KEY TERMS

acceleration due to gravity acceleration of an object that is subject only to the force of gravity; near Earth's surface this acceleration is 9.80 m/s^2

average acceleration change in velocity divided by the time interval over which it changed

constant acceleration acceleration that does not change with respect to time

instantaneous acceleration rate of change of velocity at a specific instant in time

kinematic equations the five equations that describe motion in terms of time, displacement, velocity, and acceleration

negative acceleration acceleration in the negative direction

SECTION SUMMARY

3.1 Acceleration

- Acceleration is the rate of change of velocity and may be negative or positive.
- Average acceleration is expressed in m/s^2 and, in one dimension, can be calculated using $\overline{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_o}$.

3.2 Representing Acceleration with Equations and Graphs

- The kinematic equations show how time, displacement, velocity, and acceleration are related for objects in motion.
- In general, kinematic problems can be solved by identifying the kinematic equation that expresses the unknown in terms of the knowns.
- Displacement, velocity, and acceleration may be displayed graphically versus time.

KEY EQUATIONS

3.1 Acceleration

Average acceleration	$\overline{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_o}$

3.2 Representing Acceleration with Equations and Graphs

Average velocity	$d = d_0 + \overline{v}t$, or $\overline{v} = \frac{d}{t}$ when $d_o = 0$
Average velocity	$\overline{v} = \frac{v_0 + v_f}{2}$
Velocity	$v = v_0 + at$, or when $v_o = 0$
Displacement	$d = d_0 + v_0 t + \frac{1}{2}at^2$, or $a = \frac{2d}{t^2}$ when $d_o = 0$ and $v_o = 0$
Acceleration	$v^2 = v_0^2 + 2a(d - d_0)$, or $a = \frac{v^2}{2d}$ when $d_o = 0$ and $v_o = 0$

CHAPTER REVIEW

Concept Items

3.1 Acceleration

1. How can you use the definition of acceleration to explain the units in which acceleration is measured?
   a. Acceleration is the rate of change of velocity. Therefore, its unit is m/s^2.
   b. Acceleration is the rate of change of displacement. Therefore, its unit is m/s.
   c. Acceleration is the rate of change of velocity. Therefore, its unit is m^2/s.
   d. Acceleration is the rate of change of displacement. Therefore, its unit is m^2/s.

2. What are the SI units of acceleration?
   a. m^2/s
   b. cm^2/s
   c. m/s^2
   d. cm/s^2

3. Which of the following statements explains why a racecar going around a curve is accelerating, even if the speed is constant?
   a. The car is accelerating because the magnitude as well as the direction of velocity is changing.
   b. The car is accelerating because the magnitude of velocity is changing.
   c. The car is accelerating because the direction of velocity is changing.

d. The car is accelerating because neither the magnitude nor the direction of velocity is changing.

3.2 Representing Acceleration with Equations and Graphs

4. A student calculated the final velocity of a train that decelerated from 30.5 m/s and got an answer of −43.34 m/s. Which of the following might indicate that he made a mistake in his calculation?

a. The sign of the final velocity is wrong.
b. The magnitude of the answer is too small.
c. There are too few significant digits in the answer.
d. The units in the initial velocity are incorrect.

5. Create your own kinematics problem. Then, create a flow chart showing the steps someone would need to take to solve the problem.

a. Acceleration
b. Distance
c. Displacement
d. Force

6. Which kinematic equation would you use to find the velocity of a skydiver 2.0 s after she jumps from a plane and before she opens her parachute? Assume the positive direction is downward.

a. $v = v_0 + at$
b. $v = v_0 - at$
c. $v^2 = {v_0}^2 + at$
d. $v^2 = {v_0}^2 - at$

Critical Thinking Items

3.1 Acceleration

7. Imagine that a car is traveling from your left to your right at a constant velocity. Which two actions could the driver take that may be represented as (a) a velocity vector and an acceleration vector both pointing to the right and then (b) changing so the velocity vector points to the right and the acceleration vector points to the left?

a. (a) Push down on the accelerator and then (b) push down again on the accelerator a second time.
b. (a) Push down on the accelerator and then (b) push down on the brakes.
c. (a) Push down on the brakes and then (b) push down on the brakes a second time.
d. (a) Push down on the brakes and then (b) push down on the accelerator.

8. A motorcycle moving at a constant velocity suddenly accelerates at a rate of $4.0\ \text{m/s}^2$ to a speed of 35 m/s in 5.0 s. What was the initial speed of the motorcycle?

a. −34 m/s
b. −15 m/s
c. 15 m/s
d. 34 m/s

3.2 Representing Acceleration with Equations and Graphs

9. A student is asked to solve a problem:
An object falls from a height for 2.0 s, at which point it is still 60 m above the ground. What will be the velocity of the object when it hits the ground?
Which of the following provides the correct order of kinematic equations that can be used to solve the problem?

a. First use $v^2 = {v_0}^2 + 2a(d - d_0)$, then use $v = v_0 + at$.
b. First use $v = v_0 + at$, then use $v^2 = {v_0}^2 + 2a(d - d_0)$.
c. First use $d = d_0 + v_0 t + \frac{1}{2}at^2$, then use $v = v_0 + at$.
d. First use $v = v_0 + at$, then use $d - d_0 = v_0 t + \frac{1}{2}at^2$.

10. Skydivers are affected by acceleration due to gravity and by air resistance. Eventually, they reach a speed where the force of gravity is almost equal to the force of air resistance. As they approach that point, their acceleration decreases in magnitude to near zero.
Part A. Describe the shape of the graph of the magnitude of the acceleration versus time for a falling skydiver.
Part B. Describe the shape of the graph of the magnitude of the velocity versus time for a falling skydiver.
Part C. Describe the shape of the graph of the magnitude of the displacement versus time for a falling skydiver.

a. Part A. Begins with a nonzero y-intercept with a downward slope that levels off at zero; Part B. Begins at zero with an upward slope that decreases in magnitude until the curve levels off; Part C. Begins at zero with an upward slope that increases in magnitude until it becomes a positive constant
b. Part A. Begins with a nonzero y-intercept with an upward slope that levels off at zero; Part B. Begins at zero with an upward slope that decreases in magnitude until the curve levels off; Part C. Begins at zero with an upward slope that increases in magnitude until it becomes a positive constant
c. Part A. Begins with a nonzero y-intercept with a downward slope that levels off at zero; Part B. Begins at zero with a downward slope that

decreases in magnitude until the curve levels off; Part C. Begins at zero with an upward slope that increases in magnitude until it becomes a positive constant

d. Part A. Begins with a nonzero y-intercept with an upward slope that levels off at zero; Part B. Begins at zero with a downward slope that decreases in magnitude until the curve levels off; Part C. Begins at zero with an upward slope that increases in magnitude until it becomes a positive constant

11. Which graph in the previous problem has a positive slope?

a. Displacement versus time only
b. Acceleration versus time and velocity versus time
c. Velocity versus time and displacement versus time
d. Acceleration versus time and displacement versus time

Problems

3.1 Acceleration

12. The driver of a sports car traveling at 10.0 m/s steps down hard on the accelerator for 5.0 s and the velocity increases to 30.0 m/s. What was the average acceleration of the car during the 5.0 s time interval?

a. $-1.0 \times 102\ m/s^2$
b. $-4.0\ m/s^2$
c. $4.0\ m/s^2$
d. $1.0 \times 102\ m/s^2$

13. A girl rolls a basketball across a basketball court. The ball slowly decelerates at a rate of $-0.20\ m/s^2$. If the initial velocity was 2.0 m/s and the ball rolled to a stop at 5.0 sec after 12:00 p.m., at what time did she start the ball rolling?

a. 0.1 seconds before noon
b. 0.1 seconds after noon
c. 5 seconds before noon
d. 5 seconds after noon

3.2 Representing Acceleration with Equations and Graphs

14. A swan on a lake gets airborne by flapping its wings and running on top of the water. 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?

a. −8.60 m
b. 8.60 m
c. −51.4 m
d. 51.4 m

15. 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 8 m above the pool. How long are her feet in the air?

a. 0.408 s
b. 0.816 s
c. 1.34 s
d. 1.75 s
e. 1.28 s

Performance Task

3.2 Representing Acceleration with Equations and Graphs

16. Design an experiment to measure displacement and elapsed time. Use the data to calculate final velocity, average velocity, acceleration, and acceleration.

Materials

- a small marble or ball bearing
- a garden hose
- a measuring tape
- a stopwatch or stopwatch software download
- a sloping driveway or lawn as long as the garden hose with a level area beyond

(a) How would you use the garden hose, stopwatch, marble, measuring tape, and slope to measure displacement and elapsed time? Hint—The marble is the accelerating object, and the length of the hose is total displacement.
(b) How would you use the displacement and time data to calculate velocity, average velocity, and acceleration? Which kinematic equations would you use?
(c) How would you use the materials, the measured and calculated data, and the flat area below the slope to determine the negative acceleration? What would you measure, and which kinematic equation would you use?

TEST PREP

Multiple Choice

3.1 Acceleration

17. Which variable represents displacement?
- a. *a*
- b. *d*
- c. *t*
- d. *v*

18. If a velocity increases from 0 to 20 m/s in 10 s, what is the average acceleration?
- a. 0.5 m/s²
- b. 2 m/s²
- c. 10 m/s²
- d. 30 m/s²

3.2 Representing Acceleration with Equations and Graphs

19. For the motion of a falling object, which graphs are straight lines?
- a. Acceleration versus time only
- b. Displacement versus time only
- c. Displacement versus time and acceleration versus time
- d. Velocity versus time and acceleration versus time

20. A bullet in a gun is accelerated from the firing chamber to the end of the barrel at an average rate of 6.30×10^{5} m/s² for 8.10×10^{-4} s. What is the bullet's final velocity when it leaves the barrel, commonly known as the muzzle velocity?
- a. 7.79 m/s
- b. 51.0 m/s
- c. 510 m/s
- d. 1020 m/s

Short Answer

3.1 Acceleration

21. True or False—The vector for a negative acceleration points in the opposite direction when compared to the vector for a positive acceleration.
- a. True
- b. False

22. If a car decelerates from 20 m/s to 15 m/s in 5 s, what is Δv?
- a. -5 m/s
- b. -1 m/s
- c. 1 m/s
- d. 5 m/s

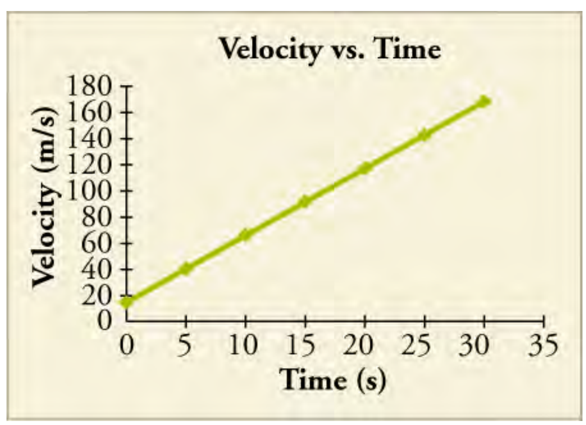
23. How is the vector arrow representing an acceleration of magnitude 3 m/s² different from the vector arrow representing a negative acceleration of magnitude 3 m/s²?
- a. They point in the same direction.
- b. They are perpendicular, forming a 90° angle between each other.
- c. They point in opposite directions.
- d. They are perpendicular, forming a 270° angle between each other.

24. How long does it take to accelerate from 8.0 m/s to 20.0 m/s at a rate of acceleration of 3.0 m/s²?
- a. 0.25 s
- b. 4.0 s
- c. 9.33 s
- d. 36 s

3.2 Representing Acceleration with Equations and Graphs

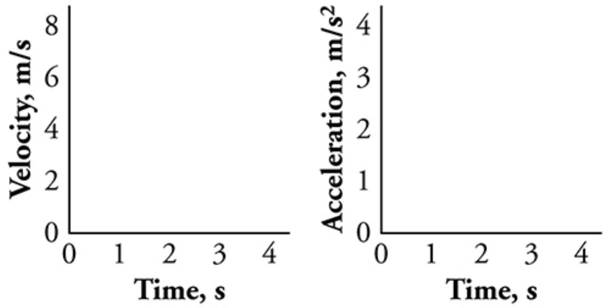
25. If a plot of displacement versus time is linear, what can be said about the acceleration?
- a. Acceleration is 0.
- b. Acceleration is a non-zero constant.
- c. Acceleration is positive.
- d. Acceleration is negative.

26.



True or False: —The image shows a velocity vs. time graph for a jet car. If you take the slope at any point on the graph, the jet car's acceleration will be 5.0 m/s².
- a. True
- b. False

27. When plotted on the blank plots, which answer choice would show the motion of an object that has uniformly accelerated from 2 m/s to 8 m/s in 3 s?



a. The plot on the left shows a line from (0,2) to (3,8) while the plot on the right shows a line from (0,2) to (3,2).
b. The plot on the left shows a line from (0,2) to (3,8) while the plot on the right shows a line from (0,3) to (3,3).
c. The plot on the left shows a line from (0,8) to (3,2) while the plot on the right shows a line from (0,2) to (3,2).
d. The plot on the left shows a line from (0,8) to (3,2) while the plot on the right shows a line from (0,3) to (3,3).

28. When is a plot of velocity versus time a straight line and when is it a curved line?
a. It is a straight line when acceleration is changing and is a curved line when acceleration is constant.
b. It is a straight line when acceleration is constant and is a curved line when acceleration is changing.
c. It is a straight line when velocity is constant and is a curved line when velocity is changing.
d. It is a straight line when velocity is changing and is a curved line when velocity is constant.

Extended Response

3.1 Acceleration

29. A test car carrying a crash test dummy accelerates from 0 to 30 m/s and then crashes into a brick wall. Describe the direction of the initial acceleration vector and compare the initial acceleration vector's magnitude with respect to the acceleration magnitude at the moment of the crash.
a. The direction of the initial acceleration vector will point towards the wall, and its magnitude will be less than the acceleration vector of the crash.
b. The direction of the initial acceleration vector will point away from the wall, and its magnitude will be less than the vector of the crash.
c. The direction of the initial acceleration vector will point towards the wall, and its magnitude will be more than the acceleration vector of the crash.
d. The direction of the initial acceleration vector will point away from the wall, and its magnitude will be more than the acceleration vector of the crash.

30. A car accelerates from rest at a stop sign at a rate of 3.0 m/s^2 to a speed of 21.0 m/s, and then immediately begins to decelerate to a stop at the next stop sign at a rate of 4.0 m/s^2. How long did it take the car to travel from the first stop sign to the second stop sign? Show your work.
a. 1.7 seconds
b. 5.3 seconds
c. 7.0 seconds
d. 12 seconds

3.2 Representing Acceleration with Equations and Graphs

31. True or False: Consider an object moving with constant acceleration. The plot of displacement versus time for such motion is a curved line while the plot of displacement versus time squared is a straight line.
a. True
b. False

32. 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?
a. 0.574 s
b. 0.956 s
c. 1.53 s
d. 1.91 s