Student #: ____________________________ Student Name: ___________________________________

AP PHYSICS 1: MOMENTUM, IMPULSE AND COLLISIONS

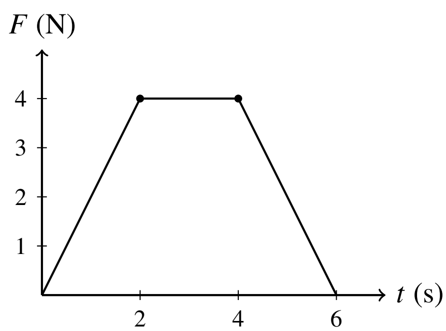
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

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

1. A toy train car of mass 3 kg rolls to the left at 2 m/s and collides with a 4 kg train car rolling to the right at 1 m/s. The two cars stick together. The velocity of the cars after the collision is

(A) $2/7$ m/s to the left
(B) $2/7$ m/s to the right
(C) $4/7$ m/s to the left
(D) $4/7$ m/s to the right
(E) $9/7$ m/s to the right

Questions 2–3. A force acts on a 2.0 kg mass during a time interval as shown in the graph.



2. The impulse given to the mass from $t = 0$ to $t = 6$ s is

(A) 4 N s
(B) 8 N s
(C) 12 N s
(D) 16 N s
(E) 24 N s

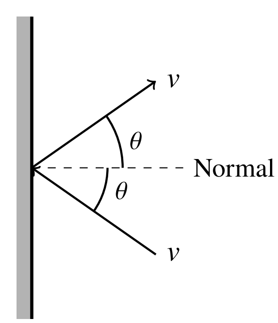
3. If the initial speed of the mass is 2 m/s at $t = 0$, what is its speed at the end of 6 s?

(A) 4 m/s
(B) 6 m/s
(C) 8 m/s
(D) 10 m/s
(E) 16 m/s

4. Two steel balls, one of mass m and the other of mass $2m$, collide and rebound in a perfectly elastic collision. Which of the following is conserved in this elastic collision?

(A) velocity only
(B) momentum only
(C) momentum and kinetic energy only
(D) momentum, velocity, and kinetic energy
(E) kinetic energy only

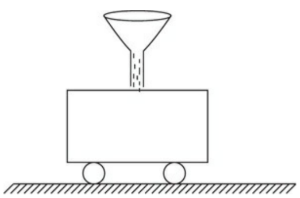
5. A rubber ball of mass m strikes a wall with a speed v at an angle θ below the normal line and rebounds from the wall at the same speed and angle above the normal line as shown. The magnitude of the change in momentum of the ball is



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

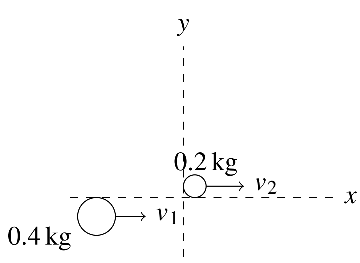
6. Two blocks are connected by a compressed spring and rest on a frictionless surface. The blocks are released from rest and pushed apart by the compressed spring. If one mass is twice the mass of the other, which of the following is the same for both blocks?
   (A) magnitude of momentum
   (B) acceleration
   (C) speed
   (D) kinetic energy
   (E) potential energy

7. A 1000 kg railroad car is rolling without friction on a horizontal track at a speed of 3.0 m/s. Sand is poured into the open top of the car for a time of 5.0 s. The speed of the car after 5.0 s is 1.0 m/s. The mass of the sand added to the car at the end of 5.0 s is



   (A) 500 kg
   (B) 1000 kg
   (C) 2000 kg
   (D) 3000 kg
   (E) 3500 kg

8. 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

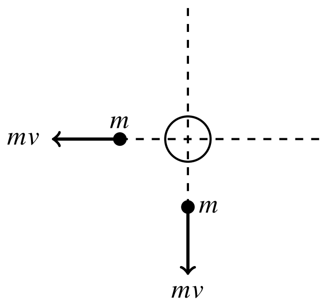
9. A 0.3 kg baseball at rest on a tee is struck by a bat. The ball leaves the at with a speed of 20 m/s at an angle of 45° above the horizontal. The magnitude of the impulse imparted to the baseball by the bat is most nearly
   (A) 2 N s
   (B) 6 N s
   (C) 12 N s
   (D) 16 N s
   (E) 20 N s

10. Two ice skaters, a large man and a small woman, are initially at rest and holding each other's hands. They push away horizontally. Afterward, which of the following statements is true?
   (A) They have equal and opposite kinetic energies.
   (B) The have equal and opposite momenta.
   (C) The large man applies a greater force to the small woman.
   (D) The small woman applies a greater force to the large man.
   (E) They recoil with equal and opposite velocities.

11. 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

12. A 100 kg cannon sits at rest with a 1 kg cannonball in the barrel. The cannonball is fired with a speed of 50 m/s to the right, causing the cannon to recoil with a speed of 0.5 m/s to the left. The velocity of the center of mass of the cannon-cannonball system is
   (A) zero
   (B) 5 m/s to the right
   (C) 5 m/s to the left
   (D) 50 m/s to the right
   (E) 50 m/s to the left

Questions 13–14. 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.



13. 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) $\frac{\sqrt{3}}{2}v$

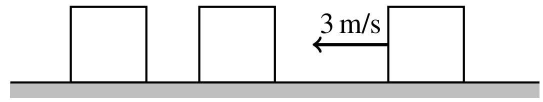
14. The direction of velocity of mass $2m$ is

(A) →
(B) ↙
(C) ↓
(D) ↗
(E) ↑

15. A block of mass m is moving to the right with a speed v_0 on a horizontal surface of negligible friction when it explodes. The explosion causes the block to break into two pieces, each of which moves in the horizontal direction. One piece of mass $m/4$ moves to the left with a speed of $2v_0$. What is the velocity of the other piece?

(A) $2v_0$ to the right
(B) v_0 to the right
(C) $34v_0$ to the right
(D) $12v_0$ to the right
(E) $14v_0$ to the left

Questions 16–17. 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.



16. 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

17. 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

Questions 18–19. A 20 kg boy runs at a speed of 3.0 m/s and jumps onto a 40 kg sled on frictionless ice that is initially at rest. The boy and the sled then move together for a short time.

18. The speed of the boy and sled after he jumps on it is

(A) 0.5 m/s
(B) 0.8 m/s
(C) 1.0 m/s
(D) 1.5 m/s
(E) 2.0 m/s

19. While the boy and sled are moving, he jumps off the back of the sled in such a way the boy is at rest, and the sled continues to move forward. The speed of the sled after the boy jumps off is

(A) 1.5 m/s
(B) 2.0 m/s
(C) 3.0 m/s
(D) 4.5 m/s
(E) 6.0 m/s

20. A 1.0 kg block is released from rest from a height h at the top of a fixed curved ramp of negligible friction. The block slides down the ramp and collides with another block of mass 1.5 kg at rest at the bottom of the ramp. The two blocks stick together and move with a speed of 5 m/s. The height h from which the 1.0 kg block began is

(A) 0.8 m
(B) 1.2 m
(C) 1.8 m
(D) 2.8 m
(E) 7.8 m

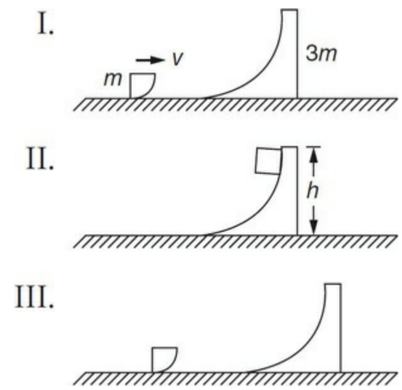
21. A dart of mass m is fired into a wooden block of mass $4m$ that hangs from a string. The dart and block then rise to a maximum height h. An expression for the initial speed v o of the dart before striking the block is

(A) $\sqrt{gh}$
(B) $\sqrt{2gh}$
(C) $\sqrt{50gh}$
(D) $\sqrt{100gh}$
(E) $\sqrt{250gh}$

22. 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) $m_1 v_0/(m_1+m_2)$

Questions 23–24. 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.



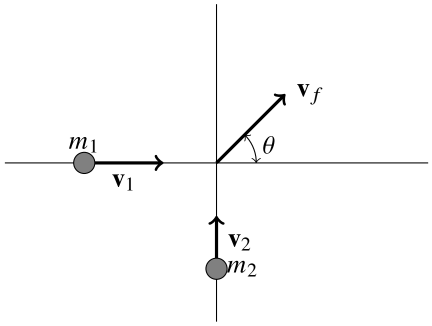
23. Which of the following is true regarding the conservation laws throughout this process?

(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.

24. 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.

25. Two masses moving along the coordinates axes as shown collide at the origin and stick to each other. What is the angle θ that the final velocity that makes with the x-axis?



(A) $\tan^{-1}(v_2/v_1)$
(B) $\tan^{-1}[m_1 v_1/(m_1+m_2)]$
(C) $\tan^{-1}(m_1 v_2/m_2 v_1)$
(D) $\tan^{-1}(m_2 v_2^2/m_1 v_1^1)$
(E) $\tan^{-1}(m_2 v_2/m_1 v_1)$

26. 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

AP PHYSICS 1 & C: MOMENTUM, IMPULSE, COLLISIONS, AND CENTER OF MASS
SECTION II
4 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.

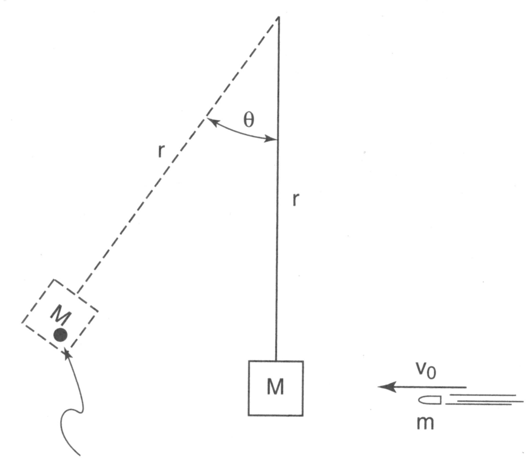
1. (Suggested time 25 minutes) A new kind of toy ball is advertised to "bounce perfectly elastically" off hard surfaces. A student suspects, however, that no collision can be perfectly elastic. The student hypothesizes that the collisions are very close to being perfectly elastic for low-speed collisions but that they deviate more and more from being perfectly elastic as the collision speed increases.

   (a) Design an experiment to test the student's hypothesis about collisions of the ball with a hard surface. The student has equipment that would usually be found in a school physics laboratory.
      i. What quantities would be measured?
      ii. What equipment would be used for the measurements, and how would that equipment be used?
      iii. Describe the procedure to be used to test the student's hypothesis. Give enough detail so that another student could replicate the experiment.

   (b) Describe how you would represent the data in a graph or table. Explain how that representation would be used to determine whether the data are consistent with the student's hypothesis.

   (c) A student carries out the experiment and analysis described in parts (a) and (b). The student immediately concludes that something went wrong in the experiment because the graph or table shows behavior that is elastic for low-speed collisions but appears to violate a basic physics principle for high-speed collisions.
      i. Give an example of a graph or table that indicates nearly elastic behavior for low-speed collisions but appears to violate a basic physics principle for high-speed collisions.
      ii. State one physics principle that appears to be violated in the graph or table given in part (c)i. Several physics principles might appear to be violated, but you only need to identify one.
      iii. Briefly explain what aspect of the graph or table indicates that th e physics principle is violated, and why.

2. The Ballistic Pendulum. To determine the muzzle speed of a gun, a bullet is shot into a mass M from a string as shown below, causing M to swing upward through a maximum angle of θ.



(A bullet lodged in the wood)

(a) What is the speed of M the instant after the bullet lodges in it?

(b) What is the speed of the bullet before it hits M?

(c) What is the tension in the string at the highest point of the pendulum's swing (when the string makes an angle of θ with the vertical as shown)?

3. An 800.0-kg car is traveling along a wet road at a velocity of 25.5 m/s. A 1000.0-kg car is traveling along the same road in the same direction at 34.7 m/s. The two cars collide and lock together. Answer the following questions.

   (a) The two interlocked cars proceed at what velocity after the collision?

   (b) Compare the kinetic energy of the two-car system immediately before the collision and after the collision.

   (c) Discuss any transfer of energy that occurs, and explain whether this is an elastic or inelastic collision.

   (d) If the coefficient of sliding friction between the tires of the cars and the wet pavement is 0.7, calculate the force of friction.

   (e) How long does it take for the two interlocked cars to come to a complete stop on the wet pavement?

4. A stream of glass beads, each with a mass of 0.5 g, comes out of a horizontal tube at 100 per second. The beads fall a distance of 0.5 m to a balance pan and bounce back to their original height as shown in the figure below. How much mass must be placed in the other pan of the balance to keep the pointer at zero?