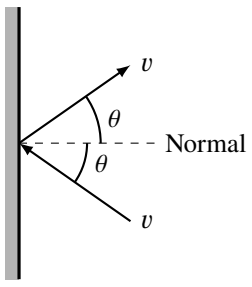
Student #: _____ Student Name: _____

AP PHYSICS C: MOMENTUM AND CENTER OF MASS

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10\,\text{m/s}^2$ in all problems.

1. A rubber ball of mass m strikes a wall with a speed v at an angle θ below the normal line and rebounds from the wall at the same speed and angle above the normal line as shown. The magnitude of the change in momentum of the ball is

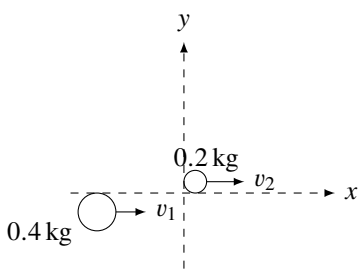


(A) mv
(B) $2mv$
(C) $mv\cos\theta$
(D) $2mv\cos\theta$
(E) zero

2. Two blocks are connected by a compressed spring and rest on a frictionless surface. The blocks are released from rest and pushed apart by the compressed spring. If one mass is twice the mass of the other, which of the following is the same for both blocks?

(A) magnitude of momentum
(B) acceleration
(C) speed
(D) kinetic energy
(E) potential energy

3. Two billiard balls are rolling to the right on a table as shown. The 0.4 kg ball is moving faster than the 0.2 kg ball, so it catches up and strikes it from behind at a slight angle. Immediately after the collision, the y-component of the 0.4 kg ball is 2 m/s downward. The y-component of the velocity of the 0.2 kg ball must be



(A) 1 m/s upward
(B) 2 m/s upward
(C) 1 m/s downward
(D) 2 m/s downward
(E) 4 m/s upward

4. A small mass m is moving with a speed v toward a stationary mass M. The speed of the center of mass of the system is

(A) $\left(\frac{m}{m+M}\right)v$
(B) $\left(\frac{m+M}{m}\right)v$
(C) $\left(\frac{m}{M}\right)v$
(D) $\left(1+\frac{m}{M}\right)v$
(E) $\left(1+\frac{M}{3m}\right)v$

5. A known net force F acts on an unknown mass for a known time Δt. From this information, you could determine the

(A) change in kinetic energy of the object
(B) change in velocity of the object
(C) acceleration of the object
(D) mass of the object
(E) change in momentum of the object

Questions 6–7
Two balls are on a horizontal billiard table. A 1.0 kg billiard ball moves downward along the y-axis with a speed of 16 m/s toward a 2.0 kg ball that is at rest. The balls collide at an angle, and move along the lines shown. After the collision, the 1.0 kg ball moves at 9 m/s along the $+x$-axis. The table below shows the x and y components of the momentum in kg · m/s of the two balls before and after the collision.

	p_{1x}	p_{1y}	p_{2x}	p_{2y}
Before Collision	0	−16	0	0
After Collision	+9	0	−9	−16

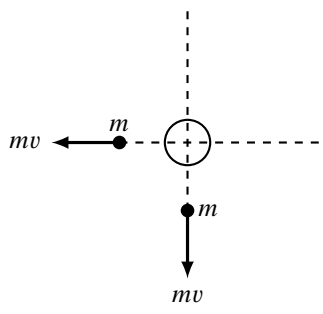
6. Which of the following statements is true?

(A) Momentum is conserved only in the x-direction in this collision.
(B) Momentum is conserved only in the y-direction in this collision.
(C) Momentum is conserved in both the x- and y-directions in this collision
(D) The momentum of the 1.0 kg ball increases after the collision.
(E) The momentum of the 2.0 kg ball decreases after the collision.

7. What is the speed of the 2.0 kg ball after the collision?

(A) 16.0 m/s
(B) 9.2 m/s
(C) 7.5 m/s
(D) 6.0 m/s
(E) 5.0 m/s

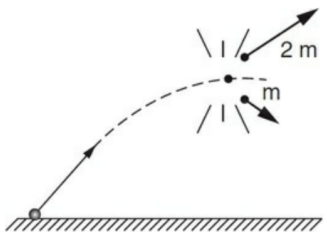
8. An object has a mass $4m$. The object explodes into three pieces of mass m, m, and $2m$. The two pieces of mass m move off at right angles to each other with the same momentum mv, as shown below. The speed of mass $2m$ after the explosion is



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

Questions 9–10

A projectile is launched at an angle to the level ground as shown. At the top of the trajectory at point P, the projectile explodes into two pieces of mass $2m$ and m.



9. Which of the following arrows best represents the direction of the velocity of the center of mass of the projectile at point P after the explosion?

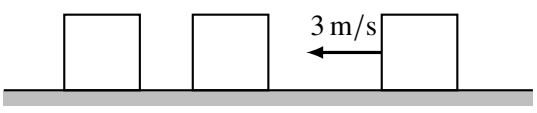
(A) ←
(B) ↙
(C) ↘
(D) →
(E) ↗

10. Which of the following statements is true of the center of mass of the projectile after the explosion?

(A) The center of mass will continue on a parabolic path and land on the ground at the place where it would have landed had it not exploded.
(B) The center of mass will alter its parabolic path and land on the ground farther from where it would have landed had it not exploded.
(C) The center of mass will alter its parabolic path and land on the ground at a shorter distance than it would have landed had it not exploded.
(D) The center of mass will fall straight downward from the point of explosion.
(E) The center of mass will travel straight upward from the point of explosion.

Questions 11–12

Three identical masses can slide freely on a horizontal surface as shown. The first mass moves with a speed of 3.0 m/s toward the second and third masses, which are initially at rest. The first and second mass collide elastically, and then the second and third masses collide inelastically.



11. The speed of the second mass after the collision is

(A) zero
(B) 1.5 m/s
(C) 3.0 m/s
(D) 6.0 m/s
(E) 9.0 m/s

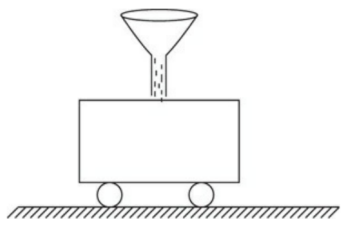
12. The speed of the second and third masses after they collide inelastically is

(A) zero
(B) 1.5 m/s
(C) 3.0 m/s
(D) 6.0 m/s
(E) 9.0 m/s

13. A mass traveling in the $+x$ direction collides with a mass at rest. Which of the following statements is true?

(A) After the collision, the two masses will move with parallel velocities
(B) After the collision, the masses will move with anti-parallel velocities
(C) After the collision, the masses will both move along the x-axis
(D) After the collision, the y-components of the velocities of the two particles will sum to zero.
(E) None of the above

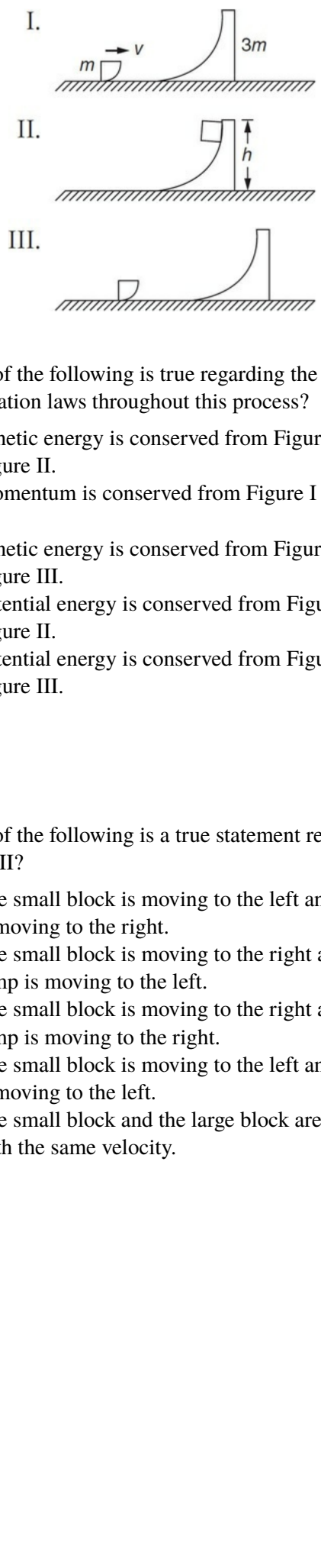
14. A 1000 kg (empty mass) railroad car is rolling without friction on a horizontal track at a speed of 2.0 m/s. Sand is poured into the open top of the car for the time interval from $t = 0$ to $t = 4.0$ s. The mass of the sand poured into the car as a function of time is $m(t) = 60t^2$. The velocity of the car at a time of 4.0 s is most nearly



(A) 1 m/s
(B) 2 m/s
(C) 3 m/s
(D) 4 m/s
(E) 5 m/s

Questions 15–16

A small block of mass m slides on a horizontal frictionless surface toward a ramp of mass $3m$ which is also free to move on the surface. The small block slides up to a height h on the ramp with no friction (Figure I), then they move together (Figure II), and the small block slides back down the ramp to the horizontal surface (Figure III). Both the block and the ramp continue to slide on the horizontal surface after they separate.



15. Which of the following is true regarding the conservation laws throughout this process?

(A) Kinetic energy is conserved from Figure I to Figure II.
(B) Momentum is conserved from Figure I to Figure III.
(C) Kinetic energy is conserved from Figure II to Figure III.
(D) Potential energy is conserved from Figure I to Figure II.
(E) Potential energy is conserved from Figure II to Figure III.

16. Which of the following is a true statement regarding Figure III?

(A) The small block is moving to the left and the ramp is moving to the right.
(B) The small block is moving to the right and the ramp is moving to the left.
(C) The small block is moving to the right and the ramp is moving to the right.
(D) The small block is moving to the left and the ramp is moving to the left.
(E) The small block and the large block are moving with the same velocity.

Questions 17–18

A remote controlled stunt car of mass 800 kg initially moving at 10 m/s is crashed into a rail car of mass m that is initially at rest. The cars stick together, and the speed v of both cars after the collision is given by $v = \dfrac{6}{t+1}$.

17. By considering the fact that the crash occurs at time $t = 0$, determine the mass m of the rail car.

    (A) 288 kg
    (B) 445 kg
    (C) 533 kg
    (D) 698 kg
    (E) 800 kg

18. The magnitude of the resisting force acting on the cars as a function of time after the collision is

    (A) $\dfrac{6m}{t+1}$
    (B) $6m(t+1)$
    (C) $6m(t+1)^2$
    (D) $\dfrac{6m}{(t+1)^2}$
    (E) $\dfrac{m(t+1)^2}{6}$

19. A moving object is changing its momentum during a time interval. If a graph of momentum vs. time is plotted, the net force acting on the mass at any time can be determined by finding the

    (A) slope of line tangent to the graph at that time
    (B) area under the graph
    (C) y-intercept of the graph
    (D) x-intercept of the graph
    (E) change in slope of the graph from beginning to end

20. A mass m_1 initially moving at speed v_0 collides with and sticks to a spring attached to a second, initially stationary mass m_2. The two masses continue to move to the right on a frictionless surface as the length of the spring oscillates. At the instant that the spring is maximally extended, the velocity of the first mass is

    (A) v_0
    (B) $m_1^2 v_0/(m_1+m_2)^2$
    (C) $m_2 v_0/m_1$
    (D) $m_1 v_0/m_2$
    (E) $m_1 v_0/(m_1+m_2)$

AP PHYSICS C: MOMENTUM, IMPULSE, COLLISIONS, AND CENTER OF MASS
SECTION II
5 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.