
Summary

- You should that distance and speed are scalar quantities while displacement, velocity, and acceleration are vector quantities.
- The slope of a graph of displacement versus time is equal to the average velocity of the motion.
 - The slope of a graph of velocity versus time is equal to the average acceleration.
- The slope of the line tangent to a curve is equal to the instantaneous rate of change of that quantity.
- The area under a graph of velocity versus time is equal to the change in displacement.
- The value of the acceleration due to gravity (**g**) is a constant near the surface of Earth.

Practice Exercises

In each case, select the choice that best answers the question or completes the statement.

1. The speeds of an object at the ends of 4 successive seconds are 20, 25, 30, and 35 meters per second, respectively. The acceleration of this object is
 - (A) 5 m/s
 - (B) 5 m/s²

(C) 5 s/m^2

(D) 5 s/m

(E) 20 m/s

2. A bomb is dropped from an airplane moving horizontally with a speed of 200 kilometers per hour. If the air resistance is negligible, the bomb will reach the ground in 5 seconds when the altitude of the plane is approximately

(A) 50 m

(B) 75 m

(C) 125 m

(D) 250 m

(E) 300 m

3. While an arrow is being shot from a bow, it is accelerated over a distance of 2 meters. At the end of this acceleration it leaves the bow with a speed of 200 meters per second. The average acceleration imparted to the arrow is

(A) 200 m/s^2

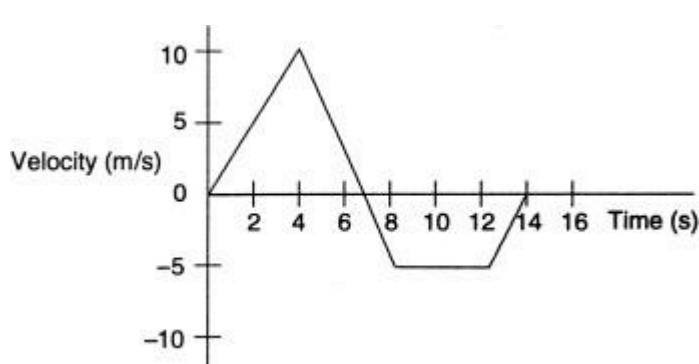
(B) 400 m/s^2

(C) 500 m/s^2

(D) $1,000 \text{ m/s}^2$

(E) $10,000 \text{ m/s}^2$

Questions 4–6 refer to the velocity versus time graph shown below.



4. The total distance traveled by the object during the indicated 14 seconds is

(A) 7.5 m

(B) 25 m

(C) 62.5 m

(D) 77.5 m

(E) 82.1 m

5. The total displacement of the object during the 14 seconds indicated is

(A) 7.5 m

(B) 25 m

(C) 62.5 m

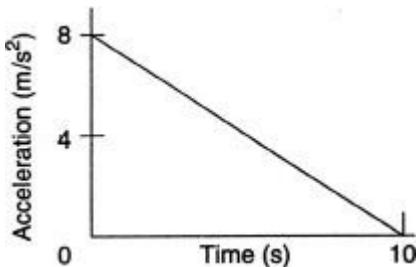
(D) 77.5 m

(E) 82.1 m

6. The average velocity, in meters per second, of the object is approximately equal to

- (A) 0
- (B) 0.5
- (C) 2.5
- (D) 4.5
- (E) 5.6

-
7. What is the total change in velocity for the object whose acceleration versus time graph is given below?



- (A) 40 m/s
- (B) -40 m/s
- (C) 80 m/s
- (D) -80 m/s
- (E) 0 m/s

8. On an unknown planet, an astronaut drops an object from rest. She observes that the object falls a distance of 10 meters during a time interval of 2 seconds. What is the magnitude of the acceleration due to gravity on that planet?

- (A) 30 m/s²
- (B) 25 m/s²
- (C) 15 m/s²
- (D) 10 m/s²
- (E) 5 m/s²

9. An object has an initial velocity of 15 meters per second. How long must it accelerate at a constant rate of 3 meters per second squared before its average velocity is equal to twice its initial velocity?

- (A) 5 s
- (B) 10 s
- (C) 15 s
- (D) 20 s
- (E) 25 s

10. A handball is tossed vertically upward with a velocity of 19.6 meters per

second. Approximately how high will it rise?

- (A) 15 m
- (B) 20 m
- (C) 25 m
- (D) 30 m
- (E) 60 m

Answer Key

- | | | |
|--------|--------|---------|
| 1. (B) | 5. (A) | 9. (B) |
| 2. (C) | 6. (B) | 10. (B) |
| 3. (E) | 7. (A) | |
| 4. (C) | 8. (E) | |

Answers Explained

1.
$$\text{B Acceleration} = \frac{\text{change in velocity}}{\text{time in which change takes place}}$$

$$= \frac{5 \text{ m/s}}{1 \text{ s}}$$
$$= \frac{5 \text{ m/s}}{\text{s}}$$

This means that each second the speed is changing 5 m/s.

2. C The horizontal velocity does not affect the vertical velocity. A suitable expression for free fall, since we know the time of falling and want to calculate the distance covered, is $d = \frac{1}{2}gt^2$. Here,

$$d = \frac{1}{2}(9.8 \text{ m/s}^2)(5 \text{ s})^2 = 123 \text{ m.}$$

3. E The arrow is accelerated from rest. Its final speed is 200 m/s; it is accelerated over a known distance, 2 m; $v^2 = 2ad$; $(200 \text{ m/s})^2 = 2a(2 \text{ m})$. Then

$$a = \frac{40,000}{4} = 10,000 \text{ m/s}^2.$$

The term *average acceleration* is used to take care of fluctuations; don't divide by 2.

4. C The total distance traveled by the object in 14 s is equal to the total area under the graph. Break the figure up into triangles and rectangles, and note that their areas add up to 62.5 m (recall that distance is a scalar).
5. A The total displacement of the object is the sum of the positive (forward) and negative (backward) areas, representing the fact that the object moves away from the origin and then back (as indicated by the velocity vs. time graph) going below the x -axis. Add and subtract the proper areas:

$$35 - 2.5 - 20 - 5 = 7.5 \text{ m}$$

- for the final displacement.
6. B Average velocity is the change in displacement for the object over the change in time (not distance). Since from question 5 you know the displacement change to be 7.5 m in 14 s, the average velocity is therefore 0.5 m/s.
7. A The change in velocity for the object is equal to the area under the graph:
 $\frac{1}{2} (+8)(10) = 40 \text{ m/s}$.
8. E We can use the formula $d = \frac{1}{2}gt^2$. A quick substitution shows a magnitude of $g = 5 \text{ m/s}^2$.
9. B For uniformly accelerated motion, the average velocity is

$$\bar{v} = \frac{v_f + v_i}{2}$$

- The question requires that the average velocity be equal to twice the initial velocity; thus, if the average velocity is 30 m/s, the final velocity attained must be 45 m/s. Now the question is: How long must the object accelerate from 15 m/s to achieve a speed of 45 m/s? A change in velocity of 30 m/s at a rate of 3 m/s^2 for 10 s is implied.
10. B This is a problem in motion with constant acceleration equal to 9.8 m/s^2 downward, in which the object has an initial velocity (19.6 m/s), but its final velocity at the moment in question is zero.

$$\begin{aligned} v_i^2 &= 2 gd \\ -(19.6 \text{ m/s})^2 &= 2(-9.8 \text{ m/s}^2)(s) \\ d &= 19.6 \text{ m} \end{aligned}$$

Problems & Exercises

2.1 Displacement

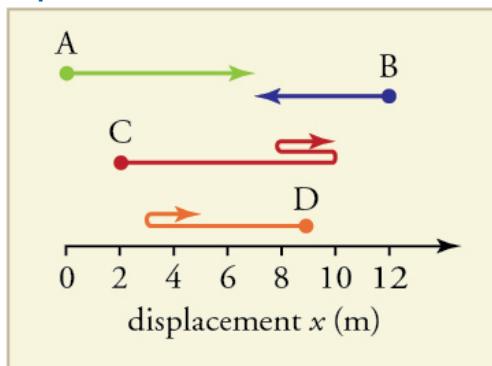


Figure 2.71

- Find the following for path A in **Figure 2.71**: (a) The distance traveled. (b) The magnitude of the displacement from start to finish. (c) The displacement from start to finish.
- Find the following for path B in **Figure 2.71**: (a) The distance traveled. (b) The magnitude of the displacement from start to finish. (c) The displacement from start to finish.
- Find the following for path C in **Figure 2.71**: (a) The distance traveled. (b) The magnitude of the displacement from start to finish. (c) The displacement from start to finish.
- Find the following for path D in **Figure 2.71**: (a) The distance traveled. (b) The magnitude of the displacement from start to finish. (c) The displacement from start to finish.

2.3 Time, Velocity, and Speed

- (a) Calculate Earth's average speed relative to the Sun. (b) What is its average velocity over a period of one year?
- A helicopter blade spins at exactly 100 revolutions per minute. Its tip is 5.00 m from the center of rotation. (a) Calculate the average speed of the blade tip in the helicopter's frame of reference. (b) What is its average velocity over one revolution?
- The North American and European continents are moving apart at a rate of about 3 cm/y. At this rate how long will it take them to drift 500 km farther apart than they are at present?
- Land west of the San Andreas fault in southern California is moving at an average velocity of about 6 cm/y northwest relative to land east of the fault. Los Angeles is west of the fault and may thus someday be at the same latitude as San Francisco, which is east of the fault. How far in the future will this occur if the displacement to be made is 590 km northwest, assuming the motion remains constant?
- On May 26, 1934, a streamlined, stainless steel diesel train called the Zephyr set the world's nonstop long-distance speed record for trains. Its run from Denver to Chicago took 13 hours, 4 minutes, 58 seconds, and was witnessed by more than a million people along the route. The total distance traveled was 1633.8 km. What was its average speed in km/h and m/s?
- Tidal friction is slowing the rotation of the Earth. As a result, the orbit of the Moon is increasing in radius at a rate of approximately 4 cm/year. Assuming this to be a constant rate, how many years will pass before the radius of the Moon's orbit increases by 3.84×10^6 m (1%)?

11. A student drove to the university from her home and noted that the odometer reading of her car increased by 12.0 km. The trip took 18.0 min. (a) What was her average speed? (b) If the straight-line distance from her home to the university is 10.3 km in a direction 25.0° south of east, what was her average velocity? (c) If she returned home by the same path 7 h 30 min after she left, what were her average speed and velocity for the entire trip?

12. The speed of propagation of the action potential (an electrical signal) in a nerve cell depends (inversely) on the diameter of the axon (nerve fiber). If the nerve cell connecting the spinal cord to your feet is 1.1 m long, and the nerve impulse speed is 18 m/s, how long does it take for the nerve signal to travel this distance?

13. Conversations with astronauts on the lunar surface were characterized by a kind of echo in which the earthbound person's voice was so loud in the astronaut's space helmet that it was picked up by the astronaut's microphone and transmitted back to Earth. It is reasonable to assume that the echo time equals the time necessary for the radio wave to travel from the Earth to the Moon and back (that is, neglecting any time delays in the electronic equipment). Calculate the distance from Earth to the Moon given that the echo time was 2.56 s and that radio waves travel at the speed of light (3.00×10^8 m/s).

14. A football quarterback runs 15.0 m straight down the playing field in 2.50 s. He is then hit and pushed 3.00 m straight backward in 1.75 s. He breaks the tackle and runs straight forward another 21.0 m in 5.20 s. Calculate his average velocity (a) for each of the three intervals and (b) for the entire motion.

15. The planetary model of the atom pictures electrons orbiting the atomic nucleus much as planets orbit the Sun. In this model you can view hydrogen, the simplest atom, as having a single electron in a circular orbit 1.06×10^{-10} m in diameter. (a) If the average speed of the electron in this orbit is known to be 2.20×10^6 m/s, calculate the number of revolutions per second it makes about the nucleus. (b) What is the electron's average velocity?

2.4 Acceleration

16. A cheetah can accelerate from rest to a speed of 30.0 m/s in 7.00 s. What is its acceleration?

17. Professional Application

Dr. John Paul Stapp was U.S. Air Force officer who studied the effects of extreme deceleration on the human body. On December 10, 1954, Stapp rode a rocket sled, accelerating from rest to a top speed of 282 m/s (1015 km/h) in 5.00 s, and was brought jarringly back to rest in only 1.40 s! Calculate his (a) acceleration and (b) deceleration. Express each in multiples of g (9.80 m/s^2) by taking its ratio to the acceleration of gravity.

18. A commuter backs her car out of her garage with an acceleration of 1.40 m/s^2 . (a) How long does it take her to reach a speed of 2.00 m/s? (b) If she then brakes to a stop in 0.800 s, what is her deceleration?

19. Assume that an intercontinental ballistic missile goes from rest to a suborbital speed of 6.50 km/s in 60.0 s (the actual speed and time are classified). What is its average acceleration in m/s^2 and in multiples of g (9.80 m/s^2)?

2.5 Motion Equations for Constant Acceleration in One Dimension

20. An Olympic-class sprinter starts a race with an acceleration of 4.50 m/s^2 . (a) What is her speed 2.40 s later? (b) Sketch a graph of her position vs. time for this period.

21. A well-thrown ball is caught in a well-padded mitt. If the deceleration of the ball is $2.10 \times 10^4 \text{ m/s}^2$, and 1.85 ms ($1 \text{ ms} = 10^{-3} \text{ s}$) elapses from the time the ball first touches the mitt until it stops, what was the initial velocity of the ball?

22. A bullet in a gun is accelerated from the firing chamber to the end of the barrel at an average rate of $6.20 \times 10^5 \text{ m/s}^2$ for $8.10 \times 10^{-4} \text{ s}$. What is its muzzle velocity (that is, its final velocity)?

23. (a) A light-rail commuter train accelerates at a rate of 1.35 m/s^2 . How long does it take to reach its top speed of 80.0 km/h, starting from rest? (b) The same train ordinarily decelerates at a rate of 1.65 m/s^2 . How long does it take to come to a stop from its top speed? (c) In emergencies the train can decelerate more rapidly, coming to rest from 80.0 km/h in 8.30 s. What is its emergency deceleration in m/s^2 ?

24. While entering a freeway, a car accelerates from rest at a rate of 2.40 m/s^2 for 12.0 s. (a) Draw a sketch of the situation. (b) List the knowns in this problem. (c) How far does the car travel in those 12.0 s? To solve this part, first identify the unknown, and then discuss how you chose the appropriate equation to solve for it. After choosing the equation, show your steps in solving for the unknown, check your units, and discuss whether the answer is reasonable. (d) What is the car's final velocity? Solve for this unknown in the same manner as in part (c), showing all steps explicitly.

25. At the end of a race, a runner decelerates from a velocity of 9.00 m/s at a rate of 2.00 m/s^2 . (a) How far does she travel in the next 5.00 s? (b) What is her final velocity? (c) Evaluate the result. Does it make sense?

26. Professional Application:

Blood is accelerated from rest to 30.0 cm/s in a distance of 1.80 cm by the left ventricle of the heart. (a) Make a sketch of the situation. (b) List the knowns in this problem. (c) How long does the acceleration take? To solve this part, first identify the unknown, and then discuss how you chose the appropriate equation to solve for it. After choosing the equation, show your steps in solving for the unknown, checking your units. (d) Is the answer reasonable when compared with the time for a heartbeat?

27. In a slap shot, a hockey player accelerates the puck from a velocity of 8.00 m/s to 40.0 m/s in the same direction. If this shot takes $3.33 \times 10^{-2} \text{ s}$, calculate the distance over which the puck accelerates.

28. A powerful motorcycle can accelerate from rest to 26.8 m/s (100 km/h) in only 3.90 s. (a) What is its average acceleration? (b) How far does it travel in that time?

29. Freight trains can produce only relatively small accelerations and decelerations. (a) What is the final velocity of a freight train that accelerates at a rate of 0.0500 m/s^2 for 8.00 min, starting with an initial velocity of 4.00 m/s? (b) If the train can slow down at a rate of 0.550 m/s^2 , how long will it take to come to a stop from this velocity? (c) How far will it travel in each case?

30. A fireworks shell is accelerated from rest to a velocity of 65.0 m/s over a distance of 0.250 m. (a) How long did the acceleration last? (b) Calculate the acceleration.

31. A swan on a lake gets airborne by flapping its wings and running on top of the water. (a) If the swan must reach a velocity of 6.00 m/s to take off and it accelerates from rest at an average rate of 0.350 m/s^2 , how far will it travel before becoming airborne? (b) How long does this take?

32. Professional Application:

A woodpecker's brain is specially protected from large decelerations by tendon-like attachments inside the skull. While pecking on a tree, the woodpecker's head comes to a stop from an initial velocity of 0.600 m/s in a distance of only 2.00 mm. (a) Find the acceleration in m/s^2 and in multiples of g ($g = 9.80 \text{ m/s}^2$). (b) Calculate the stopping time. (c)

The tendons cradling the brain stretch, making its stopping distance 4.50 mm (greater than the head and, hence, less deceleration of the brain). What is the brain's deceleration, expressed in multiples of g ?

33. An unwary football player collides with a padded goalpost while running at a velocity of 7.50 m/s and comes to a full stop after compressing the padding and his body 0.350 m. (a) What is his deceleration? (b) How long does the collision last?

34. In World War II, there were several reported cases of airmen who jumped from their flaming airplanes with no parachute to escape certain death. Some fell about 20,000 feet (6000 m), and some of them survived, with few life-threatening injuries. For these lucky pilots, the tree branches and snow drifts on the ground allowed their deceleration to be relatively small. If we assume that a pilot's speed upon impact was 123 mph (54 m/s), then what was his deceleration? Assume that the trees and snow stopped him over a distance of 3.0 m.

35. Consider a grey squirrel falling out of a tree to the ground. (a) If we ignore air resistance in this case (only for the sake of this problem), determine a squirrel's velocity just before hitting the ground, assuming it fell from a height of 3.0 m. (b) If the squirrel stops in a distance of 2.0 cm through bending its limbs, compare its deceleration with that of the airman in the previous problem.

36. An express train passes through a station. It enters with an initial velocity of 22.0 m/s and decelerates at a rate of 0.150 m/s^2 as it goes through. The station is 210 m long. (a) How long is the nose of the train in the station? (b) How fast is it going when the nose leaves the station? (c) If the train is 130 m long, when does the end of the train leave the station? (d) What is the velocity of the end of the train as it leaves?

37. Dragsters can actually reach a top speed of 145 m/s in only 4.45 s—considerably less time than given in **Example 2.10** and **Example 2.11**. (a) Calculate the average acceleration for such a dragster. (b) Find the final velocity of this dragster starting from rest and accelerating at the rate found in (a) for 402 m (a quarter mile) without using any information on time. (c) Why is the final velocity greater than that used to find the average acceleration? *Hint:* Consider whether the assumption of constant acceleration is valid for a dragster. If not, discuss whether the acceleration would be greater at the beginning or end of the run and what effect that would have on the final velocity.

38. A bicycle racer sprints at the end of a race to clinch a victory. The racer has an initial velocity of 11.5 m/s and accelerates at the rate of 0.500 m/s^2 for 7.00 s. (a) What is his final velocity? (b) The racer continues at this velocity to the finish line. If he was 300 m from the finish line when he started to accelerate, how much time did he save? (c) One other racer was 5.00 m ahead when the winner started to accelerate, but he was unable to accelerate, and traveled at 11.8 m/s until the finish line. How far ahead of him (in meters and in seconds) did the winner finish?

39. In 1967, New Zealander Burt Munro set the world record for an Indian motorcycle, on the Bonneville Salt Flats in Utah, with a maximum speed of 183.58 mi/h. The one-way course was 5.00 mi long. Acceleration rates are often described by the time it takes to reach 60.0 mi/h from rest. If this time was 4.00 s, and Burt accelerated at this rate until he reached his maximum speed, how long did it take Burt to complete the course?

40. (a) A world record was set for the men's 100-m dash in the 2008 Olympic Games in Beijing by Usain Bolt of Jamaica. Bolt "coasted" across the finish line with a time of 9.69 s. If we assume that Bolt accelerated for 3.00 s to reach his maximum speed, and maintained that speed for the rest of the race, calculate his maximum speed and his acceleration. (b) During the same Olympics, Bolt also set the world record in the 200-m dash with a time of 19.30 s. Using the same assumptions as for the 100-m dash, what was his maximum speed for this race?

2.7 Falling Objects

Assume air resistance is negligible unless otherwise stated.

41. Calculate the displacement and velocity at times of (a) 0.500, (b) 1.00, (c) 1.50, and (d) 2.00 s for a ball thrown straight up with an initial velocity of 15.0 m/s. Take the point of release to be $y_0 = 0$.

42. Calculate the displacement and velocity at times of (a) 0.500, (b) 1.00, (c) 1.50, (d) 2.00, and (e) 2.50 s for a rock thrown straight down with an initial velocity of 14.0 m/s from the Verrazano Narrows Bridge in New York City. The roadway of this bridge is 70.0 m above the water.

43. A basketball referee tosses the ball straight up for the starting tip-off. At what velocity must a basketball player leave the ground to rise 1.25 m above the floor in an attempt to get the ball?

44. A rescue helicopter is hovering over a person whose boat has sunk. One of the rescuers throws a life preserver straight down to the victim with an initial velocity of 1.40 m/s and observes that it takes 1.8 s to reach the water. (a) List the knowns in this problem. (b) How high above the water was the preserver released? Note that the downdraft of the helicopter reduces the effects of air resistance on the falling life preserver, so that an acceleration equal to that of gravity is reasonable.

45. A dolphin in an aquatic show jumps straight up out of the water at a velocity of 13.0 m/s. (a) List the knowns in this problem. (b) How high does his body rise above the water? To solve this part, first note that the final velocity is now a known and identify its value. Then identify the unknown, and discuss how you chose the appropriate equation to solve for it. After choosing the equation, show your steps in solving for the unknown, checking units, and discuss whether the answer is reasonable. (c) How long is the dolphin in the air? Neglect any effects due to his size or orientation.

46. A swimmer bounces straight up from a diving board and falls feet first into a pool. She starts with a velocity of 4.00 m/s, and her takeoff point is 1.80 m above the pool. (a) How long are her feet in the air? (b) What is her highest point above the board? (c) What is her velocity when her feet hit the water?

47. (a) Calculate the height of a cliff if it takes 2.35 s for a rock to hit the ground when it is thrown straight up from the cliff with an initial velocity of 8.00 m/s. (b) How long would it take to reach the ground if it is thrown straight down with the same speed?

48. A very strong, but inept, shot putter puts the shot straight up vertically with an initial velocity of 11.0 m/s. How long does he have to get out of the way if the shot was released at a height of 2.20 m, and he is 1.80 m tall?

49. You throw a ball straight up with an initial velocity of 15.0 m/s. It passes a tree branch on the way up at a height of 7.00 m. How much additional time will pass before the ball passes the tree branch on the way back down?

50. A kangaroo can jump over an object 2.50 m high. (a) Calculate its vertical speed when it leaves the ground. (b) How long is it in the air?

51. Standing at the base of one of the cliffs of Mt. Arapiles in Victoria, Australia, a hiker hears a rock break loose from a height of 105 m. He can't see the rock right away but then does, 1.50 s later. (a) How far above the hiker is the rock when he can see it? (b) How much time does he have to move before the rock hits his head?

52. An object is dropped from a height of 75.0 m above ground level. (a) Determine the distance traveled during the first second. (b) Determine the final velocity at which the object hits the ground. (c) Determine the distance traveled during the last second of motion before hitting the ground.

53. There is a 250-m-high cliff at Half Dome in Yosemite National Park in California. Suppose a boulder breaks loose from the top of this cliff. (a) How fast will it be going when it strikes the ground? (b) Assuming a reaction time of 0.300 s, how long will a tourist at the bottom have to get out of the way after hearing the sound of the rock breaking loose (neglecting the height of the tourist, which would become negligible anyway if hit)? The speed of sound is 335 m/s on this day.

54. A ball is thrown straight up. It passes a 2.00-m-high window 7.50 m off the ground on its path up and takes 1.30 s to go past the window. What was the ball's initial velocity?

55. Suppose you drop a rock into a dark well and, using precision equipment, you measure the time for the sound of a splash to return. (a) Neglecting the time required for sound to travel up the well, calculate the distance to the water if the sound returns in 2.0000 s. (b) Now calculate the distance taking into account the time for sound to travel up the well. The speed of sound is 332.00 m/s in this well.

56. A steel ball is dropped onto a hard floor from a height of 1.50 m and rebounds to a height of 1.45 m. (a) Calculate its velocity just before it strikes the floor. (b) Calculate its velocity just after it leaves the floor on its way back up. (c) Calculate its acceleration during contact with the floor if that contact lasts 0.0800 ms ($8.00 \times 10^{-5}\text{ s}$). (d) How much did the ball compress during its collision with the floor, assuming the floor is absolutely rigid?

57. A coin is dropped from a hot-air balloon that is 300 m above the ground and rising at 10.0 m/s upward. For the coin, find (a) the maximum height reached, (b) its position and velocity 4.00 s after being released, and (c) the time before it hits the ground.

58. A soft tennis ball is dropped onto a hard floor from a height of 1.50 m and rebounds to a height of 1.10 m. (a) Calculate its velocity just before it strikes the floor. (b) Calculate its velocity just after it leaves the floor on its way back up. (c) Calculate its acceleration during contact with the floor if that contact lasts 3.50 ms ($3.50 \times 10^{-3}\text{ s}$). (d) How much did the ball compress during its collision with the floor, assuming the floor is absolutely rigid?

2.8 Graphical Analysis of One Dimensional Motion

Note: There is always uncertainty in numbers taken from graphs. If your answers differ from expected values, examine them to see if they are within data extraction uncertainties estimated by you.

59. (a) By taking the slope of the curve in **Figure 2.72**, verify that the velocity of the jet car is 115 m/s at $t = 20\text{ s}$. (b) By taking the slope of the curve at any point in **Figure 2.73**, verify that the jet car's acceleration is 5.0 m/s^2 .

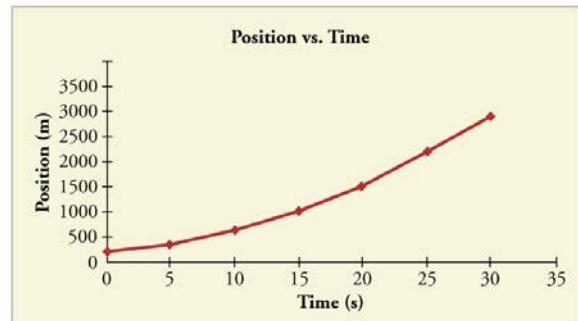


Figure 2.72

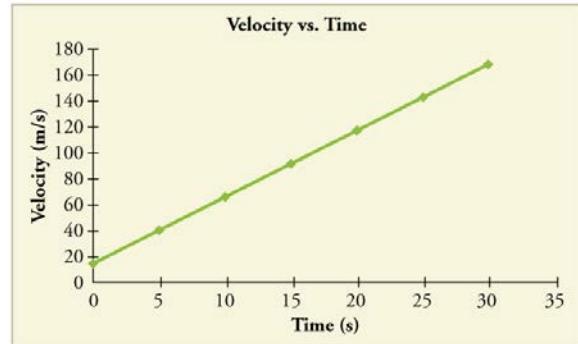


Figure 2.73

60. Using approximate values, calculate the slope of the curve in **Figure 2.74** to verify that the velocity at $t = 10.0\text{ s}$ is 0.208 m/s . Assume all values are known to 3 significant figures.

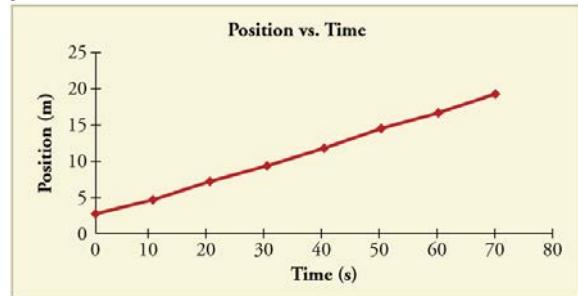


Figure 2.74

61. Using approximate values, calculate the slope of the curve in **Figure 2.74** to verify that the velocity at $t = 30.0\text{ s}$ is 0.238 m/s . Assume all values are known to 3 significant figures.

- 62.** By taking the slope of the curve in **Figure 2.75**, verify that the acceleration is approximately 3.2 m/s^2 at $t = 10 \text{ s}$.

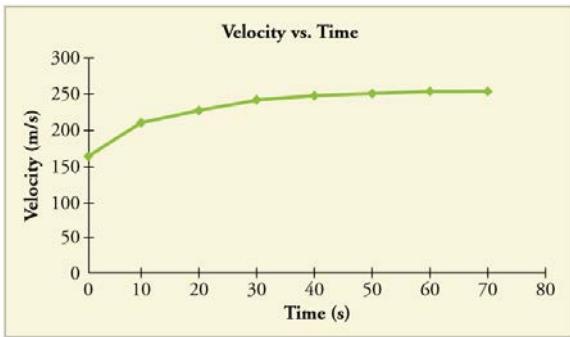


Figure 2.75

- 63.** Construct the displacement graph for the subway shuttle train as shown in **Figure 2.30(a)**. Your graph should show the position of the train, in kilometers, from $t = 0$ to 20 s . You will need to use the information on acceleration and velocity given in the examples for this figure.

- 64.** (a) Take the slope of the curve in **Figure 2.76** to find the jogger's velocity at $t = 2.5 \text{ s}$. (b) Repeat at 7.5 s . These values must be consistent with the graph in **Figure 2.77**.

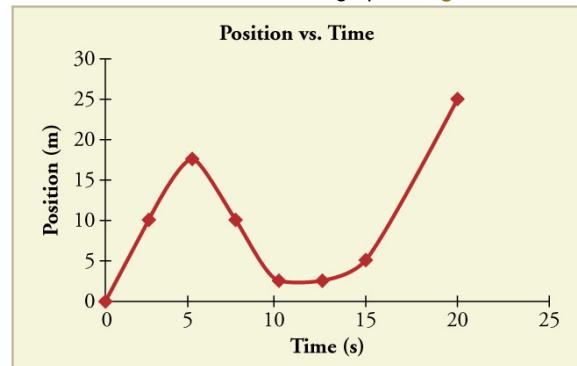


Figure 2.76

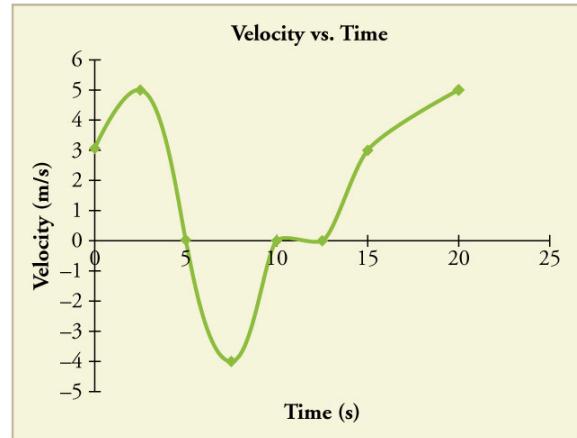


Figure 2.77

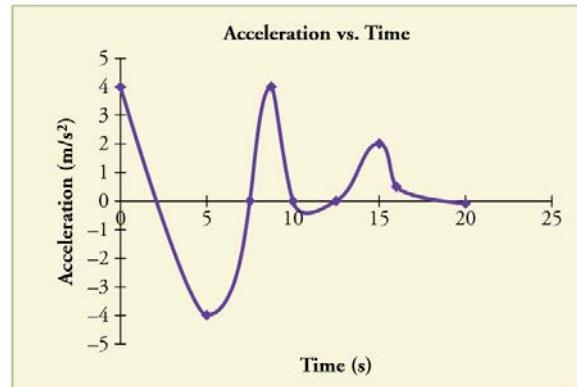


Figure 2.78

- 65.** A graph of $v(t)$ is shown for a world-class track sprinter in a 100-m race. (See **Figure 2.79**). (a) What is his average velocity for the first 4 s? (b) What is his instantaneous velocity at $t = 5$ s? (c) What is his average acceleration between 0 and 4 s? (d) What is his time for the race?

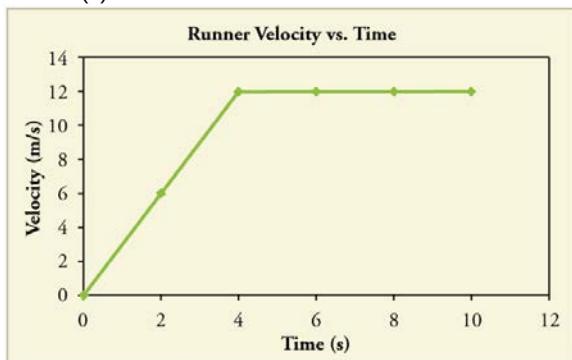


Figure 2.79

- 66.** **Figure 2.80** shows the displacement graph for a particle for 5 s. Draw the corresponding velocity and acceleration graphs.

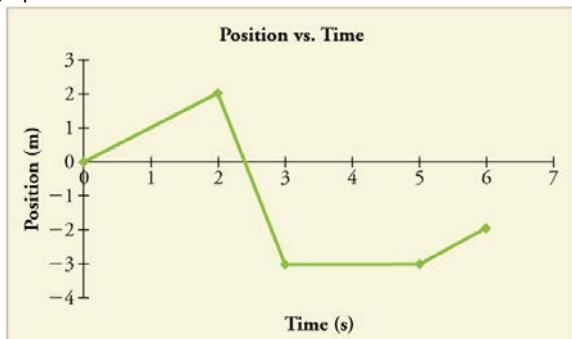


Figure 2.80

Test Prep for AP® Courses

2.1 Displacement

1. Which of the following statements comparing position, distance, and displacement is correct?
- An object may record a distance of zero while recording a non-zero displacement.
 - An object may record a non-zero distance while recording a displacement of zero.
 - An object may record a non-zero distance while maintaining a position of zero.
 - An object may record a non-zero displacement while maintaining a position of zero.

2.2 Vectors, Scalars, and Coordinate Systems

2. A student is trying to determine the acceleration of a feather as she drops it to the ground. If the student is looking to achieve a positive velocity and positive acceleration, what is the most sensible way to set up her coordinate system?

- Her hand should be a coordinate of zero and the upward direction should be considered positive.
- Her hand should be a coordinate of zero and the downward direction should be considered positive.
- The floor should be a coordinate of zero and the upward direction should be considered positive.
- The floor should be a coordinate of zero and the downward direction should be considered positive.

2.3 Time, Velocity, and Speed

3. A group of students has two carts, *A* and *B*, with wheels that turn with negligible friction. The two carts travel along a straight horizontal track and eventually collide. Before the collision, cart *A* travels to the right and cart *B* is initially at rest. After the collision, the carts stick together.

- a. Describe an experimental procedure to determine the velocities of the carts before and after the collision, including all the additional equipment you would need. You may include a labeled diagram of your setup to help in your description. Indicate what measurements you would take and how you would take them. Include enough detail so that another student could carry out your procedure.
- b. There will be sources of error in the measurements taken in the experiment both before and after the collision. Which velocity will be more greatly affected by this error: the velocity prior to the collision or the velocity after the collision? Or will both sets of data be affected equally? Justify your answer.

respect to time.

Position (cm)	Time (s)
0.0	0.0
0.3	0.5
1.25	1.0
2.8	1.5
5.0	2.0
7.75	2.5
11.3	3.0

2.4 Acceleration

4.

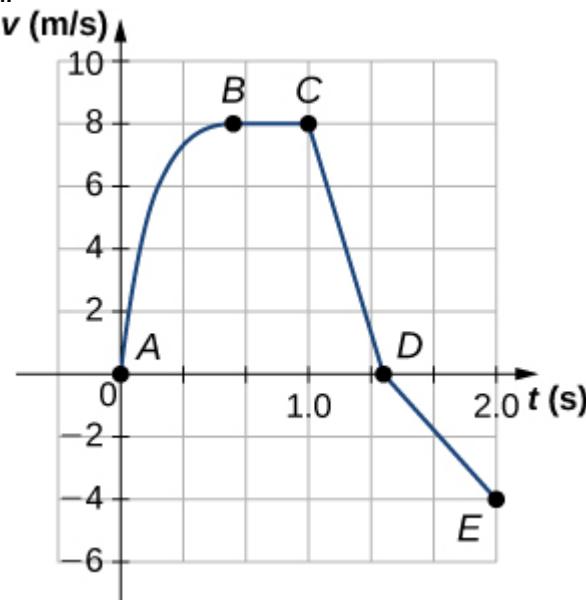


Figure 2.81 Graph showing Velocity vs. Time of a cart. A cart is constrained to move along a straight line. A varying net force along the direction of motion is exerted on the cart. The cart's velocity v as a function of time t is shown in the graph. The five labeled points divide the graph into four sections.

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. $a_{CD} > a_{AB} > a_{DE} > a_{BC}$

5. Push a book across a table and observe it slow to a stop.

Draw graphs showing the book's position vs. time and velocity vs. time if the direction of its motion is considered positive.

Draw graphs showing the book's position vs. time and velocity vs. time if the direction of its motion is considered negative.

Use the data table above to construct a graph determining the acceleration of the marble. Select a set of data points from the table and plot those points on the graph. Fill in the blank column in the table for any quantities you graph other than the given data. Label the axes and indicate the scale for each. Draw a best-fit line or curve through your data points.

Using the best-fit line, determine the value of the marble's acceleration.

2.7 Falling Objects

7. Observing a spacecraft land on a distant asteroid, scientists notice that the craft is falling at a rate of 5 m/s. When it is 100 m closer to the surface of the asteroid, the craft reports a velocity of 8 m/s. According to their data, what is the approximate gravitational acceleration on this asteroid?
- a. 0 m/s^2
 b. 0.03 m/s^2
 c. 0.20 m/s^2
 d. 0.65 m/s^2
 e. 33 m/s^2

2.5 Motion Equations for Constant Acceleration in One Dimension

6. A group of students is attempting to determine the average acceleration of a marble released from the top of a long ramp. Below is a set of data representing the marble's position with

Chapter 2

Problems & Exercises

1

- (a) 7 m
- (b) 7 m
- (c) +7 m

3

- (a) 13 m
- (b) 9 m
- (c) +9 m

5

- (a) 3.0×10^4 m/s
- (b) 0 m/s

7

2×10^7 years

9

$34.689 \text{ m/s} = 124.88 \text{ km/h}$

11

- (a) 40.0 km/h
- (b) 34.3 km/h, 25° S of E.
- (c) average speed = 3.20 km/h, $\bar{v} = 0$.

13

384,000 km

15

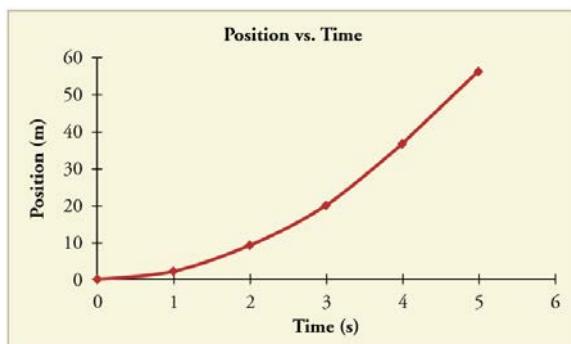
- (a) 6.61×10^{15} rev/s
- (b) 0 m/s

16

4.29 m/s^2

18

- (a) 1.43 s
 - (b) -2.50 m/s^2
- 20**
- (a) 10.8 m/s
 - (b)

**Figure 2.48.****21**

38.9 m/s (about 87 miles per hour)

23

(a) 16.5 s

(b) 13.5 s

(c) -2.68 m/s^2 **25**

(a) 20.0 m

(b) -1.00 m/s (c) This result does not really make sense. If the runner starts at 9.00 m/s and decelerates at 2.00 m/s^2 , then she will have stopped after 4.50 s. If she continues to decelerate, she will be running backwards.**27**

0.799 m

29

(a) 28.0 m/s

(b) 50.9 s

(c) 7.68 km to accelerate and 713 m to decelerate

31

(a) 51.4 m

(b) 17.1 s

33(a) -80.4 m/s^2 (b) $9.33 \times 10^{-2} \text{ s}$ **35**

(a) 7.7 m/s

(b) $-15 \times 10^2 \text{ m/s}^2$. This is about 3 times the deceleration of the pilots, who were falling from thousands of meters high!**37**(a) 32.6 m/s^2

(b) 162 m/s

(c) $v > v_{\max}$, because the assumption of constant acceleration is not valid for a dragster. A dragster changes gears, and would have a greater acceleration in first gear than second gear than third gear, etc. The acceleration would be

greatest at the beginning, so it would not be accelerating at 32.6 m/s^2 during the last few meters, but substantially less, and the final velocity would be less than 162 m/s.

39

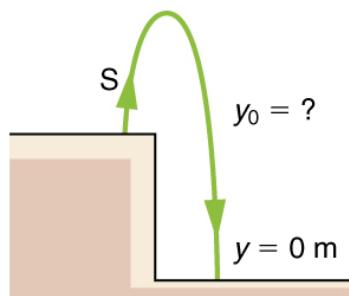
104 s

40(a) $v = 12.2 \text{ m/s}$; $a = 4.07 \text{ m/s}^2$ (b) $v = 11.2 \text{ m/s}$ **41**(a) $y_1 = 6.28 \text{ m}$; $v_1 = 10.1 \text{ m/s}$ (b) $y_2 = 10.1 \text{ m}$; $v_2 = 5.20 \text{ m/s}$ (c) $y_3 = 11.5 \text{ m}$; $v_3 = 0.300 \text{ m/s}$ (d) $y_4 = 10.4 \text{ m}$; $v_4 = -4.60 \text{ m/s}$ **43** $v_0 = 4.95 \text{ m/s}$ **45**(a) $a = -9.80 \text{ m/s}^2$; $v_0 = 13.0 \text{ m/s}$; $y_0 = 0 \text{ m}$ (b) $v = 0 \text{ m/s}$. Unknown is distance y to top of trajectory, where velocity is zero. Use equation $v^2 = v_0^2 + 2a(y - y_0)$ because it contains all known values except for y , so we can solve for y . Solving for y gives

$$\begin{aligned} v^2 - v_0^2 &= 2a(y - y_0) \\ \frac{v^2 - v_0^2}{2a} &= y - y_0 \\ y &= y_0 + \frac{v^2 - v_0^2}{2a} = 0 \text{ m} + \frac{(0 \text{ m/s})^2 - (13.0 \text{ m/s})^2}{2(-9.80 \text{ m/s}^2)} = 8.62 \text{ m} \end{aligned} \tag{2.100}$$

Dolphins measure about 2 meters long and can jump several times their length out of the water, so this is a reasonable result.

(c) 2.65 s

47**Figure 2.57.**

(a) 8.26 m

(b) 0.717 s

49

1.91 s

51

(a) 94.0 m

(b) 3.13 s

53

- (a) -70.0 m/s (downward)
 (b) 6.10 s

55

- (a) 19.6 m
 (b) 18.5 m

57

- (a) 305 m
 (b) 262 m, -29.2 m/s
 (c) 8.91 s

59

- (a) 115 m/s
 (b) 5.0 m/s^2

61

$$v = \frac{(11.7 - 6.95) \times 10^3 \text{ m}}{(40.0 - 20.0) \text{ s}} = 238 \text{ m/s}$$

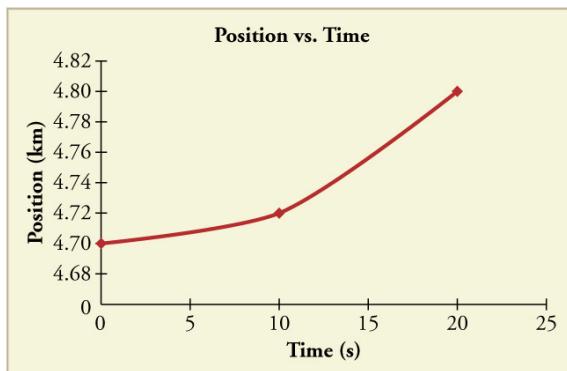
63

Figure 2.63.

65

- (a) 6 m/s
 (b) 12 m/s
 (c) 3 m/s^2
 (d) 10 s

Test Prep for AP® Courses

1

(b)

3

- Use tape to mark off two distances on the track — one for cart A before the collision and one for the combined carts after the collision. Push cart A to give it an initial speed. Use a stopwatch to measure the time it takes for the cart(s) to cross the marked distances. The speeds are the distances divided by the times.
- If the measurement errors are of the same magnitude, they will have a greater effect after the collision. The speed of the combined carts will be less than the initial speed of cart A. As a result, these errors will be a greater percentage of the actual velocity value after the collision occurs. (Note: Other arguments could properly be made for 'more error before the collision' and error that 'equally affects both sets of measurement'.)

5

The position vs. time graph should be represented with a positively sloped line whose slope steadily decreases to zero. The y-intercept of the graph may be any value. The line on the velocity vs. time graph should have a positive

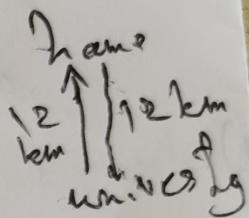
1-D Kinematics:

Problems and Exercises Solutions.

$$11/ \bar{v} = \frac{\text{Distance}}{\text{Time}} = \frac{12}{\frac{18}{60}} = 40 \text{ km/h}$$

$$12/ \bar{v} = \frac{\text{Displacement}}{\text{Time}} = \frac{\Delta x}{\Delta t} = \frac{18.3}{\frac{18}{60}} = 34.3 \text{ km/h}$$

$$13/ \bar{v} = \frac{12.2}{7.5} = \frac{24}{7.5} = 3.2 \text{ km/h}$$



$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{0}{\Delta t} = 0$$

$$14/ \lambda = \frac{d}{s} = \frac{1.1}{18} = 0.06 \text{ D}$$

$$15/ t_{\text{trip}} = 2.56 \text{ s}; t_{\text{Moon-Earth}} = \frac{2.56}{2} = 1.28$$

$$d = 5 \cdot t_{\text{Moon-Earth}} = 3 \cdot 10^8 \cdot 1.28 = 384000000 \text{ m}$$

$$16/ \text{Circumference} = 2\pi r = 2\pi \frac{d}{2} = 3.3 \cdot 10^{-10}$$

~~Number rev/D~~ = ~~Number rev/D~~ = $\frac{\text{Speed}}{\text{Circumference}} = 6.5 \cdot 10^5$

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{0}{\Delta t} = 0$$

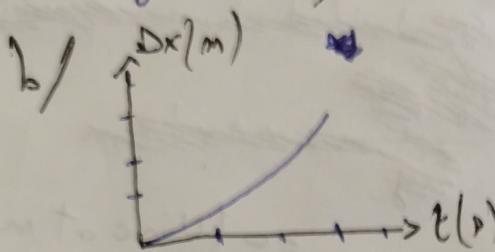
$$17/ a = \frac{\Delta v}{\Delta t} = \frac{30}{4} = 7.5 \text{ m/s}^2$$

(1)

$$18/01 \quad v_f - v_i = at \rightarrow t = \frac{v_f - v_i}{a} = \frac{2}{1.6} = 1.25 \text{ s}$$

$$b/ \frac{v_i}{a} = \frac{v_f - v_i}{t} = \frac{-2}{0.8} = -2.5 \text{ m/s}^2$$

$$20/01 \quad v_f = v_i + at = 4.5 + 2.4 = 10.8 \text{ m/s}$$



$$\Delta x = \frac{1}{2} a t^2 \quad (v_i = 0)$$

$$\Delta x(1\text{s}) = \frac{1}{2} a \cdot 1^2$$

$$\Delta x(2\text{s}) = \frac{1}{2} a \cdot 2^2$$

$$21/01 \quad v_f - v_i = at \rightarrow v_i = -at = -(-2.1 \cdot 10^4) \cdot 185 \cdot 10^{-3}$$

~~v_i~~ $v_i = 38.9 \text{ m/s}$

$$23/01 / t = \frac{v_f - v_i}{a} = \frac{80 \cdot 10^3}{3600} = 16.5 \text{ s}$$

$$b/ \frac{v_i}{t} = \frac{v_f - v_i}{a} = \frac{-22.23}{-1.65} = 13.5 \text{ s}$$

$$c/ \frac{v_i}{a} = \frac{v_f - v_i}{t} = \frac{-22.23}{8.3} = -2.68 \text{ m/s}^2$$

$$47/01 \quad \Delta x = v_i t + \frac{1}{2} a t^2 = v_i t - \frac{1}{2} g t^2 = -8.96$$

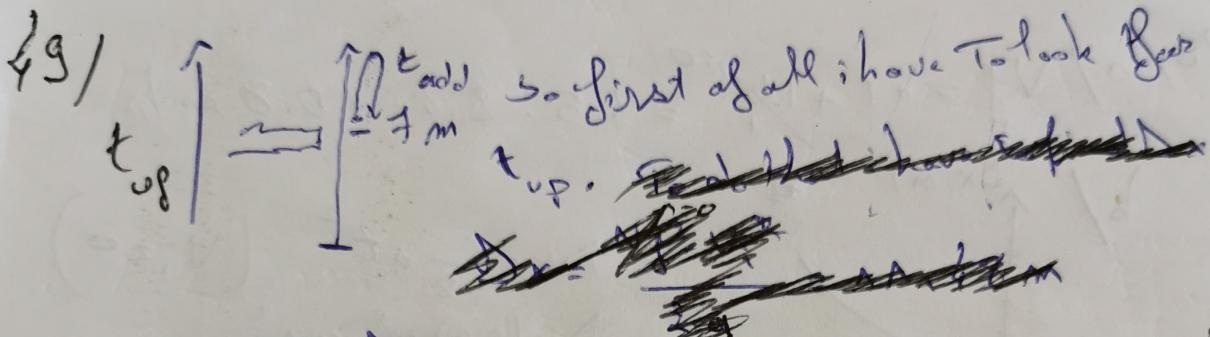
→ height = 8.26 m.

We have to look for the v_f just before it hits the ground

$$v_f^2 = v_i^2 + 2ad \rightarrow v_f = \sqrt{v_i^2 + 2g \cdot \Delta x} = 15 \text{ m/s}$$

~~$$t = \frac{Dx}{\bar{v}}$$~~ with $\bar{v} = \frac{V_i + V_f}{2} = 11.5 \text{ m/s}$

$$t = \frac{8.26}{11.5} = 0.71 \text{ s}$$



~~$$V_f = V_i + at$$~~
$$= 0 (\text{at boot max height})$$

$$V_f - V_i = at \rightarrow t_{up} = \frac{V_f - V_i}{g} = 1.53 \text{ s}$$

$$t_{f,m} = \frac{Dx}{\bar{v}} \text{ with } \bar{v} = \frac{V_f + V_i}{2}$$

$$V_f = \sqrt{V_i^2 + 2 \cdot g \cdot Dx} = \sqrt{V_i^2 - 2gDx} = \sqrt{15^2 - 2 \cdot 9.8 \cdot 7} = 9.37 \text{ m/s}$$

$$\rightarrow \bar{v} = \frac{9.37 + 15}{2} = 12.185 \text{ m/s}$$

$$\rightarrow t_{f,m} = \frac{7}{12.185} = 0.57$$

$$t_{add} = (t_{up} - t_{f,m}) \cdot 2 = 1.92 \text{ s}$$