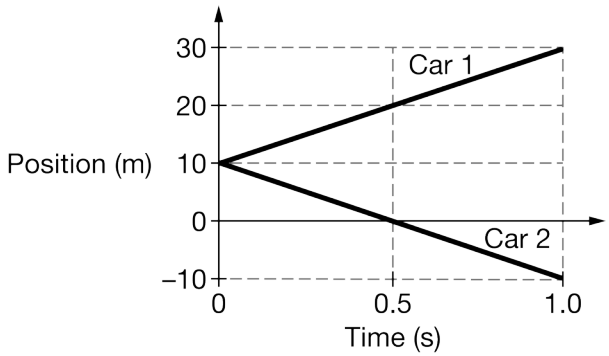
chapter1

1.



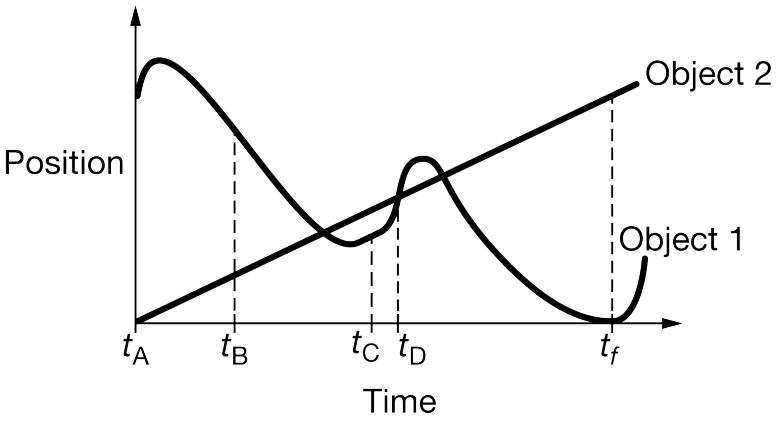
Two identical cars, car 1 and car 2, are moving in opposite directions on a straight road. The position of each car as a function of time is represented in the graph. What is the speed of the center of mass of the two-car system?

(A) Zero

(B) $10\ \mathrm{m/s}$

(C) $20\ \mathrm{m/s}$

(D) $40\ \mathrm{m/s}$



The position as a function of time for two objects moving along a straight line is shown in the graph.

2. Which statement is true about the distances the two object have traveled at time t_f?

(A) Object 1 has traveled a greater distance.

(B) Object 2 has traveled a greater distance.

(C) Both objects have traveled the same distance.

(D) The total distance traveled by each object cannot be compared using the graph.

3. At which of the following times do the two objects have the same velocity?

(A) t_A
(B) t_B
(C) t_C
(D) t_D

---

4. A ball is thrown straight up in the air. When the ball reaches its highest point, which of the following is true?

(A) It is in equilibrium.
(B) It has zero acceleration.
(C) It has maximum momentum.
(D) It has maximum kinetic energy.
(E) None of the above

5. A ball is thrown with an initial speed of 20 m/s at an angle of 60° to the ground. If air resistance is negligible, what is the ball's speed at the instant it reaches its maximum height from the ground?

(A) Zero
(B) 10 m/s
(C) 14 m/s
(D) 17 m/s
(E) 20 m/s

6. A block is projected up a frictionless plane with an initial speed v_o. The plane is inclined 30° above the horizontal. What is the approximate acceleration of the block at the instant that it reaches its highest point on the inclined plane?

(A) Zero
(B) 5 m/s^2 down the incline
(C) 10 m/s^2 down the incline
(D) 10 m/s^2 up the incline
(E) It cannot be calculated without knowing the value of v_o

7. A blue sphere and a red sphere with the same diameter are released from rest at the top of a ramp. The red sphere takes a longer time to reach the bottom of the ramp. The spheres are then rolled off a horizontal table at the same time with the same speed and fall freely to the floor. Which sphere reaches the floor first?

(A) The red sphere
(B) The blue sphere
(C) The sphere with the greater mass
(D) Neither; the spheres reach the floor at the same time.

8. A car goes from rest to 30 m/s in 12 s with constant acceleration. How long does it take the car to go from rest to 15 m/s with the same acceleration?

---

chapter1

(A) 3.0s

(B) $12/\sqrt{2}\ s$

(C) 6.0s

(D) $12\sqrt{2}\ s$

(E) 24s

9. Balls 1 and 2 are each thrown horizontally from the same height above level ground, but ball 2 has a greater initial velocity after leaving the thrower's hand. If air resistance is negligible, how do the accelerations of the balls and the times it takes them to hit the ground compare?

(A)

Acceleration *a*	**Time to Hit Ground**
Greater for ball 2	Greater for ball 2

(B)

Acceleration *a*	**Time to Hit Ground**
Greater for ball 2	Equal

(C)

Acceleration *a*	**Time to Hit Ground**
Equal	Greater for ball 2

(D)

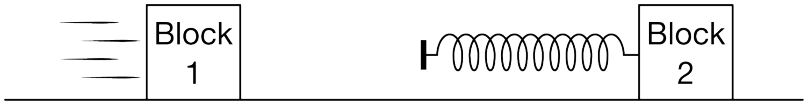
Acceleration a	Time to Hit Ground
Equal	Less for ball 2

(E)

Acceleration a	Time to Hit Ground
Equal	Equal

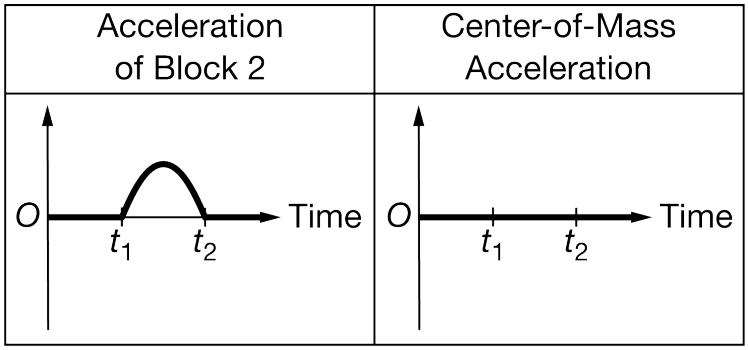
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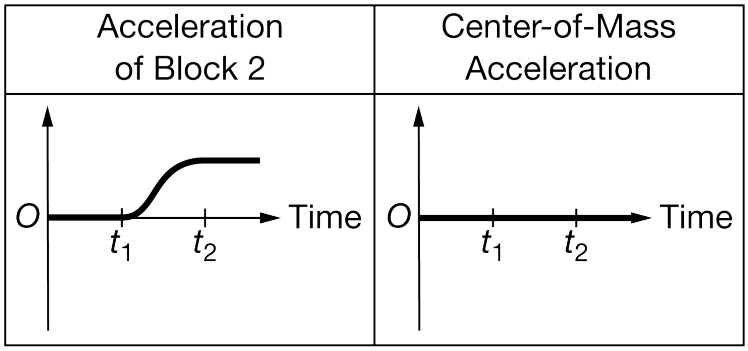


Block 1 slides rightward on the floor toward an ideal spring attached to block 2, as shown. At time t_1, block 1 reaches the spring and starts compressing it as block 2 also starts to slide to the right. At a later time, t_2, block 1 loses contact with the spring. Both blocks slide with negligible friction. Taking rightward as positive, which pair of graphs could represent the acceleration of block 2 and the center-of-mass acceleration of the two-block system?

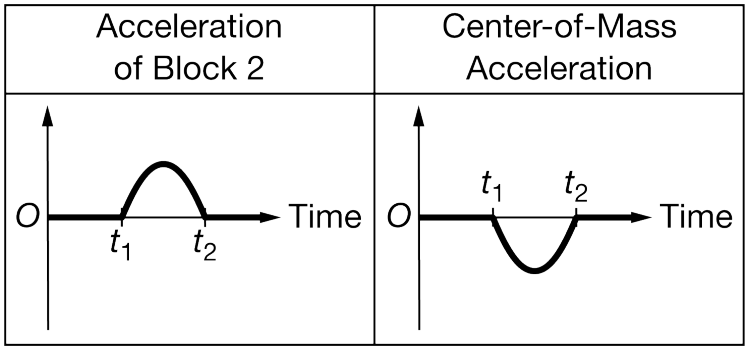
(A)



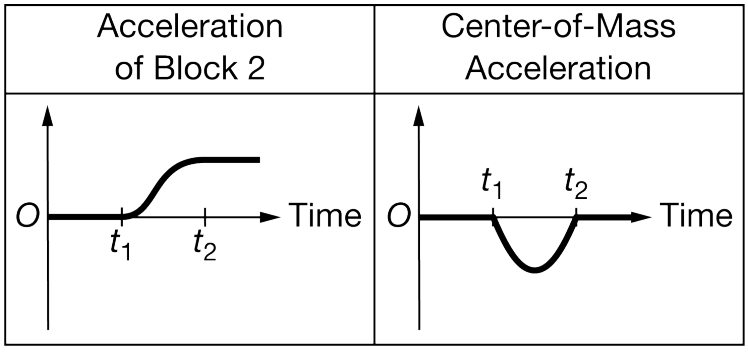
(B)



(C)



(D)



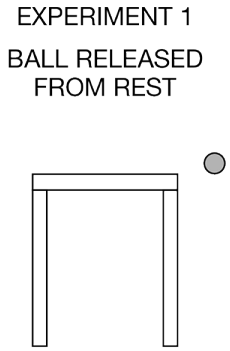


Figure 1

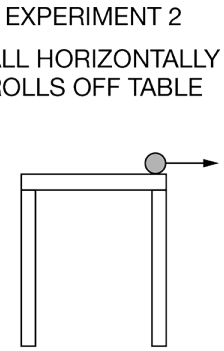
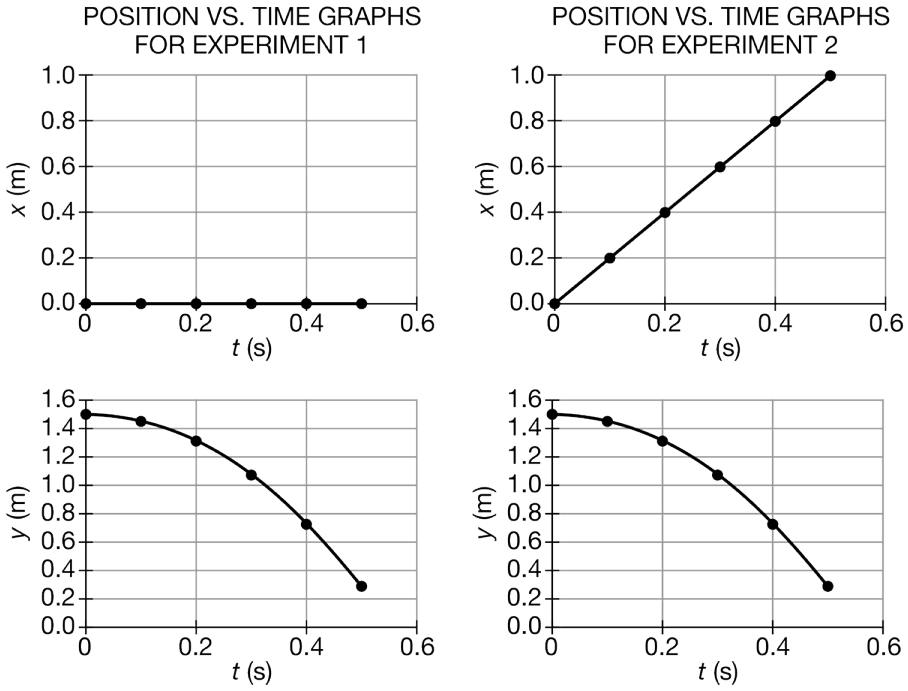


Figure 2



A student wants to investigate the motion of a ball by conducting two different experiments, as shown in Figure 1 and Figure 2 above. In Experiment 1, the student releases a ball from rest and uses a slow-motion camera to film the ball as it falls to the ground. Using video analysis, the student is able to plot the ball's horizontal position x and vertical position y as a function of time t. In Experiment 2, the student horizontally rolls the same ball off a table, and uses video analysis to plot the ball's horizontal position x and vertical position y as a function of time t starting from the instant the ball leaves the table. The graphs from each experiment are shown above along with each graph's best-fit curve line.

11. Suppose that Experiment 1 and Experiment 2 are conducted at the same time; one student drops the ball from rest at the same instant that a second student horizontally rolls an identical off the table. After both balls have traveled half their vertical distance to the floor, what is the acceleration of the center of mass of the two-ball system relative to Earth?

chapter1

(A) Greater than g

(B) Equal to g

(C) Less than g, but not zero

(D) Zero

12. Which of the following conclusions can the student draw from the graphs, and why?

(A) The horizontally rolled ball travels a greater horizontal distance and takes a longer amount of time to reach the ground.

(B) The released ball travels with a slower speed and takes a longer amount of time to reach the ground.

(C) Since both balls have zero horizontal acceleration, they reach the ground at the same time.

(D) Since the balls have the same vertical position at any given time, they reach the ground at the same time.

13. In Experiment 1, what is the speed of the ball the instant it makes contact with the ground?

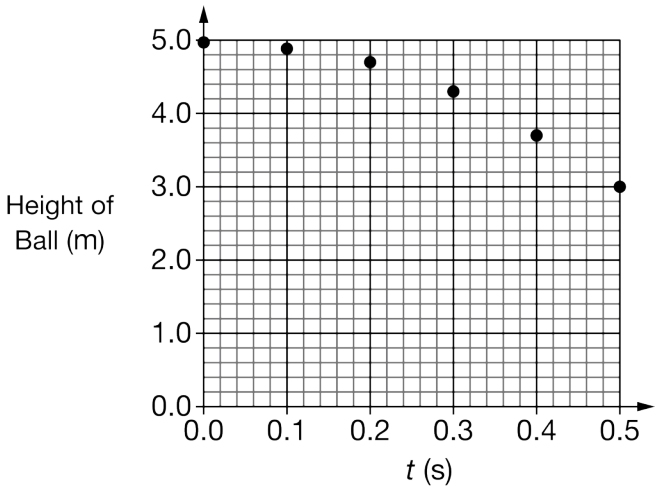
(A) $0 \ \frac{\text{m}}{\text{s}}$

(B) $0.55 \ \frac{\text{m}}{\text{s}}$

(C) $1.5 \ \frac{\text{m}}{\text{s}}$

(D) $5.4 \ \frac{\text{m}}{\text{s}}$

14.



On another planet, a ball is in free fall after being released from rest at time $t = 0$. A graph of the height of the ball above the planet's surface as a function of time t is shown. The acceleration due to gravity on the planet is most nearly

(A) $8 \ \text{m/s}^2$

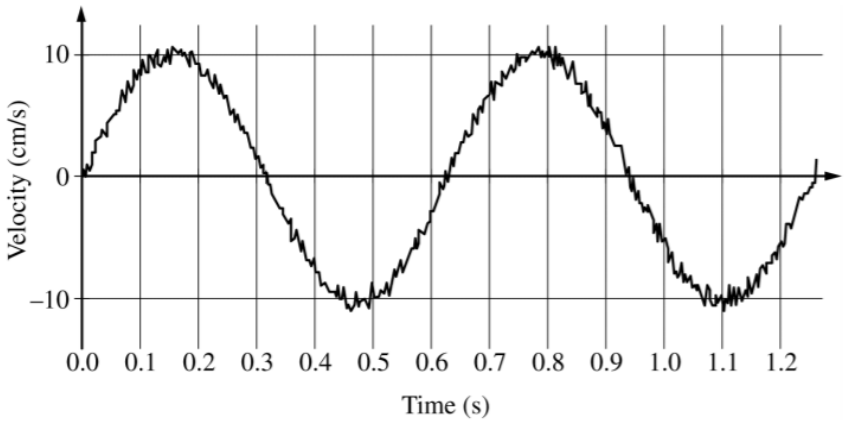
(B) $16 \ \text{m/s}^2$

(C) $20 \ \text{m/s}^2$

(D) $40 \ \text{m/s}^2$

---

chapter1



A student sets an object attached to a spring into oscillatory motion and uses a motion detector to record the velocity of the object as a function of time. A portion of the recorded data is shown in the figure above.

15. The acceleration of the object at time t = 0.7 s is most nearly equal to which of the following?

(A) The value of the graph where it crosses the 0.7 s grid line
(B) The slope of the line connecting the origin and the point where the graph crosses the 0.7 s grid line
(C) The area under the curve between where the graph crosses the time axis near 0.63 s and time 0.7 s
(D) The slope of the tangent to a best-fit sinusoidal curve at 0.7 s

16. The total change in the object's speed between 1.0 s and 1.1 s is most nearly

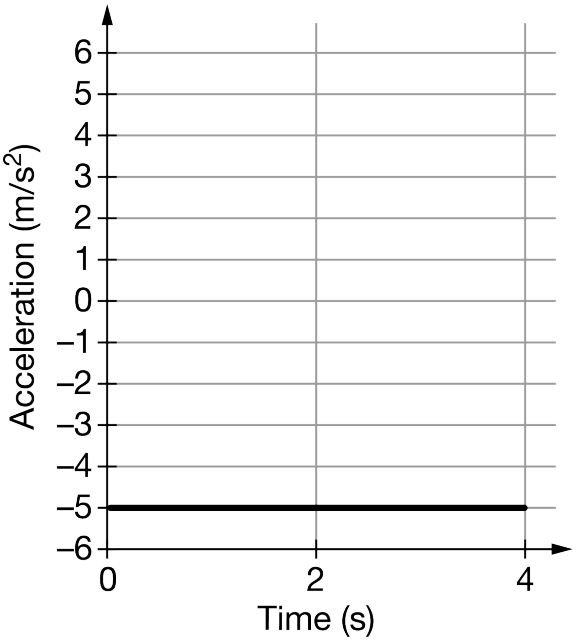
(A) zero
(B) 5 cm /s
(C) 10 cm / s
(D) 15 cm / s

17. An object attached to one end of a string moves in a circle at constant speed. Which of the following is correct?

(A) The object is accelerating as it moves.
(B) The object's velocity is the same as its speed.
(C) The object does not require a force to keep its state of circular motion.
(D) If the string breaks, the object will keep its circular motion.
(E) If the string breaks, the object will move radially away from the center of the circle.

chapter1

18.



An object is released from rest near a planet's surface. A graph of the acceleration as a function of time for the object is shown for the $4\,\text{s}$ after the object is released. The positive direction is considered to be upward. What is the displacement of the object after $2\,\text{s}$?

(A) $-20\,\text{m}$

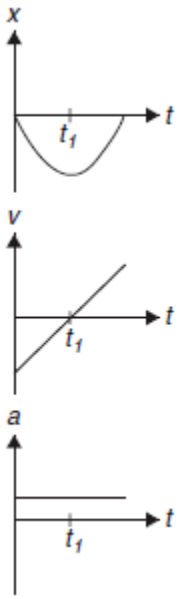
(B) $-10\,\text{m}$

(C) $10\,\text{m}$

(D) $20\ \text{m}$

chapter1

19.



The graphs above represent the position x, velocity v, and acceleration a as a function of time t for a marble moving in one dimension. Which of the following could describe the motion of the marble?

(A) Rolling along the floor and then bouncing off a wall

(B) Rolling down one side of a bowl and then rolling up the other side

(C) Rolling up a ramp and then rolling back down

(D) Falling and then bouncing elastically off a hard floor

20. A kitten sits in a lightweight basket near the edge of a table. A person accidentally knocks the basket off the table. As the kitten and basket fall, the kitten rolls, turns, kicks, and catches the basket in its claws. The basket lands on the floor with the kitten safely inside. If air resistance is negligible, what is the acceleration of the kitten-basket system while the kitten and basket are in midair?

(A) The acceleration is directed downward with magnitude less than g because the basket is light.

(B) The acceleration is directed downward with magnitude equal to g because the system is a projectile.

(C) The acceleration fluctuates because of the rolling, turning, and kicking motion of the kitten.

(D) The acceleration cannot be determined without knowing how hard the basket is pushed.

21. An object is thrown with a horizontal velocity of 20 m/s from a cliff that is 125 m above level ground. If air resistance is negligible, the time that it takes the object to fall to the ground from the cliff is most nearly

(A) 3 s

(B) 5 s

(C) 6 s

(D) 12 s

(E) 25 s

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An object is thrown with an initial speed v near the surface of Earth. Assume that air resistance is negligible and the gravitational field is constant.

22. An object is thrown with an initial speed u near the surface of Earth. Assume that air resistance is negligible and the gravitational field is constant.

If the object is thrown horizontally, the direction and magnitude of its acceleration while it is in the air is

(A) upward and decreasing
(B) upward and constant
(C) downward and decreasing
(D) downward and increasing
(E) downward and constant

23. If the object is thrown vertically upward, the direction and magnitude of its acceleration while it is in the air is

(A) upward and decreasing
(B) upward and constant
(C) downward and decreasing
(D) downward and increasing
(E) downward and constant

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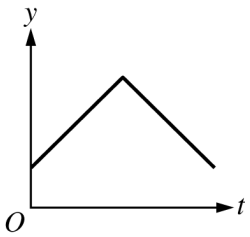
24. A person driving a car suddenly applies the brakes. The car takes 4 s to come to rest while traveling 20 m at constant acceleration. Can the speed of the car immediately before the brakes were applied be determined without first determining the car's acceleration?

(A) Yes, by dividing the distance (20 m) by the time (4 s).
(B) Yes, by determining the average speed while braking and doubling it.
(C) No, because the acceleration is needed to use standard equations such as $\Delta x = v_o t + 1/2\ at^2$.
(D) No, because the fundamental relationship that defines velocity contains acceleration.

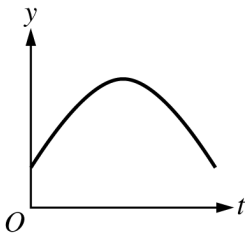
25. A person throws a marble straight up into the air, releasing it a short height above the ground and catching it at that same height. If air resistance is negligible, which of the following graphs of position y versus time t is correct for the motion of the marble as it goes up and then comes down?

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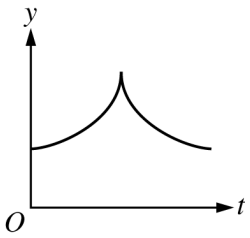
(A)



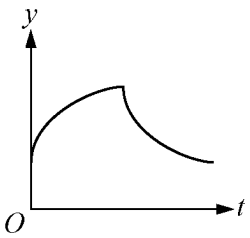
(B)



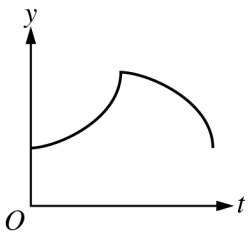
(C)



(D)



(E)



26. A solid metal ball and a hollow plastic ball of the same external radius are released from rest in a large vacuum chamber. When each has fallen 1 m, they both have the same

(A) inertia
(B) speed
(C) momentum
(D) kinetic energy
(E) change in potential energy

chapter1

27. A student throws a rock horizontally from the edge of a cliff that is 20 m high. The rock has an initial speed of 10 m/s. If air resistance is negligible, the distance from the base of the cliff to where the rock hits the level ground below the cliff is most nearly

(A) 5 m

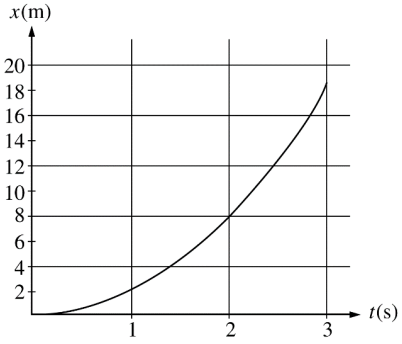
(B) 10 m

(C) 20 m

(D) 40 m

(E) 200 m

28.



The graph above represents position *x versus* time *t* for an object being acted on by a constant force. The average speed during the interval between 1 s and 2 s is most nearly

(A) 2 m/s

(B) 4 m/s

(C) 5 m/s

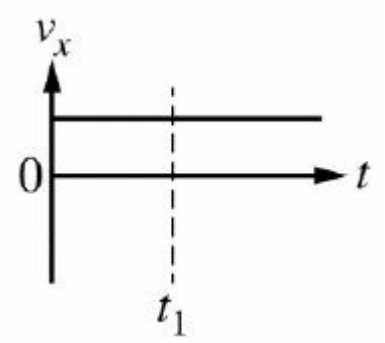
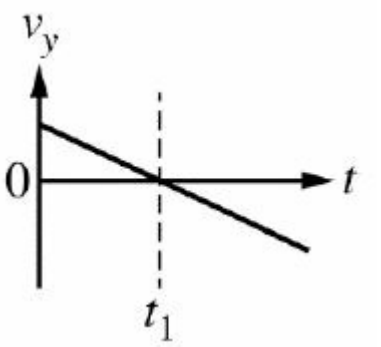
(D) 6 m/s

(E) 8 m/s

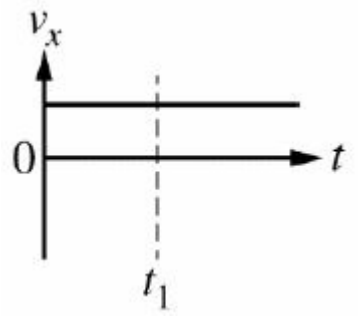
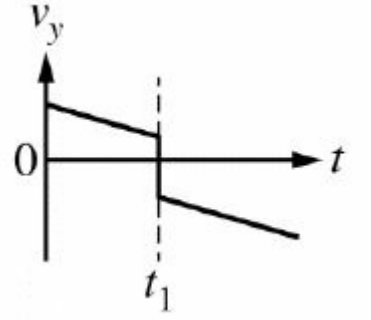
29. In a classroom at time $t = 0$, a sphere is thrown upward at a 45° angle to the horizontal. At time t_1, while the sphere is still rising, it bounces off the ceiling elastically and with no friction. Which of the following pairs of graphs could represent the sphere's horizontal velocity and vertical velocity as functions of time *t*?

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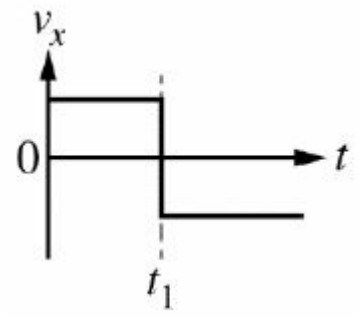
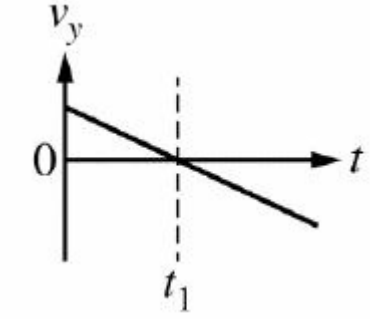
(A)

Horizontal Velocity	Vertical Velocity
	

(B)

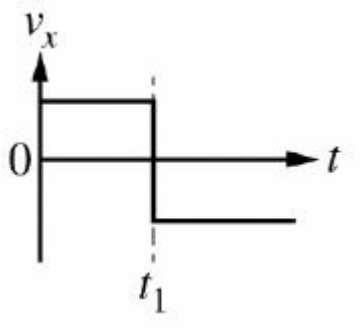
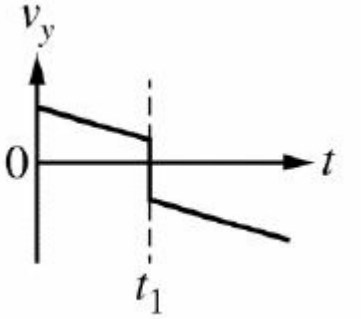
Horizontal Velocity	Vertical Velocity
	

(C)

Horizontal Velocity	Vertical Velocity
	

(D)

chapter1

Horizontal Velocity	Vertical Velocity
	

30. A ball is released from rest from the twentieth floor of a building. After 1 s, the ball has fallen one floor such that it is directly outside the nineteenth-floor window. The floors are evenly spaced. Assume air resistance is negligible. What is the number of floors the ball would fall in 3 s after it is released from the twentieth floor?

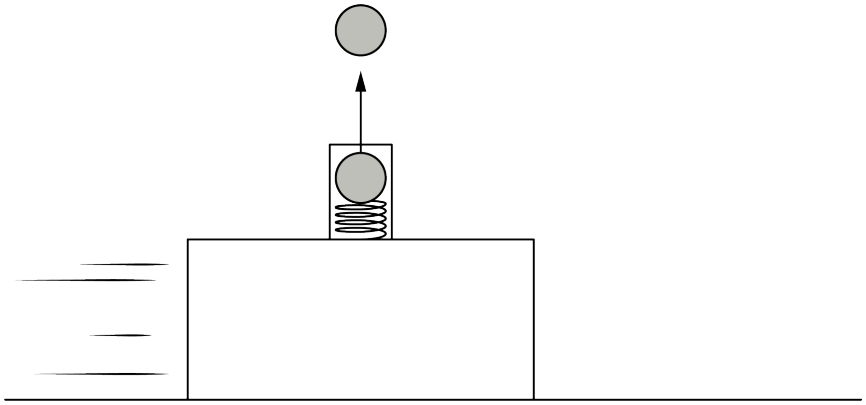
(A) 3 floors or less

(B) 4 to 6 floors

(C) 7 to 10 floors

(D) 11 floors or more

31.



A vertical spring launcher is attached to the top of a block and a ball is placed in the launcher, as shown in the figure. While the block slides at constant speed to the right across a horizontal surface with negligible friction between the block and the surface, the ball is launched upward. When the ball reaches its maximum height, what will be the position of the ball relative to the spring launcher?

(A) Above and to the right of the spring launcher

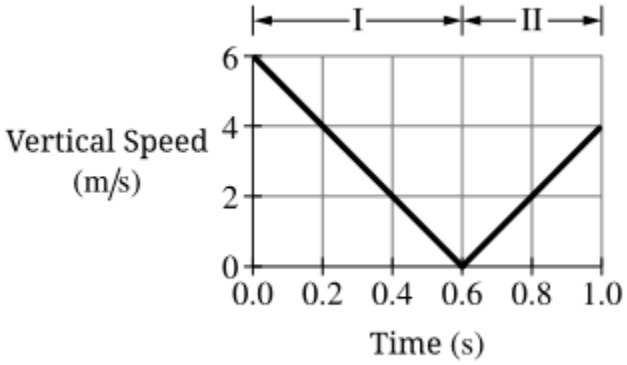
(B) Directly above the spring launcher

(C) Above and to the left of the spring launcher

(D) The relative position of the ball depends on the horizontal speed of the block.

chapter1

32.



A student standing on the ground throws a ball to another student who stands on a platform that is raised above the ground. The ball's vertical speed as a function of time is shown in the graph above. Time interval I is from 0.0 s to 0.6 s while the ball is moving upward. Time interval II is from 0.6 s to 1.0 s while the ball is moving downward. Which of the following methods will allow the students to best estimate the total vertical displacement of the ball during the total time interval shown?

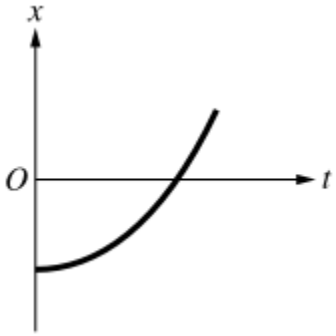
(A) Find the slope of the line of best fit for all of the data. Then multiply the result by the total time interval shown.

(B) Average the slopes of the lines of best fit for time intervals I and II. Then multiply the result by the total time interval shown.

(C) Calculate the sum of the areas under the curves for time intervals I and II.

(D) Calculate the difference between the areas under the curves for time intervals I and II.

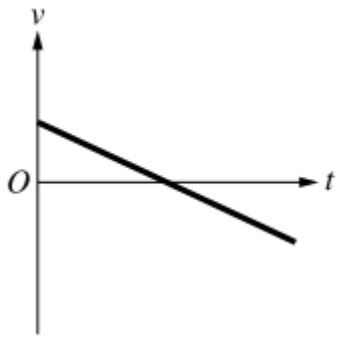
33.



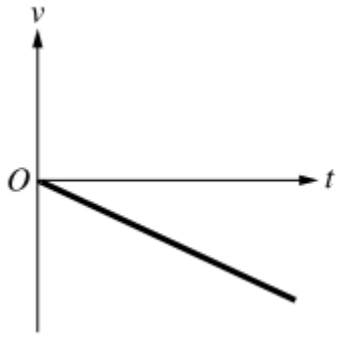
The graph shows the position x as a function of time t for a bicycle moving in a straight path. Which of the following graphs best represents the velocity v of the bicycle as a function of time t ?

chapter1

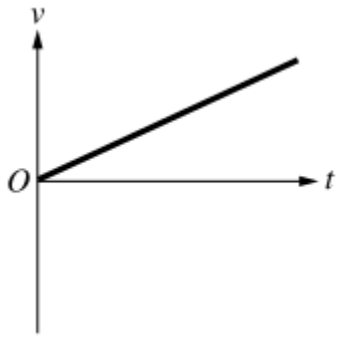
(A)



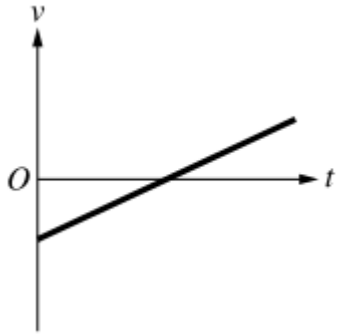
(B)



(C)

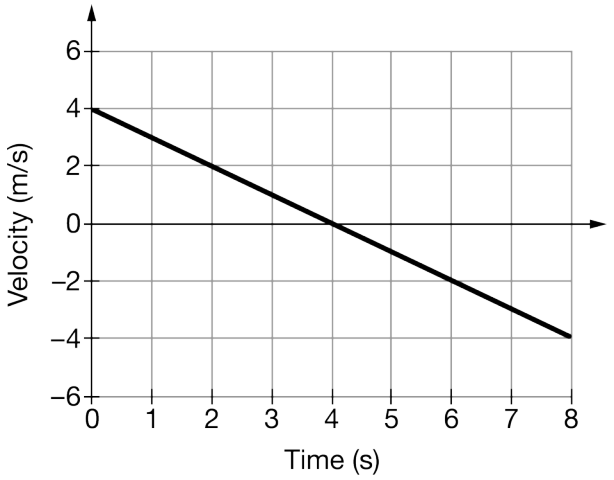


(D)



chapter1

34.



An object is sliding to the right along a straight line on a horizontal surface. The graph shows the object's velocity as a function of time. What is the object's displacement during the time depicted in the graph?

(A) $0\,\text{m}$

(B) $1\,\text{m}$

(C) $8\,\text{m}$

(D) $16\,\text{m}$



Figure 1

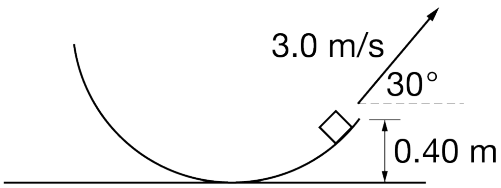


Figure 2

Note: Figures not drawn to scale.

The figures above show a small block of mass $0.20\ \text{kg}$ on a track in the shape of a circular arc. The block is released from rest at a height H above the floor, as shown in Figure 1. The block slides along the track with negligible friction and leaves it at a height of $0.40\ \text{m}$ above the floor and a speed of $3.0\ \text{m/s}$ at a 30° angle, as shown in Figure 2.

35. After the block leaves the track, what is the block's speed when it reaches the highest point of its motion?

(A) 0

(B) $1.5\ \text{m/s}$

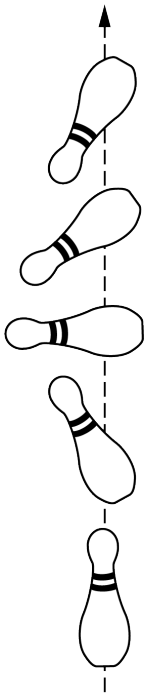
(C) $2.6\ \text{m/s}$

(D) $3.0\ \text{m/s}$

---

chapter1

36.



A bowling pin is thrown vertically upward such that it rotates as it moves through the air, as shown in the figure. Initially, the center of mass of the bowling pin is moving upward with a speed v_i of $10\ \frac{\text{m}}{\text{s}}$. The maximum height of the center of mass of the bowling pin is most nearly

(A) $\frac{v_i^2}{2g}$

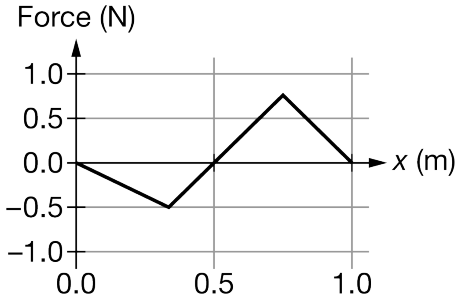
(B) $\frac{2g}{v_i^2}$

(C) The answer cannot be determined without knowing how long it takes the bowling pin to reach its maximum height.

(D) The answer cannot be determined because an irregularly shaped object is too complex to treat as a single point mass.

chapter1

37.



A cart is traveling in the positive direction with speed v_0 on a horizontal, frictionless track when it reaches position $x = 0$. The graph above shows the net horizontal force exerted on the cart as a function of position between $x = 0$ and $x = 1\ \text{m}$. The cart's speed at $x = 1\ \text{m}$ is v_f.

How does v_f compare to v_0 ?

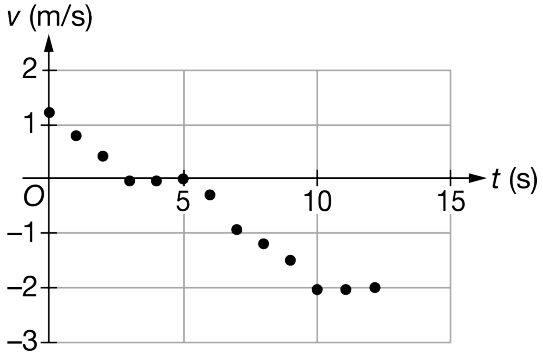
(A) $v_f > v_0$

(B) $v_f = v_0$

(C) $v_f < v_0$

(D) The relationship cannot be determined without knowing the numerical value of v_0.

38.



An engineer measures the velocity v of a remote-controlled cart on a straight track at regular time intervals. The data are shown in the graph above. During which of the following time intervals did the cart return to its position at time $t = 0\,\text{s}$?

(A) $3\,\text{s} \le t < 5\,\text{s}$

(B) $5\,\text{s} \le t < 7\,\text{s}$

(C) $7\,\text{s} \le t < 10\,\text{s}$

(D) $10\,\text{s} \le t < 12\,\text{s}$

39. Two objects, *X* and *Y*, accelerate from rest with the same constant acceleration. Object *X* accelerates for twice the time as object *Y*. Which of the following is true of these objects at the end of their respective periods of acceleration?

chapter1

(A) Object *X* is moving at the same speed as object *Y*.

(B) Object *X* is moving four times faster than object *Y*.

(C) Object *X* has traveled the same distance as object *Y*.

(D) Object *X* has traveled twice as far as object *Y*.

(E) Object *X* has traveled four times as far as object *Y*.

40. A student is provided with a battery-powered toy car that the manufacturer claims will always operate at a constant speed. The student must design an experiment in order to test the validity of the claim. Which of the following measuring tools can the student use to test the validity of the claim? Select two answers.

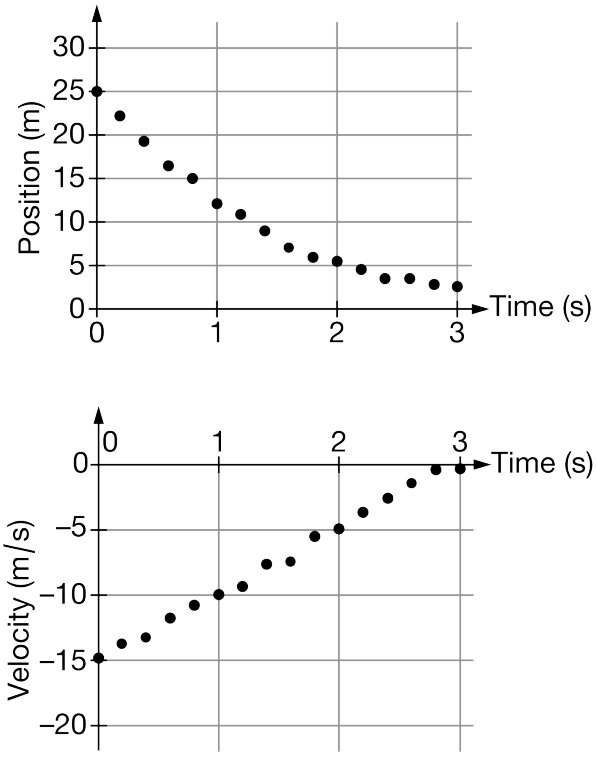
A Photogates placed at the beginning, end, and at various locations along the track that the car travels on

B A meterstick to measure the distance of the track that the car travels on

C A motion detector that is oriented perpendicular to the direction that the car travels

D A mass balance to determine the mass of the car

41.



The position and velocity of a car moving along a straight road are recorded as functions of time, as shown in the graphs above. Which of the following correctly describes the car's speed and acceleration?

chapter1

(A)

Speed	Acceleration
Increasing	Positive

(B)

Speed	Acceleration
Increasing	Negative

(C)

Speed	Acceleration
Decreasing	Positive

(D)

Speed	Acceleration
Decreasing	Negative

42. Two students want to determine the speed at which a ball is released when thrown vertically upward into the air. One student throws the ball into the air while the other student measures the total time that the ball is in the air. The students use a meterstick to measure the release height of the ball. Which of the following equations should the students use to determine the speed at which the ball was released?

(A) Use $y = y_0 + v_{y0}t + \frac{1}{2}a_y t^2$ from the moment in time in which the ball was released to the moment in time in which the ball reaches its highest point.

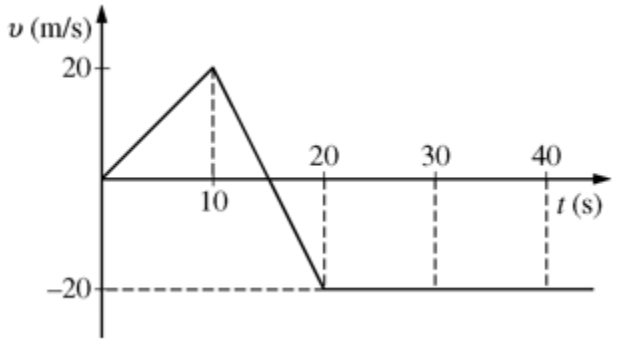
(B) Use $y = y_0 + v_{y0}t + \frac{1}{2}a_y t^2$ from the moment in time in which the ball was released to the moment in time in which the ball hits the ground.

(C) $v_y^2 = v_{y0}^2 + 2a_y(y - y_0)$ from the moment in time in which the ball was released to the moment in time in which the ball reaches its highest point.

(D) $v_y^2 = v_{y0}^2 + 2a_y(y - y_0)$ from the moment in time in which the ball was released to the moment in time in which the ball hits the ground.

chapter1

43.



An object begins at position $x = 0$ and moves one-dimensionally along the x-axis with a velocity v expressed as a function of time t according to the graph above. At what time does the object pass through $x = 0$ again?

(A) Between 10 s and 20 s

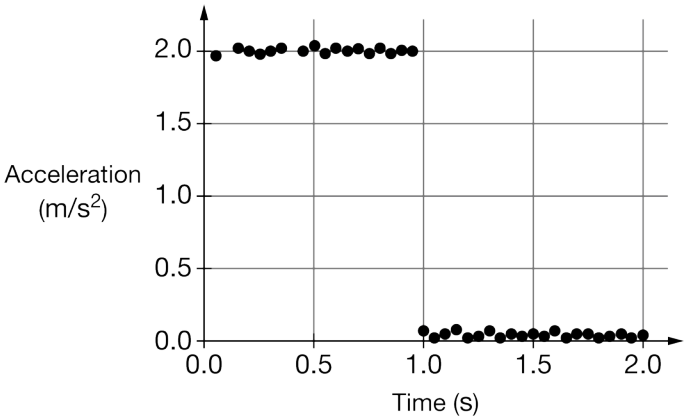
(B) Between 20 s and 30 s

(C) At 30 s exactly

(D) Between 30 s and 40 s

(E) After 40 s

44.



The graph shows the acceleration as a function of time for an object that is at rest at time $t = 0$ s. The distance traveled by the object between 0 and 2 s is most nearly

(A) 1 m

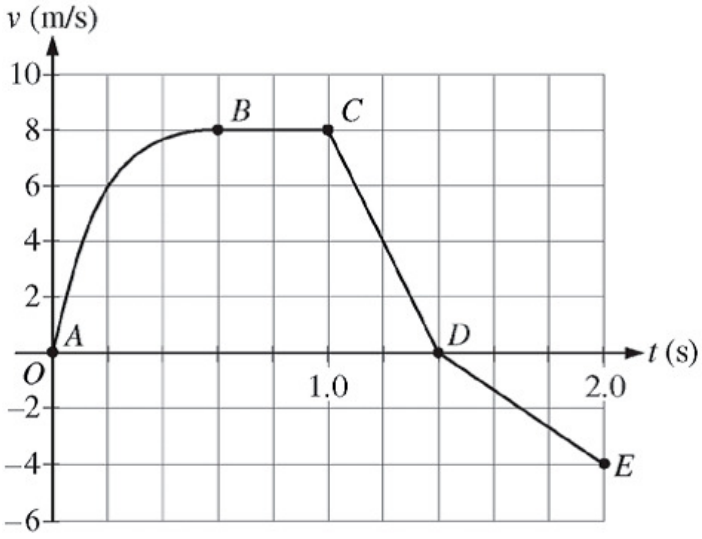
(B) 2 m

(C) 3 m

(D) 4 m

chapter1

Refer to the following material for answering the questions.



A cart is constrained to move along a straight line. A varying net force along the direction of motion is exerted on the cart. The cart's velocity v as a function of time t is shown in the graph above. The five labeled points divide the graph into four sections.

45. For which segment does the cart move the greatest distance?

(A) AB
(B) BC
(C) CD
(D) DE

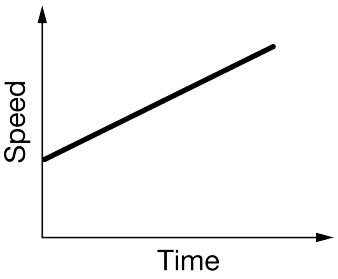
46. Which of the following correctly ranks the magnitude of the average acceleration of the cart during the four sections of the graph?

(A) $a_{CD} > a_{AB} > a_{BC} > a_{DE}$
(B) $a_{BC} > a_{AB} > a_{CD} > a_{DE}$
(C) $a_{AB} > a_{BC} > a_{DE} > a_{CD}$
(D) $a_{CD} > a_{AB} > a_{DE} > a_{BC}$

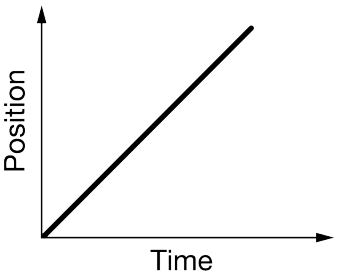
47. An object undergoes an acceleration as it travels along a straight, horizontal section of a track. Which of the following graphs could represent the motion of the object? Select two answers.

chapter1

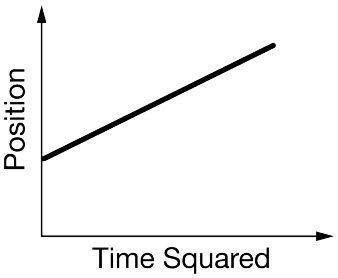
A



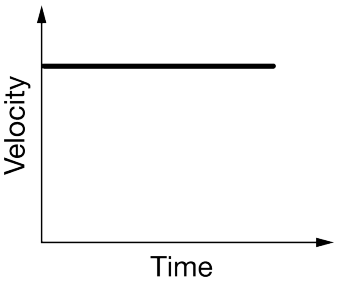
B



C

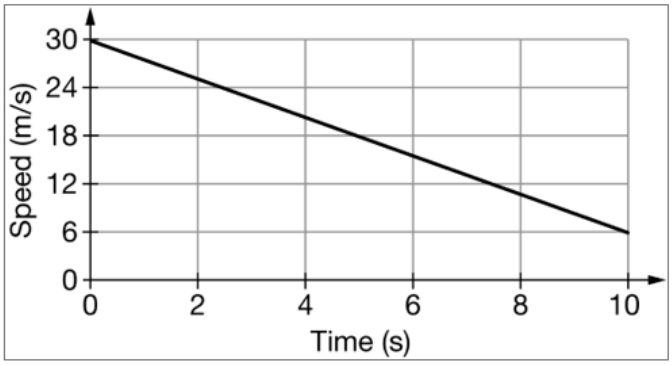


D



chapter1

48.



The graph above shows the speed of a truck as it moves along a straight, level road. How far does the truck travel in the 10 s time interval shown?

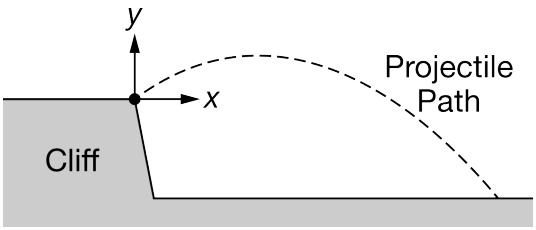
(A) 120 m

(B) 180 m

(C) 240 m

(D) 300 m

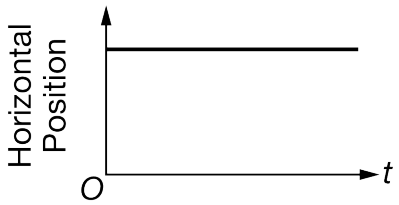
49.



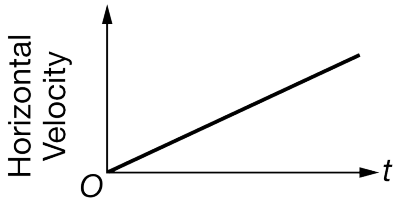
A projectile launched from a cliff at time $t = 0$ follows the path indicated by the dashed line in the above figure. The axes indicate the positive horizontal and vertical directions. Which of the following graphs could represent the projectile's motion?

chapter1

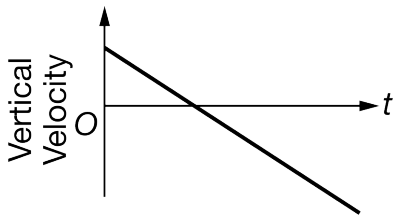
(A)



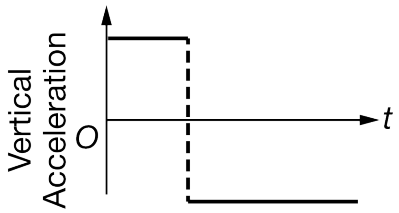
(B)



(C)



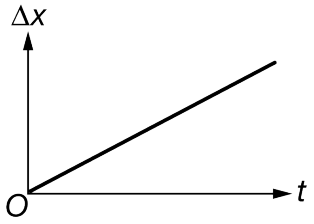
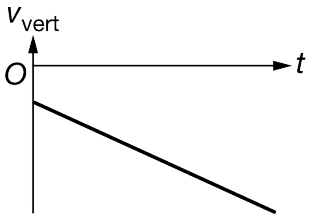
(D)



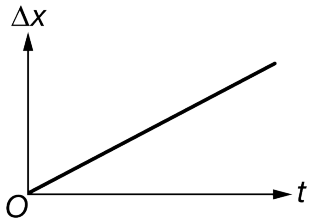
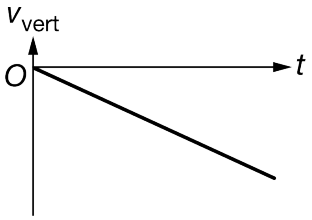
50. At time $t = 0$, a projectile is launched from the top of a cliff at an angle of 30 degrees below the horizontal. Which of the following pairs of graphs best represents the horizontal displacement Δx and the vertical velocity component v_{vert} of the projectile as a function of time t?

chapter1

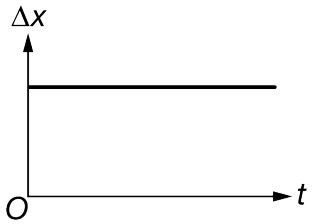
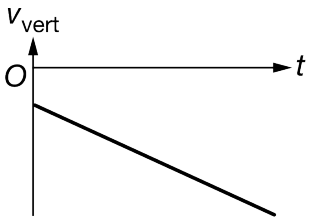
(A)

Horizontal Displacement	Vertical Velocity Component
	

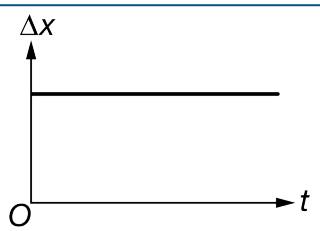
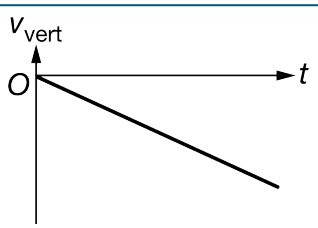
(B)

Horizontal Displacement	Vertical Velocity Component
	

(C)

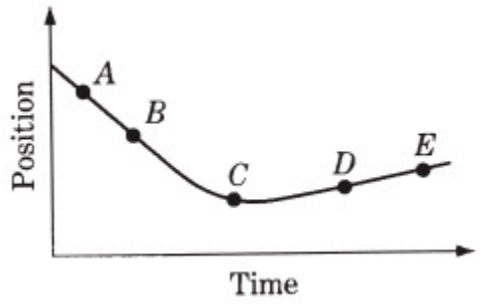
Horizontal Displacement	Vertical Velocity Component
	

(D)

Horizontal Displacement	Vertical Velocity Component
	

chapter1

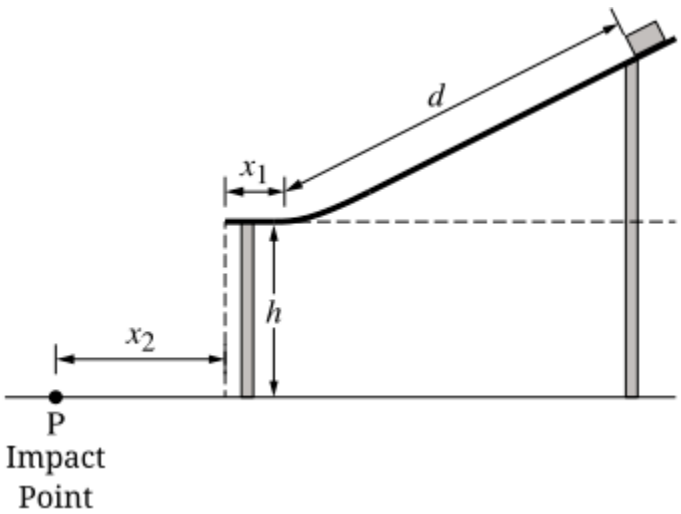
51.



The motion of a particle along a straight line is represented by the position *versus* time graph above. At which of the labeled points on the graph is the magnitude of the acceleration of the particle greatest?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

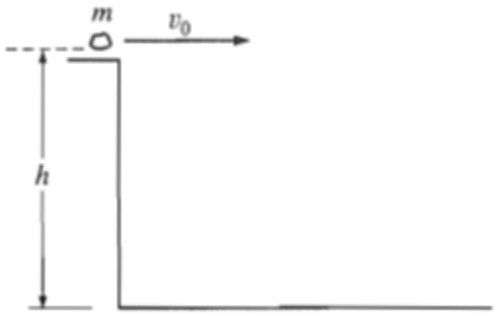
52.



A student is conducting an experiment using the apparatus shown. A block is released from the top of an incline of an unknown angle and slides with negligible friction a distance d down the incline, across a horizontal section of track a distance x_1, and then off the table. The block falls a vertical distance h and lands on the ground at the impact point P at a horizontal distance x_2 from the edge of the table. Which two measurements could be used together, without any additional data, to determine the speed of the block as it leaves the table?

(A) d and x_1
(B) d and x_2
(C) h and x_1
(D) h and x_2

chapter1

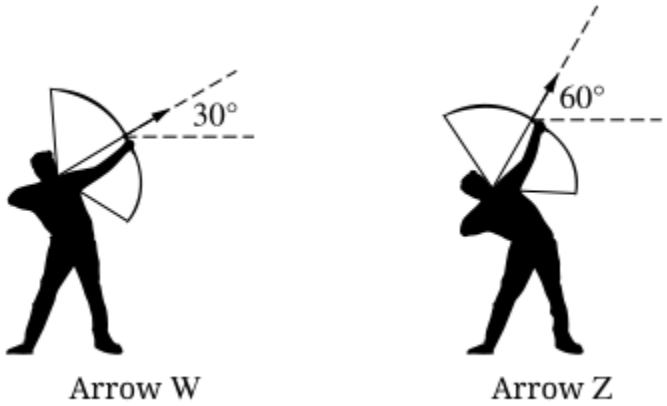


A rock of mass *m* is thrown horizontally off a building from a height *h,* as shown above. The speed of the rock as it leaves the thrower's hand at the edge of the building is v_0

53. How much time does it take the rock to travel from the edge of the building to the ground?

(A) $\sqrt{hv_0}$
(B) h/v_0
(C) hv_0/g
(D) $2h/g$
(E) $\sqrt{2h/g}$

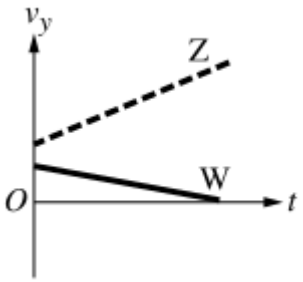
54.



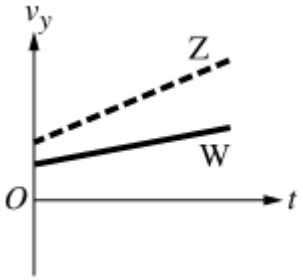
Arrows W and Z are launched at the same time with the same initial speed at angles of 30° and 60° from the horizontal, as shown. Which of the following graphs represents each arrow's vertical component of velocity v_y as a function of time t ? Consider upward to be the positive y-direction.

chapter1

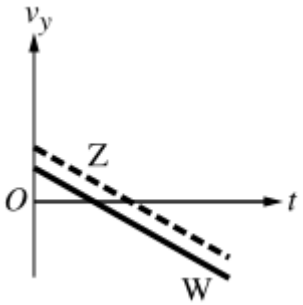
(A)



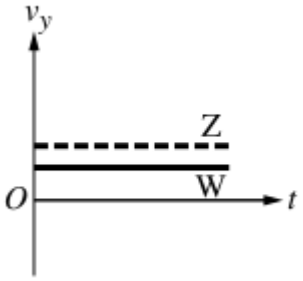
(B)



(C)

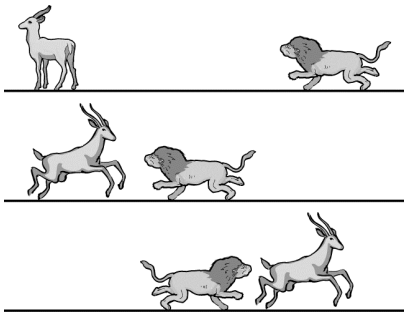


(D)



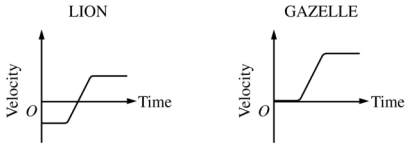
chapter1

55.

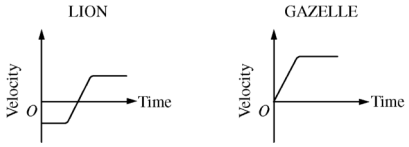


A lion is running at constant speed toward a gazelle that is standing still, as shown in the top figure above. After several seconds, the gazelle notices the lion and accelerates directly toward him, hoping to pass the lion and force him to reverse direction. As the gazelle accelerates toward and past the lion, the lion changes direction and accelerates in pursuit of the gazelle. The lion and the gazelle eventually each reach constant but different speeds. Which of the following sets of graphs shows a reasonable representation of the velocities of the lion and the gazelle as functions of time?

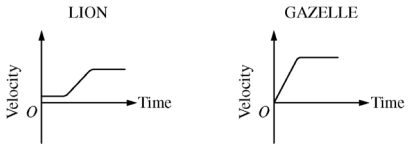
(A)



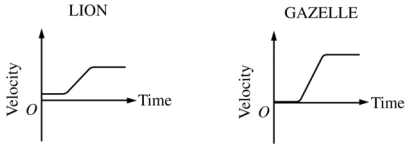
(B)



(C)

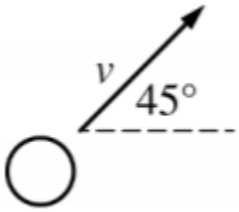


(D)

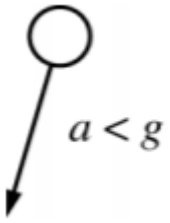


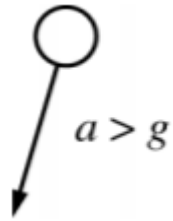
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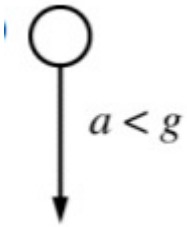
56.

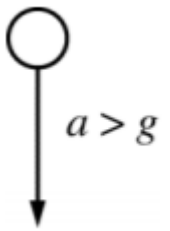


A hollow plastic ball is projected into the air. There is significant air resistance opposing the ball's motion, so the magnitude of the ball's acceleration is not equal to g. At time t, the ball is moving up and to the right at an angle of 45° to the horizontal, as shown above. Which of the following best shows the magnitude a and the direction of the ball's acceleration at time t ?

(A) 

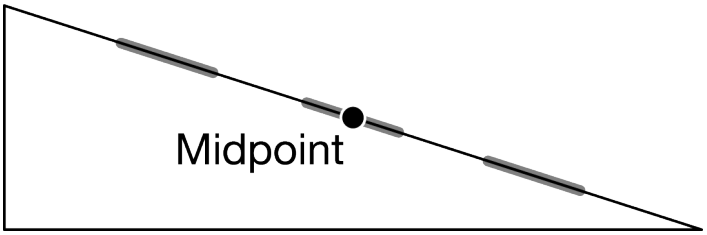
(B) 

(C) 

(D) 

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57.



A block is released from rest and slides down a ramp. The surface of the ramp has three rough sections where the friction between the surface and the block is not negligible, as shown by the shaded regions above. Measuring which of the following will allow for the best estimate of the block's instantaneous acceleration when the block is at the midpoint of the ramp?

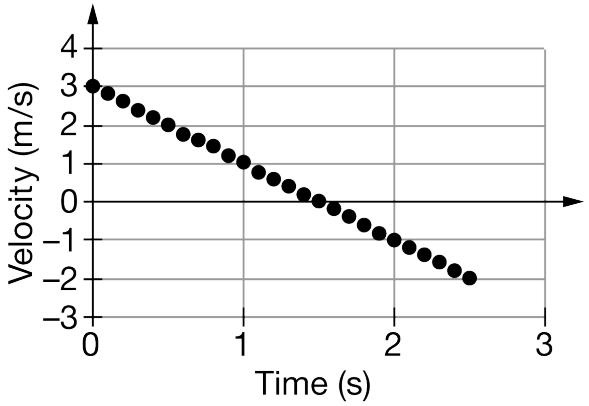
(A) The total distance traveled by the block and the total elapsed time

(B) The final speed of the block and the total elapsed time

(C) The distance between points just before and just after the midpoint and the time it takes the block to travel between them

(D) The speed of the block at points just before and just after the midpoint and the time it takes the block to travel between them

58.



At time $t = 0$, a moving cart on a horizontal track is at position $0.5\ \text{m}$. Using a motion detector, students generate a graph of the cart's velocity as a function of time, as shown above. At $t = 2.5\ \text{s}$, the cart's position is most nearly

(A) $0.5\ \text{m}$

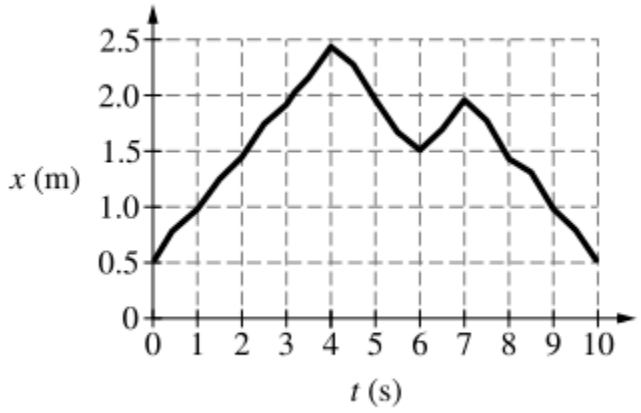
(B) $1.25\ \text{m}$

(C) $1.75\ \text{m}$

(D) $2\ \text{m}$

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59.



A student walks in a straight line in front of a motion detector. The graph shows the data of the student's position x as a function of time t. Which of the following statements regarding the student's motion from time $t = 0$ s to $t = 10$ s is correct?

(A) The distance traveled by the student is 0 m.

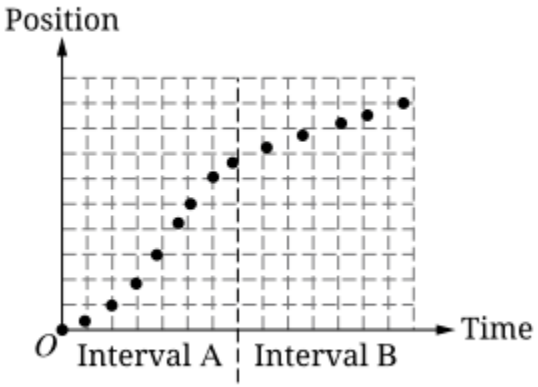
(B) The student's velocity is always positive.

(C) The student has an instantaneous velocity of 0 m/s at three distinct times.

(D) The student's average speed is 0 m/s.

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60.



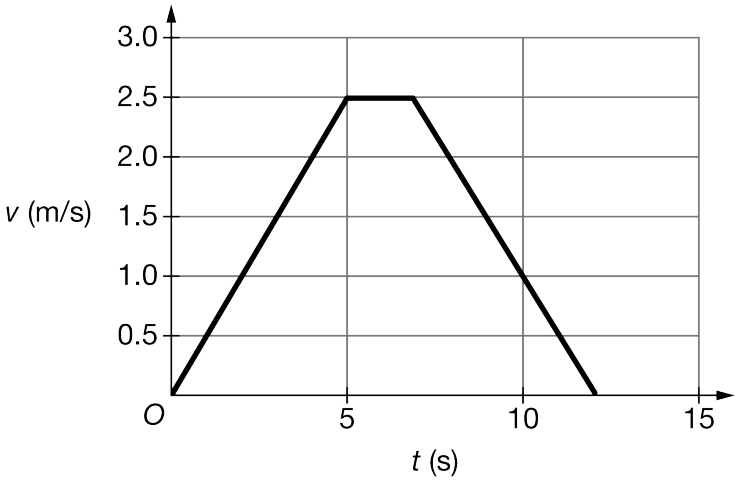
The graph shows the position of an object as a function of time. Which of the following correctly describes the speed of the object for the given time intervals?

	Time Interval A	**Time Interval B**
A	Constant speed	Constant speed
B	Constant speed	Changing speed
C	Changing speed	Constant speed
D	Changing speed	Changing speed

(A) A
(B) B
(C) C
(D) D

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61.



The motion of an object is shown in the velocity-time graph. Which best describes the motion of the object?

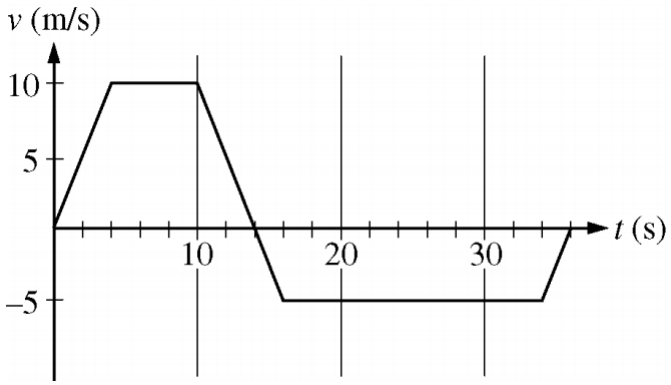
(A) The object is either speeding up or slowing down the entire time.

(B) The object starts and finishes at the same position.

(C) The object travels in the same direction for the entire time.

(D) The object undergoes positive acceleration the entire time.

62.



An object's velocity *v* as a function of time t is given in the graph above. Which of the following statements is true about the motion of the object?

(A) The object is not moving from $t = 4$ s to $t = 10$ s.

(B) The object's initial and final positions are the same.

(C) The object is slowing down from $t = 14$ s to $t = 16$ s.

(D) The average acceleration of the object from $t = 0$ s to $t = 4$ s is different from the acceleration from $t = 34$ s to $t = 36$ s.

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63.

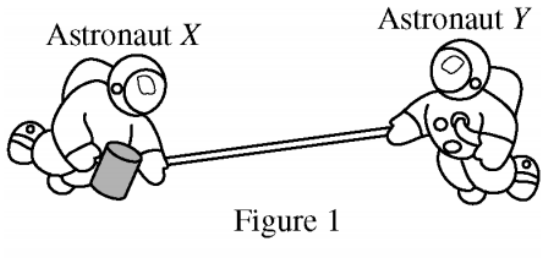


Figure 1

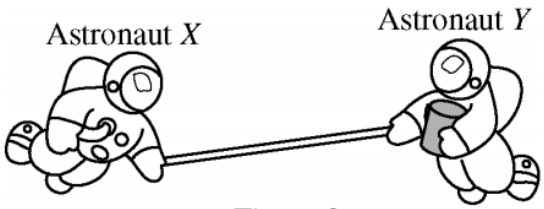


Figure 2

Two astronauts are connected by a taut cable and are initially at rest with respect to a nearby space station. Astronaut *X* throws a large container to Astronaut *Y*. Figure 1 above shows the astronauts immediately after the container is thrown by Astronaut *X*, and Figure 2 shows the astronauts immediately after the container is caught by Astronaut *Y*. Which of the following describes the motion of Astronaut *Y* in Figures 1 and 2 ?

(A)

Figure 1	Figure 2
Does not move	Moves to the right

(B)

Figure 1	Figure 2
Moves to the left	Moves to the right

(C)

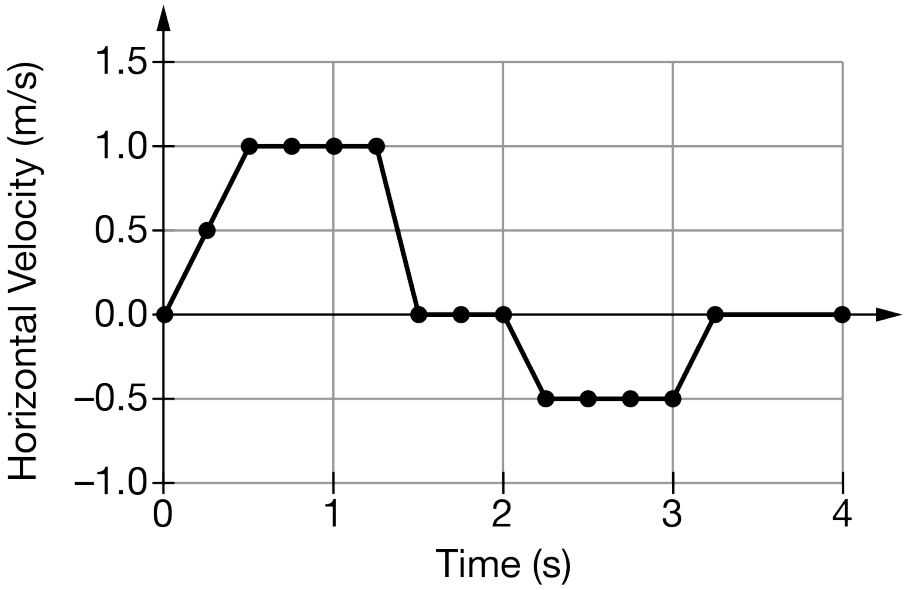
Figure 1	Figure 2
Does not move	Does not move

(D)

Figure 1	Figure 2
Moves to the left	Does not move

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64.



A motion sensor is used to create the graph of a student's horizontal velocity as a function of time as the student moves toward and away from the sensor, as shown above. The positive direction is defined as the direction away from the sensor. Which of the following describes the student's final position x_f in relation to the starting position x_0 and the student's average horizontal acceleration a_x between $0.0\ \text{s}$ and $3.0\ \text{s}$?

(A) Position x_f is farther away from the sensor than x_0, and a_x is positive.

(B) Position x_f is farther away from the sensor than x_0, and a_x is negative.

(C) Position x_f is closer to the sensor than x_0, and a_x is positive.

(D) Position x_f is closer to the sensor than x_0, and a_x is negative.

65. At time $t = 0\ \text{s}$, an object is moving to the right with a velocity v that can be modeled by the equation $v = (4.2\ \text{m/s}) - \left(1.4\ \text{m/s}^2\right)t$. At what time, if any, does the object change its direction of motion?

(A) $0.33\ \text{s}$

(B) $3.0\ \text{s}$

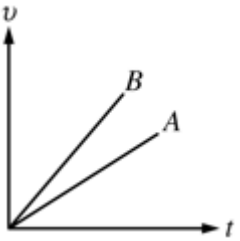
(C) $5.6\ \text{s}$

(D) At no time; the object never changes direction.

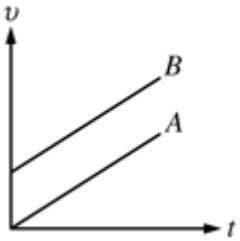
66. Object *A* is released from rest at height *h*. At the same instant, object *B* is thrown downward from the same location. Which of the following graphs of speed of *v* as a function of time *t* is correct for the two objects?

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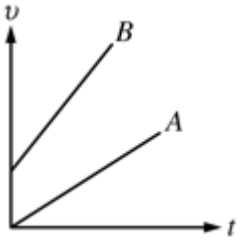
(A)



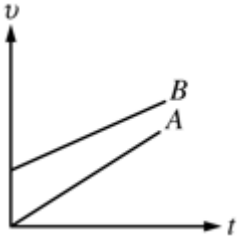
(B)



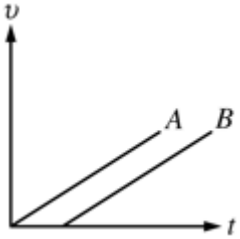
(C)



(D)



(E)



67. At time $t = 0$, a cart is at $x = 10\ \text{m}$ and has a velocity of $3\ \text{m/s}$ in the $-x$-direction. The cart has a constant acceleration in the $+x$-direction with magnitude $3\ \text{m/s}^2 < a < 6\ \text{m/s}^2$. Which of the following gives the possible range of the position of the cart at $t = 1\ \text{s}$?

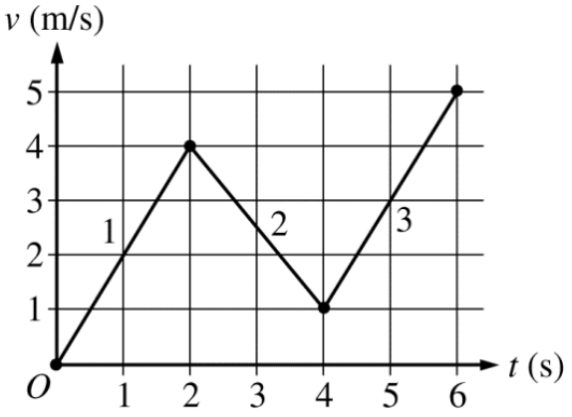
(A) $4\,\text{m} < x < 5.5\,\text{m}$

(B) $8.5\,\text{m} < x < 10\,\text{m}$

(C) $11.5\,\text{m} < x < 13\,\text{m}$

(D) $14.5\,\text{m} < x < 16\,\text{m}$

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The graph above shows velocity v as a function of time t for a 0.50 kg object traveling along a straight line. The graph has three segments labeled 1, 2, and 3. A rope exerts a constant force of magnitude F_T on the object along its direction of motion the whole time. During segment 2 only, a frictional force of magnitude F_f is also exerted on the object.

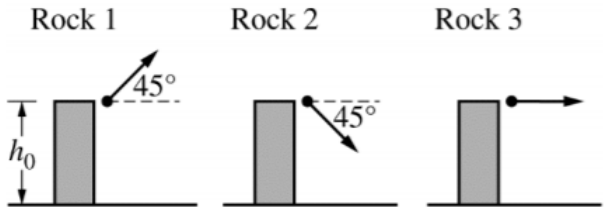
68. Which of the following correctly ranks the displacement Δx for the three segments of the object's motion?

(A) $\Delta x_3 > \Delta x_2 > \Delta x_1 > 0$

(B) $\Delta x_1 = \Delta x_2 = \Delta x_3 > 0$

(C) $(\Delta x_1 = \Delta x_3) > \Delta x_2 > 0$

(D) $(\Delta x_1 = \Delta x_3) > 0 > \Delta x_2$



Three identical rocks are launched with identical speeds from the top of a platform of height 0 h . The rocks are launched in the directions indicated above.

69. Which of the following correctly relates the magnitude v_y of the vertical component of the velocity of each rock immediately before it hits the ground?

(A) $(v_{y1} = v_{y2}) > v_{y3}$

(B) $v_{y1} > v_{y3} > v_{y2}$

(C) $v_{y2} > v_{y3} > v_{y1}$

(D) $v_{y1} = v_{y2} = v_{y3}$

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70. A car initially at rest accelerates at $10\,\frac{\text{m}}{\text{s}^2}$. The car's speed after it has traveled 25 meters is most nearly

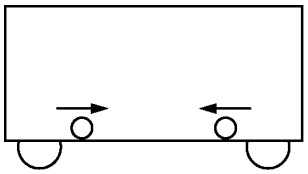
(A) $0.0\,\frac{\text{m}}{\text{s}}$

(B) $10.0\,\frac{\text{m}}{\text{s}}$

(C) $22.0\,\frac{\text{m}}{\text{s}}$

(D) $25.0\,\frac{\text{m}}{\text{s}}$

71.



A train is traveling east with constant speed v_t. Two identical spheres are rolling on the floor of one train car. In the frame of reference of the train, the spheres are moving directly toward each other at one instant with the same speed v_p parallel to the train's motion, as shown in the figure above. What is the velocity of the center of mass of the spheres in the frame of reference of the train and in the frame of reference of a person standing at rest alongside the train?

(A)

Train	**Person**
Zero	Zero

(B)

Train	Person
Zero	v_t east

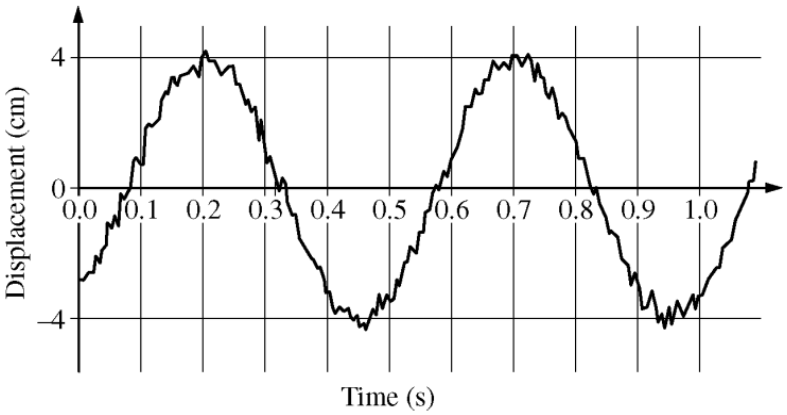
(C)

Train	**Person**
v_t east	$v_p + v_t$ east

(D)

Train	Person
$v_p + v_t$ east	Zero

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A student sets an object attached to a spring into oscillatory motion and uses a position sensor to record the displacement of the object from equilibrium as a function of time. A portion of the recorded data is shown in the figure above.

72. The total distance traveled by the object between 0.35 s and 0.40 s is most nearly

(A) 0 cm

(B) 2 cm

(C) 4 cm

(D) 6 cm

73. A student rolls a ball along the floor so that the ball has a speed of $16\ \mathrm{m/s}$. What is the speed of the ball relative to a second student who is running at $6\ \mathrm{m/s}$ in the same direction that the ball is rolling?

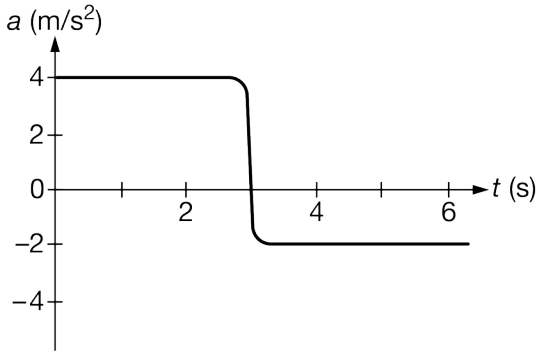
(A) $6\ \mathrm{m/s}$

(B) $10\ \mathrm{m/s}$

(C) $16\ \mathrm{m/s}$

(D) $22\ \mathrm{m/s}$

74.

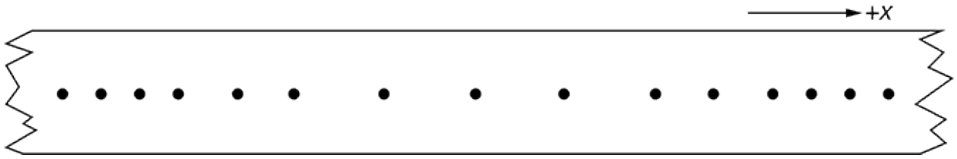


The graph above shows the acceleration a of a car as a function of time t. Assuming the car starts from rest, the total displacement of the car from time $t = 0$ s to time $t = 6$ s is most nearly

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(A) 6 m
(B) 9 m
(C) 18 m
(D) 45 m

75.

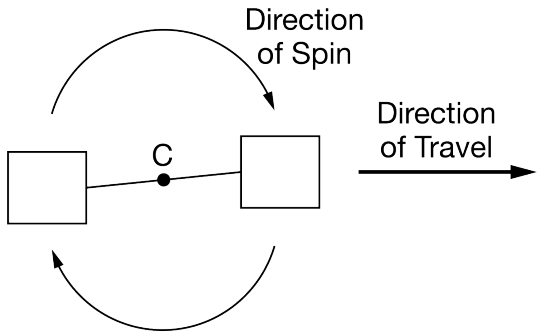


A student performs an experiment in which the horizontal position of a toy car is recorded on ticker tape from a device that places dots on the tape in equal time intervals. The series of dots in the figure represents the motion of an object moving from the negative direction to the positive direction along the horizontal direction. The time interval between each recorded dot is 1 s. Which of the following experiments could the student have conducted to create the data shown on the ticker tape?

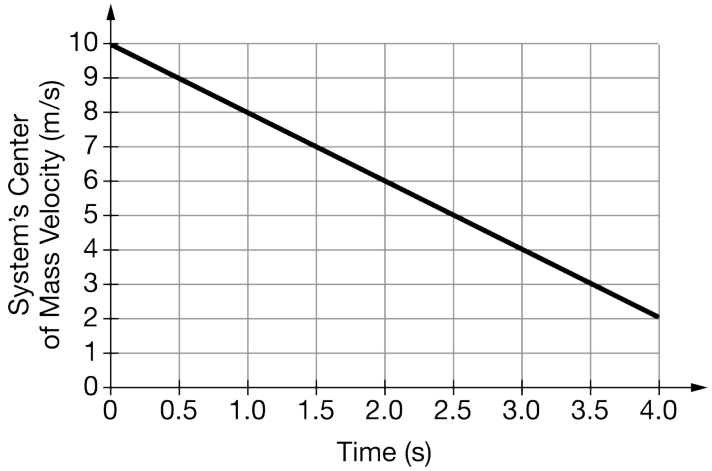
(A) A toy car that initially increases its speed, travels at a constant speed, and then increases its speed again.
(B) A toy car that initially increases its speed, travels at a constant speed, and then decreases its speed.
(C) A toy car that initially decreases its speed, stops, and then increases its speed.
(D) A toy car that initially decreases its speed, travels at a constant speed, and then increases its speed.

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76.



Top View



Two blocks are tied together with a string. They are thrown onto a layer of ice such that they spin around their center of mass C as they slide horizontally across the icy surface, as shown in the figure. A graph of the two-block system's velocity as a function of time is shown. Based on the graph, which of the following claims are correct about the system? Select two answers.

A The total displacement of an individual block is zero because it travels in a perfect circle around the center of mass of the system.

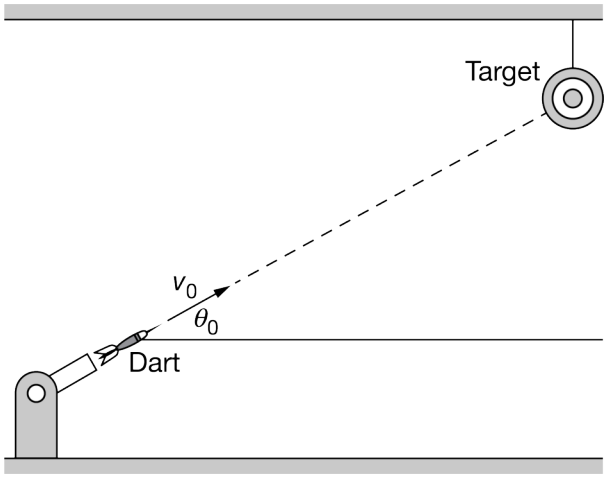
B The acceleration of the center of mass of the system is constant.

C The change in velocity per unit of time for the system's center of mass changes as time increases.

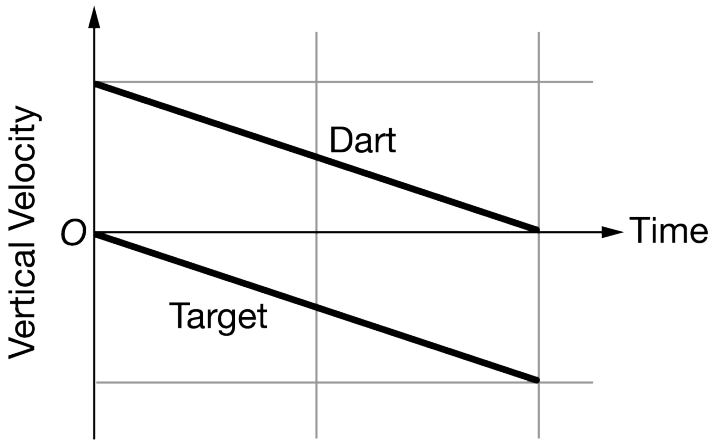
D The system's acceleration vector is opposite to the direction of the system's velocity vector.

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A student wants to launch a toy dart toward a target that hangs from a light string. At time $t = 0$, the dart is launched with an initial speed v_0 at an angle θ_0 above the horizontal ground. At the instant the dart is launched, the string is cut such that the target begins to fall straight down. The positive horizontal direction is considered to be to the right, and the positive vertical direction is considered to be up.



77.



A student makes the necessary measurements to create the graph shown, which represents the vertical component of the velocity as a function of time for the dart and for the target from $t = 0$ until the instant the dart hits the target. At $t = 0$, the target is a vertical distance h above the dart. The curves for the dart and the target each have the same area between them and the horizontal axis. Both curves also have the same slope. Which of the following is the best method to determine the distance h from the graph?

(A) Find the area under the curve for the dart's data.

(B) Find twice the area under the curve for the dart's data.

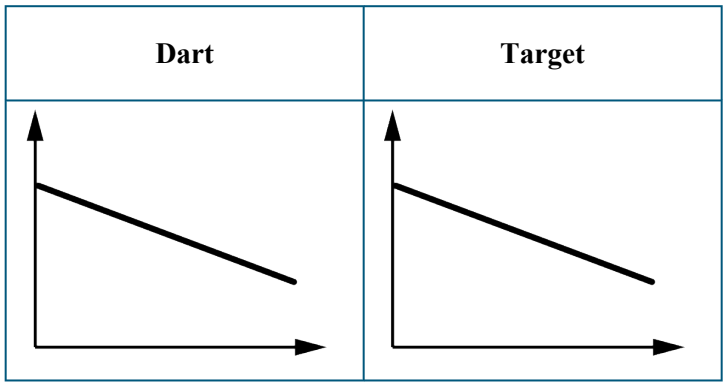
(C) Find the slope of the curve for the dart's data.

(D) Find twice the slope of the curve for the dart's data.

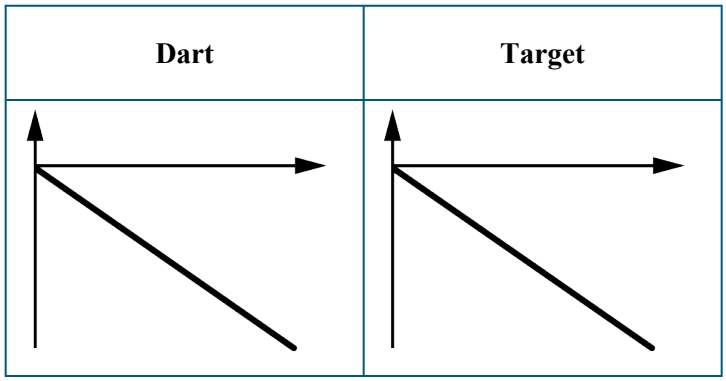
78. Which of the following graphs could represent the vertical component of the velocity as a function of time for the dart and the target immediately after the dart is launched and the target begins to fall?

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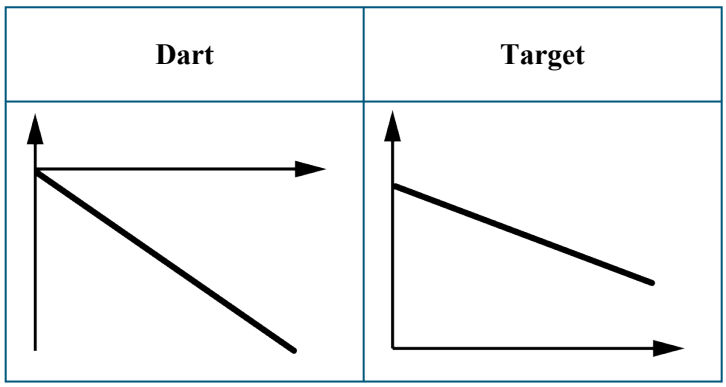
(A)



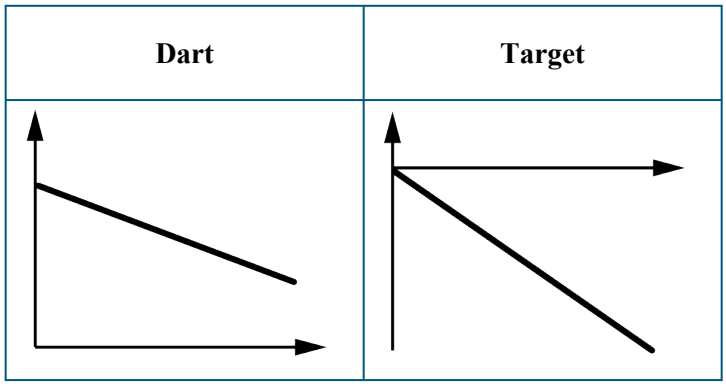
(B)



(C)



(D)



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79.

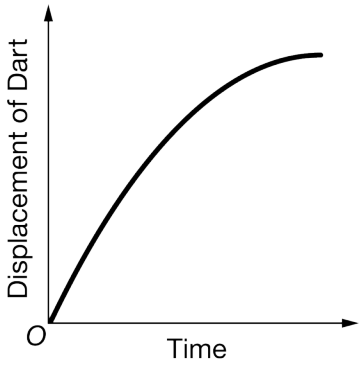


Figure 1

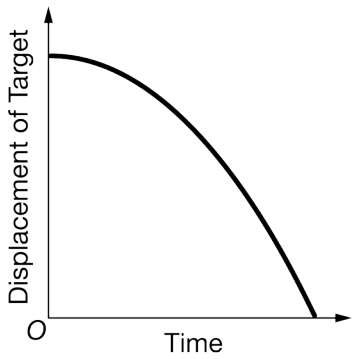


Figure 2

Figure 1 shows a displacement-versus-time graph for the dart. Figure 2 shows a displacement-versus-time graph for the target. For both graphs, the component of the displacement is not indicated.

Which displacement component, horizontal or vertical, is represented by the graph for each object?

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(A)

Dart	Target
Horizontal	Horizontal

(B)

Dart	Target
Vertical	Horizontal

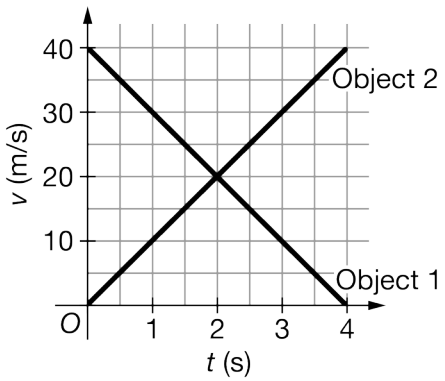
(C)

Dart	Target
Horizontal	Vertical

(D)

Dart	Target
Vertical	Vertical

80.



Object 1 and object 2 travel across a horizontal surface, and their horizontal velocity as a function of time is shown in the graph. Which of the following statements is correct about the two-object system?

(A) The magnitude of acceleration for object 2 is greater than the magnitude of the acceleration of object 1.

(B) After 2 s, object 1 travels a greater distance than object 2 travels.

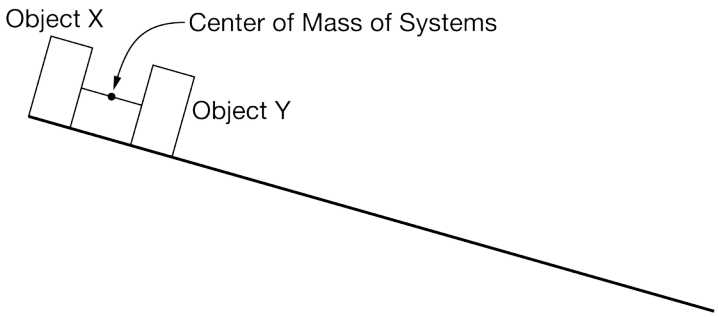
(C) Object 1 and object 2 are at the same horizontal position at 2 s.

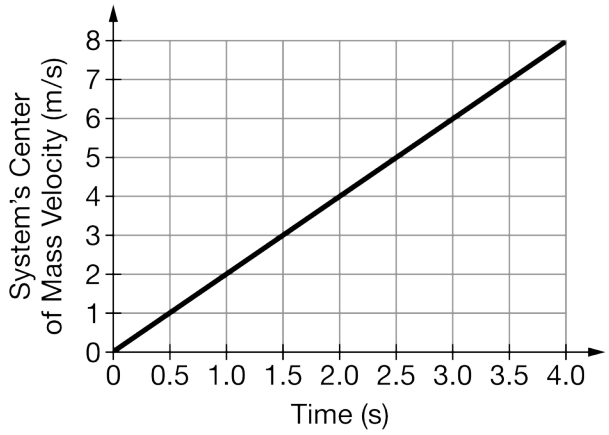
(D) After 4 s, the speed of object 1 is greater than the speed of object 2.

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81.





Identical objects, object X and object Y, are tied together by a string and placed at rest on an incline, as shown in the graph. The string has a length of $2\,\mathrm{m}$. The system of the two objects is released from rest, and a graph of the velocity of the center of mass of the system as a function of time is shown in the figure. If the string was cut and object Y was released from rest while object X was held at rest, which of the following claims is correct about the new acceleration of the center of mass of system a_{new} compared to the original acceleration of the center of mass of the system a_{original} ?

(A) a_{new} will be greater than a_{original}

(B) a_{new} will be less than a_{original}

(C) a_{new} will be equal to a_{original}

(D) The answer cannot be determined without data provided for the velocity as a function of time for object Y as it travels down the incline.

82. Two identical objects, 1 and 2, are initially at rest. Object 1 remains at rest while Object 2 begins to accelerate in the $+x$-direction. Which of the following claims regarding the location of the center of mass of the two-object system is correct?

(A) The location of the center of mass does not change.

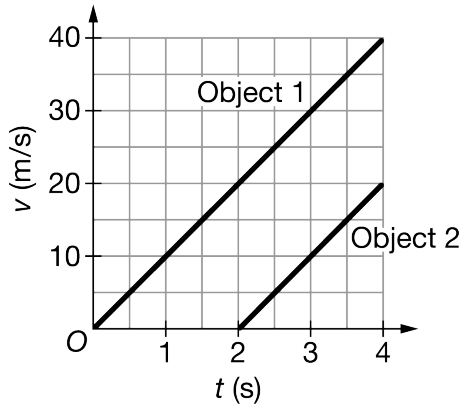
(B) The location of the center of mass moves in the $+x$-direction at a constant speed.

(C) The location of the center of mass accelerates in the $+x$-direction and is located between the two objects.

(D) The location of the center of mass accelerates in the $+x$-direction and is located at the same location as Object 2.

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83.



An object is dropped from the top of a building near Earth's surface. After $2\ \text{s}$, a second identical object is dropped from the same building from the same height. After $4\ \text{s}$, the first object strikes the ground. The graph shows the speeds v of both objects as a function of time t. What is the approximate acceleration of the center of mass of the two-object system at the moment right before the first object reaches the ground?

(A) $0\ \text{m/s}^2$

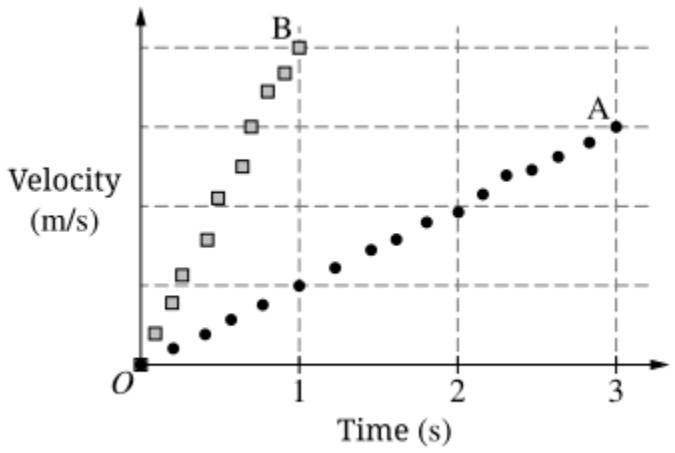
(B) $5\ \text{m/s}^2$

(C) $10\ \text{m/s}^2$

(D) $20\ \text{m/s}^2$

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84.



The graph shows the velocity as a function of time for two objects, A and B. Which of the following correctly compares the displacement Δx_{A} of Object A after 3 s to the displacement Δx_{B} of Object B after 1 s and provides correct justification?

	Displacement	Justification
A	$\Delta x_{\mathrm{A}} > \Delta x_{\mathrm{B}}$	Object A travels for a greater time interval than Object B travels.
B	$\Delta x_{\mathrm{A}} > \Delta x_{\mathrm{B}}$	The area under the curve for Object A is greater than the area under the curve for Object B.
C	$\Delta x_{\mathrm{A}} < \Delta x_{\mathrm{B}}$	The slope for Object B is greater than the slope for Object A.
D	$\Delta x_{\mathrm{A}} < \Delta x_{\mathrm{B}}$	Object B has a greater final velocity than Object A has.

(A) A

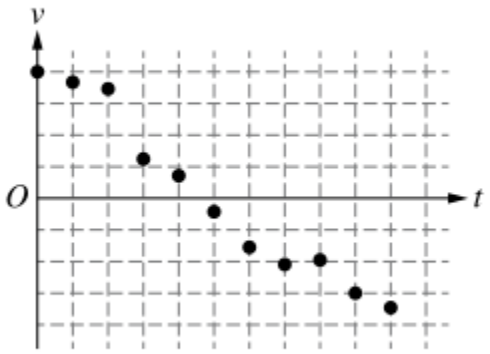
(B) B

(C) C

(D) D

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85.



The graph shows the measured values of the velocity v as a function of time t for an object moving in a straight line. For the time interval shown on the graph, which of the following statements is correct?

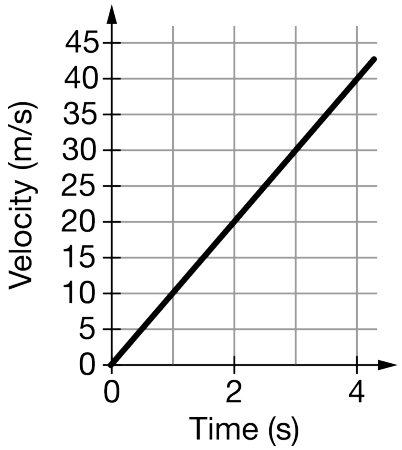
(A) The object starts from rest.

(B) The object reverses direction.

(C) The object has a speed that decreases at a constant rate during the entire time interval.

(D) The object moves in the negative direction during the entire time interval.

86.



A student drops a rock from the top of a cliff such that the rock falls downward toward Earth's surface in the absence of air resistance. The downward direction is considered to be the positive direction. The graph shows the rock's velocity as a function of time. Which of the following methods should be used to determine the total distance traveled by the rock after 4 s ?

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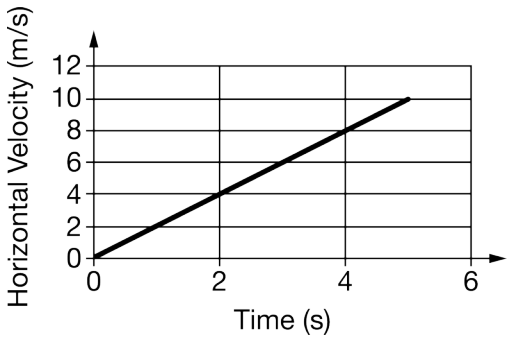
(A) Use the maximum value of the curve, as it states that the rock traveled 40 meters in 1 second, which means that the rock traveled 160 meters in total.

(B) Use the area under the curve, as it states that the rock traveled 80 meters in total.

(C) Use the slope of the curve, as it states that the rock traveled $10\ \frac{\text{m}}{\text{s}}$ in 1 second, which means that the rock traveled 40 meters in total.

(D) The answer cannot be determined unless a graph of the object's position as a function of time is given.

87.



An object travels along a straight line across a horizontal surface, and its motion is described by the velocity versus time graph shown in the figure. Which of the following methods will determine the total displacement of the object between $0\ \text{s}$ and $5\ \text{s}$? Select two answers.

A Finding the slope of the line between $0\ \text{s}$ to $5\ \text{s}$

B Dividing the change in velocity between $0\ \text{s}$ to $5\ \text{s}$ by the change in time

C Finding the area bound by the horizontal axis and the curve from $0\ \text{s}$ to $5\ \text{s}$

D Using $\text{Average Speed} = \frac{\text{total distance}}{\text{total}}$ and multiplying the average speed of $5\ \frac{\text{m}}{\text{s}}$ by a total time of $5\ \text{s}$

88. A student wants to study the motion of an object that has a constant acceleration. Which of the following experiments could the student conduct to provide the best situations in which an object has a constant acceleration? Select two answers.

A Release a ball from rest near Earth's surface.

B Release a toy car from rest such that it travels along different looped sections of a track.

C Launch a water-propelled rocket from rest such that it travels into the air and falls back to Earth's surface.

D Release a cart from rest such that it travels down an incline of 40° with respect to the ground.