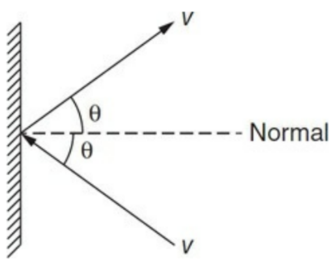
AP PHYSICS 1 & C: MOMENTUM AND ENERGY
(Classes 1 & 2)

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.

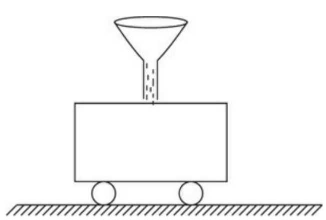
Note: To simplify calculations, you may use $g = 10\,\mathrm{m/s^2}$ in all problems.

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 change in momentum of the ball is



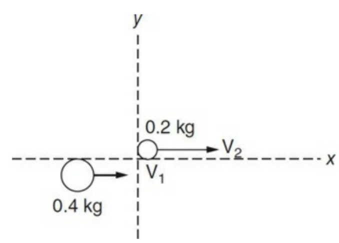
(A) mv
(B) $2mv$
(C) $mv\cos\theta$
(D) $2mv\cos\theta$
(E) zero

2. 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

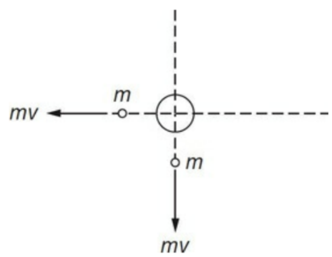
3. Two billiard balls are rolling to the right on a table as shown. The 0.4 kg ball is moving faster than the 0.2 kg ball, so it catches up and strikes it from behind at a slight angle. Immediately after the collision, the y-component of the 0.4 kg ball is 2 m/s downward. The y-component of the velocity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

Questions 4-5

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.

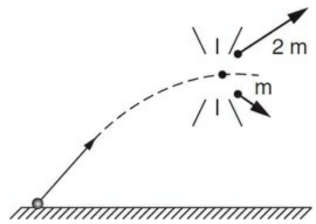


4. The speed of mass 2m after the explosion is
   - (A) $2v$
   - (B) $\sqrt{2}v$
   - (C) $\frac{\sqrt{2}}{2}v$
   - (D) $\frac{\sqrt{2}}{3}v$
   - (E) $\frac{\sqrt{3}}{2}v$

5. The direction of velocity of mass $2m$ is
   - (A) $\rightarrow$
   - (B) $\swarrow$
   - (C) $\downarrow$
   - (D) $\nearrow$
   - (E) $\uparrow$

Questions 6-7

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.



6. 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) $\leftarrow$
   - (B) $\swarrow$
   - (C) $\searrow$
   - (D) $\rightarrow$
   - (E) $\nearrow$

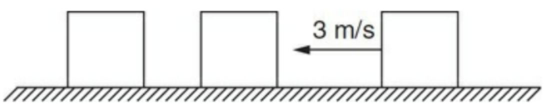
7. Which of the following statements is true of the center of mass of the projectile after the explosion?
   - (A) The center of mass will continue on a parabolic path and land on the ground at the place where it would have landed had it not exploded.
   - (B) The center of mass will alter its parabolic 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.

8. A small mass m is moving with a speed v toward a stationary mass $2m$. The speed of the center of mass of the system is

(A) $\left(\frac{m}{m+2m}\right)v$
(B) $\left(\frac{m+2m}{m}\right)v$
(C) $\left(\frac{m}{2m}\right)v$
(D) $\left(1+\frac{m}{2m}\right)v$
(E) $\left(1+\frac{32m}{m}\right)v$

Questions 9-10

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.



9. 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

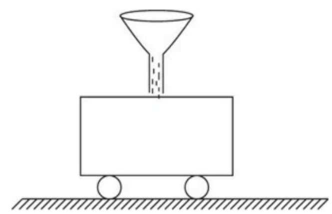
10. The speed of the second and third masses after they collide inelastically is

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

11. 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

12. 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 13-14

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 $v = \dfrac{6}{t+1}$.

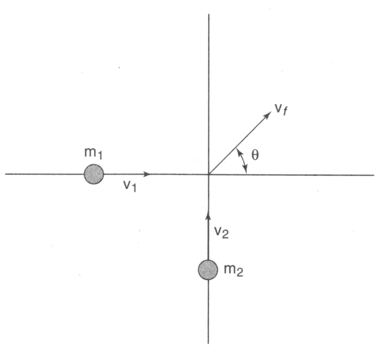
13. By considering the fact that the crash occurs at time $t = 0$, determine the mass m of the rail car.

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

14. 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) $\dfrac{m(t+1)^2}{6}$

15. 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) $\tan^{-1}[m_1v_1/(m_1+m_2)]$
(C) $\tan^{-1}(m_1v_2/m_2v_1)$
(D) $\tan^{-1}(m_2v_2^2/m_1v_1^1)$
(E) $\tan^{-1}(m_2v_2/m_1v_1)$

16. If a projectile thrown directly upward reaches a maximum height h and spends a total time in the air of T, the average power of the gravitational force during the trajectory is

(A) $P = 2mgh/T$
(B) $P = -2mgh/T$
(C) 0
(D) $P = mgh/T$
(E) $P = -mgh/T$

17. Given that the constant net force on an object and the object's displacement, which of the following quantities can be calculated?

(A) the net change in the object's velocity
(B) the net change in the object's mechanical energy
(C) the average acceleration
(D) the net change in the object's kinetic energy
(E) the net change in the object's potential energy

18. If the only force acting on an object is given by the equation $F(x) = 2 - 4x$ (where the force is measured in newtons and position in meters), what is the change in the object's kinetic energy as it moves from $x = 2$ to $x = 1$?

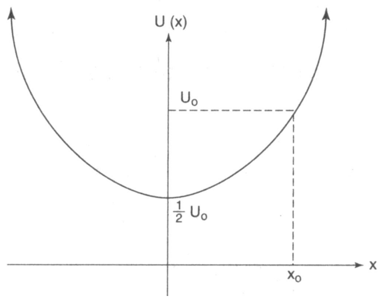
(A) +4 J
(B) -4 J
(C) +2 J
(D) -2 J
(E) +8 J

19. 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 antiparallel 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

Questions 20-21

20. Consider the potential energy function shown below. Assuming that no non-conservative forces are present, if a particle of mass m is released from position x_0, what is the maximum speed it will achieve?

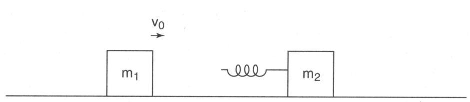


(A) $\sqrt{4U_0/m}$
(B) $\sqrt{2U_0/m}$
(C) $\sqrt{U_0/m}$
(D) $\sqrt{U_0/2m}$
(E) The particle will achieve no maximum speed but instead will continue to accelerate indefinitely.

21. Which of the following is the most accurate description of the system introduced in the previous question?

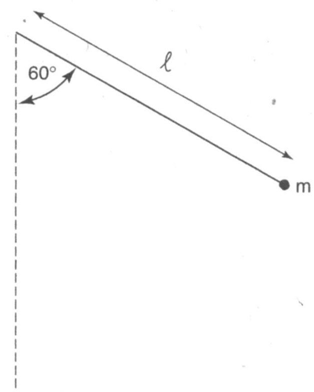
(A) stable equilibrium
(B) unstable equilibrium
(C) neutral equilibrium
(D) a bound system
(E) There is a linear restoring force

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



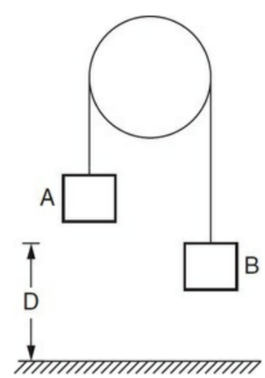
(A) v_0
(B) $m_1^2 v_0/(m_1+m_2)^2$
(C) $m_2 v_0/m_1$
(D) $m_1 v_0/m_2$
(E) $m_1 v_0/(m_1+m_2)$

23. A pendulum bob of mass m is released from rest as shown in the figure below. What is the tension in the string as the pendulum swings through the lowest point of its motion?



(A) $T = \frac{1}{2}mg$
(B) $T = mg$
(C) $T = \frac{3}{2}mg$
(D) $T = 2mg$
(E) None of the above

24. Two blocks of mass m_A and m_B are connected by a string that passes over a light pulley. The mass of A is larger than the mass of B. The speed of mass A just before reaching the floor is:



(A) $\sqrt{\frac{m_A - m_B}{m_A + m_B} gD}$
(B) $\sqrt{\frac{m_A + m_B}{m_A - m_B} gD}$
(C) $\sqrt{\frac{m_A}{m_A + m_B} gD}$
(D) $\sqrt{\frac{m_B}{m_A + m_B} gD}$
(E) $\sqrt{\frac{m_A}{m_B} gD}$

25. A particle of mass m moves according to the displacement equation $x = 2t^{5/2}$. The kinetic energy of the particle as a function of time is
   (A) $10mt^{5/2}$
   (B) $10mt^{3/2}$
   (C) $\frac{5}{2}mt^3$
   (D) $5mt^2$
   (E) $2mt^{3/2}$

26. The potential energy of an object varies with the equation $U(x) = 2x^2 + x6$, where force is in newtons and displacement is in meters. A force F vs. displacement x graph would yield which of the following?
   (A) A straight, horizontal line
   (B) A parabola
   (C) An exponential decay curve
   (D) A straight line with a positive slope
   (E) A straight line with a negative slope

AP® Physics 1 &C: Momentum and Energy
Student Answer Sheet for Multiple-Choice Section

No.	Answer
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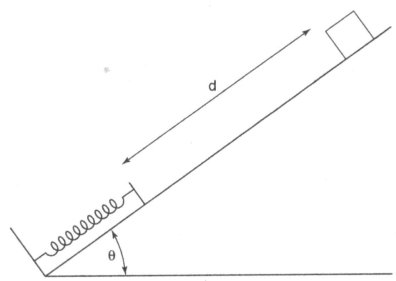
AP PHYSICS 1 & C: MOMENTUM AND ENERGY
SECTION II
5 Questions

Directions: Answer all questions. The suggested time is about 10 minutes for answering each of the 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. A mass m is placed on an incline of angle θ at a distance d from the end of a spring as shown below. The coefficient of kinetic friction between the mass and the plane is μ.

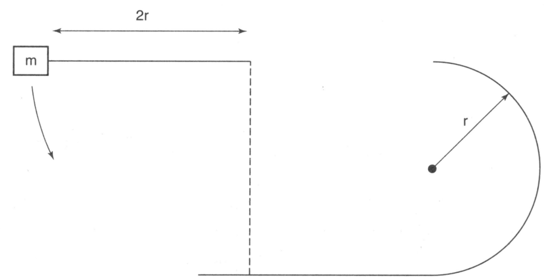


(a) The mass is released from rest at the position shown. Using Newton's laws, calculate the block's speed when it reaches the spring.

(b) Using energy conservation, alculate the block's speed when it reaches the spring.

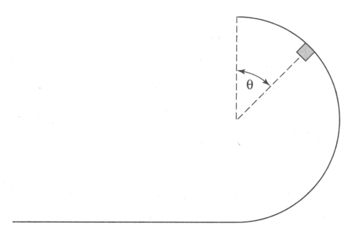
(c) The spring has spring constant k. At what value x of the compression of the spring does the object reach its maximum speed?

2. A mass m attached to a string of length $2r$ swings, starting at rest when the string is horizontal, until the string is vertical. At the instant the string is vertical, the mass makes contact with the horizontal surface, the string is cut, and the mass continues along a frictionless track as shown below.



(a) What is the speed of the mass attached to the string the instant the string is cut?

(b) Sketch the forces acting on the mass when it is in the position shown below.



When the mass is in the position shown above,

(c) Find the object's speed as a function of θ

(d) Find the object's centripetal acceleration as a function of θ

(e) Determine at what angle θ the mass will fall of the track

3. A projectile is fired from the edge of a cliff 100 m high with an initial speed of 60 m/s at an angle of elevation of 45°.

   (a) Write equation for $x(t)$, $y(t)$, v_x and v_y. Choose the origin of your coordinate system at the particle's original location.

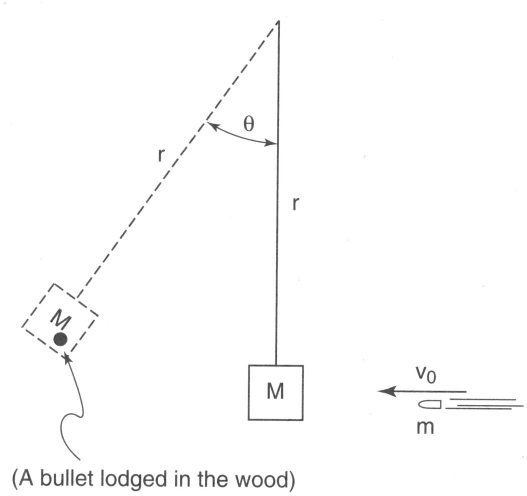
   (b) Calculate the location and velocity of the particle at time $t = 5\,\mathrm{s}$.

   Suppose the projectile experiences an internal explosion at time $t = 4\,\mathrm{s}$ with an internal force purely in the y-direction, causing it to break into 2 kg and a 1 kg fragment.

   (c) If the 2 kg fragment is 77 m above the height of the cliff at $t = 5\,\mathrm{s}$, what is the y-coordinate of the position of the 1 kg piece?

   (d) If the speed of the 2 kg fragment is 46 m/s and the fragment is falling at $t = 5\,\mathrm{s}$, what is the y-component of the velocity of the 1 kg fragment?

4. The Ballastic 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) What is the speed of M the instant after the bullet lodges in it?

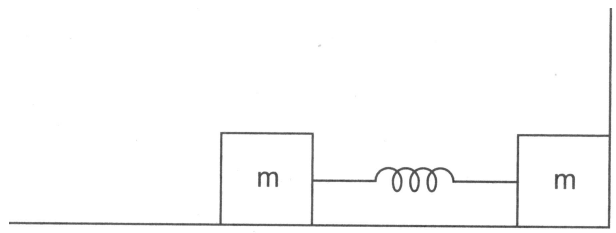
(b) What is the speed of the bullet before it hits M?

(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)?

5. Two masses are connected by a spring (spring constant k) resting on a frictionless horizontal surface as shown. The right mass is initially in contact with a wall. A brief blow to the left block leaves it with an initial velocity v_0 to the right.

   (a) What is the maximum compression of the spring as the left block moves to the right?

   After the spring is maximally compressed, it eventually moves to the left, away from wall. As it moves away from the wall, it continues oscillating.



   (b) What is the net momentum of the two masses after they leave the wall?

   (c) What is the total mechanical energy of the oscillating spring system?

   (d) What is the relative velocity of the two masses when the spring is maximally compressed?

   (e) What is the maximum compression of the spring after the two masses have left the wall? Compare the compression to the maximum compression calculated in part (a) and explain any similarities and differences.