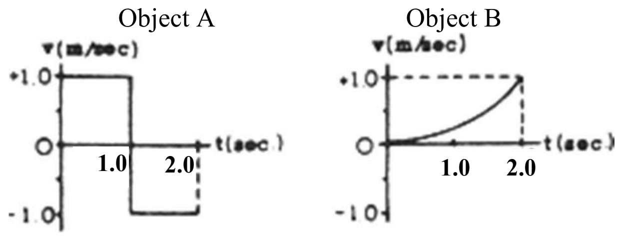
AP Physics Multiple Choice Practice – Kinematics

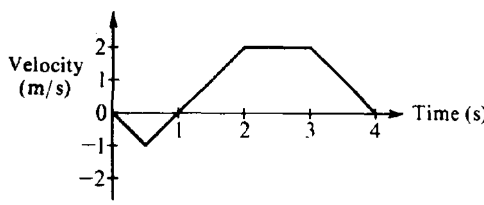
Questions 1 – 3 relate to two objects that start at x = 0 at t = 0 and move in one dimension independently of one another. Graphs, of the velocity of each object versus time are shown below



1. Which object is farthest from the origin at t = 2 seconds.
(A) A (B) B (C) they are in the same location at t = 2 seconds (D) They are the same distance from the origin, but in opposite directions

2. Which object moves with constant non-zero acceleration?
(A) A (B) B (C) both A and B (D) neither A nor B

3. Which object is in its initial position at t = 2 seconds?
(A) A (B) B (C) both A and B (D) neither A nor B

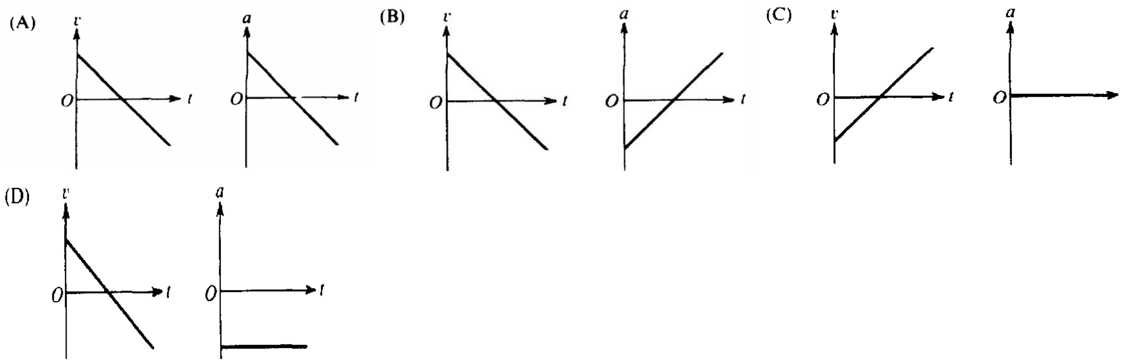


4. The graph above shows the velocity versus time for an object moving in a straight line. At what time after t = 0 does the object again pass through its initial position?
(A) 1 s (B) Between 1 and 2 s (C) 2 s (D) Between 2 and 3 s

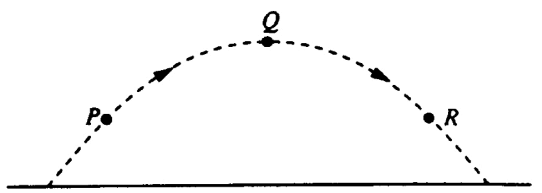
5. A body moving in the positive x direction passes the origin at time t = 0. Between t = 0 and t = 1 second, the body has a constant speed of 24 meters per second. At t = 1 second, the body is given a constant acceleration of 6 meters per second squared in the negative x direction. The position x of the body at t = 11 seconds is
(A) + 99m (B) + 36m (C) – 36 m (E) – 99 m

6. A diver initially moving horizontally with speed v dives off the edge of a vertical cliff and lands in the water a distance *d* from the base of the cliff. How far from the base of the cliff would the diver have landed if the diver initially had been moving horizontally with speed 2v?
(A) d (B) $\sqrt{2d}$ (C) $2d$ (D) $4d$

7. A projectile is fired with initial velocity v_o at an angle θ_0 with the horizontal and follows the trajectory shown above. Which of the following pairs of graphs best represents the vertical components of the velocity and acceleration, v and a, respectively, of the projectile as functions of time t?



Questions 8-9

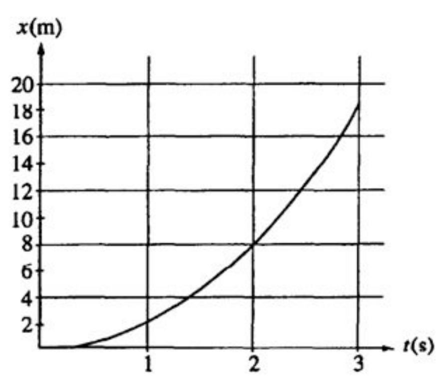


A ball is thrown and follows the parabolic path shown above. Air friction is negligible. Point Q is the highest point on the path. Points P and R are the same height above the ground.

8. How do the speeds of the ball at the three points compare?
(A) $v_P < v_Q < v_R$ (B) $v_R < v_Q < v_P$ (C) $v_Q < v_R < v_P$ (D) $v_Q < v_P = v_R$

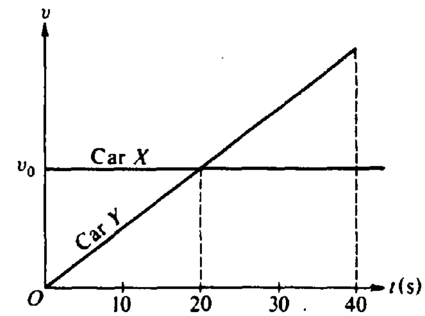
9. Which of the following diagrams best shows the direction of the acceleration of the ball at point P?

(A) ↗ (B) → (C) ↘ (D) ↓



10. 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

Questions 11 – 12

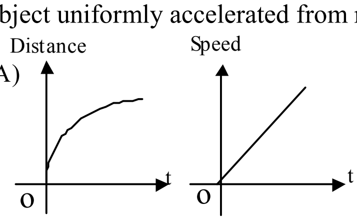


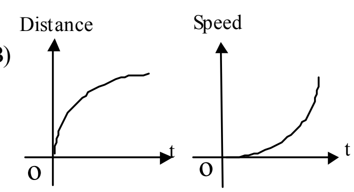
At time t = 0, car X traveling with speed v_0 passes car Y which is just starting to move. Both cars then travel on two parallel lanes of the same straight road. The graphs of speed v versus time t for both cars are shown above.

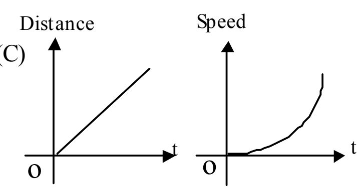
11. Which of the following is true at time t = 20 seconds?
(A) Car Y is behind car X. (B) Car Y is passing car X. (C) Car Y is in front of car X.
(D) Car X is accelerating faster than car Y.

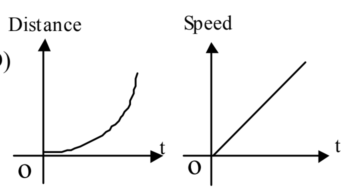
12. From time t = 0 to time t = 40 seconds, the areas under both curves are equal. Therefore, which of the following is true at time t = 40 seconds?
(A) Car Y is behind car X. (B) Car Y is passing car X. (C) Car Y is in front of car X.
(d) Car X is accelerating faster than car Y.

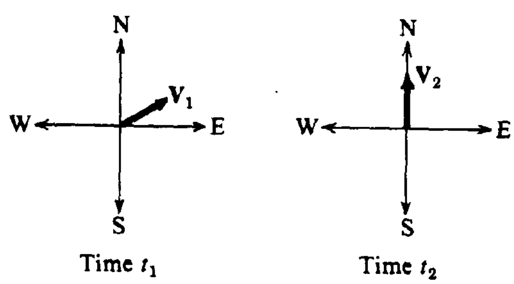
13. Which of the following pairs of graphs shows the distance traveled versus time and the speed versus time for an object uniformly accelerated from rest?

(A)


(B)


(C)


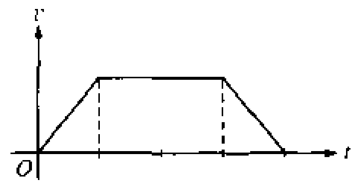
(D)




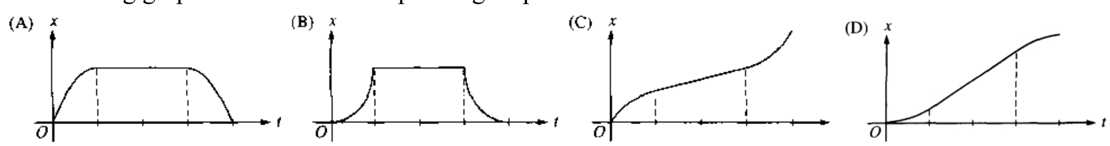
14. Vectors $\mathbf{V_1}$ and $\mathbf{V_2}$ shown above have equal magnitudes. The vectors represent the velocities of an object at times t_1, and t_2, respectively. The average acceleration of the object between time t_1 and t_2 was
(A) directed north (B) directed west (C) directed north of east (D) directed north of west

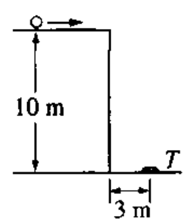
15. The velocity of a projectile at launch has a horizontal component v_h and a vertical component v_v. Air resistance is negligible. When the projectile is at the highest point of its trajectory, which of the following shows the vertical and horizontal components of its velocity and the vertical component of its acceleration?

	Vertical Velocity	Horizontal Velocity	Vertical Acceleration
(A)	v_v	v_h	0
(B)	0	v_h	0
(C)	0	0	g
(D)	0	v_h	g



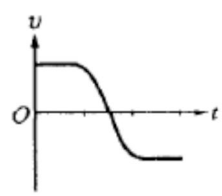
16. The graph above shows the velocity v as a function of time t for an object moving in a straight line. Which of the following graphs shows the corresponding displacement x as a function of time t for the same time interval?



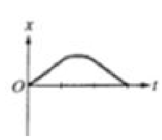
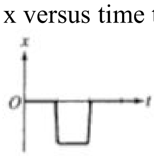
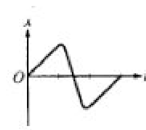


17. A target T lies flat on the ground 3 m from the side of a building that is 10 m tall, as shown above. A student rolls a ball off the horizontal roof of the building in the direction of the target. Air resistance is negligible. The horizontal speed with which the ball must leave the roof if it is to strike the target is most nearly

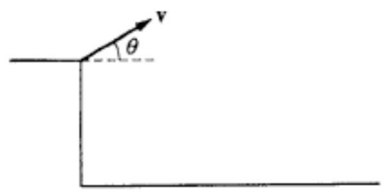
(A) 3/10 m/s (B) $\sqrt{2}$ m/s (C) $\frac{3}{\sqrt{2}}$ m/s (D) 3 m/s



18. The graph above shows velocity v versus time t for an object in linear motion. Which of the following is a possible graph of position x versus time t for this object?

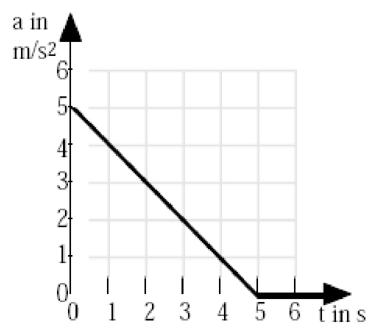
(A)  (B)  (C)  (D) 

19. A student is testing the kinematic equations for uniformly accelerated motion by measuring the time it takes for light-weight plastic balls to fall to the floor from a height of 3 m in the lab. The student predicts the time to fall using g as 9.80 m/s^2 but finds the measured time to be 35% greater. Which of the following is the most likely cause of the large percent error?
(A) The acceleration due to gravity is 70% greater than 9.80 m/s^2 at this location.
(B) The acceleration due to gravity is 70% less than 9.80 m/s^2 at this location.
(C) Air resistance increases the downward acceleration.
(D) The acceleration of the plastic balls is not uniform.



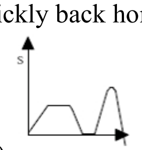
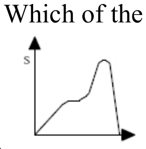
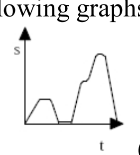
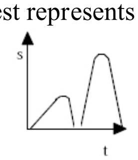
Note: Figure not drawn to scale.

20. An object is thrown with velocity **v** from the edge of a cliff above level ground. Neglect air resistance. In order for the object to travel a maximum horizontal distance from the cliff before hitting the ground, the throw should be at an angle θ with respect to the horizontal of
(A) greater than 60° above the horizontal
(B) greater than 45° but less than 60° above the horizontal
(C) greater than zero but less than 45° above the horizontal
(D) greater than zero but less than 45° below the horizontal



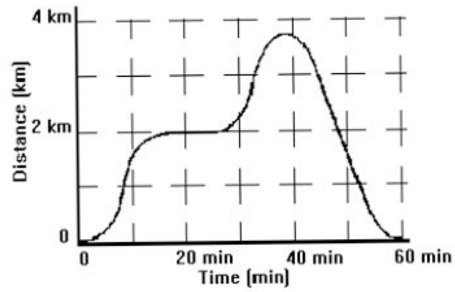
21. Starting from rest at time t = 0, a car moves in a straight line with an acceleration given by the accompanying graph. What is the speed of the car at t = 3 s?
(A) 1.0 m/s (B) 2.0 m/s (C) 6.0 m/s (D) 10.5 m/s

22. A child left her home and started walking at a constant velocity. After a time she stopped for a while and then continued on with a velocity greater than she originally had. All of a sudden she turned around and walked very quickly back home. Which of the following graphs best represents the distance versus time graph for her walk?

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

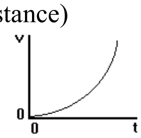
23. A whiffle ball is tossed straight up, reaches a highest point, and falls back down. Air resistance is not negligible. Which of the following statements are true?
I. The ball's speed is zero at the highest point.
II. The ball's acceleration is zero at the highest point.
III. The ball takes a longer time to travel up to the highest point than to fall back down.

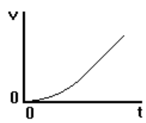
(A) I only (B) II only (C) I & II only (D) I & III only

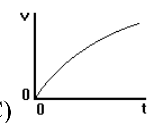


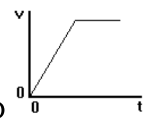
24. Above is a graph of the distance vs. time for car moving along a road. According the graph, at which of the following times would the automobile have been accelerating positively?
(A) 0, 20, 38, & 60 min. (B) 5, 12, 29, & 35 min. (C) 5, 29, & 57 min. (D) 12, 35, & 41 min.

25. A large beach ball is dropped from the ceiling of a school gymnasium to the floor about 10 meters below. Which of the following graphs would best represent its velocity as a function of time? (do not neglect air resistance)

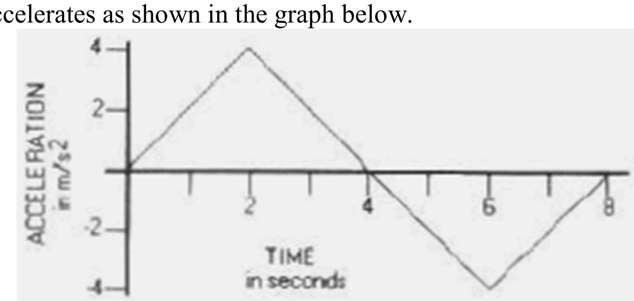
(A) 

(B) 

(C) 

(D 

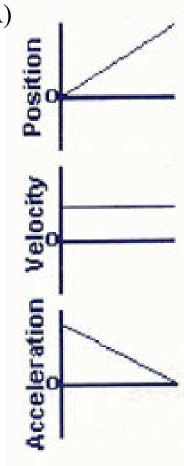
<u>Questions 26-27</u>
A car starts from rest and accelerates as shown in the graph below.

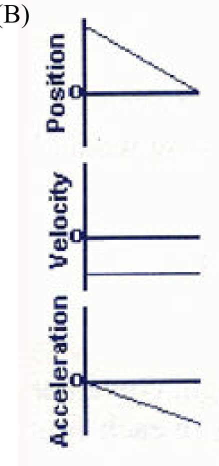


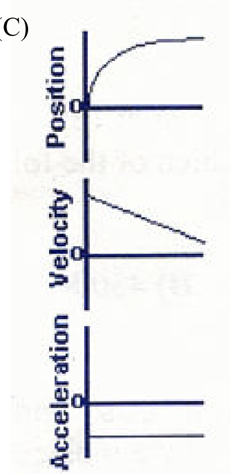
26. At what time would the car be moving with the greatest velocity?
(B) 2 seconds (C) 4 seconds (D) 6 seconds (E) 8 seconds

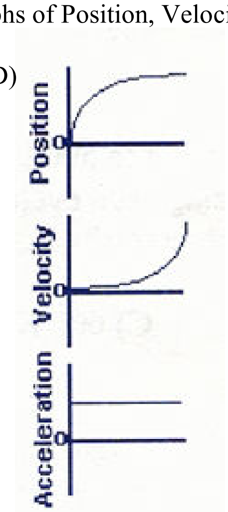
27. At what time would the car be farthest from its original starting position?
(A) 2 seconds (B) 4 seconds (C) 6 seconds (D) 8 seconds

28. Which of the following sets of graphs might be the corresponding graphs of Position, Velocity, and Acceleration vs. Time for a moving particle?

(A) 

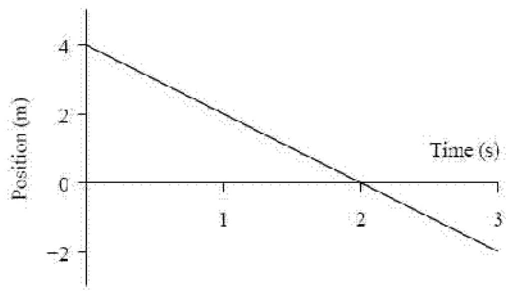
(B) 

(C) 

(D) 

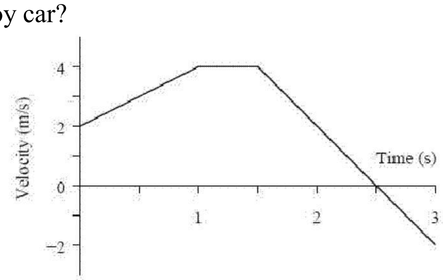
29. An object is thrown with a fixed initial speed v_0 at various angles α relative to the horizon. At some constant height h above the launch point the speed v of the object is measured as a function of the initial angle α. Which of the following best describes the dependence of v on α? (Assume that the height h is achieved, and assume that there is no air resistance.)
(A) v will increase monotonically with α.
(B) v will increase to some critical value v_{max} and then decrease.
(C) v will remain constant, independent of α.
(D) v will decrease to some critical value v_{min} and then increase.

30. The position vs. time graph for an object moving in a straight line is shown below. What is the instantaneous velocity at $t = 2$ s?



(A) – 2 m/s (B) ½ m/s (C) 0 m/s (D) 2 m/s

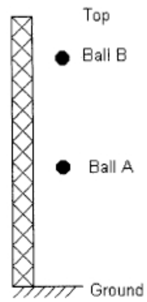
31. Shown below is the velocity vs. time graph for a toy car moving along a straight line. What is the maximum displacement from start for the toy car?



(A) 5 m (B) 6.5 m (C) 7 m (D) 7.5 m

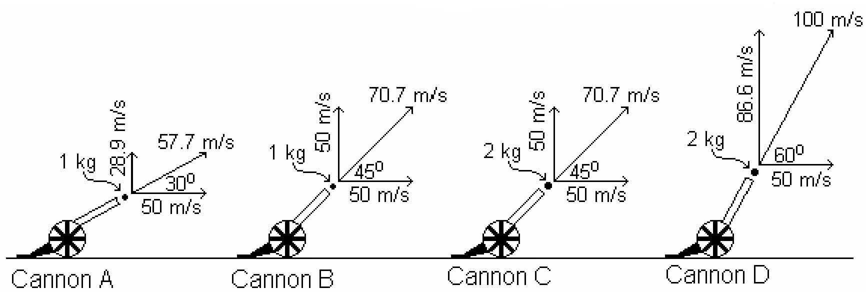
32. An object is released from rest and falls a distance h during the first second of time. How far will it fall during the next second of time?
(A) h (B) $2h$ (C) $3h$ (D) $4h$

33. Two identical bowling balls A and B are each dropped from rest from the top of a tall tower as shown in the diagram below. Ball A is dropped 1.0 s before ball B is dropped but both balls fall for some time before ball A strikes the ground. Air resistance can be considered negligible during the fall. After ball B is dropped but before ball A strikes the ground, which of the following is true?



(A) The distance between the two balls decreases.
(B) The velocity of ball A increases with respect to ball (B)
(C) The velocity of ball A decreases with respect to ball (B)
(D) The distance between the two balls increases.

34. The diagram below shows four cannons firing shells with different masses at different angles of elevation. The horizontal component of the shell's velocity is the same in all four cases. In which case will the shell have the greatest range if air resistance is neglected?



(A) cannon A (B) cannon B only (C) cannon C only (D) cannon D

35. Starting from rest, object 1 falls freely for 4.0 seconds, and object 2 falls freely for 8.0 seconds. Compared to object 1, object 2 falls:
(A) half as far (B) twice as far (C) three times as far (D) four times as far

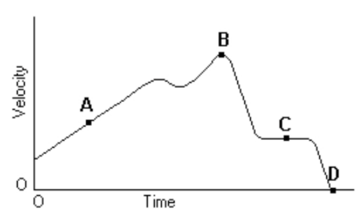
36. A car starts from rest and uniformly accelerates to a final speed of 20.0 m/s in a time of 15.0 s. How far does the car travel during this time?
(A) 150 m (B) 300 m (C) 450 m (D) 600 m

37. An arrow is aimed horizontally, directly at the center of a target 20 m away. The arrow hits 0.050 m below the center of the target. Neglecting air resistance, what was the initial speed of the arrow?
(A) 20 m/s (B) 40 m/s (C) 100 m/s (D) 200 m/s

38. A rocket near the surface of the earth is accelerating vertically upward at 10 m/s^2. The rocket releases an instrument package. Immediately after release the acceleration of the instrument package is:
(A) 20 m/s^2 up (B) 10 m/s^2 up (C) 0 (D) 10 m/s^2 down

39. A ball which is dropped from the top of a building strikes the ground with a speed of 30 m/s. Assume air resistance can be ignored. The height of the building is approximately:
(A) 15 m (B) 30 m (C) 45 m (D) 75 m

40. In the absence of air resistance, if an object were to fall freely near the surface of the Moon,
(A) its acceleration would gradually decrease until the object moves with a terminal velocity.
(B) the acceleration is constant.
(C) it will fall with a constant speed.
(D) the acceleration is zero

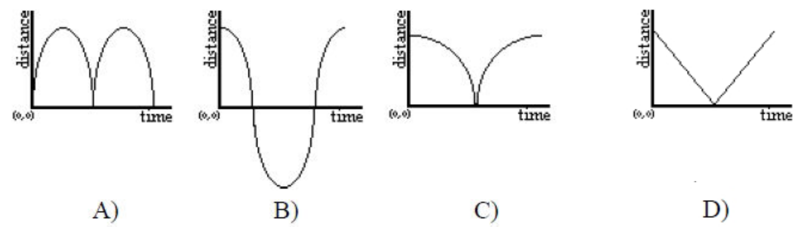


41. Given the graph of the velocity vs. time of a duck flying due south for the winter. At what point did the duck stop its forward motion?
(A) A (B) B (C) C (D) D

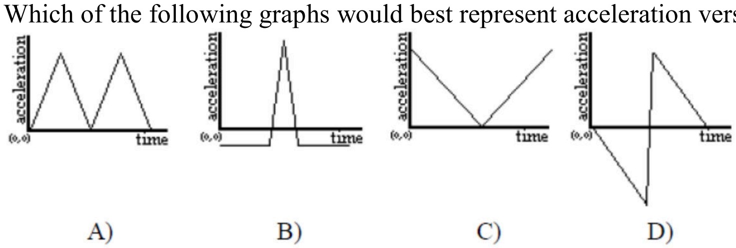
Questions 42-43

The following TWO questions refer to the following information. An ideal elastic rubber ball is dropped from a height of about 2 meters, hits the floor and rebounds to its original height.

42. Which of the following graphs would best represent the distance above the floor versus time for the above bouncing ball?

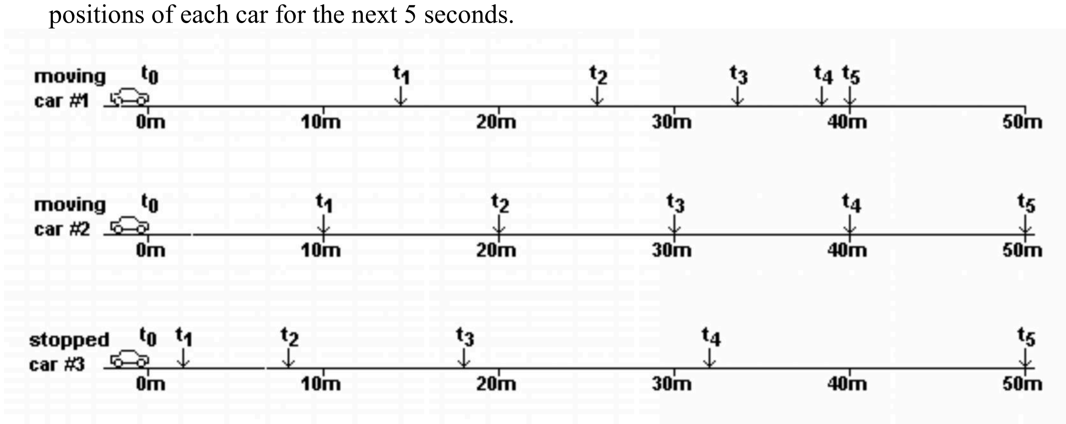


43. Which of the following graphs would best represent acceleration versus time for the bouncing ball?



Questions 44-46

The following TWO questions refer to the following information. At t_0, two cars moving along a highway are side-by-side as they pass a third car stopped on the side of the road. At this moment the driver of the first car steps on the brakes while the driver of the stopped car begins to accelerate. The diagrams below show the positions of each car for the next 5 seconds.

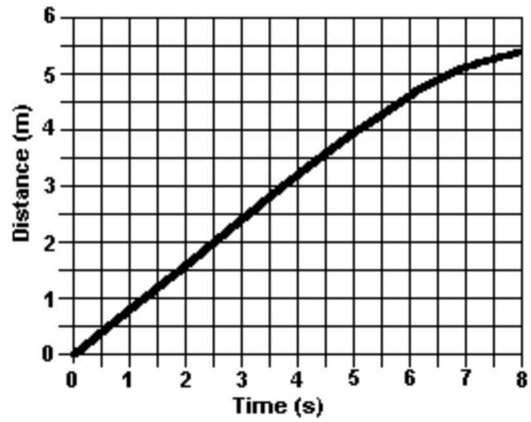


44. During which time interval would cars #2 and #3 be moving at the same average speed?
(A) t_0 to t_1 (B) t_1 to t_2 (C) t_2 to t_3 (D) t_3 to t_4

45. Which of the three cars had the greatest average speed during these 5 seconds?
(A) car #2 and car #3 had the same average speed (B) car #2
(C) all three cars had the same average speed (C) car #3

46. If car #3 continues to constantly accelerate at the same rate what will be its position at the end of 6 seconds?
(A) 24 m (B) 68 m (C) 72 m (D) 78 m

Questions 47-48



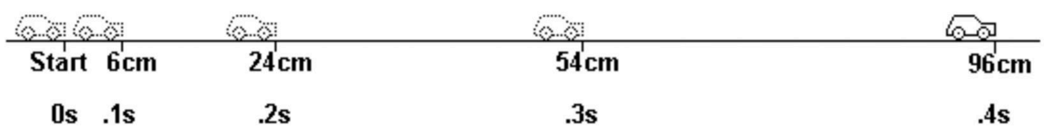
47. The graph represents the relationship between distance and time for an object that is moving along a straight line. What is the instantaneous speed of the object at $t = 5.0$ seconds?
(A) 0.0 m/s (B) 0.8 m/s (C) 2.5 m/s (D) 4.0 m/s

48. Between what times did the object have a non-zero acceleration?
(A) 0 s on (B) 0 s to 5 s (C) the object was not accelerating at any time (D) 5 s to 8 s

49. If a ball is thrown directly upwards with twice the initial speed of another, how much higher will it be at its apex?
(A) 8 times (B) 2 times (C) 4 times (D) 2 times

Questions 50-51

The diagram below represents a toy car starting from rest and uniformly accelerating across the floor. The time and distance traveled from the start are shown in the diagram.

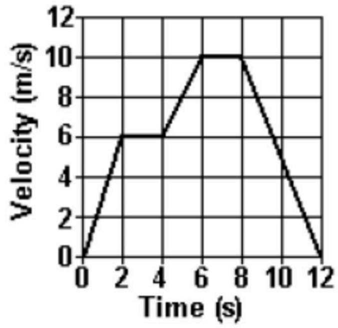


50. What was the acceleration of the cart during the first 0.4 seconds?
(A) 25 m/s^2 (B) 9.8 m/s^2 (C) 50 m/s^2 (D) 12 m/s^2

51. What was the instantaneous velocity of the cart at 96 centimeters from the start?
(A) 0.6 m/s (B) 4.8 m/s (C) 1.9 m/s (D) 60 m/s (E) 2.4 m/s

Questions 52-53

The motion of a circus clown on a unicycle moving in a straight line is shown in the graph below



52. What would be the acceleration of the clown at 5 s?
    (A) 1.6 m/s^2 (B) 8.0 m/s^2 (C) 2.0 m/s^2 (D) 3.4 m/s^2

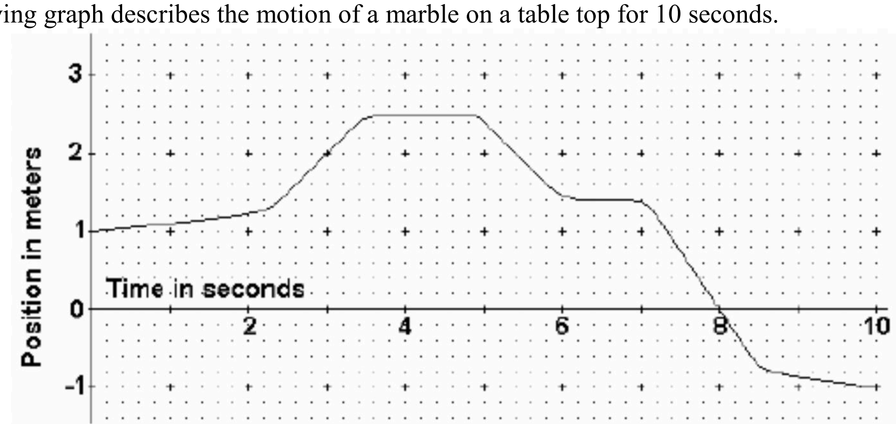
53. After 12 seconds, how far is the clown from her original starting point?
    (A) 0 m (B) 10 m (C) 47 m (D) 74 m

54. When an object falls freely in a vacuum near the surface of the earth
    (A) the terminal velocity will be greater than when dropped in air
    (B) the velocity will increase but the acceleration will be zero
    (C) the acceleration will constantly increase
    (D) the acceleration will remain constant

55. Two arrows are launched at the same time with the same speed. Arrow A at an angle greater than 45 degrees, and arrow B at an angle less than 45 degrees. Both land at the same spot on the ground. Which arrow arrives first?
    (A) arrow A arrives first (B) arrow B arrives first (C) they both arrive together
    (D) it depends on the elevation where the arrows land

Questions 56-57

The accompanying graph describes the motion of a marble on a table top for 10 seconds.

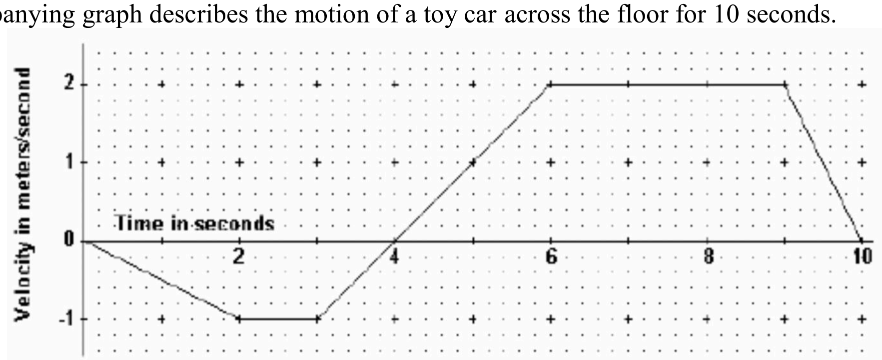


56. For which time interval(s) did the marble have a negative velocity?
    (A) from t = 8.0 s to t = 10.0 s only (B) from t = 6.9 s to t = 10.0 s only
    (C) from t = 4.8 s to t = 10.0 s only (D) from t = 4.8 s to t = 6.2 s and from t = 6.9 s to t = 10.0 s only

57. For which time interval(s) did the marble have a positive acceleration?
    (A) from t = 0.0 s to t = 8.0 s only (B) from t = 0.0 s to t = 3.6 only
    (C) from t = 3.8 s to t = 4.8 s and t = 6.2 s to t = 6.8 s only
    (D) from t = 2.0 s to t = 2.5 s, from t = 5.8 s to t = 6.2 s, and from t = 8.4 s to t = 8.8 s only

58. What is the marbles average acceleration between $t = 3.1$ s and $t = 3.8$ s
(A) -2.0 m/s^2 (B) 0.8 m/s^2 (C) 2.0 m/s^2 (D) 3.0 m/s^2

<u>Questions 59-60</u>
The accompanying graph describes the motion of a toy car across the floor for 10 seconds.



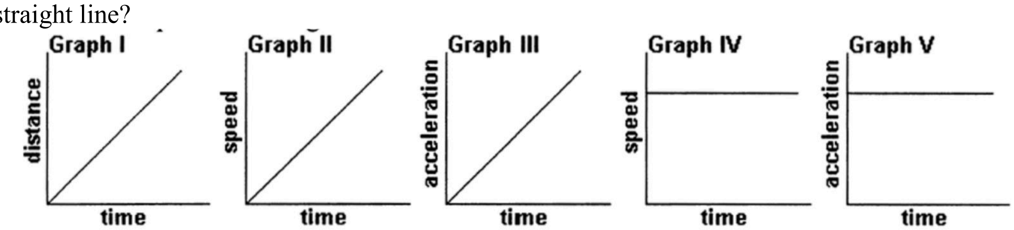
59. What is the acceleration of the toy car at $t = 4$ s?
(A) –1 m/s^2 (B) 0 m/s^2 (C) 1 m/s^2 (D) 2 m/s^2

60. What was the total displacement of the toy car for the entire 10 second interval shown?
(A) 0 meters (B) 6.5 meters (C) 9 meters (D) 10 meters

61. An object is thrown upwards with a velocity of 30 m/s near the surface of the earth. After two seconds what would be the direction of the displacement, velocity and acceleration?

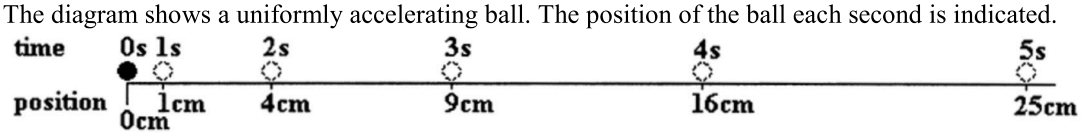
	Displacement	velocity	acceleration
(A)	up	up	up
(B)	up	up	down
(C)	up	down	down
(D)	up	down	up

62. Which of the following graphs could correctly represent the motion of an object moving with a constant speed in a straight line?



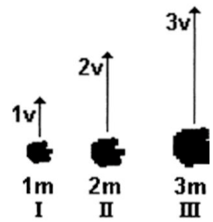
(A) Graph I only (B) Graphs II and V only (C) Graph II only (D) Graphs I and IV only

<u>Questions 63-64</u>
The diagram shows a uniformly accelerating ball. The position of the ball each second is indicated.



63. What is the average speed of the ball between 3 and 4 seconds?
(A) 3.0 cm/s (B) 7.0 cm/s (C) 3.5 cm/s (D) 12.5 cm/s

64. Which of the following is closest to the acceleration of the ball?
(A) 1 cm/s^2 (B) 4 cm/s^2 (C) 2 cm/s^2 (D) 5 cm/s^2



65. Three stones of different mass (1 *m, 2m* & *3m)* are thrown vertically upward with different velocities (l v, 2v & 3v respectively). The diagram indicates the mass and velocity of each stone. Rank from high to low the maximum height of each stone. Assume air resistance is negligible.
(A) I, II, III (B) II, I, III (C) III, II, I (D) I, III, II

66. A rubber ball bounces on the ground as shown. After each bounce, the ball reaches one-half the height of the bounce before it. If the time the ball was in the air between the first and second bounce was 1 second. What would be the time between the second and third bounce?
(A) 0.50 sec (B) 0.71 sec (C) 1.0 sec (D) 1.4 sec

67. The driver of a car makes an emergency stop by slamming on the car's brakes and skidding to a stop. How far would the car have skidded if it had been traveling twice as fast?
(A) 4 times as far (B) the same distance (C) 2 times as far (D)the mass of the car must be known

68. A snail is moving along a straight line. Its initial position is $x_0 = -5$ meters and it is moving away from the origin and slowing down. In this coordinate system, the signs of the initial position, initial velocity and acceleration, respectively, are

Choice	x_0	v_0	a
(A)	–	+	+
(B)	–	–	+
(C)	–	–	–
(D)	–	+	–

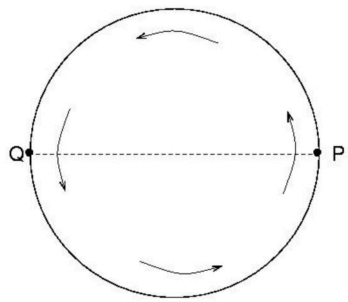
69. A rock is dropped from the top of a tall tower. Half a second later another rock, twice as massive as the first, is dropped. Ignoring air resistance,
(A) the distance between the rocks increases while both are falling.
(B) the acceleration is greater for the more massive rock.
(C) they strike the ground more than half a second apart.
(D) they strike the ground with the same kinetic energy.

70. A cart is initially moving at 0.5 m/s along a track. The cart comes to rest after traveling 1 m. The experiment is repeated on the same track, but now the cart is initially moving at 1 m/s. How far does the cart travel before coming to rest?
(A) 1 m (B) 2 m (C) 3 m (D) 4 m

71. During an interval of time, a tennis ball is moved so that the angle between the velocity and the acceleration of the ball is kept at a constant 120º. Which statement is true about the tennis ball during this interval of time?
(A) Its speed increases and it is changing its direction of travel.
(B) Its speed decreases and it is changing its direction of travel.
(C) Its speed remains constant, but it is changing its direction of travel.
(D) Its speed remains constant and it is not changing its direction of travel.

Questions 72-73

A particle continuously moves in a circular path at constant speed in a counterclockwise direction. Consider a time interval during which the particle moves along this circular path from point P to point Q. Point Q is exactly half-way around the circle from Point P.

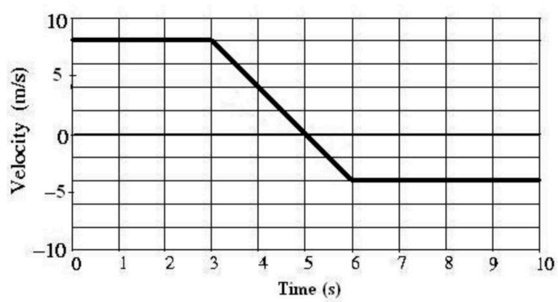


72. What is the direction of the average velocity during this time interval?
(A) → (B) ← (C) ↑ (D) The average velocity is zero.

73.What is the direction of the average acceleration during this time interval?
(A) → (B) ← (C) ↓ (D) The average acceleration is zero.

Questions 74-75

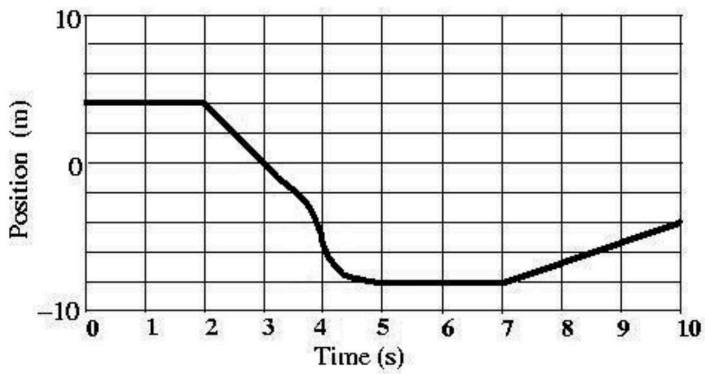
The velocity vs. time graph for the motion of a car on a straight track is shown in the diagram. The thick line represents the velocity. Assume that the car starts at the origin $x = 0$.



74. At which time is the car the greatest distance from the origin?
(A) t = 10 s (B) t = 5s (C) t = 3s (D) t = 0 s

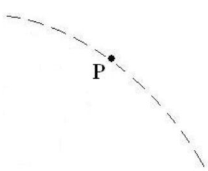
75. What is the average speed of the car for the 10 second interval?
(A) 1.20 m/s (B) 1.40 m/s (C) 3.30 m/s (D) 5.00 m/s

76. Consider the motion of an object given by the position vs. time graph shown. For what time(s) is the speed of the object greatest?



(A) At all times from $t = 0.0\ s \rightarrow t = 2.0\ s$ (B) At time $t = 3.0\ s$ (C) At time $t = 4.0\ s$
(D) At time $t = 8.5\ s$

77. The free fall trajectory of an object thrown horizontally from the top of a building is shown as the dashed line in the figure. Which sets of arrows best correspond to the directions of the velocity and of the acceleration for the object at the point labeled P on the trajectory?



	velocity	acceleration
(A)	↘	↓
(B)	→	↓
(C)	→	↖
(D)	↘	↙

78. A toy car moves 3.0 m to the North in one second. The car then moves at 9.0 m/s due South for two seconds. What is the average speed of the car for this three second trip?
(A) 4.0 m/s (B) 5.0 m/s (C) 6.0 m/s (D) 7 m/s

79. Two automobiles are 150 kilometers apart and traveling toward each other. One automobile is moving at 60 km/h and the other is moving at 40 km/h. In how many hours will they meet?
(A) 1.5 (B) 1.75 (C) 2.0 (D) 2.5

80. Is it possible for an object's velocity to increase while its acceleration decreases?
(A) No, because if acceleration is decreasing the object will be slowing down
(B) No, because velocity and acceleration must always be in the same direction
(C) Yes, an example would be a falling object near the surface of the moon
(D) Yes, an example would be a falling object in the presence of air resistance

Questions 81-82

During a recent winter storm, bales of hay had to be dropped from an airplane to a herd of cattle below. Assume the airplane flew horizontally at an altitude of 180 m with a constant velocity of 50 m/s and dropped one bale of hay every two seconds. It is reasonable to assume that air resistance will be negligible for this situation.

81. As the bales are falling through the air, what will happen to their distance of separation?
(A) the distance of separation will increase
(B) the distance of separation will decrease
(C) the distance of separation will remain constant
(D) the distance of separation will depend on the mass of the bales

82. About how far apart from each other will the bales land on the ground?
(A) 300 m (B) 180 m (C) 100 m (D) 50 m

AP Physics Free Response Practice – Kinematics

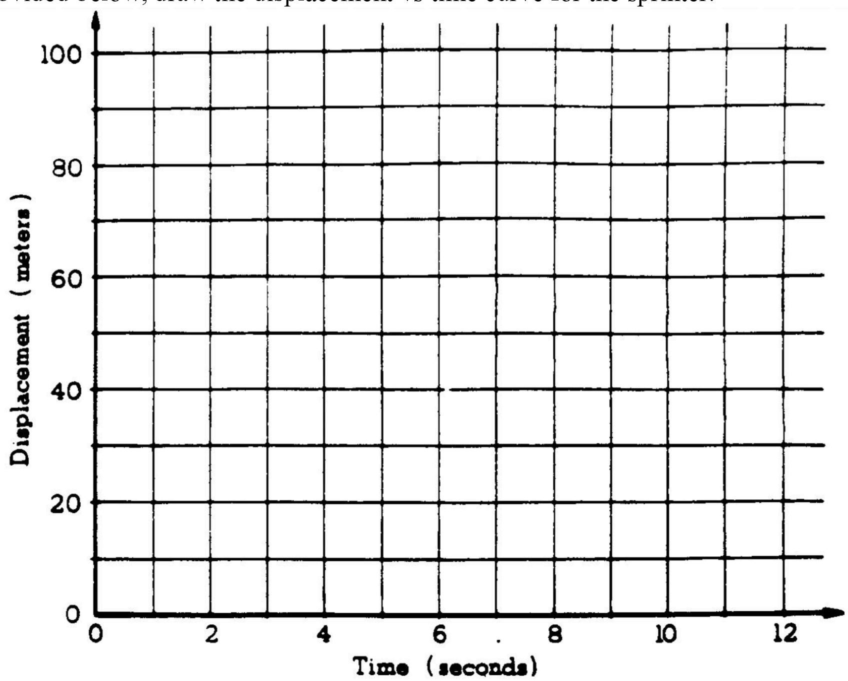
1982B1. The first meters of a 100-meter dash are covered in 2 seconds by a sprinter who starts from rest and accelerates with a constant acceleration. The remaining 90 meters are run with the same velocity the sprinter had after 2 seconds.

a. Determine the sprinter's constant acceleration during the first 2 seconds.

b. Determine the sprinters velocity after 2 seconds have elapsed.

c. Determine the total time needed to run the full 100 meters.

d. On the axes provided below, draw the displacement vs time curve for the sprinter.



2006B2. A world-class runner can complete a 100 m dash in about 10 s. Past studies have shown that runners in such a race accelerate uniformly for a time *t* and then run at constant speed for the remainder of the race. A world-class runner is visiting your physics class. You are to develop a procedure that will allow you to determine the uniform acceleration *a* and an approximate value of *t* for the runner in a 100 m dash. By necessity your experiment will be done on a straight track and include your whole class of eleven students.

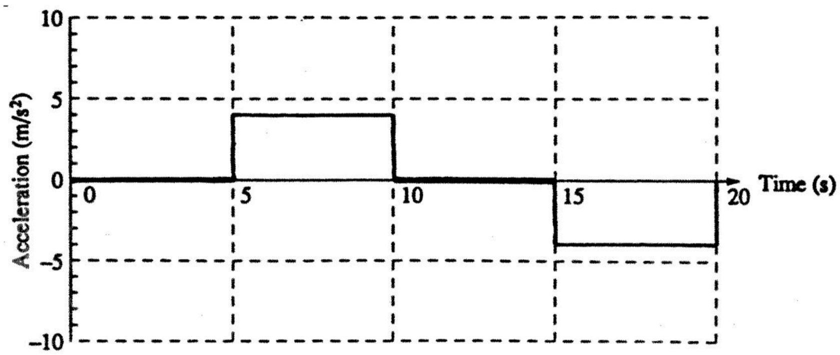
(a) By checking the line next to each appropriate item in the list below, select the equipment, other than the runner and the track, that your class will need to do the experiment.

____Stopwatches ____Tape measures ____ Rulers ____ Masking tape

____Metersticks ____ Starter's pistol ____ String ____ Chalk

(b) Outline the procedure that you would use to determine *a* and *t*, including a labeled diagram of the experimental setup. Use symbols to identify carefully what measurements you would make and include in your procedure how you would use each piece of the equipment you checked in part (a).

(c) Outline the process of data analysis, including how you will identify the portion of the race that has uniform acceleration, and how you would calculate the uniform acceleration.

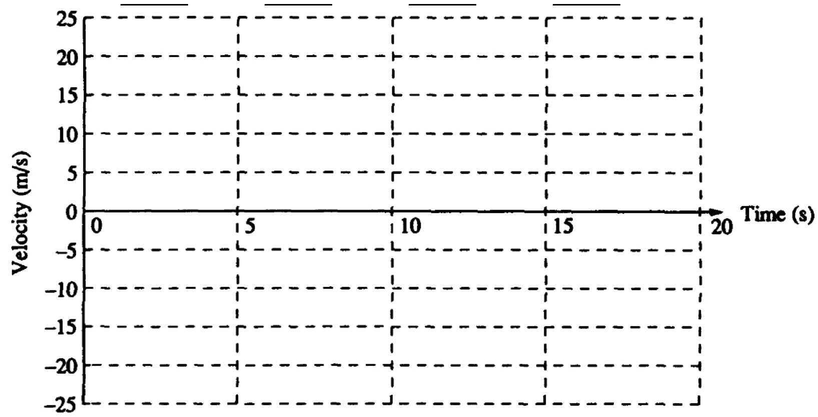


1993B1 (modified) A student stands in an elevator and records his acceleration as a function of time. The data are shown in the graph above. At time t = 0, the elevator is at displacement x = 0 with velocity v = 0. Assume that the positive directions for displacement, velocity, and acceleration are upward.

a. Determine the velocity v of the elevator at the end of each 5-second interval.

i. Indicate your results by completing the following table.

Time Interval (s)	0–5	5–10	10–15	15–20
v (m/s)	_____	_____	_____	_____



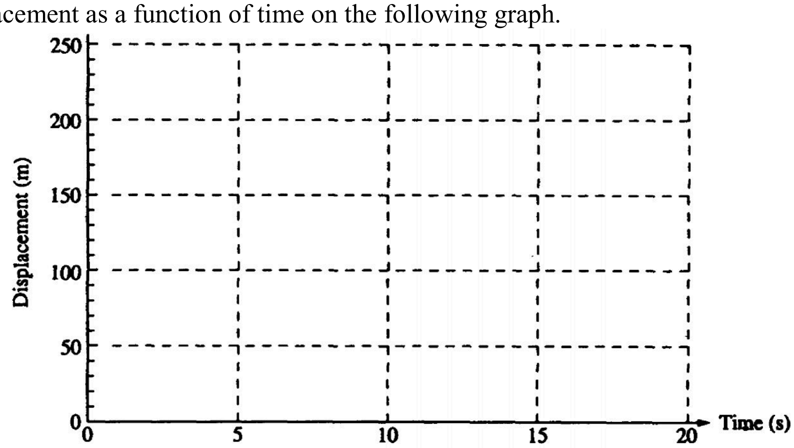
ii. Plot the velocity as a function of time on the following graph.

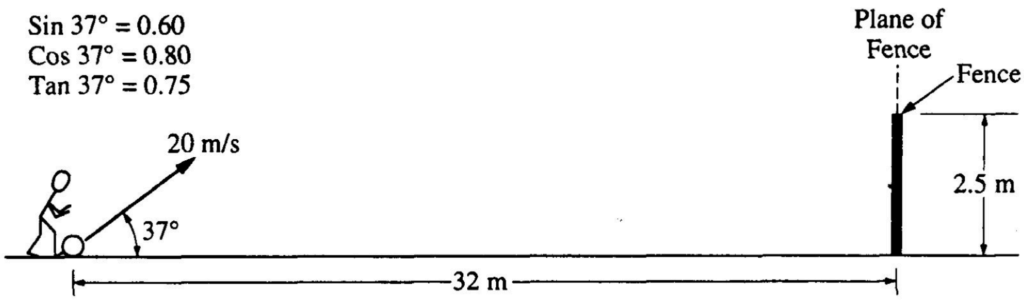
b. Determine the displacement x of the elevator above the starting point at the end of each 5-second interval.

i. Indicate your results by completing the following table.

Time Interval (s)	0–5	5–10	10–15	15–20
x (m)	_____	_____	_____	_____

ii. Plot the displacement as a function of time on the following graph.





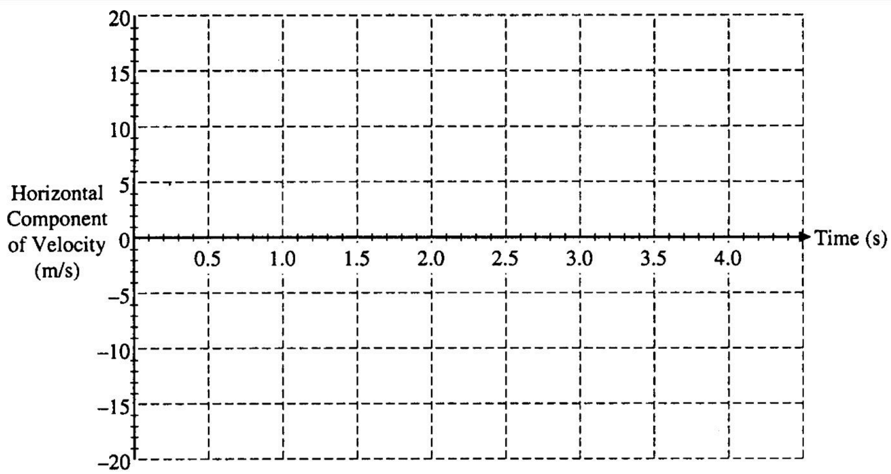
Note: Diagram not drawn to scale.

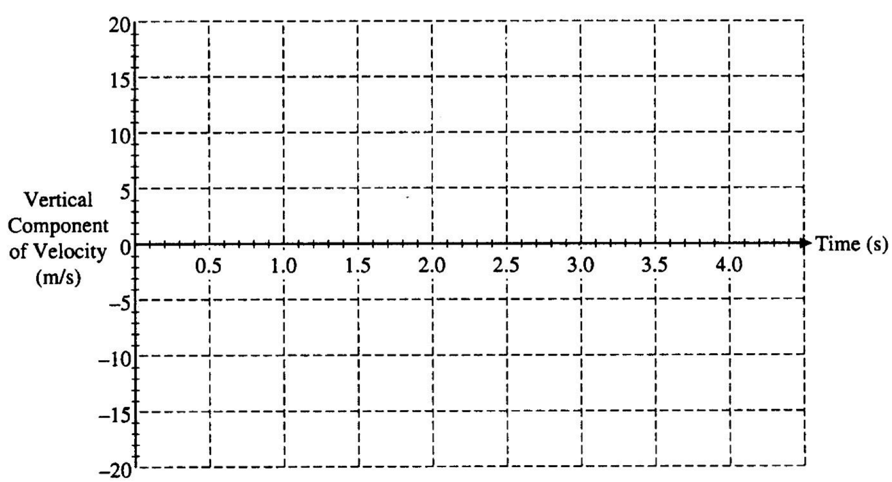
1994B1 (modified) A ball of mass 0.5 kilogram, initially at rest, is kicked directly toward a fence from a point 32 meters away, as shown above. The velocity of the ball as it leaves the kicker's foot is 20 meters per second at an angle of 37° above the horizontal. The top of the fence is 2.5 meters high. The ball hits nothing while in flight and air resistance is negligible.

a. Determine the time it takes for the ball to reach the plane of the fence.

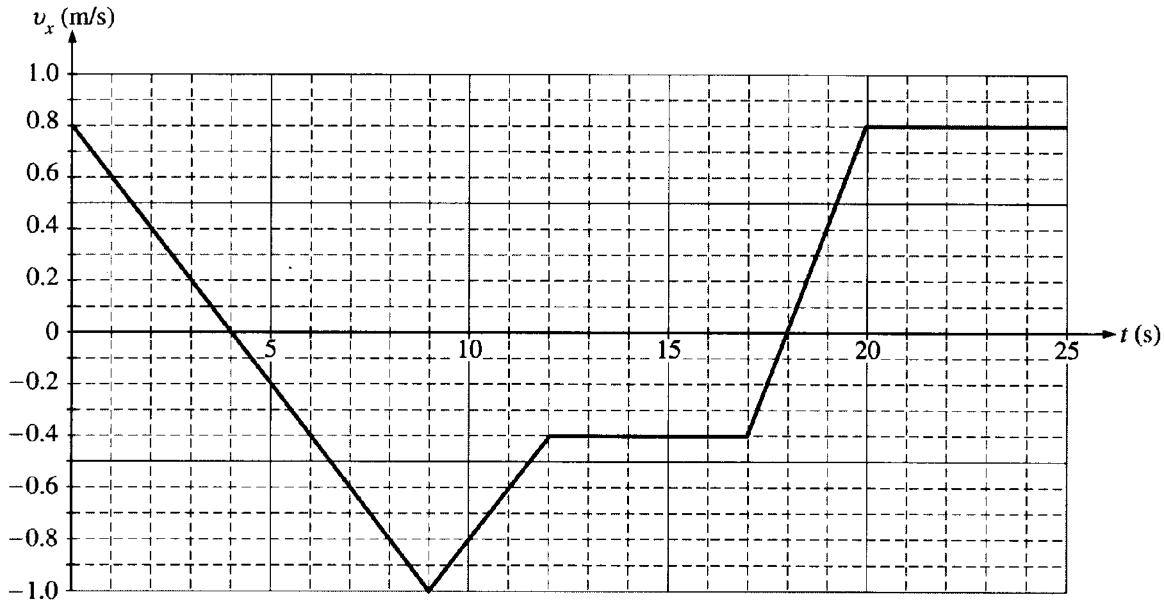
b. Will the ball hit the fence? If so, how far below the top of the fence will it hit? If not, how far above the top of the fence will it pass?

c. On the axes below, sketch the horizontal and vertical components of the velocity of the ball as functions of time until the ball reaches the plane of the fence.





2000B1 (modified) A 0.50 kg cart moves on a straight horizontal track. The graph of velocity v versus time t for the cart is given below.

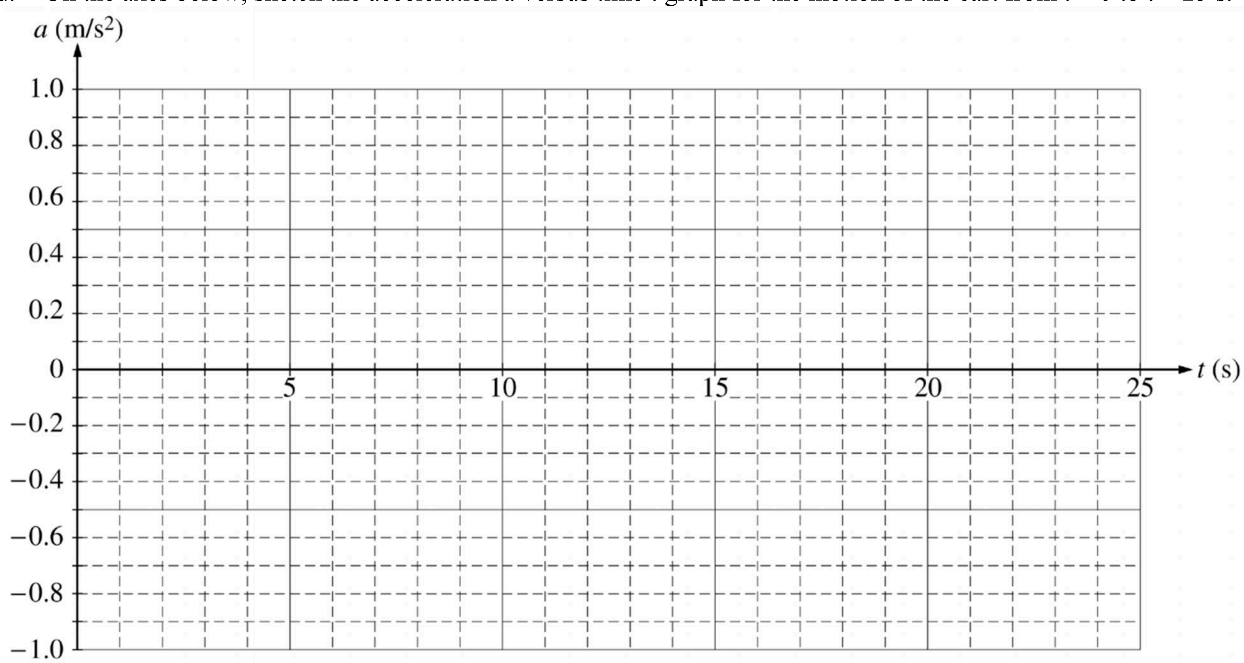


a. Indicate every time t for which the cart is at rest.

b. Indicate every time interval for which the speed (magnitude of velocity) of the cart is increasing.

c. Determine the horizontal position x of the cart at t = 9.0 s if the cart is located at x = 2.0 m at t = 0.

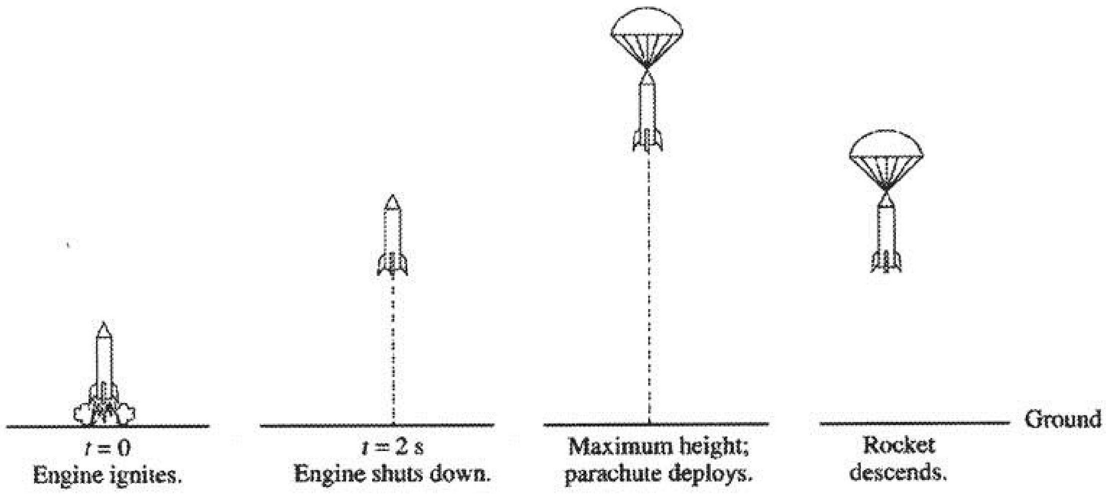
d. On the axes below, sketch the acceleration a versus time t graph for the motion of the cart from t = 0 to t = 25 s.



e. From t = 25 s until the cart reaches the end of the track, the cart continues with constant horizontal velocity. The cart leaves the end of the track and hits the floor, which is 0.40 m below the track. Neglecting air resistance, determine each of the following:

i. The time from when the cart leaves the track until it first hits the floor

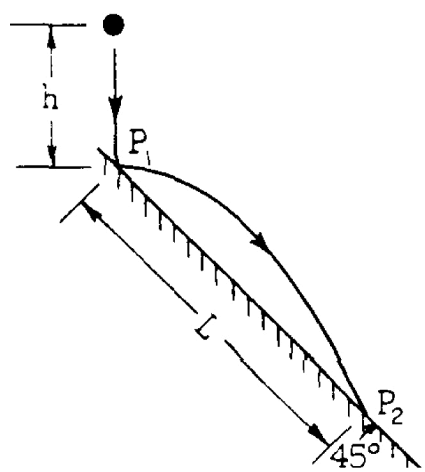
ii. The horizontal distance from the end of the track to the point at which the cart first hits the floor



Note: Figures not drawn to scale.

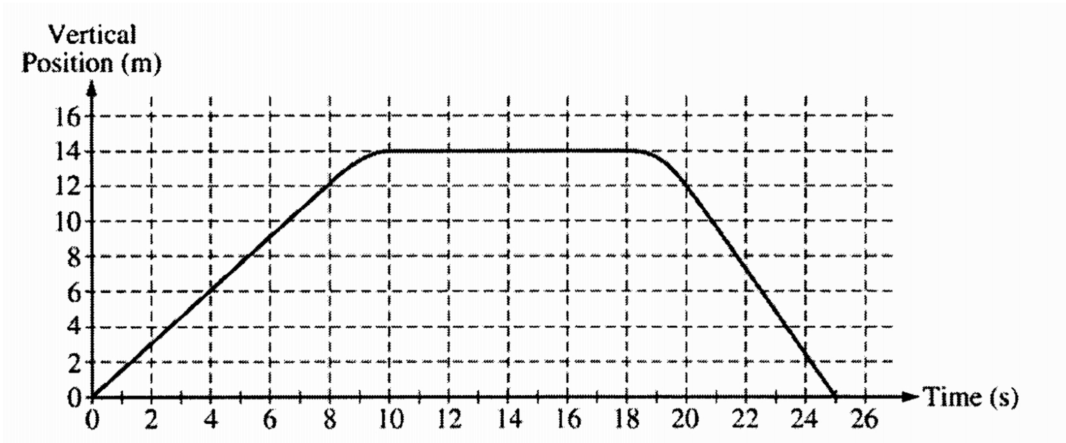
2002B1 (modified) A model rocket is launched vertically with an engine that is ignited at time t = 0, as shown above. The engine provides an upward acceleration of 30 m/s^2 for 2.0 s. Upon reaching its maximum height, the rocket deploys a parachute, and then descends vertically to the ground.

a. Determine the speed of the rocket after the 2 s firing of the engine.
b. What maximum height will the rocket reach?
c. At what time after t = 0 will the maximum height be reached?



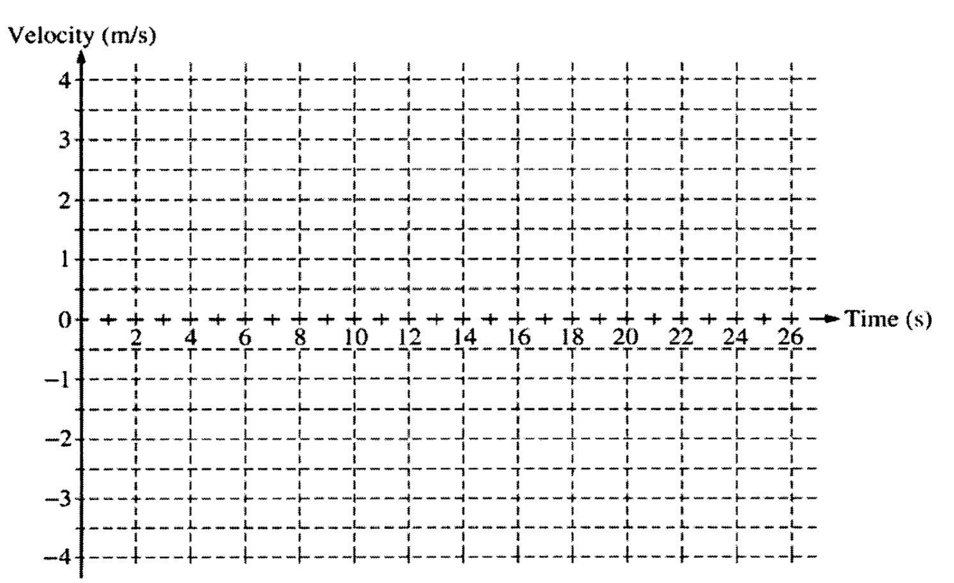
*1979M1 (modified) A ball of mass m is released from rest at a distance h above a frictionless plane inclined at an angle of 45° to the horizontal as shown above. The ball bounces horizontally off the plane at point P_1 with the same speed with which it struck the plane and strikes the plane again at point P_2. In terms of g and h determine each of the following quantities:

a. The speed of the ball just after it first bounces off the plane at P_1.
b. The time the ball is in flight between points P_1 and P_2.
c. The distance L along the plane from P_1 to P_2.
d. The speed of the ball just before it strikes the plane at P_2.

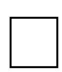


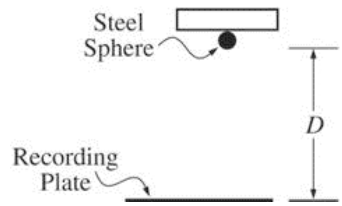
2005B1 (modified) The vertical position of an elevator as a function of time is shown above.

a. On the grid below, graph the velocity of the elevator as a function of time.



b. i. Calculate the average acceleration for the time period t = 8 s to t = 10 s.
ii. On the box below that represents the elevator, draw a vector to represent the direction of this average acceleration.

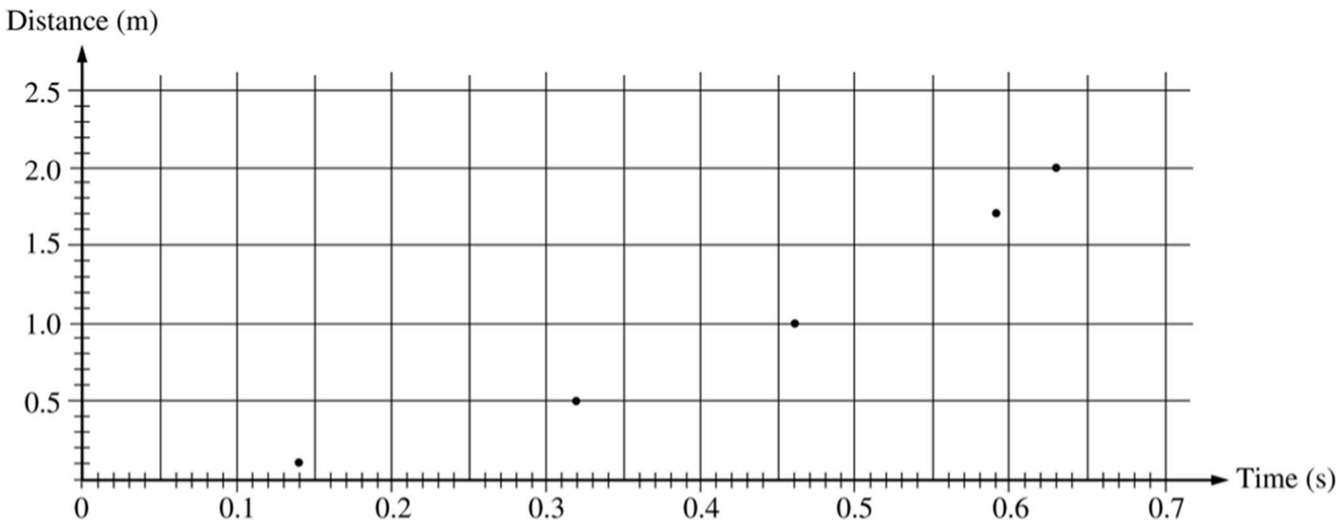




2006Bb1. A student wishing to determine experimentally the acceleration g due to gravity has an apparatus that holds a small steel sphere above a recording plate, as shown above. When the sphere is released, a timer automatically begins recording the time of fall. The timer automatically stops when the sphere strikes the recording plate.

The student measures the time of fall for different values of the distance D shown above and records the data in the table below. These data points are also plotted on the graph.

Distance of Fall (m)	0.10	0.50	1.00	1.70	2.00
Time of Fall (s)	0.14	0.32	0.46	0.59	0.63

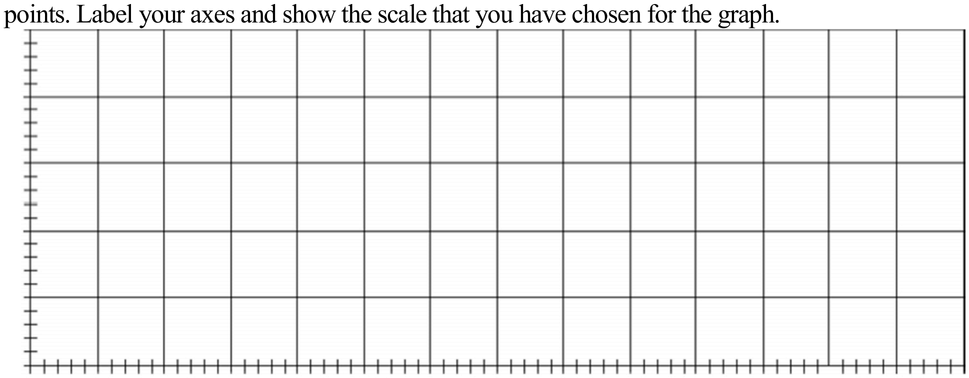


(a) On the grid above, sketch the smooth curve that best represents the student's data

The student can use these data for distance D and time t to produce a second graph from which the acceleration g due to gravity can be determined.

(b) If only the variables D and t are used, what quantities should the student graph in order to produce a linear relationship between the two quantities?

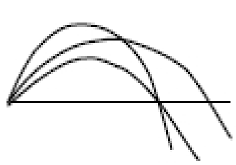
(c) On the grid below, plot the data points for the quantities you have identified in part (b), and sketch the best straight-line fit to the points. Label your axes and show the scale that you have chosen for the graph.



(d) Using the slope of your graph in part (c), calculate the acceleration g due to gravity in this experiment.

(e) State one way in which the student could improve the accuracy of the results if the experiment were to be performed again. Explain why this would improve the accuracy.

ANSWERS - AP Physics Multiple Choice Practice – Kinematics

	Solution	Answer
1.	Area bounded by the curve is the displacement By inspection of particle A the positive area between 0 and 1s will be countered by an equal negative area between 1 and 2s.	B
2.	Constant non-zero acceleration would be a straight line with a non -zero slope	D
3.	Area bounded by the curve is the displacement By inspection of particle A the positive area between 0 and 1s will be countered by an equal negative area between 1 and 2s.	A
4.	Area bounded by the curve is the displacement By inspection the negative area between 0 and 1s will be countered by an equal negative area sometime between 1 and 2s.	B
5.	Between 0 and 1 s; $d_1 = vt$; from 1 to 11 seconds; $d_2 = v_0t + ½at^2$; $d = d_1 + d_2$	C
6.	The time in the air for a horizontal projectile is dependent on the height and independent of the initial speed. Since the time in the air is the same at speed v and at speed 2v, the distance (d = vt) will be twice as much at a speed of 2v	C
7.	The acceleration is constant and negative which means the slope of the velocity time graph must have a constant negative slope. (Only one choice has the correct acceleration anyway)	D
8.	At the top of its path, the vertical component of the velocity is zero, which makes the speed at the top a minimum. With symmetry, the projectile has the same speed when at the same height, whether moving up or down.	D
9.	g points down in projectile motion. Always.	D
10.	Average speed = total distance/total time = (8 m – 2 m)/(1 second)	D
11.	The area under the curve is the displacement. There is more area under the curve for Car X.	A
12.	Area under the curve is the displacement. Car Y is moving faster as they reach the same point.	B
13.	Uniformly accelerated means the speed-time graph should be a stright line with non-zero slope. The corresponding distance-time graph should have an increasing slope (curve upward)	D
14.	Acceleration is proportional to Δv. $\Delta v = v_2 - v_1 = v_2 + (-v_1)$	D
15.	horizontal velocity v_x remains the same thorughout the flight. g remains the same as well.	D
16.	A velocity-time graph represents the *slope* of the displacement-time graph. Analyzing the v -t graph shows an increasing slope, then a constant slope, then a decreasing slope (to zero)	D
17.	For a horizontal projectile, the initial speed does not affect the time in the air. Use $v_{0y} = 0$ with 10 m = $½gt^2$ to get $t = \sqrt{2}$ For the horizontal part of the motion; v = d/t	C
18.	A velocity-time graph represents the *slope* of the displacement-time graph. Analyzing the v -t graph shows a constant slope, then a decreasing slope to zero, becoming negative and increasing, then a constant slope. Note this is an analysis of the *values* of v, not the slope of the graph itself	A
19.	By process of elimination (A and B are unrealistic; C is wrong, air resistance should decrease the acceleration)	D
20.	 The 45° angle gives the maximum horizontal travel to the original elevation, but the smaller angle causes the projectile to have a greater horizontal component of velocity, so given the additional time of travel allows such a trajectory to advance a greater horizontal distance. In other words given enough time the smaller angle of launch gives a parabola which will eventual cross the parabola of the 45° launch.	C

21. The area under the curve of an acceleration-time graph is the change in speed. D

22. The slope of the line represents her velocity. Beginning positive and constant, going to zero, then positive and larger than the initial, then negative while the line returns to the time axis B

23. Positive acceleration is an increasing slope (including negative slope increasing toward zero) or upward curvature C

24. Positive acceleration is an increasing slope (including negative slope increasing toward zero) or upward curvature C

25. With air resistance, the acceleration (the slope of the curve) will decrease toward zero as the ball reached terminal velocity. Note: without air resistance, choice (A) would be correct C

26. Since for the first 4 seconds, the car is accelerating positively the entire time, the car will be moving fastest just beofre slowing down after t = 4 seconds. C

27. The area under the curve represents the change in velocity. The car begins from rest with an increasing positive velocity, after 4 seconds the car begins to slow and the area under the curve from 4 to 8 seconds couters the increase in velocity form 0 to 4 seconds, bringing the car to rest. However, the car never changed direction and was moving away from its original starting position the entire time. D

28. The velocity-time graph should represent the slope of the position-time graph and the acceleration-time graph should represent the slope of the velocity-time graph C

29. It's a surprising result, but while both the horizontal and vertical components change at a given height with varying launch angle, the *speed* $(v_x^2 + v_y^2)^{1/2}$ will be independent of θ (try it!) C

30. Instantaneous velocity is the slope of the line at that point A

31. Displacement is the area under the curve. Maximum displacement is just before the car turns around at 2.5 seconds. C

32. From the equation $d = \frac{1}{2}at^2$, displacement is proportional to time squared. Traveling from rest for twice the time gives 4 times the displacement (or 4 h). Since the object already travelled h in the first second, during the time interval from 1 s to 2 s the object travelled the remaining 3h C

33. Looking at choices A and D eliminates the possibility of choices B and C (each ball increases its speed by 9.8 m/s each second, negating those choices anyway). Since ball A is moving faster than ball B at all times, it will continue to pull away from ball B (the relative speed between the balls separates them). D

34. Since they all have the same horizontal component of the shell's velocity, the shell that spends the longest time in the air will travel the farthest. That is the shell launched at the largest angle (mass is irrelevant). D

35. Since (from rest) $d = \frac{1}{2}gt^2$, distance is proportional to time squared. An object falling for twice the time will fall four times the distance. D

36. $$\bar{v} = \frac{v_i + v_f}{2} = \frac{d}{t}$$ A

37. For a horizontal projectile (v_{iy} = 0 m/s) to fall 0.05 m takes (using $0.05\text{ m} = \frac{1}{2}gt^2$) 0.1 seconds. To travel 20 m in this time requires a speed of d/t = (20 m)/(0.1 s) D

38. Once released, the package is in free-fall (subject to gravity only) D

39. To reach a speed of 30 m/s when dropped takes (using v = at) about 3 seconds. The distance fallen after three seconds is found using $d = \frac{1}{2}at^2$ C

40. Falling on the Moon is no different conceptually than falling on the Earth B

41. Since the line is above the t axis for the entire flight, the duck is always moving in the positive (forward) direction, until it stops at point D — D

42. One could analyze the graphs based on slope, but more simply, the graph of position versus time should represent the actual path followed by the ball as seen on a platform moving past you at constant speed. — C

43. Other than the falling portions ($a = -9.8\ m/s^2$) the ball should have a spike in the acceleration when it bounces due to the rapid change of velocity from downward to upward. — B

44. The same average speed would be indicated by the same distance traveled in the time interval — C

45. Average speed = (total distance)/(total time). Cars #2 and #3 travelled the same distance. — A

46. If you look at the distance covered in each time interval you should nitce a pattern: 2 m, 6 m, 10 m, 14 m, 18 m; making the distance in the next second 22 m. — C

47. Instantaneous speed is the slope of the line at that point. — B

48. A non-zero accleeration is inidcated by a curve in the line — D

49. Maximum height of a projectile is found from $v_y = 0$ m/s at max height and $(0\ m/s)^2 = v^2 + 2gh$ and gives $h = v^2/2g$. At twice the initial speed, the height will be 4 times as much — C

50. $d = \frac{1}{2}at^2$ (use any point) — D

51. $v = v_i + at$ — B

52. Acceleration is the slope of the line segment — C

53. Displacement is the area under the line — D

54. In a vacuum, there is no air resistance and hence no terminal velocity. It will continue to accelerate. — D

55. A projectile launched at a smaller angle does not go as high and will fall to the ground first. — B

56. Velocity is the slope of the line. — D

57. Positive acceleration is an upward curvature — D

58. Average acceleration = $\Delta v/\Delta t$ — A

59. Acceleration is the slope of the line segment — C

60. Displacement is the area between the line and the t-axis. Area is negative when the line is below the t-axis. — B

61. After two seconds, the object would be above it's original position, still moving upward, but the acceleration due to gravity is always pointing down — B

62. Constant speed is a constant slope on a position-time graph, a horizontal line on a velocity time graph or a zero value on an acceleration -time graph — D

63. Average speed = total distance divided by total time = (7 cm)/(1 s) — B

64. $d = \frac{1}{2}at^2$ (use any point) — C

65. Maximum height of a projectile is found from $v_y = 0$ m/s at max height and $(0\ m/s)^2 = v^2 + 2gh$ and gives $h = v^2/2g$. Mass is irrelevant. Largest initial speed = highest. — C

66. Using $d = \frac{1}{2}at^2$ shows the height is proportional to the time squared. the maximum height is $\frac{1}{\sqrt{2}}$ times the time. — B

67. Stopping distance is found using $v_f = 0 = v_i^2 + 2ad$ which gives $d = v_i^2/2a$ where stopping distance is proportional to initial speed squared. A

68. Moving away from the origin will maintain a negative position and velocity. Slowing down indicates the acceleration is opposite in direction to the velocity. B

69. Since the first rock is always traveling faster, the relative distance between them is always increasing. A

70. Stopping distance is found using $v_f = 0 = v_i^2 + 2ad$ which gives $d = v_i^2/2a$ where stopping distance is proportional to initial speed squared. B

71. At an angle of 120°, there is a component of the acceleration perpendicular to the velocity causing the direction to change and a component in the opposite direction of the velocity, causing it to slow down. B

72. The displacement is directly to the left. The average velocity is proportional to the displacement B

73. The velocity is initially pointing up, the final velocity points down. The acceleration is in the same direction as $\Delta v = v_f + (-v_i)$ C

74. The car is the greatest distance just before it reverses direction at 5 seconds. B

75. Average speed = (total *distance*)/(total time), the total distance is the magnitude of the area under the line (the area below the t-axis is considered positive) D

76. Speed is the slope of the line. C

77. Velocity is pointing tangent to the path, acceleration (gravity) is downward. A

78. Average speed = (total *distance*)/(total time) D

79. The relative speed between the two cars is $v_1 - v_2 = (60\text{ km/h}) - (-40\text{ km/h}) = 100\text{ km/h}$. They will meet in $t = d/v_{relative} = 150\text{ km}/100\text{ km/h}$ A

80. Acceleration is independent of velocity (you can accelerate in any direction while traveling in a ny direction). If the accleration is in the same direction as the velocity, the object is speeding up. D

81. As the first bales dropped will always be traveling faster than the later bales, their relative velocity will cause their separation to always iincrease. A

82. Horizontally, the bales will all travel at the speed of the plane, as gravity will not affect their horizontal motion. D = vt = (50 m/s)(2 seconds apart) C

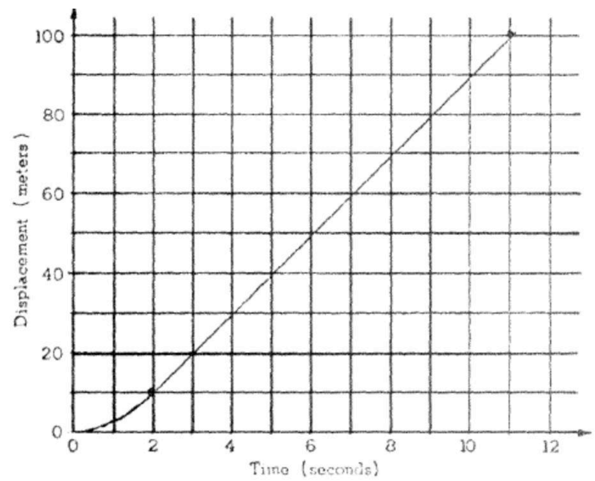
1982B1

a. For the first 2 seconds, while acceleration is constant, $d = \frac{1}{2} at^2$
Substituting the given values d = 10 meters, t = 2 seconds gives $a = 5\ m/s^2$

b. The velocity after accelerating from rest for 2 seconds is given by v = at, so v = 10 m/s

c. The displacement, time, and constant velocity for the last 90 meters are related by d = vt.
To cover this distance takes t = d/v = 9 s. The total time is therefore 9 + 2 = 11 seconds

d.



2006B2

Two general approaches were used by most of the students.

Approach A: Spread the students out every 10 meters or so. The students each start their stopwatches as the runner starts and measure the time for the runner to reach their positions.

[illegible] Make a position vs. time graph. Fit the parabolic and linear parts of the graph and establish the position and time at which the parabola makes the transition to the straight line.

[illegible] Use the position and time measurements to determine a series of average velocities ($v_{avg} = \Delta x/\Delta t$) for the intervals. Graph these velocities vs. time to obtain a horizontal line and a line with positive slope. Establish the position and time at which the sloped and horizontal lines intersect.

[illegible] Use the position and time measurements to determine a series of average accelerations ($\Delta x = v_0 t + \frac{1}{2} at^2$). Graph these accelerations vs. time to obtain two horizontal lines, one with a nonzero value and one at zero acceleration. Establish the position and time at which the acceleration drops to zero.

Approach B: Concentrate the students at intervals at the end of the run, in order to get a very precise value of the constant speed v_c, or at the beginning in order to get a precise value for a. The total distance *D* is given by $D = \frac{1}{2} a t_u^2 + v_c(T - t_u)$, where T is the total measured run time. In addition $v_c = a t_u$. These equations can be solved for a and t_u (if v_c is measured directly) or v_c and t_u (if a is measured directly). Students may have also defined and used distances, speeds, and times for the accelerated and constant-speed portions of the run in deriving these relationships.

1993B1

a. i. Use the kinematic equation applicable for constant acceleration: $v = v_0 + at$. For each time interval, substitute the initial velocity for that interval, the appropriate acceleration from the graph and a time of 5 seconds.

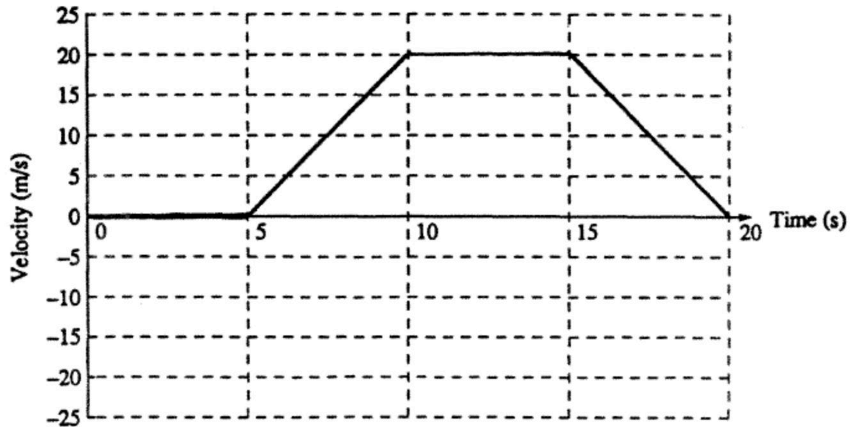
5 seconds: $v = 0 + (0)(5\ s) = 0$

10 seconds: $v = 0 + (4\ m/□)(5\ s) = 20\ mls$

15 seconds: $v = 20\ mls + (0)(5\ s) = 20\ mls$

20 seconds: $v = 20\ mls + (-4\ m/s^2)(5\ s) = 0$

ii.



b. i. Use the kinematic equation applicable for constant acceleration, $x = x_0 + v_0t + ½ at^2$. For each time interval, substitute the initial position for that interval, the initial velocity for that interval from part (a), the appropriate acceleration, and a time of 5 seconds.

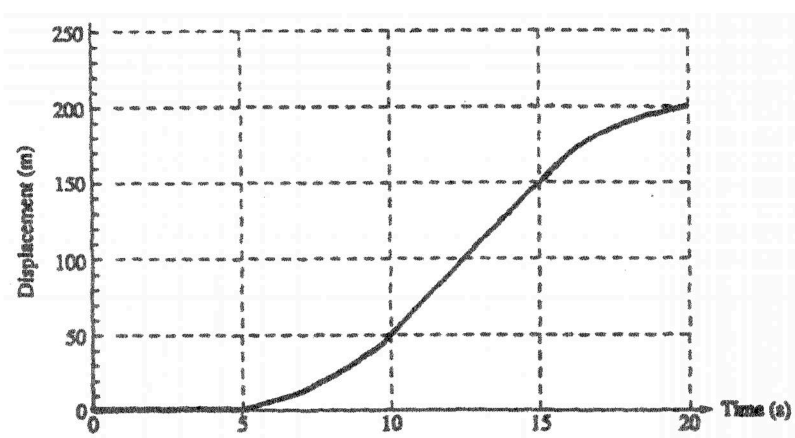
5 seconds: $x = 0 + (0)(5\ s) + ½\ (0)(5\ s)^2 = 0$

10 seconds: $x = 0 + (0)(5\ s) + ½\ (4\ m/s^2)(5\ s)^2 = 50\ m$

15 seconds: $x = 50\ m + (20\ m/s)(5\ s) + ½\ (0)(5\ s)^2 = 150\ m$

20 seconds: $x = 150\ m + (20\ m/s)(5\ s) + ½\ (–4\ m/s^2)(5\ s)^2 = 200\ m$

ii.

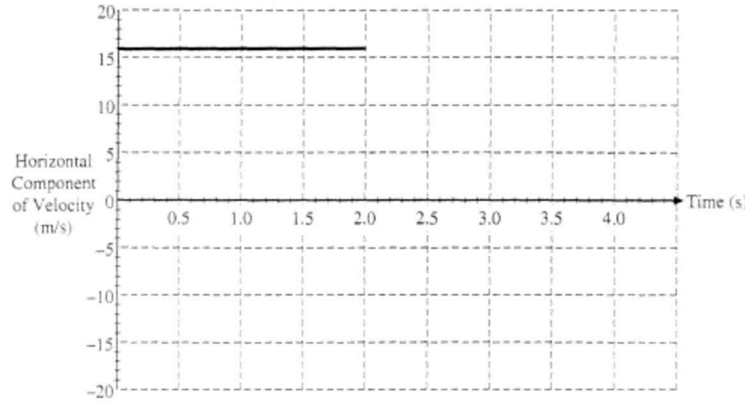


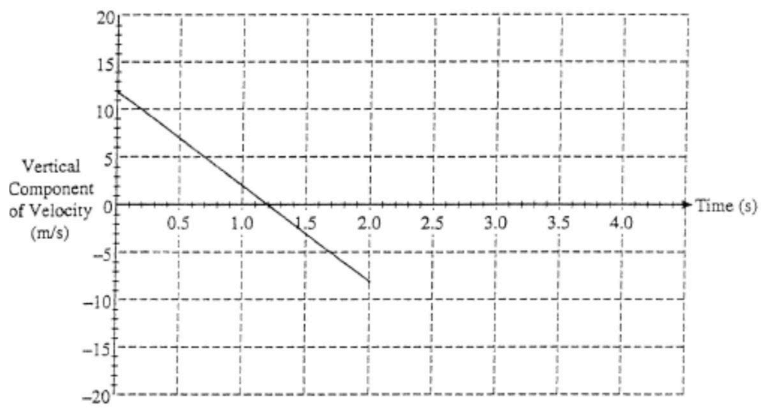
1994B1

a. The horizontal component of the velocity is constant so $v_x t = d$ where $v_x = v_0 \cos\theta = 16$ m/s
$t = d/v = 2$ s

b. The height of the ball during its flight is given by $y = v_{0y}t + \frac{1}{2}gt^2$ where $v_{0y} = v_0 \sin\theta = 12$ m/s and $g = -9.8$ m/s^2 which gives at $t = 2$ s, $y = 4.4$ m. The fence is 2.5 m high so the ball passes above the fence by 4.4 m – 2.5 m = 1.9 m

c.





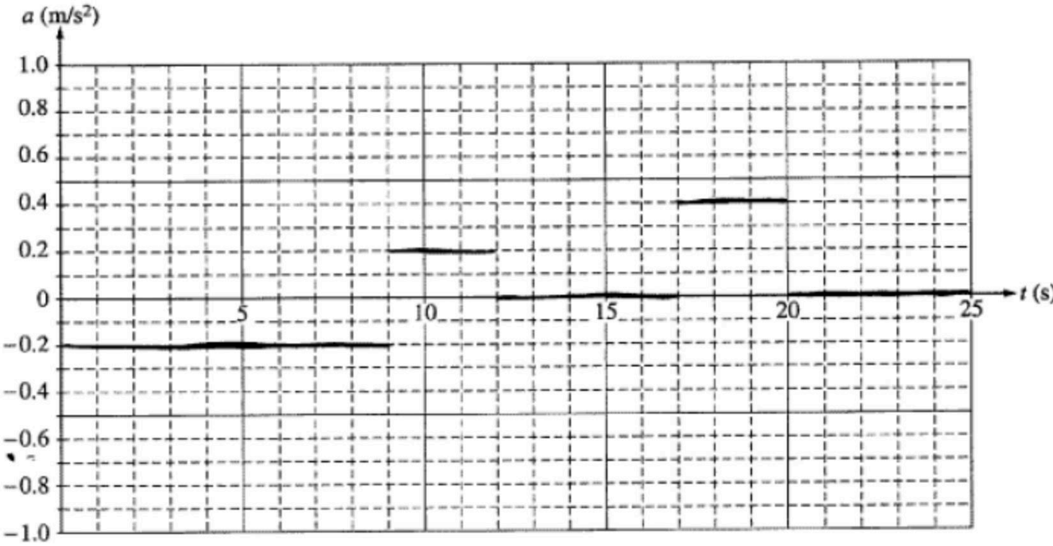
2000B1

a. The car is at rest where the line crosses the t axis. At t = 4 s and 18 s.

b. The speed of the cart increases when the line moves away from the t axis (larger values of v, positive or negative). This occurs during the intervals t = 4 to 9 seconds and t = 18 to 20 seconds.

c. The change in position is equal to the area under the graph. From 0 to 4 seconds the area is positive and from 4 to 9 seconds the area is negative. The total area is –0.9 m. Adding this to the initial position gives $x = x_0 + \Delta x = 2.0\text{ m} + (-0.9\text{ m}) = 1.1\text{ m}$

d.



e. i. $y = \frac{1}{2} gt^2$ ($v_{0y} = 0$ m/s) gives t = 0.28 seconds.
 ii. $x = v_x t = 0.22$ m

2002B1

a. $v_1 = v_0 + at = 60$ m/s

b. The height of the rocket when the engine stops firing $y_1 = \frac{1}{2} at^2 = 60$ m
To determine the extra height after the firing stops, use $v_f^2 = 0$ m/s $= v_1^2 + 2(-g)y_2$ giving $y_2 = 180$ m
total height $= y_1 + y_2 = 240$ m

c. To determine the time of travel from when the engine stops firing use $v_f = 0$ m/s $= v_1 + (-g)t_2$ giving $t_2 = 6$ s.
The total time is then 2 s + 6 s = 8 seconds

1979M1

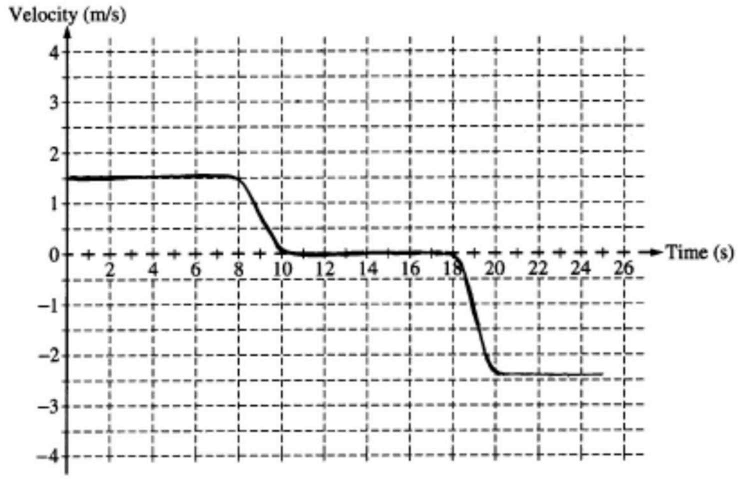
a. The speed after falling a height h is found from $v_f^2 = v_i^2 + 2gh$, where $v_i = 0$ m/s giving $v_f = \sqrt{2gh}$

b/c. During the flight from P_1 to P_2 the ball maintains a horizontal speed of $\sqrt{2gh}$ and travels a horizontal distance of $\frac{L}{\sqrt{2}}$ thus (using d = vt) we have $\frac{L}{\sqrt{2}} = \sqrt{2gh}\,t$. During the same time t the ball travels the same distance vertically given by $\frac{L}{\sqrt{2}} = \frac{1}{2}gt^2$. Setting these expressions equal gives us $\sqrt{2gh}\,t = \frac{1}{2}gt^2$. Solving for t and substituting into the expression of L gives $t = \sqrt{8h/g}$ $and\ L = 4\sqrt{2}h$

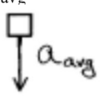
d. During the flight from P_1 to P_2 the ball maintains a horizontal speed of $\sqrt{2gh}$ and the vertical speed at P_2 can be found from $v_y = v_i + at$ where $v_i = 0$, a = g and t is the time found above. Once v_x and v_y are known the speed is $\sqrt{v_x^2 + v_y^2}$ giving $v = \sqrt{10gh}$

2005B1

a.

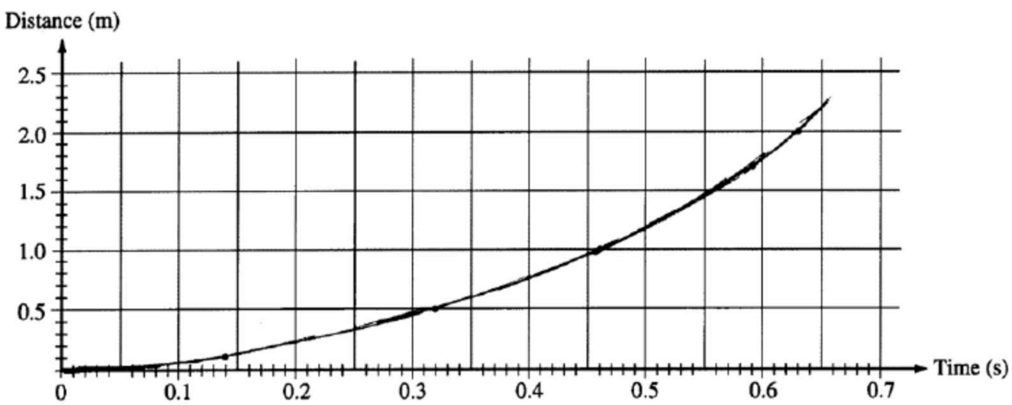


b. i. $a_{avg} = \Delta v/\Delta t = (0 - 1.5\text{ m/s})/(2\text{ s}) = -0.75\text{ m/s}^2$

ii. 

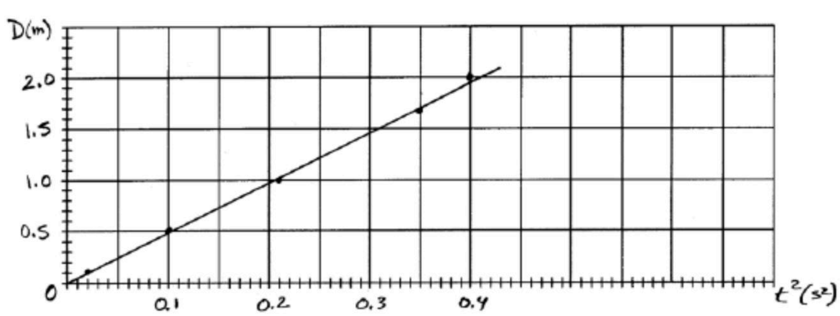
2006Bb1

a.



b. Distance and time are related by the equation $D = \frac{1}{2} gt^2$. To yield a straight line, the quantities that should be graphed are D and t^2 or $\sqrt{D}$ and t.

c.



d. The slope of the graph of D vs. t^2 is ½ g. The slope of the line shown is 4.9 m/s^2 giving g = 9.8 m/s^2

e. (example) Do several trials for each value of *D* and take averages. This reduces personal and random error.