 200 N

(D) 300 N

6. An automated 3.0 kg supply cart is initially at rest and moves along a straight horizontal guide rail. A propulsion system exerts a net horizontal force on the cart in the $+x$ direction. The graph shows the magnitude of the net force acting on the cart as a function of time.



(i) What is the net impulse delivered to the cart by the applied force?

(A) 6 N · s
(B) 24 N · s
(C) 30 N · s
(D) 36 N · s

(ii) What is the net work done on the cart by the applied force?

(A) 30 J
(B) 50 J
(C) 120 J
(D) 150 J

7. A robotic arm pushes a 40 kg equipment crate that is moving at 2.0 m/s in the $-x$ direction along a straight track. The push causes the crate to move at 4.0 m/s in the $+x$ direction. If the robotic arm exerts a constant net force of 60 N, how long must the force act on the crate?

   (A) 1 s
   (B) 2 s
   (C) 3 s
   (D) 4 s

8. A machine uses a heavy metal block to hit the top of a metal post and push it into the ground. To produce the greatest average force on the post during the collision, the machine should:

   (A) Hit the post and pull the block back slowly after the collision.
   (B) Hit the post straight on (perpendicular to the surface) and pull the block back as quickly as possible after the collision.
   (C) Hit the post and not pull the block back after the collision.
   (D) Hit the post at an angle to the surface and pull the block back as quickly as possible after the collision.

Conservation of Momentum

9. A 3.0 kg supply crate is initially at rest on a frictionless warehouse floor. A 40.0 kg worker standing on the same frictionless surface pushes the crate, causing it to move with a speed of 8.0 m/s. Which of the following best describes the worker's velocity immediately after the push?

   (A) 0.6 m/s in the same direction as the crate.
   (B) 0.6 m/s in the opposite direction of the crate.
   (C) 1.7 m/s in the same direction as the crate.
   (D) 1.7 m/s in the opposite direction of the crate.

10. A motorized cart moves along a frictionless horizontal track at a constant speed. The cart carries an open container. Sand falls vertically into the container at a steady rate while the cart continues to move. What happens to the speed of the cart as the sand is added?

    (A) Increases.
    (B) Remains the same.
    (C) Decreases.
    (D) Increases and then decreases.

11. A worker is standing at one end of a small platform that can move without friction along a horizontal track. The mass of the worker is equal to the mass of the platform. The worker walks a distance L toward the opposite end of the platform. Which of the following best describes the motion of the platform?

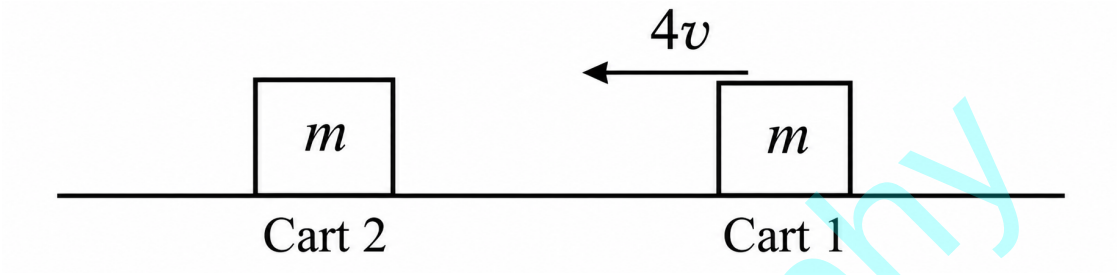
    (A) The platform moves a distance L in the direction opposite the worker's motion.
    (B) The platform moves a distance $\frac{L}{2}$ in the direction opposite the worker's motion.
    (C) The platform moves a distance $2L$ in the direction opposite the worker's motion.
    (D) The center of mass of the worker-platform system moves in the direction of the worker's motion.

Types of collision

12. A 3.0 kg equipment cart moves freely along a frictionless track with a speed of 2.0 m/s. It collides with a 1.0 kg supply cart that is initially at rest. After the collision, the two carts lock together and continue moving as a single object. What is the speed of the combined carts immediately after the collision?

    (A) 1.5 m/s
    (B) 2.0 m/s
    (C) 2.5 m/s
    (D) 3.0 m/s

13. Two carts are on a frictionless horizontal track and each has mass m. Cart 2 is initially at rest. Cart 1 moves to the left with speed $4v$ and undergoes a perfectly inelastic collision with Cart 2, so that the two carts stick together after the collision. What is the speed of the combined carts immediately after the collision?



(A) 0
(B) v
(C) $2v$
(D) $4v$

14. Two carts are on a frictionless horizontal track and each has mass m. Cart 2 is initially at rest. Cart 1 moves to the left with speed $4v$ and collides elastically with Cart 2.

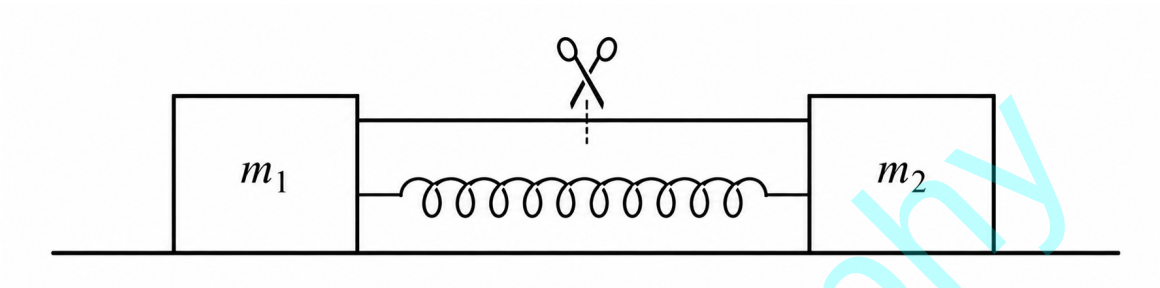
(i) What is the final speed of Cart 1 after the collision?

(A) 0
(B) v
(C) $2v$
(D) $4v$

(ii) What is the final speed of Cart 2 after the collision?

(A) 0
(B) v
(C) $2v$
(D) $4v$

15. Two blocks with different masses, m_1 and m_2, rest on a frictionless horizontal surface. A compressed spring is placed between the blocks and is initially held compressed by a light string. The string is cut, allowing the spring to expand and push the blocks apart. Which of the following must be true after the blocks lose contact with the spring?



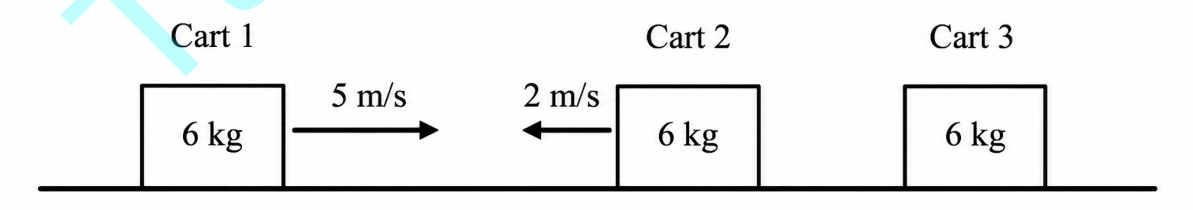
(A) The two blocks have equal speeds in opposite directions.

(B) The two blocks have equal kinetic energies.

(C) The total kinetic energy of the two-block system is the same before and after the string is cut.

(D) The total momentum of the two-block system is zero.

16. Three identical 6 kg carts move along a frictionless horizontal track. Initially, Cart 1 moves to the right with a speed of 5 m/s, Cart 2 moves to the left with a speed of 2 m/s, and Cart 3 is at rest. Cart 1 collides elastically with Cart 2. After that collision, Cart 2 collides elastically with Cart 3.



(i) What is the speed of Cart 1 immediately after the first collision?

(A) 0

(B) 2 m/s

(C) 5 m/s

(D) 7 m/s

(ii) What is the speed of Cart 2 immediately after the first collision?

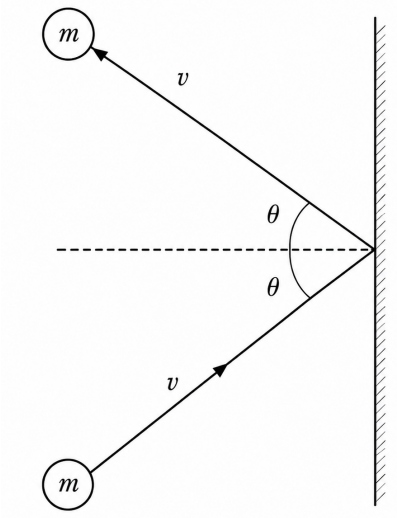
(A) 0
(B) 2 m/s
(C) 5 m/s
(D) 7 m/s

(iii) What is the speed of Cart 3 immediately after the second collision?

(A) 0
(B) 2 m/s
(C) 5 m/s
(D) 7 m/s

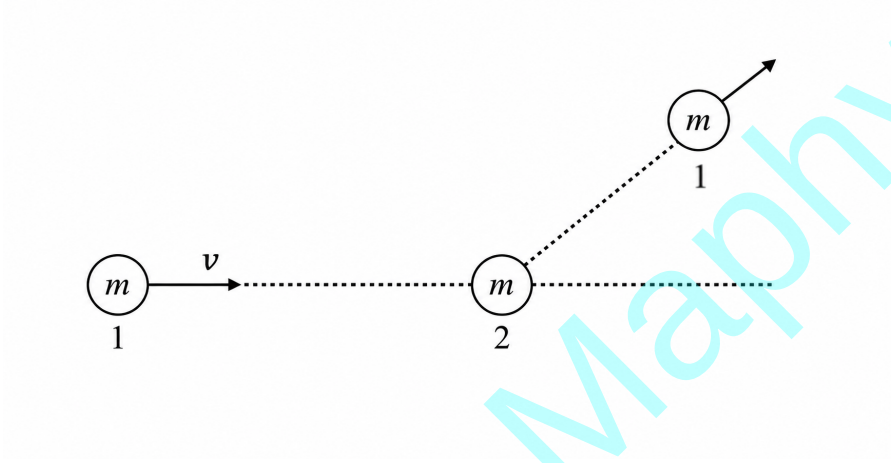
2D collision

17. As shown above, a rubber puck of mass m strikes a smooth vertical barrier with speed v at an angle θ to the normal. The puck rebounds from the barrier with the same speed v, making the same angle θ with the normal. What is the magnitude of the change in momentum of the puck?



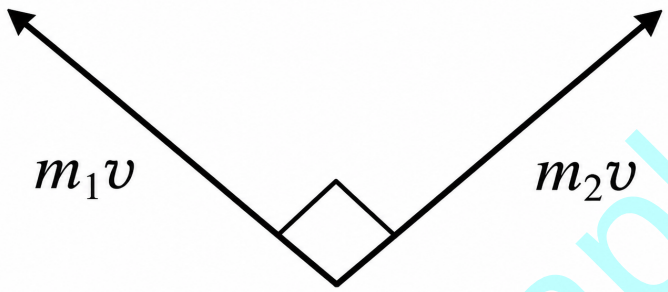
(A) $2mv \sin\theta$
(B) $2mv \cos\theta$
(C) $2mv$
(D) 0

18. A steel disk (1) moves with constant speed v across a smooth horizontal air table and collides obliquely with an identical steel disk (2) that is initially at rest. The figure above shows the velocity of disk (1) immediately before and immediately after the collision. Which of the following best represents the direction of the velocity of disk (2) immediately after the collision?



(A) $\rightarrow$
(B) $\leftarrow$
(C) $\searrow$
(D) $\nearrow$

19. A fireworks shell is initially at rest and explodes into three fragments with masses m, m, and $2m$. The momentum vectors of the two fragments with mass m are shown in the diagram.



(i) What is the direction of the momentum of the fragment with mass $2m$?

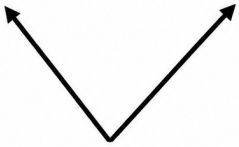
(A) $\rightarrow$
(B) $\downarrow$
(C) $\leftarrow$
(D) $\uparrow$

(ii) What is the speed of the fragment with mass $2m$?

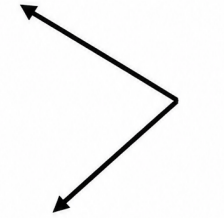
(A) $\frac{\sqrt{7}}{2}v$
(B) $\frac{\sqrt{5}}{2}v$
(C) $\frac{\sqrt{3}}{2}v$
(D) $\frac{\sqrt{2}}{2}v$

20. A moving air-hockey puck collides with an identical puck that is initially at rest on a frictionless table. The initial momentum of the moving puck is shown below. Which of the following pairs of vectors could represent the momenta of the two pucks immediately after the collision?

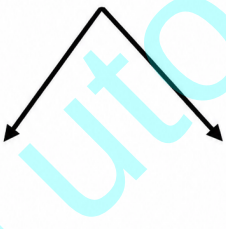
A.



B.

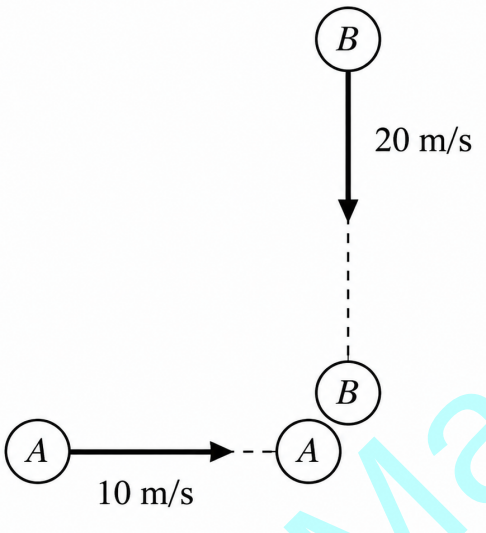


C.



D.

21. Two carts move on a frictionless horizontal surface. Cart A has a mass of 8.0 kg and moves east with a speed of 10.0 m/s. Cart B has a mass of 3.0 kg and moves south with a speed of 20.0 m/s. The carts collide and stick together.



(i) What is the speed of the combined carts immediately after the collision?

(A) 1.8 m/s
(B) 9.1 m/s
(C) 13 m/s
(D) 25 m/s

(ii) What is the direction of motion of the combined carts immediately after the collision?

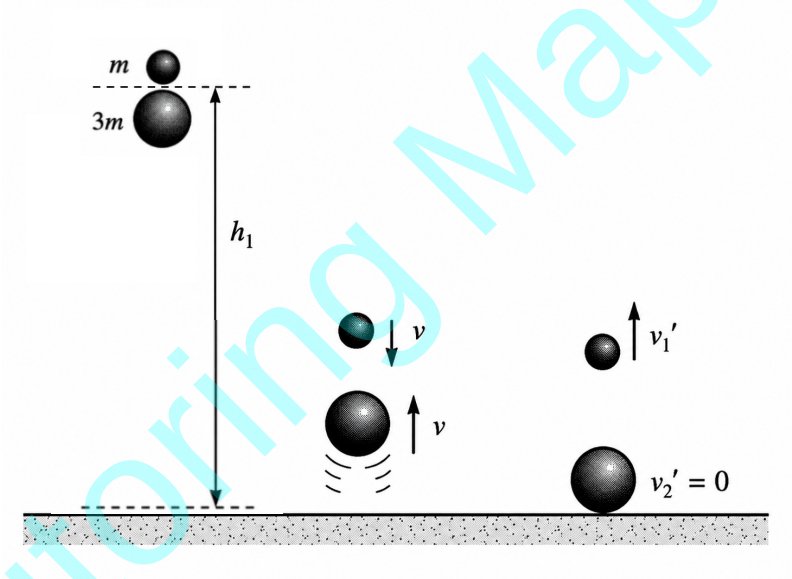
(A) 30° south of east
(B) 37° south of east
(C) 45° south of east
(D) 53° south of east

FRQ

22. Part I

A small rubber ball of mass m is released from rest from a height h_1 directly above a larger rubber ball of mass $3m$, as shown in the figure. The larger ball is initially at rest and is positioned just above a rigid horizontal floor. Assume that both the collision between the larger ball and the floor and the collision between the two balls are perfectly elastic.

Both balls are released simultaneously. The larger ball strikes the floor first and rebounds upward. At the instant the two balls collide, they are moving with equal speeds v but in opposite directions. After the collision, the larger ball comes to rest, while the smaller ball continues upward.



(a) Without using any equations, indicate whether the smaller ball rises to a height that is greater than, less than, or equal to the original release height h_1.

_____ Greater than h_1 _____ Less than h_1 _____ Equal to h_1

Explain your reasoning qualitatively.

(b) Determine the maximum height reached by the smaller ball after the collision in terms of h_1. Show your work clearly. Does your quantitative result agree with your qualitative prediction in part (a)? Briefly explain.

(c) Consider the time interval beginning immediately after the collision between the two balls and ending when the smaller ball reaches its maximum height. For the system consisting of the two balls and Earth, determine whether the total mechanical energy of the system increases, decreases, or remains constant during this interval. Justify your answer.

_____ Increases _____ Decreases _____ Remains constant

Part II

A modified experiment is performed. Initially, both balls are released from rest from the same positions as in the original experiment. Just before the larger ball strikes the floor, both balls have the same speed v. The collision between the larger ball and the floor is not perfectly elastic; instead, the larger ball rebounds upward with speed αv, where $0 < \alpha < 1$. At the instant the two balls collide, the smaller ball is moving downward with speed v, while the larger ball is moving upward with speed αv. The collision between the two balls remains perfectly elastic. As before, the larger ball comes to rest immediately after colliding with the smaller ball.

(d) During the collision between the larger ball and the floor, the contact time is Δt. Assume that the impulse due to the gravitational force during this short time interval is negligible compared to the impulse exerted by the floor. Determine an expression for the magnitude of the average normal force exerted by the floor on the larger ball. Your answer should be expressed in terms of m, α, v, and Δt.

(e) Determine the value of α for which the smaller ball reaches one-half the maximum height found in part (b).