Chapter 4: Acceleration

Practice Problems

page 46

1. An Indy–500 race car's velocity increases from +4.0 m/s to +36 m/s over a 4.0–second period. What is its acceleration?

$$a = \frac{\Delta v}{\Delta t} = \frac{(36 \text{ m/s} - 4.0 \text{ m/s})}{(4.0 \text{ s})} = 8.0 \text{ m/s}^2$$

2. The same race car slows from +36 m/s to +15 m/s over 3.0 s. What is its average acceleration over this time interval?

$$a = \frac{(v_2 - t_1)}{(t_2 - t_1)} = \frac{(15 \text{ m/s} - 36 \text{ m/s})}{(3.0 \text{ s})} = -7.0 \text{ m/s}^2$$

3. A car is coasting backwards down a hill at –3.0 m/s when the driver gets the engine started. After 2.5 s the car is moving uphill at a velocity of +4.5 m/s. What is the car's average acceleration?

$$a = \frac{(v_2 - v_1)}{(t_2 - t_1)} = \frac{(4.5 \text{ m/s} - (-3.0 \text{ m/s}))}{(2.5 \text{ s})} = 3.0 \text{ m/s}^2$$

4. A bus is moving at 25 m/s. The driver steps on the brakes, and the bus stops in 3.0 s.

   a. What is the average acceleration of the bus while braking?

$$a = \frac{(v_2 - v_1)}{(t_2 - t_1)} = \frac{(0 \text{ m/s} - 25 \text{ m/s})}{(3.0 \text{ s})} = -8.3 \text{ m/s}^2$$

   b. Suppose the bus took twice as long to stop. How would the acceleration compare to the acceleration you found above?

   Half as great (–4.2 m/s²).

page 68

5. Describe, in your own words, the velocity of the toy train shown in Figure 4–6 between 0 and 20 s.

   Starting from rest, it accelerates to 10 m/s in the first five seconds. It remains at this speed for 10 s, before slowing to 4 m/s over the last 5 s.

Practice Problems

6. Figure 4–6 shows a velocity–time graph of a toy train.

   a. During which time interval or intervals is the speed constant?

   5 to 15 s and 21 to 28 s.

   b. During which interval or intervals is the train's acceleration positive?

   0 to 6 s.

   c. During which interval or intervals is its acceleration less than zero?

   15 to 20 s, 28 s to 40 s.

   d. During which time interval is the acceleration most negative?

   16 to 19 s.

7. For Figure 4–6 find the average acceleration over the given time intervals.

   a. 0 to 5 s.

   2 m/s^2.

   b. 0 to 10 s.

   1 m/s^2.

   c. 15 to 20 s.

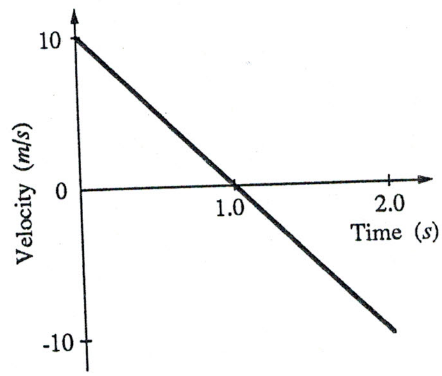
   -1.2 m/s^2.

   d. 0 to 40 s.

   0 m/s^2.

Practice Problems

8. **a.** Draw a velocity–time graph for an object whose velocity is constantly decreasing from 10 m/s at t = 0.0 s to −10 m/s at t = 2.0 s. Assume it has constant acceleration.



b. What is its average acceleration between 0.0 s and 2.0 s?

$$a = \frac{\Delta v}{\Delta t} = \frac{(-10 \text{ m/s} - 10 \text{ m/s})}{(2 \text{ s})} = -10 \text{ m/s}^2.$$

c. What is its acceleration when its velocity is 0 m/s?

The same, -10 m/s^2.

page 69

9. A golf ball rolls up a hill on a Putt–Putt hole.

a. If it starts with a velocity of +2.0 m/s and accelerates at a rate of −0.50 m/s^2, what is its velocity after 2.0 s?

$$v_f = v_i + at = 2.0 \text{ m/s} + (-0.50 \text{ m/s}^2)(2.0 \text{ s}) = 1.0 \text{ m/s}$$

b. If the acceleration occurs for 6.0 s, what is its final velocity?

$$v_f = v_i + at = 2.0 \text{ m/s} + (-0.50 \text{ m/s}^2)(6.0 \text{ s}) = -1.0 \text{ m/s}$$

c. Describe, in words, the motion of the golf ball.

The ball velocity simply decreased in the first case. In the second case the ball slowed to a stop and then began rolling back down the hill.

Practice Problems

10. A bus traveling at +30 km/h accelerates at +3.5 m/s^2 for 6.8 s. What is its final velocity in km/h?

$$a = (3.5 \text{ m/s}^2)(1 \text{ km/1000 m})(3600 \text{ s/1 h}) = 12.6 \text{ (km/h)/s}$$

$$v_f = v_i + at = 30 \text{ km/h} + (12.6\text{(km/h)/s})(6.8 \text{ s}) = 30 \text{ km/h} + 86 \text{ km/h} = 116 \text{ km/h}$$

11. If a car accelerates from rest at a constant 5.5 m/s^2, how long will be required to reach 28 m/s?

$$v_f = v_i + at \text{ so } t = \frac{(v_f - v_i)}{a} = \frac{(28 \text{ m/s} - 0 \text{ m/s})}{(5.5 \text{ m/s}^2)} = 5.1 \text{ s}$$

12. A car slows from 22 m/s to 3 m/s with a constant acceleration of −2.1 m/s^2. How long does it require?

$$v_f = v_i + at$$

$$\text{so } t = \frac{(v_f - v_i)}{a} = \frac{(3 \text{ m/s} - 22 \text{ m/s})}{(-2.1 \text{ m/s}^2)} = 9.0 \text{ s}$$

page 72

13. A race car traveling at +44 m/s is uniformly accelerated to a velocity of +22 m/s over an 11–s interval. What is its displacement during this time?

$$d = \frac{1}{2}(v_f + v_i)t = \frac{1}{2}(22 \text{ m/s} + 44 \text{ m/s})(11 \text{ s}) = 3.6 \times 10^2 \text{ m}$$

14. A rocket traveling at +88 m/s is accelerated uniformly to +132 m/s over a 15–s interval. What is the rocket's displacement during this time?

$$d = \frac{1}{2}(v_f + v_i)t = \frac{1}{2}(132 \text{ m/s} + 88 \text{ m/s})(15 \text{ s}) = 1.7 \times 10^3 \text{ m}$$

Practice Problems

15. A car accelerates at a constant rate from 15 m/s to 25 m/s while it travels 125 m. How long does this motion take?

$$d = \frac{1}{2}(v_f + v_i)t$$

$$\text{so } t = \frac{2d}{(v_f + v_i)}$$

$$= \frac{2(125 \text{ m})}{(25 \text{ m/s} + 15 \text{ m/s})} = 6.3 \text{ s.}$$

16. A bike rider accelerates constantly to a velocity of 7.5 m/s during 4.5 s. The bike's displacement is +19 m. What was the initial velocity of the bike?

$$d = \frac{1}{2}(v_f + v_i)t,$$

$$\text{so } v_i = \frac{2d}{t} - v_f$$

$$= \frac{2(19 \text{ m})}{(4.5 \text{ s}) - 7.5 \text{ m/s}} = 0.9 \text{ m/s}$$

page 74

17. An airplane starts from rest and accelerates at a constant +3.00 m/s² for 30.0 s before leaving the ground. What is its displacement during this time?

$$d = v_i t + \frac{1}{2}at^2$$

$$= (0 \text{ m/s})(30.0 \text{ s}) + \frac{1}{2}(3.00 \text{ m/s}^2)(30.0 \text{ s})^2$$

$$= 0 \text{ m} + 1350 \text{ m} = 1.35 \times 10^3 \text{ m}$$

18. Starting from rest, a race car moves 110 m in the first 5.0 s of uniform acceleration. What is the car's acceleration?

Using $d = v_i t + \frac{1}{2}at^2$ with $v_i = 0$,

$$a = \frac{2d}{t^2} = \frac{2(110 \text{ m})}{(5.0 \text{ s})^2} = 8.8 \text{ m/s}^2$$

Practice Problems

19. A driver brings a car traveling at +22 m/s to a full stop in 2.0 s. Assume its acceleration is constant.

a. What is the car's acceleration?

$$a = \frac{(v_1 - v_2)}{(t_2 - t_1)} = \frac{(0 \text{ m/s} - 22 \text{ m/s})}{(2.0 \text{ s})}$$
$$= -11 \text{ m/s}^2$$

b. How far does it travel before stopping?

$$d = v_i t + \frac{1}{2}at^2$$

$$= (22 \text{ m/s})(2.0 \text{ s}) + \frac{1}{2}(-11 \text{ m/s}^2)(2.0 \text{ s})^2$$

$$= 44 \text{ m} - 22 \text{ m}$$
$$= 22 \text{ m}$$

20. A biker passes a lamp post at the crest of a hill at +4.5 m/s. She accelerates down the hill at a rate of +0.40 m/s² for 12 s. How far does she move down the hill during this time?

$$d = v_i t + \frac{1}{2}at^2$$

$$= (4.5 \text{ m/s})(12 \text{ s}) + \frac{1}{2}(0.40 \text{ m/s}^2)(12 \text{ s})^2$$

$$= 54 \text{ m} + 29 \text{ m} = 83 \text{ m}$$

page 75

21. An airplane accelerates from a velocity of 21 m/s at the constant rate of 3.0 m/s² over a distance of 535 m. What is its final velocity?

$$v_f^2 = v_i^2 + 2ad$$
$$= (21 \text{ m/s})^2 + 2(3.0 \text{ m/s}^2)(535 \text{ m})$$
$$= 3651 \text{ m}^2/\text{s}^2.$$

$$v_f = 60 \text{ m/s.}$$

22. The pilot stops the same plane in 484 m using a constant acceleration of −8.0 m/s². How fast was the plane moving before braking began?

$$v_f^2 = v_i^2 + 2ad$$
$$\text{so } v_i^2 = v_f^2 - 2ad$$
$$= (0 \text{ m/s})^2 - 2(-8.0 \text{ m/s}^2)(484 \text{ m})$$
$$= 7744 \text{ m}^2/\text{s}^2,$$
$$v_i = 88 \text{ m/s}$$

Practice Problems

23. A person with shoulder harness can survive a car crash if the acceleration is smaller than –300 m/s². Assuming constant acceleration, how far must the front end of the car collapse if it crashes at 101 km/h?

Using $v_f^2 = v_i^2 + 2ad$ with
v_i = 101 km/h
= 28.1 m/s and $v_f = 0$,

$$d = \frac{(v_f^2 - v_i^2)}{2a} = \frac{((0\text{ m/s})^2 - (28.1\text{ m/s})^2)}{2(-300\text{ m/s}^2)}$$

$$= 1.32\text{ m}$$

24. A car is initially sliding backwards down a hill at –25 km/h. The driver guns the car. By the time the car's velocity is +35 km/h, it is +3.2 m from its starting point. Assuming the car was uniformly accelerated, find the acceleration.

Convert speeds to m/s.

$v_i = -6.9$ m/s, $v_f = 9.7$ m/s,

$$d = \frac{(v_f^2 - v_i^2)}{2a},$$

$$\text{so } a = \frac{(v_f^2 - v_i^2)}{2d}$$

$$= \frac{((9.7\text{ m/s})^2 - (-6.9\text{ m/s})^2)}{2(3.2\text{ m})}$$

$$= 7.3\text{ m/s}^2.$$

page 77

25. A brick falls freely from a high scaffold.

a. What is its velocity after 4.0 s?

$$v_f = v_i + gt$$
$$= 0\text{ m/s} + (-9.80\text{ m/s}^2)(4.0\text{ s})$$
$$v_i = -39\text{ m/s (downward)}$$

b. How far does the brick fall during the first 4.0 s?

$$d = v_it + \frac{1}{2}gt^2$$

$$= 0 + \frac{1}{2}(-9.80\text{ m/s}^2)(4.0\text{ s})^2$$

$$= \frac{1}{2}(-9.81\text{ m/s}^2)(16\text{ s}^2)$$

$$d = -78\text{ m (downward)}$$

Practice Problems

26. Now that you know about acceleration, test your reaction time. Ask a friend to hold a ruler just even with the top of your fingers. Then have your friend drop the ruler. Taking the number of centimeters that the ruler falls before you can catch it, calculate your reaction time. An average of several trials will give more accurate results. The reaction time for most people is more than 0.15 seconds.

Using $d = \frac{1}{2}gt^2$ the reaction time can be calculated from $t = \sqrt{\frac{2d}{g}}$

page 79

27. If you drop a golf ball, how far does it fall in $\frac{1}{2}$ s?

$$d = v_it + \frac{1}{2}gt^2 = 0 + \frac{1}{2}(-9.80\text{ m/s}^2)(0.50\text{ s})^2$$

$$= -1.2\text{ m.}$$

28. A spacecraft traveling at a velocity of +1210 m/s is uniformly accelerated at –150 m/s². If the acceleration lasts for 8.68 seconds, what is the final velocity of the craft? Explain your results in words.

$$v_f = v_i + at = 1210\text{ m/s} + (-150\text{ m/s}^2)(8.68\text{ s})$$
$$= 1210\text{ m/s} - 1300\text{ m/s}$$
$$= -90\text{ m/s}$$

Spacecraft slows to a stop then reverses motion.

29. A man falls 1.0 m to the floor.

a. How long does the fall take?

Using $d = v_it + \frac{1}{2}gt^2$ with $v_i = 0$,

$$t = \sqrt{\frac{2d}{g}} = \sqrt{\frac{2(-1.0\text{ m})}{(-9.80\text{ m/s}^2)}} = 0.45\text{ s}$$

b. How fast is he going when he hits the floor?

$$v_f = v_i + gt = 0\text{ m/s} + (-9.80\text{ m/s}^2)(0.45\text{ s})$$
$$= -4.4\text{ m/s}$$

4

30. On wet pavement a car can be accelerated with a maximum acceleration $a = 0.20g$ before its tires slip.

a. Starting from rest, how fast is it moving after 2.0 seconds?

$v_i = 0$ m/s,
so $v_f = at = (0.2)(9.80 \text{ m/s}^2)(2.0 \text{ s})$
$= 3.9$ m/s

b. How far has it moved after 4.0 seconds?

$$d = \frac{1}{2}at^2 = \frac{1}{2}(0.2)(9.8 \text{ m/s}^2)(4.0 \text{ s})^2 = 16 \text{ m}.$$

page 80

31. A pitcher throws a baseball straight up with an initial speed of 27 m/s.

a. How long does it take the ball to reach its highest point?

Since $v_f = 0$ at high point, $v_f = v_i + gt$

becomes $t = \frac{-v_i}{g} = \frac{-(27 \text{ m/s})}{(-9.80 \text{ m/s}^2)} = 2.8$ s

b. How high does the ball rise above its release point?

$$d = v_i t + \frac{1}{2}gt^2$$

$$= (27 \text{ m/s})(2.8 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(2.8 \text{ s})^2$$

$$= 75.6 \text{ m} - 38.4 \text{ m} = 37 \text{ m}$$

32. A motor of a certain elevator gives it a constant upward acceleration of 46 m/min/s. The elevator starts from rest, accelerates for 2.0 s, then continues with constant speed.

a. Explain what this statement of acceleration means

$a = 46$ m/min/s can be interpreted as a speed change of either 46 m/min each second or 46 m/s each minute.

Practice Problems

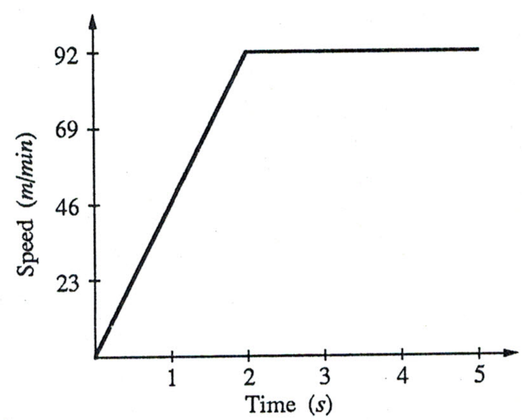
b. What is the final speed after 2 s?

$v_f = v_i + at$
$= 0 \text{ m/min} + (46 \text{ m/min/s})(2.0 \text{ s})$
$= 92$ m/min

c. Calculate speed after 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, and 5.0 s. Sketch graph showing speed vs time.

Speeds before 2.0 s are given by $v_f = at$; speeds after are 92 m/min

t(s)	v_f(m/min)
0.5	23
1.0	46
1.5	69
2.0	92
3.0	92
4.0	92
5.0	92



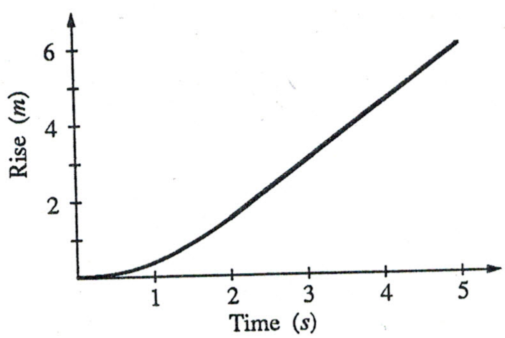
Practice Problems

d. How far has it risen 1.0, 2.0, 3.0, 4.0, and 5.0 s after start? Sketch graph.

For first 2 seconds $d = \frac{1}{2}at^2$ where

a = (46 m/min/s)(1 min/60 s)
= 0.767 m/s^2
and after 2 seconds it continues to rise
(92 m/min)(1/60 min) = 1.5 m each second

t(s)	d(m)
1.0	0.4
2.0	1.5
3.0	3.0
4.0	4.5
5.0	6.0



Chapter Review Problems

pages 105–107

1. Find the uniform acceleration that causes a car's velocity to change from 32 m/s to 96 m/s in an 8.0–s period.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t} = \frac{96 \text{ m/s} - 32 \text{ m/s}}{8.0 \text{ s}} = 8.0 \text{ m/s}^2$$

Chapter Review Problems

2. Rocket–powered sleds are used to test the responses of humans to acceleration. Starting from rest, one sled can reach a speed of 444 m/s in 1.80 s and can be brought to a stop again in 2.15 s.

a. Calculate the acceleration of the sled when starting and compare it to the acceleration due to gravity, 9.80 m/s^2.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t} = \frac{444 \text{ m/s} - 0}{1.80 \text{ s}}$$

$$= 247 \text{ m/s}^2$$

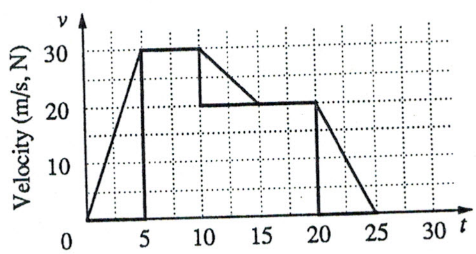
$$\frac{247 \text{ m/s}^2}{9.80 \text{ m/s}^2} = 25.2$$

b. Find the acceleration of the sled when braking and compare it to the magnitude of the acceleration due to gravity.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t} = \frac{0 - 444 \text{ m/s}}{2.15 \text{ s}} = -207 \text{ m/s}^2$$

$$\frac{207 \text{ m/s}^2}{9.80 \text{ m/s}^2} = 21.1$$

3. Use Figure 4–18 to find the acceleration of the moving object



a. during the first five seconds of travel.

$$a = \frac{\Delta v}{\Delta t} = \frac{30 \text{ m/s} - 0 \text{ m/s}}{5 \text{ m/s}} = 6 \text{ m/s}^2$$

b. between the fifth and the tenth second of travel.

$$a = \frac{\Delta v}{\Delta t} = \frac{30 \text{ m/s} - 30 \text{ m/s}}{5 \text{ s}} = 0$$

Chapter Review Problems

c. between the tenth and the fifteenth second of travel.

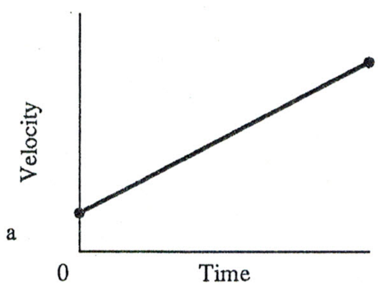
$$a = \frac{\Delta v}{\Delta t} = \frac{20\ \text{m/s} - 30\ \text{m/s}}{5\ \text{s}} = -2\ \text{m/s}^2$$

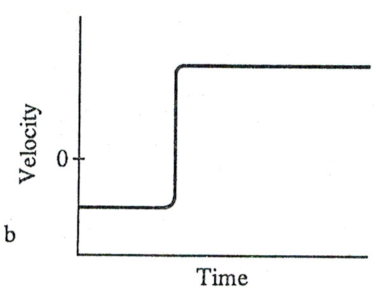
d. between the twentieth and twenty–fifty second of travel.

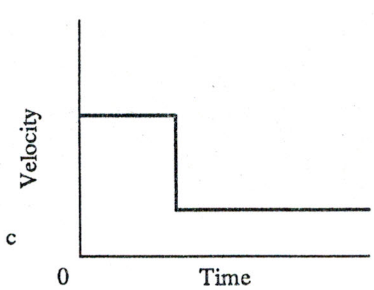
$$a = \frac{\Delta v}{\Delta t} = \frac{0 - 20\ \text{m/s}}{5\ \text{s}} = -4\ \text{m/s}^2$$

4. To accompany each of the graphs in Figure 4–19, draw

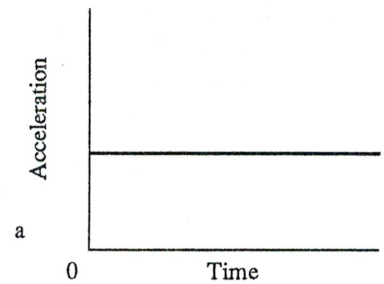
a. a velocity–time graph.

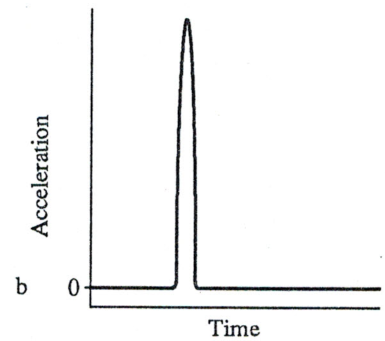


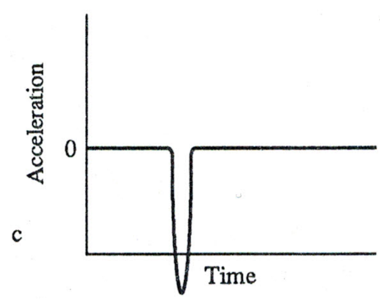




b. an acceleration–time graph.







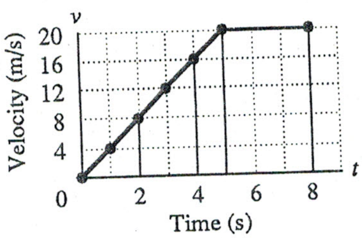
5. A car with a velocity of 22 m/s is accelerated uniformly at the rate of 1.6 m/s² for 6.8 s. What is its final velocity?

$$v_f = v_i + at = 22\ \text{m/s} + (1.6\ \text{m/s}^2)(6.8\ \text{s}) = 33\ \text{m/s}$$

6. The velocity of an automobile changes over an 8.0–s time period as shown in Table 4–3.

Time (s)	Velocity (m/s)	Time (s)	Velocity (m/s)
0.0	0.0	5.0	20.0
1.0	4.0	6.0	20.0
2.0	8.0	7.0	20.0
3.0	12.0	8.0	20.0
4.0	16.0		

a. Plot the velocity–time graph of the motion.



b. Determine the displacement of the car during the first 2.0 s.

$$d = \frac{1}{2}bh = \frac{1}{2}(2.0\ \text{s})(8.0\ \text{m/s} - 0) = 8.0\ \text{m}$$

c. What displacement does the car have during the first 4.0 s?

$$d = \frac{1}{2}bh = \frac{1}{2}(4.0\ \text{s})(16.0\ \text{m/s} - 0) = 32\ \text{m}$$

d. What displacement does the car have during the entire 8.0 s?

$$d = \frac{1}{2}bh + bh$$

$$= \frac{1}{2}(5.0\ \text{s})(20.0\ \text{m/s} - 0)$$

$$+ (8.0\ \text{s} - 5.0\ \text{s})(20.0\ \text{m/s}) = 110\ \text{m}$$

e. Find the slope of the line between $t = 0$ s and $t = 4.0$ s. What does this slope represent?

$$a = \frac{\Delta v}{\Delta t} = \frac{16\ \text{m/s} - 0\ \text{m/s}}{4\ \text{s} - 0\ \text{s}}$$

$$= 4\ \text{m/s}^2 \text{ acceleration}$$

f. Find the slope of the line between $t = 5.0$ s and $t = 7.0$ s. What does this slope indicate?

$$a = \frac{\Delta v}{\Delta t} = \frac{20\ \text{m/s} - 20\ \text{m/s}}{7\ \text{s} - 5\ \text{s}}$$

$$= 0 \text{ constant velocity}$$

7. Figure 4–20 shows the position–time and velocity–time graphs of a karate expert using a fist to break wooden boards.

a. Use the velocity–time graph to describe the motion of the expert's fist during the first 10 ms.

The fist moves downward at about –13 m/s for about 5 ms. It then suddenly comes to a halt (accelerates).

b. Estimate the slope of the velocity–time graph to determine the acceleration of the fist when it suddenly stops.

$$a = \frac{\Delta v}{\Delta t} = \frac{0 - (-13\ \text{m/s})}{7.5\ \text{ms} - 5.0\ \text{ms}}$$

$$= 5.2 \times 10^3\ \text{m/s}^2$$

c. Express the acceleration as a multiple of the gravitational acceleration, $g = 9.80\ \text{m/s}^2$.

$$\frac{5.2 \times 10^3\ \text{m/s}^2}{9.80\ \text{m/s}^2} = 5.3 \times 10^2$$

the acceleration is about 530 g

d. Determine the area under the velocity–time curve to find the displacement of the fist in the first 6 ms. Compare with the position–time graph.

The area is almost rectangular:

(–13 m/s)(0.006 s) = –8 cm. This is in agreement with the position–time graph where the hand moves from +8 cm to 0 cm, for a net displacement of –8 cm.

Chapter Review Problems

8. A supersonic jet that is flying at 145 m/s is accelerated uniformly at the rate of 23.1 m/s^2 for 20.0 s.

   a. What is its final velocity?

$$v_f = v_i + at$$
$$= 145 \text{ m/s} + (23.1 \text{ m/s}^2)(20.0 \text{ s})$$
$$= 607 \text{ m/s}$$

   b. The speed of sound in air is 331 m/s. How many times the speed of sound is the plane's final speed?

$$N = \frac{607 \text{ m/s}}{331 \text{ m/s}}$$
$$= 1.83 \text{ times the speed of sound}$$

9. Determine the final velocity of a proton that has an initial velocity of 2.35×10^5 m/s and then is accelerated uniformly in an electric field at the rate of -1.10×10^{12} m/s^2 for 1.50×10^{-7} s.

$$v_f = v_i + at$$
$$= 2.35 \times 10^5 \text{ m/s} + (-1.10 \times 10^{12} \text{ m/s}^2)(1.50 \times 10^{-7} \text{ s})$$
$$= 2.35 \times 10^5 \text{ m/s} - 1.65 \times 10^5 \text{ m/s}$$
$$= 7.0 \times 10^4 \text{ m/s}$$

10. Determine the displacement of a plane that is uniformly accelerated from 66 m/s to 88 m/s in 12 s.

$$d = \frac{(v_f + v_i)t}{2} = \frac{(88 \text{ m/s} + 66 \text{ m/s})(12 \text{ s})}{2}$$
$$= 9.2 \times 10^2 \text{ m}$$

11. How far does a plane fly in 15 s while its velocity is changing from +145 m/s to +75 m/s at a uniform rate of acceleration?

$$d = \frac{(v_f + v_i)t}{2} = \frac{(75 \text{ m/s} + 145 \text{ m/s})(15 \text{ s})}{2}$$
$$= 1.7 \times 10^3 \text{ m}$$

12. A car moves at 12 m/s and coasts up a hill with a uniform acceleration of -1.6 m/s^2.

   a. How far has the car traveled after 6.0 s?

$$d = v_i t + \frac{1}{2}at^2$$
$$= (12 \text{ m/s})(6.0 \text{ s}) + \frac{1}{2}(-1.6 \text{ m/s}^2)(6.0 \text{ s})^2$$
$$= 43 \text{ m}$$

   b. How far has it gone after 9.0 s?

$$d = v_i t + \frac{1}{2}at^2$$
$$= (12 \text{ m/s})(9.0 \text{ s}) + \frac{1}{2}(-1.6 \text{ m/s}^2)(6.0 \text{ s})^2$$
$$= 43 \text{ m}$$

   the car is on the way back down the hill.

13. Four cars start from rest. Car A accelerates at 6.0 m/s^2; car B at 5.4 m/s^2; car C at 8.0 m/s^2, and car D at 12 m/s^2.

   a. In the first column of a table, show the velocity of each car at the end of 2.0 s.

   b. In the second column, show the displacement of each car travels during the same 2.0 s.

   c. What conclusions do you reach about the velocity attained and the displacement of a body starting from rest at the end of the first 2.0 s of acceleration?

   Tables should indicate that, for a body accelerating uniformly from rest, displacement traveled and velocity attained are numerically the same at the end of two seconds.

Car	Velocity (m/s)	Displacement (m)
A	12	12
B	11	11
C	16	16
D	24	24

14. An astronaut drops a feather from 1.2 m above the surface of the moon. If the acceleration of gravity on the moon is 1.62 m/s², how long does it take the feather to hit the surface?

$$d = v_i t + \frac{1}{2}at^2$$

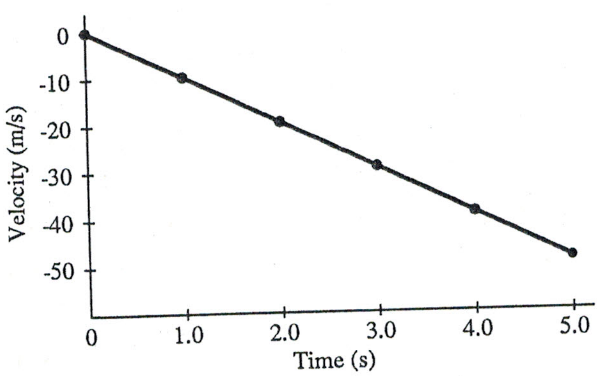
$$t = \sqrt{\frac{2d}{g}} = \sqrt{\frac{(2)(-1.2\ \text{m})(6)}{(-9.8\ \text{m/s}^2)}} = 1.2\ \text{s}$$

15. Table 4–4 is a table of the displacements and velocities of a ball at the end of each second for the first 5.0 s of free-fall from rest.

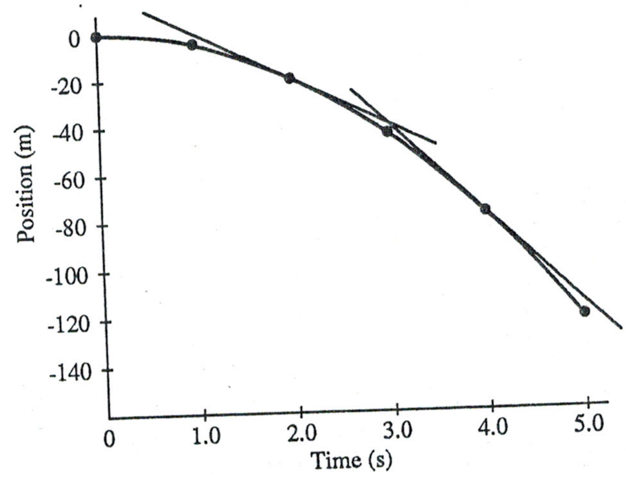
Table 4–4

Time (s)	Displacement (m)	Velocity (m/s)
0.0	0.0	0.0
1.0	–4.9	–9.8
2.0	–19.6	–19.6
3.0	–44.1	–29.4
4.0	–78.4	–39.2
5.0	–122.5	–49.0

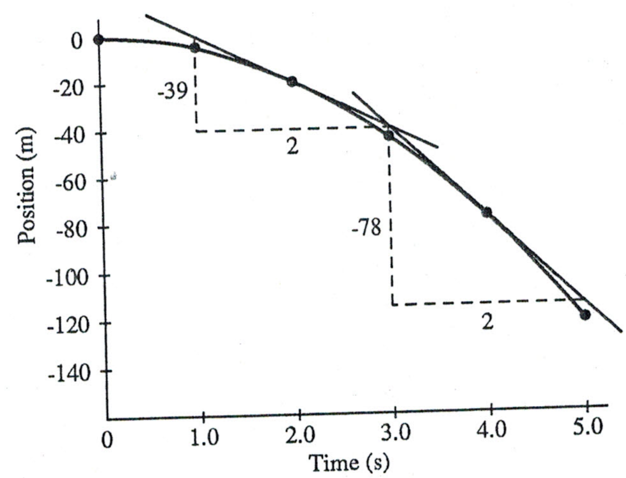
a. Use the data in the table to plot a velocity–time graph.



b. Use the data in the table to plot a position–time graph.



c. Find the slope of the curve at the end of 2.0 and 4.0 s on the position–time graph. What are the approximate slopes? Do these values agree with the table of velocity?



At t = 2.0 s,

$$\text{slope} = \frac{-40\ \text{m} - (-1\ \text{m})}{3.0\ \text{s} - 1.0\ \text{s}} = -20\ \text{m/s}$$

At t= 4.0 s,

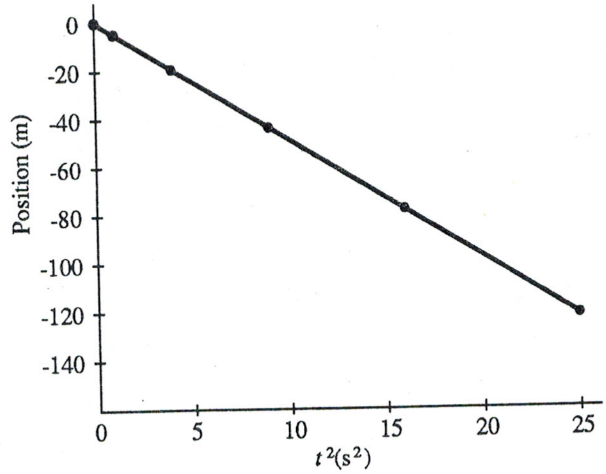
$$\text{slope} = \frac{-118\ \text{m} - (-40\ \text{m})}{5.0\ \text{s} - 3.0\ \text{s}} = -39\ \text{m/s}$$

Yes, the values agree.

4

d. Use the data in the table to plot a position versus time–squared graph. What type of curve is obtained?

A straight line is obtained



e. Find the slope of the line at any point. Explain the significance of the value you obtain.

$$\text{slope} = \frac{-122.5\ \text{m} - 0}{25\ \text{s}^2 - 0} = -4.9\ \text{m/s}^2$$

The slope is $\frac{1}{2}g$.

f. Does this curve agree with the equation $d = \frac{1}{2}gt^2$?

Yes. Since it is a straight line $y = mx + b$ where y is d, m is $\frac{1}{2}g$, x is t^2 and b is 0.

16. A plane travels 5.0×10^2 m while being accelerated uniformly from rest at the rate of $5.0\ \text{m/s}^2$. What final velocity does it attain?

$$v_f^2 = v_i^2 + 2ad$$

$$v_f = \sqrt{v_i^2 + 2ad}$$
$$= \sqrt{0 + 2(5.0\ \text{m/s}^2)(5.0 \times 10^2\ \text{m})} = 71\ \text{m/s}$$

Chapter Review Problems

17. A race car can be slowed with a constant acceleration of $-11\ \text{m/s}^2$.

a. If the car is going 55 m/s, how many meters will it take to stop?

$$v_f^2 = v_i^2 + 2ad$$

$$d = \frac{v_f^2 - v_i^2}{2a} = \frac{0 - (+55\ \text{m/s})^2}{(2)(-11\ \text{m/s}^2)} = 1.4 \times 10^2\ \text{m}$$

b. Repeat for a car going 110 m/s.

$$d = \frac{v_f^2 - v_i^2}{2a} = \frac{0 - (110\ \text{m/s})^2}{(2)(-11\ \text{m/s}^2)} = 5.5 \times 10^2\ \text{m}$$

18. An engineer must design a runway to accommodate airplanes that must reach a ground velocity of 61 m/s before they can take off. These planes are capable of being accelerated uniformly at the rate of $2.5\ \text{m/s}^2$.

a. How long will it take the planes to reach takeoff speed?

$$v_f = v_i + at,$$

$$\text{so } t = \frac{v_f - v_i}{a} = \frac{61\ \text{m/s} - 0}{2.5\ \text{m/s}^2} = 24\ \text{s}$$

b. What must be the minimum length of the runway?

$$v_f^2 = v_i^2 + 2ad,$$

$$\text{so } d = \frac{v_f^2 - v_i^2}{2a}$$

$$= \frac{(61\ \text{m/s})^2 - 0}{2(2.5\ \text{m/s}^2)} = 7.4 \times 10^2\ \text{m}$$

19. A rocket traveling at 155 m/s is accelerated at a rate of $-31.0\ \text{m/s}^2$.

a. How long will it take before the instantaneous speed is 0 m/s?

$$v_f = v_i + at$$

$$t = \frac{v_f - v_i}{a} = \frac{0 - (+155\ \text{m/s})}{-31.0\ \text{m/s}^2} = 5.00\ \text{s}$$

 Chapter Review Problems

b. How far will it travel during this time?

$$d = v_it + \frac{1}{2}at^2$$
$$= (+155\ \text{m/s})(5.00\ \text{s}) + \frac{1}{2}(-31.0\ \text{m/s})(5.00\ \text{s})^2$$
$$= 388\ \text{m}$$

c. What will be its velocity after 8.00 s?

$$v_f = v_i + at$$
$$= (+155\ \text{m/s}) + (-31.0\ \text{m/s}^2)(8.00\ \text{s})$$
$$= -93\ \text{m/s}$$

The rocket is moving in a direction opposite to its original direction.

20. Engineers are developing new types of guns that might someday be used to launch satellites as if they were bullets. One such gun can give a small object a velocity of 3.5 km/s moving it through only 2.0 cm.

a. What acceleration does the gun give this object?

$$v_f^2 = v_i^2 + 2ad, \text{ or } v_f^2 = 2ad$$

$$a = \frac{v_f^2}{2d} = \frac{(3.5 \times 10^3\ \text{m/s})^2}{2(0.020\ \text{m})} = 3.1 \times 10^8\ \text{m/s}^2$$

b. Over what time interval does the acceleration take place?

$$d = \frac{(v_f + v_i)t}{2}$$

$$t = \frac{2d}{(v_f + v_i)} = \frac{2(2.0 \times 10^{-2}\ \text{m})}{(3.5 \times 10^3\ \text{m/s} + 0)}$$
$$= 11 \times 10^{-6}\ \text{s}$$
$$= 11\ \text{microseconds}$$

21. An express train, traveling at 36.0 m/s, is accidentally sidetracked onto a local train track. The express engineer spots a local train exactly 1.00×10^2 m ahead on the same track and traveling in the same direction. The engineer jams on the brakes and slows the express at a constant rate of $-3.00\ \text{m/s}^2$. The local engineer is unaware of the situation. If the speed of the local is 11.0 m/s, will the express be able to stop in time or will there be a collision? To solve this problem take the position of the express when it first sights the local as a point of origin. Next, keeping in mind that the local has exactly a 1.00×10^2 m lead, calculate how far each train is from the origin at the end of the 12.0 s it would take the express to stop.

a. On the basis of your calculations, would you conclude that there is or is not a collision?

$$d_{\text{Express}} = v_it + \frac{1}{2}at^2$$
$$= (36.0\ \text{m/s})(12.0\ \text{s}) + \frac{1}{2}(-3.00\ \text{m/s}^2)(12.0\ \text{s})^2$$
$$= 432\ \text{m} - 216\ \text{m} = 216\ \text{m}$$

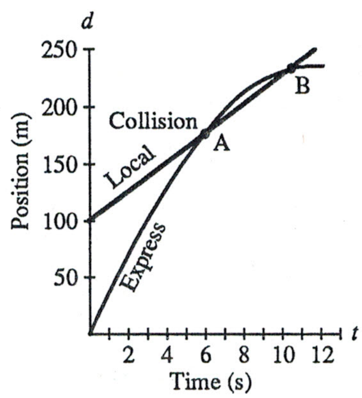
$$d_{\text{Local}} = 100\ \text{m} + v_it + \frac{1}{2}at^2$$
$$= 100\ \text{m} + (11.0\ \text{m/s})(12.0\ \text{s}) + 0$$
$$= 100\ \text{m} + 132\ \text{m} = 232\ \text{m}$$

On this basis no collision will occur.

b. The calculations you made in part **a** do not allow for the possibility that a collision might take place before the end of the twelve seconds required for the express to come to a halt. To check on this, take the position of the express when it first sights the local as the point of origin and calculate the position of each train at the end of each second after sighting. Make a table showing the distance of each train from the origin at the end of each second. Plot these positions on the same graph and draw two lines.

4

t (s)	d(Local) (m)	d(Express) (m)
1	111	35
2	122	66
3	133	95
4	144	120
5	155	143
6	166	162
7	177	179
8	188	192
9	199	203
10	210	210
11	221	215
12	232	216



c. Use your graph to check your answer to part a.

The collision occurs at point A (not B).

22. Highway safety engineers build soft barriers so that cars hitting them will slow down at a safe rate. A person wearing a safety belt can withstand an acceleration of –300 m/s². How thick should barriers be to safely stop a car that hits a barrier at 110 km/h?

$$v_i = \frac{(110 \text{ km/h})(1000 \text{ m/km})}{3600 \text{ s/h}} = 31 \text{ m/s}$$

$v_f^2 = v_i^2 + 2ad$ with $v_f = 0$, $v_i^2 = -2\,ad$, or

$$d = \frac{-v_i^2}{2a} = \frac{-(31 \text{ m/s})^2}{2(-300 \text{ m/s}^2)} = 1.6 \text{ m thick}$$

Chapter Review Problems

23. A baseball pitcher throws a fastball at a speed of 44 m/s. The acceleration occurs as the pitcher holds the ball in his hand and moves it through an almost straight–line distance of 3.5 m. Calculate the acceleration, assuming it is uniform. Compare the acceleration to the acceleration due to gravity, 9.80 m/s².

$$v_f^2 = v_i^2 + 2ad$$

$$a = \frac{v_f^2 - v_i^2}{2d}$$

$$= \frac{(44 \text{ m/s})^2 - 0}{2(3.5 \text{ m})} = 2.8 \times 10^2 \text{ m/s}^2,$$

$$\frac{2.8 \times 10^2 \text{ m/s}^2}{9.80 \text{ m/s}^2} = 29, \text{ or } 29 \text{ times } g$$

24. If a bullet leaves the muzzle of a rifle with a speed of 600 m/s, and the barrel of the rifle is 0.9 m long, what is the acceleration of the bullet while in the barrel?

$$v_f^2 = v_i^2 + 2ad$$

$$a = \frac{v_f^2 - v_i^2}{2d} = \frac{(600 \text{ m/s})^2 - 0}{(2)(0.9 \text{ m})}$$

$$= \frac{3.6 \times 10^5 \text{ m}^2/\text{s}^2}{1.8 \text{ m}}$$

$$= 2 \times 10^5 \text{ m/s}^2$$

25. A driver of a car going 90.0 km/h suddenly sees the lights of a barrier 40.0 m ahead. It takes the driver 0.75 s before he applies the brakes, and the average acceleration during braking is –10.0 m/s².

a. Determine if the car hits the barrier.

$$v_i = \frac{(90.0 \text{ km/h})(1000 \text{ m/km})}{(3600 \text{ s/h})} = 25.0 \text{ m/s}$$

$$v_f = v_i + at$$

$$t = \frac{v_f - v_i}{a} = \frac{0 - (25.0 \text{ m/s})}{-10.0 \text{ m/s}^2} = 2.50 \text{ s}$$

The car will travel

$$d = vt = (25.0 \text{ m/s})(0.75 \text{ s})$$
$$= 18.75 \text{ m} = 19 \text{ m}$$

before the driver applies the brakes. The total distance the car must travel to stop is

$$d = 19 \text{ m} + v_i t + \frac{1}{2}at^2$$

$$= 19 \text{ m} + (25.0 \text{ m/s})(2.50 \text{ s}) + \frac{1}{2}(-10.0 \text{ m/s}^2)(2.50 \text{ s})^2$$

$$= 50 \text{ m, yes it hits the barrier.}$$

b. What is the maximum speed at which the car could be moving and not hit the barrier 40.0 m ahead? Assume the acceleration rate doesn't change. Hint: The displacement at constant speed plus the displacement while decelerating equals the total displacement.

$d_{total} = d_{constant\ v} + d_{decelerating} = 40.0\text{ m}$

$d_c = vt = (0.75\text{ s})v$

$$d_d = \frac{-v^2}{2a} = \frac{-v^2}{2(-10.0\text{ m/s}^2)} = \frac{v^2}{20.0\text{ m/s}^2}$$

$$40\text{ m} = (0.75\text{ s})v + \frac{v^2}{20.0\text{ m/s}^2}$$

$v^2 + 15v - 800 = 0$

Using the quadratic equation:

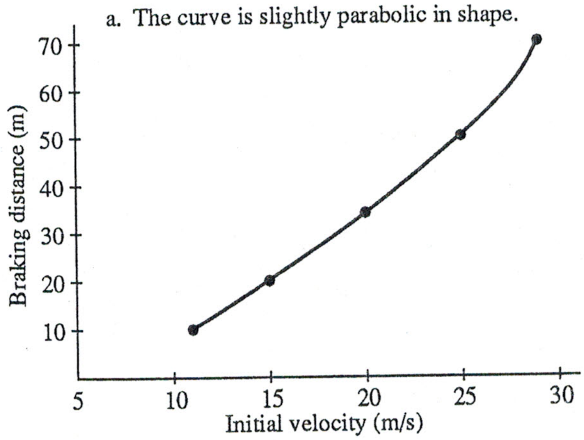
$v = 22$ m/s (The sense of the problem excludes the negative value.)

26. Data in Table 4–5, taken from a driver's handbook, show the distance a car travels when it brakes to a halt from a specific initial velocity.

Initial Velocity (m/s)	Braking distance (m)
11	10
15	20
20	34
25	50
29	70

a. Plot the braking distance versus the initial velocity. Describe the shape of the curve you obtain.

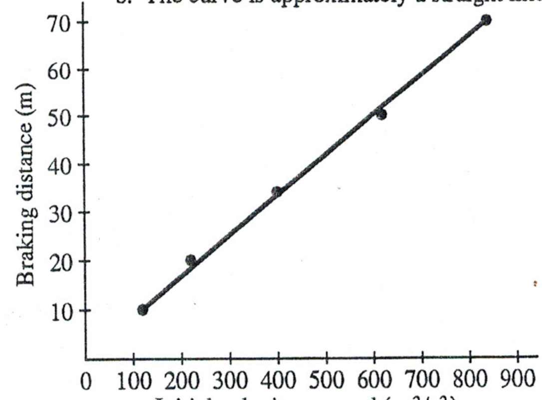
a. The curve is slightly parabolic in shape.



Chapter Review Problems

b. Plot the braking distance versus the square of the initial velocity. Describe the shape of the curve you obtain.

b. The curve is approximately a straight line.



c. Calculate the slope of your graph from part **b.** Find the value and units of the quantity 1/slope of the curve.

$$\text{slope} = \frac{70\text{ m} - 10\text{ m}}{(29\text{ m/s})^2 - (11\text{ m/s})^2}$$

$$= 0.083\text{ s}^2\text{/m}$$

$$\frac{1}{\text{slope}} = 12\text{ m/s}^2$$

d. Does this curve agree with the equation $v_i^2 = -2ad$? What is the value of a?

yes, –6 m/s²

27. A car moving with a constant acceleration covers the distance between two points 60 m apart in 6.0 s. Its velocity as it passes the second point is 15 m/s.

a. What was the speed at the first point?

$$d = \left[\frac{v_i + v}{2}\right]t, \text{ so } v_i + v = \frac{2d}{t}, \text{ and}$$

$$v_i = \frac{2d}{t} - v = \frac{2(60\text{ m})}{6.0\text{ s}} - 15\text{ m/s} = 5\text{ m/s}$$

b. What is the constant acceleration?

$$a = \frac{\Delta v}{t} = \frac{v - v_i}{t} = \frac{15\text{ m/s} - 5\text{ m/s}}{6.0\text{ s}} = 1.7\text{ m/s}^2$$

c. How far behind the first point was the car at rest?

$v^2 = v_i^2 + 2ad$,

so $d = \frac{v^2 - v_i^2}{2a} = \frac{(5\ m/s)^2 - 0}{2(1.7\ m/s^2)} = 7.5\ m$

28. Just as a traffic light turns green, a waiting car starts with a constant acceleration of 6.0 m/s². At the instant the car begins to accelerate, a truck with a constant velocity of 21 m/s passes in the next lane. Hint: Equate the displacements in the two displacement equations.

a. How far will the car travel before it overtakes the truck?

$d_{car} = v_i t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(6.0\ m/s^2)t^2$

$= 3.0\ t^2\ m/s^2$

$d_{truck} = v_i t + \frac{1}{2}at^2 = (21\ m/s)t$

$d_{car} = d_{truck}$, when the truck overtakes the car
$3.0\ t^2\ m/s^2 = (21\ m/s)t$
$t = 7.0\ s$
$d_{car} = (3.0\ m/s^2)(7.0\ s)^2 = 1.5 \times 10^2\ m$

b. How fast will the car be traveling when it overtakes the truck?

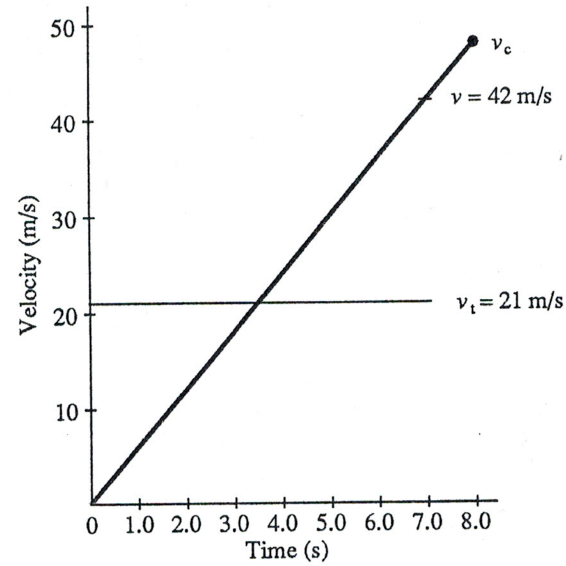
$v_f = v_i + at = 0 + (6.0\ m/s^2)(7.0\ s)$
$= 42\ m/s$

Chapter Review Problems

page 15

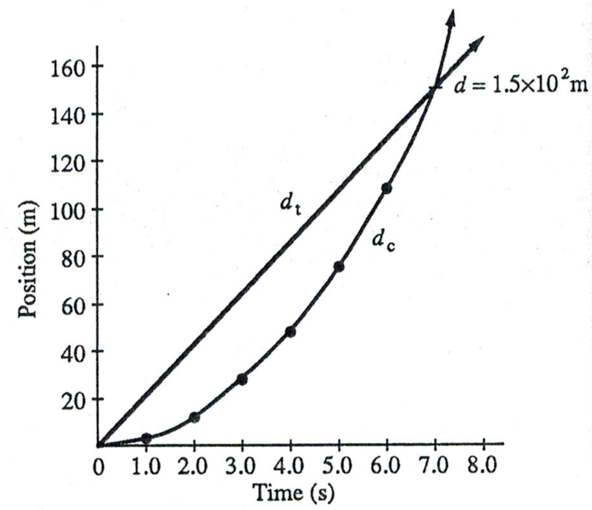
29. Use the information from the previous problem.

a. Draw velocity–time and position–time graphs for the car and truck.



b. Do the graphs confirm the answer you calculated for the exercise?

b. The graphs confirm the calculated answer.



Yes

30. A stone falls from rest for 8.0 s.

a. Calculate the stone's velocity after 8.0 s.

$v_f = v_i + gt = 0 + (-9.8\ m/s^2)(8.0\ s)$
$= -78\ m/s$ (downward)

Chapter Review Problems

b. What is the stone's displacement during this time?

$$d = v_i t + \frac{1}{2}gt^2 = 0 + \frac{1}{2}(-9.8\ \text{m/s}^2)(8.0\ \text{s})^2$$

$$= -3.1 \times 10^2\ \text{m}$$

31. A student drops a rock from a bridge to the water 12.0 m below. With what speed does the rock strike the water?

$$v_f^2 = v_i^2 + 2gd$$

$$v_f = \sqrt{v_i^2 + 2gd}$$

$$= \sqrt{0 + (2)(-9.80\ \text{m/s}^2)(-12.0\ \text{m})}$$

$$= \sqrt{235.2\ \text{m}^2/\text{s}^2} = 15.3\ \text{m/s}$$

32. Kyle is flying a helicopter when he drops a bag. When the bag has fallen 2.0 s,

a. What is the bag's velocity?

$$v_f = v_i + gt = 0 + (-9.80\ \text{m/s}^2)(2.0\ \text{s})$$
$$= -20\ \text{m/s}$$

b. How far has the bag fallen?

$$d = v_i t + \frac{1}{2}gt^2 = 0 + \frac{1}{2}(-9.80\ \text{m/s}^2)(2.0\ \text{s})^2$$

$$= -20\ \text{m}$$

33. Kyle is flying the same helicopter and it is rising at 5.0 m/s when he releases the bag. After 2.0 s,

a. What is the bag's velocity?

$$v_f = v_i + gt = 5.0\ \text{m/s} + (-9.80\ \text{m/s})(2.0\ \text{s})$$
$$= -15.\ \text{m/s}$$

b. How far has the bag fallen?

$$d = v_i t + \frac{1}{2}gt^2$$

$$= (5.0\ \text{m/s})(2.0\ \text{s})$$

$$+ \frac{1}{2}(-9.80\ \text{m/s})(2.0\ \text{s})^2$$

$$= -10\ \text{m}$$

c. How far below the helicopter is the bag?

The helicopter has risen
$d = v_i t = (5.0\ \text{m/s})(2.0) = 10\ \text{m}$
The bag is 10 m below the origin and 20 m below the helicopter.

34. Now Kyle's helicopter is falling at 5.0 m/s as he releases the bag. After 2.0 s,

a. What is the bag's velocity?

$$v_f = v_i + gt$$
$$= -5.0\ \text{m/s} + (-9.80\ \text{m/s}^2)(2.0\ \text{s})$$
$$= 25\ \text{m/s}$$

b. How far has the bag fallen?

$$d = v_i t + \frac{1}{2}gt^2$$

$$= (-5.0\ \text{m/s})(2.0) + \frac{1}{2}(-9.80\ \text{m/s}^2)(2.0\ \text{s})^2$$

$$= -30\ \text{m}$$

c. How far below the helicopter is the bag?

The helicopter has fallen
$d = vt = (-5.0\ \text{m/s})(2.0\ \text{s}) = -10\ \text{m}$ and the bag is 20 m below the helicopter.

d. What is common to the three answers above?

The bag is 20 m below the helicopter after 2.0 s.

35. A weather balloon is floating at a constant height above Earth when it releases a pack of instruments.

a. If the pack hits the ground with a velocity of –73.5 m/s, how far does the pack fall?

$$v_f^2 = v_i^2 + 2gd$$

$$d = \frac{v_f^2 - v_i^2}{2g} = \frac{(-73.5\ \text{m/s})^2 - 0}{(2)(-9.80\ \text{m/s}^2)}$$

$$= \frac{5402\ \text{m}^2/\text{s}^2}{-19.6\ \text{m/s}^2} = -276\ \text{m}$$

b. How long does the pack fall?

$$v_f = v_i + gt$$

$$t = \frac{v_f - v_i}{g} = \frac{-73.5\ \text{m/s} - 0}{-9.80\ \text{m/s}^2} = 7.50\ \text{s}$$

36. During a baseball game, a batter hits a high pop–up. If the ball remains in the air for 6.0 s, how high does it rise? Hint: Calculate the height using the second half of the trajectory.

Let the time be 3.0 s

$$d = v_i t + \frac{1}{2}gt^2$$

$$= 0 + \frac{1}{2}(-9.8\ \text{m/s}^2)(3.0\ \text{s})^2 = -44\ \text{m}$$

The ball rises 44 m, the same distance it falls.

37. A tennis ball is dropped from 1.20 m above the ground. It rebounds to a height of 1.00 m.

a. With what velocity does it hit the ground?

Using $v_f^2 = v_i^2 + 2gd$,
$v_f^2 = 2gd$
$= 2(-9.80\ \text{m/s}^2)(1.20\ \text{m})$
$v_f = -4.85$ m/s (downward)

b. With what velocity does it leave the ground?

Using $v_f^2 = v_i^2 + 2gd$,
$v_i^2 = -2gd$
$= -2(-9.80\ \text{m/s}^2)(1.00\ \text{m})$,
$v_i = 4.43$ m/s

c. If the tennis ball were in contact with the ground for 0.010 s, find its acceleration while touching the ground. Compare to g.

$$a = \frac{(v_f - v_i)}{t} = \frac{(4.43\ \text{m/s} - (-4.85\ \text{m/s}))}{0.010\ \text{s}}$$

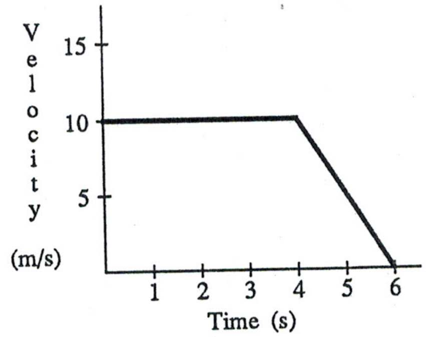
$= +930$ m/s², or some 95 times g

Supplemental Problems (Appendix B)

1. From the moment a 40 m/s fastball touches the catcher's glove until it is completely stopped takes 0.012 s. Calculate the average acceleration of the ball as it is being caught.

$$a = \frac{v_f - v_i}{t} = \frac{0 - 40}{0.012} = -3.3 \times 10^3\ \text{m/s}^2$$

2. The following velocity–time graph describes a familiar motion of a car traveling during rush hour traffic.



a. Describe the car's motion from $t = 0$ s to $t = 4$ s.

Constant velocity of 10 m/s.

b. Describe the car's motion from $t = 4$ s to $t = 6$ s.

Slowing down to a stop.

c. What is the average acceleration for the first 4 seconds?

0 m/s²

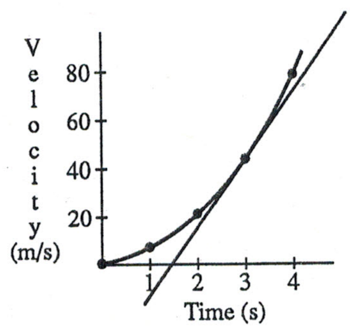
d. What is the average acceleration from $t = 4$ s to $t = 6$ s?

$$\frac{-10\ \text{m/s}}{2\ \text{s}} = -5\ \text{m/s}^2$$

3. Given the following table:

Time (s)	Velocity (m/s)
0.0	0.0
1.0	5.0
2.0	20.0
3.0	45.0
4.0	80.0

a. Plot a velocity–time graph for this motion.



b. Is this motion constant velocity? uniform acceleration?

No, No

c. Calculate the instantaneous acceleration at $t = 3.0$ s.

Slope of the tangent is $\approx$ 30 m/s²

4. Top fuel drag racers are able to uniformly accelerate at 12.5 m/s² from rest to 100 m/s before crossing the finish line. How much time elapses during the run?

$$t = \frac{v_f - v_i}{a} = \frac{100\ \text{m/s} - 0}{12.5\ \text{m/s}^2} = 8.00\ \text{s}$$

Supplemental Problems

5. A race car accelerates from rest at +7.5 m/s² for 4.5 s. How fast will it be going at the end of that time?

$$v_f = v_i + at = 0 + (7.5\ \text{m/s}^2)(4.5\ \text{s}) = 34\ \text{m/s}$$

6. A race car starts from rest and is accelerated uniformly to +41 m/s in 8.0 s. What is the car's displacement?

$$d = \frac{(v_f + v_i)t}{2} = \frac{(41\ \text{m/s} + 0)(8.0\ \text{s})}{2} = 160\ \text{m}$$

7. A jet plane traveling at +88 m/s lands on a runway and comes to rest in 11 s.

a. Calculate its uniform acceleration.

$$a = \frac{(v_f - v_i)}{t} = \frac{(0 - 88\ \text{m/s})}{(11\ \text{s})} = -8.0\ \text{m/s}^2$$

b. Calculate the distance it travels.

$$d = v_i t + \frac{1}{2}at^2$$
$$= (88\ \text{m/s})(11\ \text{s}) + \left[\frac{1}{2}\right](-8.0\ \text{m/s}^2)(11\ \text{s})^2$$
$$= 480\ \text{m}$$

8. A bullet accelerates at 6.8 × 10⁴ m/s² from rest as it travels the 0.80 m of the rifle barrel.

a. How long was the bullet in the barrel?

$$d = v_i t + \frac{1}{2}at^2$$

$$0.80 = (0\ \text{m/s})t + \frac{1}{2}(6.8 \times 10^4\ \text{m/s}^2)t^2$$

$$t = \sqrt{\frac{2(0.80\ \text{m})}{6.8 \times 10^4\ \text{m/s}}} = 4.9 \times 10^{-3}\ \text{s}$$

b. What velocity does the bullet have as it leaves the barrel?

$$v_f = v_i + at$$
$$= 0 + (6.8 \times 10^4\ \text{m/s})(4.9 \times 10^{-3}\ \text{s})$$
$$= 3.3 \times 10^2\ \text{m/s}$$

9. A car traveling at 14 m/s encounters a patch of ice and takes 5.0 s to stop.

a. What is the car's acceleration?

$$a = \frac{v_f - v_i}{t} = \frac{0 - 14\ \text{m/s}}{5.0\ \text{s}} = -2.8\ \text{m/s}^2$$

4

b. How far does it travel before stopping?

$$d = \left[\frac{v_f + v_i}{2}\right]t = \left[\frac{0 + 14\text{ m/s}}{2}\right]5.0\text{ s} = 35\text{ m}$$

10. A motorcycle traveling at 16 m/s accelerates at a constant rate of 4.0 m/s² over 50 m. What is its final velocity?

$$v_f^2 = v_i^2 + 2ad = (16\text{ m/s})^2 + 2(4.0\text{ m/s})(50\text{ m}) = 656\text{ m}^2/\text{s}^2$$

$$v_f = 26\text{ m/s}$$

11. A hockey player skating at 18 m/s comes to a complete stop in 2.0 m. What is the acceleration of the hockey player?

$$a = \frac{v_f^2 - v_i^2}{2d} = \frac{0^2 - (18\text{ m/s})^2}{2(2.0\text{ m})} = -81\text{ m/s}^2$$

12. Police find skid marks 60 m long on a highway showing where a car made an emergency stop. Assuming that the acceleration was –10 m/s² (about the maximum for dry pavement), how fast was the car going? Was the car exceeding the 80 km/h speed limit?

$v_f^2 = v_i^2 + 2ad.$
Since $v_f = 0$, $v_i^2 = -2ad$
$= -2(-10\text{ m/s}^2)(60\text{ m})$
$= 1200\text{ m}^2/\text{s}^2$,
$v_i = 35\text{ m/s} = 130\text{ km/h}$.
Yes, the car was exceeding the speed limit.

13. An accelerating lab cart passes through two photo gate timers 3.0 m apart in 4.2 s. The velocity of the cart at the second timer is 1.2 m/s.

a. What is the cart's velocity at the first gate?

$$d = \left[\frac{v_f + v_i}{2}\right]t$$

$$3.0 = \left[\frac{1.2 + v_i}{2}\right]4.2$$

$$\frac{6.0}{4.2} = 1.2 + v_i$$

$$v_i = 0.2\text{ m/s}$$

Supplemental Problems

b. What is the acceleration?

$$a = \frac{v_f - v_i}{t}$$

$$a = \frac{1.2\text{ m/s} - .23\text{ m/s}}{4.2\text{ s}}$$

$$a = 0.24\text{ m/s}^2$$

14. A camera is accidentally dropped from the edge of a cliff and 6.0 s later reaches the bottom.

a. How fast was it going just before it hit?

$v_f = v_i + at$
$= 0 + 9.8\text{ m/s}^2(6.0\text{ s}) = 59\text{ m/s}$

b. How high is the cliff?

$$d = v_i t + \frac{1}{2}at^2$$

$$= 0(6.0\text{ s}) + \frac{1}{2}(9.8\text{ m/s}^2)(6.0\text{ s})^2$$

$$= 1.8 \times 10^2\text{ m}$$

15. A rock is thrown vertically with a velocity of 20 m/s from the edge of a bridge 42 m above a river. How long does the rock stay in the air?

To get back to bridge height

$$t = \frac{v_f - v_i}{a} = \frac{-20 - 20}{-9.8} = 4.1\text{ s}$$

Velocity before going into river

$v_f^2 = v_i^2 + 2ad$
$= (20\text{ m/s})^2 + 2(9.8\text{ m/s}^2)(42\text{ m})$
$= 1223.2\text{ m}^2/\text{s}^2$
$v_f = 35\text{ m/s}$

Time to fall from bridge to river

$$t = \frac{v_f - v_i}{a} = \frac{35\text{ m/s} - 20\text{ m/s}}{9.8\text{ m/s}^2} = 1.5\text{ s}$$

Total time

4.1 s + 1.5 s = 5.6 s

16. A platform diver jumps vertically with a velocity of 4.2 m/s. 2.5 s later the diver enters the water. How high is the platform above the water?

$$d = v_i t + \frac{1}{2}at^2$$

$$= (4.2\ \text{m/s})(2.5\ \text{s}) + \frac{1}{2}(-9.8\ \text{m/s}^2)(2.5\ \text{s})^2$$

$$= -20\ \text{m}$$

Diver is 20 m below starting point
platform is 20 m high.

4