Chapter 1: Motion in a Straight Line

Mini Investigation: The Effect of Gravity on the Motion of Objects, page 7

A. Answers may vary. Sample answer:
Yes, I predicted that the spheres would take the same amount of time to fall and they did.
B. No, the spheres took the same amount of time to fall.
C. Unlike in the first drop, the paper takes longer to fall than the sphere. The sphere falls in a straight line while the paper floats in different directions.
D. Once the sheet of paper is crumpled, it falls in the same amount of time as the spheres, and falls in a straight line.

Section 1.1: Distance, Position, and Displacement

Tutorial 1 Practice, page 11

1. Given: $\vec{d}_{\text{inital}}$ = 16.4 m [W];
$\vec{d}_{\text{final}}$ = 64.9 m [W]

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}\\ &= 64.9 \text{ m [W]} - 16.4 \text{ m [W]}\\ \Delta\vec{d}_{\text{T}} &= 48.5 \text{ m [W]}\end{aligned}$$

Statement: The displacement of the golf ball is 48.5 m [W].

2. Given: $\Delta\vec{d}_1$ = 3.8 m [N]; $\Delta\vec{d}_2$ = 6.3 m [N]

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \Delta\vec{d}_1 + \Delta\vec{d}_2\\ &= 3.8 \text{ m [N]} + 6.3 \text{ m [N]}\\ \Delta\vec{d}_{\text{T}} &= 10.1 \text{ m [N]}\end{aligned}$$

Statement: The rabbit's total displacement is 10.1 m [N].

3. Given: $\Delta\vec{d}_1$ = 4.2 m [up]; $\Delta\vec{d}_2$ = 2.7 m [down]

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution:
$$\begin{aligned}\Delta\vec{d}_{\text{T}} &= \Delta\vec{d}_1 + \Delta\vec{d}_2\\ &= 4.2 \text{ m [up]} + 2.7 \text{ m [down]}\\ &= 4.2 \text{ m [up]} - 2.7 \text{ m [up]}\\ \Delta\vec{d}_{\text{T}} &= 1.5 \text{ m [up]}\end{aligned}$$

Statement: The skateboarder's total displacement is 1.5 m [up].

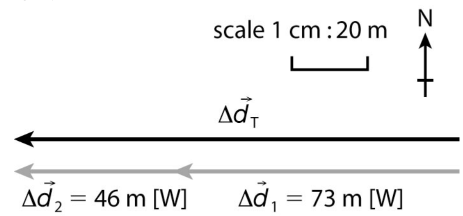
Tutorial 2 Practice, page 13

1. Given: $\Delta\vec{d}_1$ = 73 m [W]; $\Delta\vec{d}_2$ = 46 m [W]

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution:



This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$. The resultant vector, $\Delta\vec{d}_{\text{T}}$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_2$. The direction of $\Delta\vec{d}_{\text{T}}$ is [W].
$\Delta\vec{d}_{\text{T}}$ measures 6.0 cm in length, so using the scale of 1 cm : 20 m, the actual magnitude of $\Delta\vec{d}_{\text{T}}$ is 120 m [W].

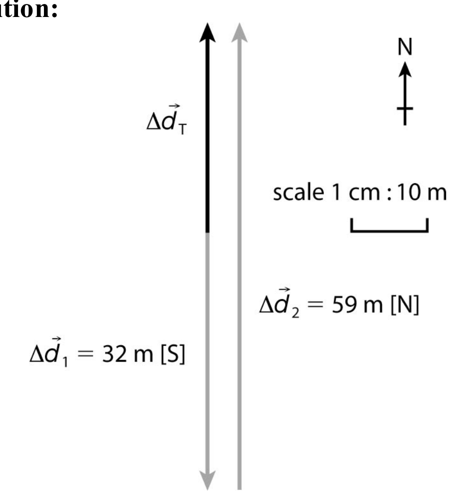
Statement: The car's total displacement is 120 m [W].

2. Given: $\Delta\vec{d}_1$ = 32 m [S]; $\Delta\vec{d}_2$ = 59 m [N]

Required: $\Delta\vec{d}_{\text{T}}$

Analysis: $\Delta\vec{d}_{\text{T}} = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution:



This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$. The resultant vector, $\Delta\vec{d}_T$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_2$. The direction of $\Delta\vec{d}_T$ is [N].

$\Delta\vec{d}_T$ measures 2.7 cm in length, so using the scale of 1 cm : 10 m, the actual magnitude of $\Delta\vec{d}_T$ is 27 m [N].

Statement: The robin's total displacement is 27 m [N].

Section 1.1 Questions, page 13

1. (a) The quantity is a scalar because no direction is given.

(b) The quantity is a vector because it includes both distance and direction.

(c) The quantity is a scalar because no direction is given.

2. Answers may vary. Sample answers:

(a) Position is the distance and direction of an object from the point of reference. Displacement is the change in position of an object.

(b) Distance is a scalar quantity of the total length of the path travelled by an object in motion. Displacement is a vector quantity of the change in distance in a certain direction.

3. Given: $\vec{d}_{\text{initial}} = 25$ m [W]; $\vec{d}_{\text{final}} = 76$ m [W]

Required: $\Delta\vec{d}_T$

Analysis: $\Delta\vec{d}_T = \vec{d}_{\text{final}} - \vec{d}_{\text{initial}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_T &= \vec{d}_{\text{final}} - \vec{d}_{\text{initial}}\\ &= 76 \text{ m [W]} - 25 \text{ m [W]}\\ \Delta\vec{d}_T &= 51 \text{ m [W]}\end{aligned}$$

Statement: The displacement of the locomotive is 51 m [W].

4. Given: $\vec{d}_{\text{inital}} = 52$ km [W]; $\vec{d}_{\text{final}} = 139$ km [E]

Required: $\Delta\vec{d}_T$

Analysis: $\Delta\vec{d}_T = \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}$

Solution:
$$\begin{aligned}\Delta\vec{d}_T &= \vec{d}_{\text{final}} - \vec{d}_{\text{inital}}\\ &= 139 \text{ km [E]} - 52 \text{ km [W]}\\ &= 139 \text{ km [E]} + 52 \text{ km [E]}\\ \Delta\vec{d}_T &= 191 \text{ km [E]}\end{aligned}$$

Statement: The total displacement of the car is 191 km [E].

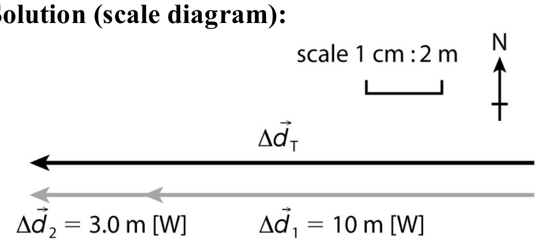
5. (a) Given: $\Delta\vec{d}_1 = 10$ m [W]; $\Delta\vec{d}_2 = 3.0$ m [W]

Required: $\Delta\vec{d}_T$

Analysis: $\Delta\vec{d}_T = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution (algebraic):
$$\begin{aligned}\Delta\vec{d}_T &= \Delta\vec{d}_1 + \Delta\vec{d}_2\\ &= 10 \text{ m [W]} + 3.0 \text{ m [W]}\\ \Delta\vec{d}_T &= 13.0 \text{ m [W]}\end{aligned}$$

Solution (scale diagram):



This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$. The resultant vector, $\Delta\vec{d}_T$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_2$. The direction of $\Delta\vec{d}_T$ is [W].

$\Delta\vec{d}_T$ measures 6.5 cm in length, so using the scale of 1 cm : 2 m, the actual magnitude of $\Delta\vec{d}_T$ is 13 m [W].

Statement: The total displacement is 13 m [W].

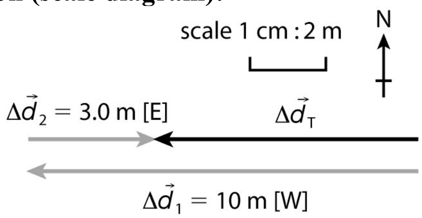
(b) Given: $\Delta\vec{d}_1 = 10$ m [W]; $\Delta\vec{d}_2 = 3.0$ m [E]

Required: $\Delta\vec{d}_T$

Analysis: $\Delta\vec{d}_T = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution (algebraic):
$$\begin{aligned}\Delta\vec{d}_T &= \Delta\vec{d}_1 + \Delta\vec{d}_2\\ &= 10 \text{ m [W]} + 3.0 \text{ m [E]}\\ &= 10 \text{ m [W]} - 3.0 \text{ m [W]}\\ \Delta\vec{d}_T &= 7.0 \text{ m [W]}\end{aligned}$$

Solution (scale diagram):



This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$. The resultant vector, $\Delta\vec{d}_T$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_2$. The direction of $\Delta\vec{d}_T$ is [W].

$\Delta\vec{d}_T$ measures 3.5 cm in length, so using the scale of 1 cm : 2 m, the actual magnitude of $\Delta\vec{d}_T$ is 7.0 m [W].

Statement: The total displacement is 7.0 m [W].

(c) Given: $\Delta\vec{d}_1 = 28$ m [N]; $\Delta\vec{d}_2 = 7.0$ m [S]

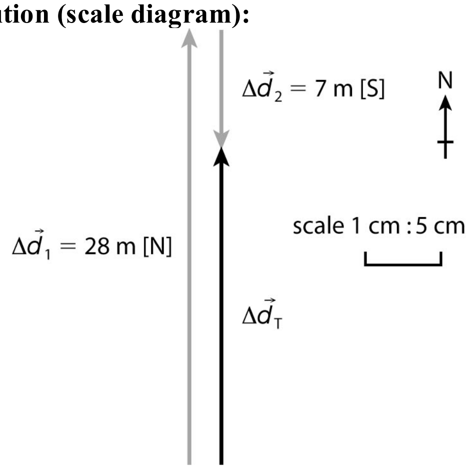
Required: $\Delta\vec{d}_T$

Analysis: $\Delta\vec{d}_T = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Solution (algebraic):

$$\begin{aligned}
\Delta\vec{d}_T &= \Delta\vec{d}_1 + \Delta\vec{d}_2 \\
&= 28 \text{ m [N]} + 7.0 \text{ m [S]} \\
&= 28 \text{ m [N]} - 7.0 \text{ m [N]} \\
\Delta\vec{d}_T &= 21.0 \text{ m [N]}
\end{aligned}$$

Solution (scale diagram):



This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$. The resultant vector, $\Delta\vec{d}_T$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_2$. The direction of $\Delta\vec{d}_T$ is [W].

$\Delta\vec{d}_T$ measures 4.2 cm in length, so using the scale of 1 cm : 5 m, the actual magnitude of $\Delta\vec{d}_T$ is 21.0 m [N].

Statement: The total displacement is 21.0 m [N].

(d) Given: $\Delta\vec{d}_1 = 7.0$ km [W]; $\Delta\vec{d}_2 = 12$ km [E]; $\Delta\vec{d}_3 = 5.0$ km [W]

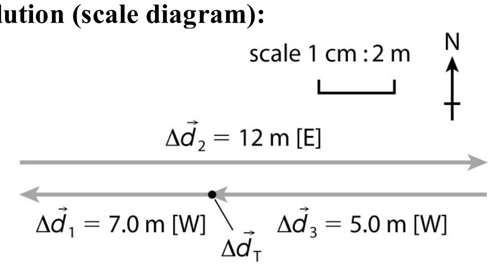
Required: $\Delta\vec{d}_T$

Analysis: $\Delta\vec{d}_T = \Delta\vec{d}_1 + \Delta\vec{d}_2 + \Delta\vec{d}_3$

Solution (algebraic):

$$\begin{aligned}
\Delta\vec{d}_T &= \Delta\vec{d}_1 + \Delta\vec{d}_2 + \Delta\vec{d}_3 \\
&= 7.0 \text{ km [W]} + 12 \text{ km [E]} + 5.0 \text{ km [W]} \\
&= 7.0 \text{ km [W]} - 12 \text{ km [W]} + 5.0 \text{ km [W]} \\
\Delta\vec{d}_T &= 0.0 \text{ km}
\end{aligned}$$

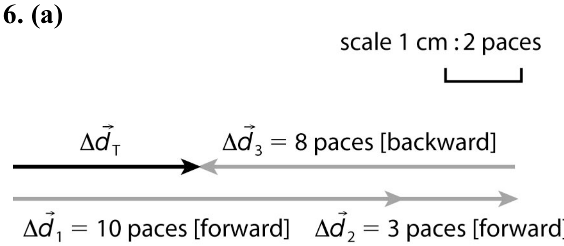
Solution (scale diagram):



This figure shows the given vectors, with the tip of $\Delta\vec{d}_1$ joined to the tail of $\Delta\vec{d}_2$ and the tip of $\Delta\vec{d}_2$ joined to the tail of $\Delta\vec{d}_3$. The resultant vector, $\Delta\vec{d}_T$ is drawn in black, from the tail of $\Delta\vec{d}_1$ to the tip of $\Delta\vec{d}_3$. $\Delta\vec{d}_T$ has no magnitude or direction.

Statement: The total displacement is 0.0 km.

6. (a)



(b) Answers may vary. Sample answer:
I got the result of 5 paces total displacement from the vector scale diagram, so I marked my fifth step while making the 10 paces forward. When I finished the 8 paces backwards, I was almost right at my marker. My experimental results were almost exactly the same as my predicted result.

Section 1.2: Speed and Velocity

Tutorial 1 Practice, page 15

1. Given: Δd = 3.7 m; Δt = 1.8 s

Required: v_{av}

Analysis: $v_{av} = \dfrac{\Delta d}{\Delta t}$

Solution:
$$\begin{aligned} v_{av} &= \frac{\Delta d}{\Delta t} \\ &= \frac{3.7\text{ m}}{1.8\text{ s}} \\ v_{av} &= 2.1\text{ m/s} \end{aligned}$$

Statement: The average speed of the paper airplane is 2.1 m/s.

2. Given: v_{av} = 8.33 m/s; Δt = 3.27 s

Required: Δd

Analysis:
$$\begin{aligned} v_{av} &= \frac{\Delta d}{\Delta t} \\ \Delta d &= v_{av}\,\Delta t \end{aligned}$$

Solution:
$$\begin{aligned} \Delta d &= v_{av}\,\Delta t \\ &= \left(8.33\,\frac{\text{m}}{\cancel{\text{s}}}\right)\left(3.27\,\cancel{\text{s}}\right) \\ \Delta d &= 27.2\text{ m} \end{aligned}$$

Statement: A cheetah can run 27.2 m in 3.27 s.

3. Given: v_{av} = 1.2 m/s; Δd = 2.8 m

Required: Δt

Analysis:
$$\begin{aligned} v_{av} &= \frac{\Delta d}{\Delta t} \\ \Delta t &= \frac{\Delta d}{v_{av}} \end{aligned}$$

Solution:
$$\begin{aligned} \Delta t &= \frac{\Delta d}{v_{av}} \\ &= \frac{2.8\,\cancel{\text{m}}}{1.2\,\dfrac{\cancel{\text{m}}}{\text{s}}} \\ \Delta t &= 2.3\text{ s} \end{aligned}$$

Statement: It will take the rock 2.3 s to fall through 2.8 m of water.

Research This: Searching for Speeders, page 15

Answers may vary. Sample answers:

A. The use of laser speed devices and other methods of monitoring speed decreases the number of automobile collisions and fatalities in Canada. Police are able to go to high-risk areas and even just by their presence, remind drivers to slow down and be careful. If the locations where police often monitor speeds become known, then drivers who want to avoid tickets will obey the speed limits even when there are no police present.

B. The use of laser speed devices may be the preferred way for police to monitor speed because it is accurate, can be operated from the roadside and at a distance, and is probably much more affordable than patrolling or using aircraft to monitor speed.

C. I do not support the use of devices like these because they do nothing to prevent collisions. These devices allow speeders to go as fast as they want, then pay the tickets later when they should be stopped and warned or fined immediately.

Tutorial 2 Practice, page 18

1. Given: $\Delta\vec{d}$ = 2.17 m [E]; Δt = 1.36 s

Required: $\vec{v}_{av}$

Analysis: $\vec{v}_{av} = \dfrac{\Delta\vec{d}}{\Delta t}$

Solution:
$$\begin{aligned} \vec{v}_{av} &= \frac{\Delta\vec{d}}{\Delta t} \\ &= \frac{2.17\text{ m [E]}}{1.36\text{ s}} \\ \vec{v}_{av} &= 1.60\text{ m/s [E]} \end{aligned}$$

Statement: The average velocity of the soccer ball is 1.60 m/s [E].

2. Given: $\Delta\vec{d}$ = 8.2 m [N]; $\vec{v}_{av}$ = 3.7 m/s [N]

Required: Δt

Analysis:
$$\begin{aligned} \vec{v}_{av} &= \frac{\Delta\vec{d}}{\Delta t} \\ \Delta t &= \frac{\Delta\vec{d}}{\vec{v}_{av}} \end{aligned}$$

Solution:
$$\begin{aligned} \Delta t &= \frac{\Delta\vec{d}}{\vec{v}_{av}} \\ &= \frac{8.2\,\cancel{\text{m}}\text{ [N]}}{3.7\,\dfrac{\cancel{\text{m}}}{\text{s}}\text{ [N]}} \\ \Delta t &= 2.2\text{ s} \end{aligned}$$

Statement: It will take a cat 2.2 s to run 8.2 m.

Mini Investigation: Bodies in Motion, page 20

Answers may vary. Sample answers:

A. I predicted the graphs for slow and fast constant speed would be straight lines, and that slow constant speed would be less steep than fast constant speed, which is true. I predicted the graphs for variable speed (speeding up and slowing down) would be curves, which they are.

B. It is difficult to make most letters because you cannot have two positions for the same time, so for example, you cannot go back and make the little horizontal line in an A. Also, you cannot make vertical lines, so I had to cheat a bit. The easiest letters to make were U, V, and W, and I could make graphs that looked like I, J, L, M, and N.

Section 1.2 Questions, page 20

1. Answers may vary. Sample answer:
When solving a problem, if no direction is provided with the value, then the value is a scalar (speed). If direction is provided, then the value is a vector (velocity).

2. Answers may vary. Sample answer:
Motion with uniform velocity describes an object moving in just one direction at a constant speed.

3. Answers may vary. Sample answer:
Two examples of uniform velocity are an anchor sinking in a lake at a constant speed and a runner travelling in a straight line at 3 m/s.
Two examples of non-uniform velocity are a car slowing down and a speed skater going in laps around a rink.

4. Given: $\Delta\vec{d} = 15$ m [W]; $\Delta t = 5$ s

Required: $\vec{v}_{\text{av}}$

Analysis: $\vec{v}_{\text{av}} = \dfrac{\Delta\vec{d}}{\Delta t}$

Solution:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t} = \frac{15\text{ m [W]}}{5\text{ s}}$$
$$\vec{v}_{\text{av}} = 3\text{ m/s [W]}$$

Statement: The average velocity described by the graph is 3 m/s [W].

5.

$\vec{v}_{\text{av}}$	$\Delta\vec{d}$	Δt
0.773 m/s [S]	12.6 m [S]	16.3 s
2.0×10^3 m/s [E]	25 m [E]	**0.01 s**
40 m/s [N]	**10 m [N]**	0.25 s

First Row:

Given: $\Delta\vec{d} = 12.6$ m [S]; $\Delta t = 16.3$ s

Required: $\vec{v}_{\text{av}}$

Analysis: $\vec{v}_{\text{av}} = \dfrac{\Delta\vec{d}}{\Delta t}$

Solution:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t} = \frac{12.6\text{ m [S]}}{16.3\text{ s}}$$
$$\vec{v}_{\text{av}} = 0.773\text{ m/s [S]}$$

Statement: The average velocity is 0.773 m/s [S].

Second Row:

Given: $\vec{v}_{\text{av}} = 2.0 \times 10^3$ m/s [E]; $\Delta\vec{d} = 25$ m [E]

Required: Δt

Analysis:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\Delta t = \frac{\Delta\vec{d}}{\vec{v}_{\text{av}}}$$

Solution:
$$\Delta t = \frac{\Delta\vec{d}}{\vec{v}_{\text{av}}} = \frac{25\ \cancel{\text{m}}\text{ [E]}}{2000\ \frac{\cancel{\text{m}}}{\text{s}}\text{ [E]}}$$
$$\Delta t = 0.01\text{ s}$$

Statement: The time required is 0.01 s.

Third Row:

Given: $\vec{v}_{\text{av}} = 40$ m/s [N]; $\Delta t = 0.25$ s

Required: $\Delta\vec{d}$

Analysis:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\Delta\vec{d} = \vec{v}_{\text{av}}\Delta t$$

Solution:
$$\Delta\vec{d} = \vec{v}_{\text{av}}\Delta t = \left(40\ \frac{\text{m}}{\cancel{\text{s}}}\text{ [N]}\right)(0.25\ \cancel{\text{s}})$$
$$\Delta\vec{d} = 10\text{ m [N]}$$

Statement: The displacement is 10 m [N].

6. Given: $\vec{v}_{\text{av}} = 3.2$ m/s [S]; $\Delta t = 12$ s

Required: $\Delta\vec{d}$

Analysis:
$$\vec{v}_{\text{av}} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\Delta\vec{d} = \vec{v}_{\text{av}}\Delta t$$

Solution:
$$\Delta\vec{d} = \vec{v}_{\text{av}}\Delta t = \left(3.2\ \frac{\text{m}}{\cancel{\text{s}}}\text{ [S]}\right)(12\ \cancel{\text{s}})$$
$$\Delta\vec{d} = 38\text{ m [S]}$$

Statement: The displacement of the horse is 38 m [S].

7. Given: v_{av} = 100.0 km/h; Δd = 16 m [E]
Required: Δt

Analysis: $v_{av} = \frac{\Delta d}{\Delta t}$

$$\Delta t = \frac{\Delta d}{v_{av}}$$

Solution: Convert the units from kilometres per hour to metres per second:

$$v_{av} = \left(100.0\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\ \text{s}}\right)\left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)$$
$$= 27.7778\ \text{m/s (two extra digits carried)}$$

$$\Delta t = \frac{\Delta d}{v_{av}}$$
$$= \frac{16\ \cancel{\text{m}}}{27.7778\ \frac{\cancel{\text{m}}}{\text{s}}}$$
$$\Delta t = 0.58\ \text{s}$$

Statement: The car will take 0.58 s to travel 16 m.

8. Given: $\Delta \vec{d}$ = 8.864 km [S]; Δt = 0.297 min
Required: $\vec{v}_{av}$

Analysis: $\vec{v}_{av} = \frac{\Delta \vec{d}}{\Delta t}$

Solution: Convert the units from kilometres to metres and from minutes to seconds:

$$\Delta \vec{d} = \left(8.864\ \cancel{\text{km}}\ [\text{S}]\right)\left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)$$
$$= 8864\ \text{m [S]}$$

$$\Delta t = \left(0.297\ \cancel{\text{min}}\right)\left(\frac{60\ \text{s}}{1\ \cancel{\text{min}}}\right)$$
$$= 17.82\ \text{s (one extra digit carried)}$$

$$\vec{v}_{av} = \frac{\Delta \vec{d}}{\Delta t}$$
$$= \frac{8864\ \text{m [S]}}{17.82\ \text{s}}$$
$$\vec{v}_{av} = 497\ \text{m/s [S]}$$

Statement: The velocity of the fighter jet is 497 m/s [S].

Section 1.3: Acceleration

Tutorial 1 Practice, page 24

1. Given: $\vec{v}_i = 0$ m/s; $\vec{v}_f = 15.0$ m/s [S]; $\Delta t = 12.5$ s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\Delta \vec{v}}{\Delta t}$

$$\vec{a}_{av} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

Solution: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$\begin{aligned} &= \frac{15.0 \text{ m/s [S]} - 0 \text{ m/s}}{12.5 \text{ s}} \\ &= \frac{15.0 \text{ m/s [S]}}{12.5 \text{ s}} \\ \vec{a}_{av} &= 1.20 \text{ m/s}^2 \text{ [S]} \end{aligned}$$

Statement: The rock's average acceleration is 1.20 m/s^2 [S].

2. Given: $\vec{v}_i = 17$ m/s [N]; $\vec{v}_f = 25$ m/s [N]; $\Delta t = 12$ s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

Solution: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$\begin{aligned} &= \frac{25 \text{ m/s [N]} - 17 \text{ m/s [N]}}{12 \text{ s}} \\ &= \frac{8 \text{ m/s [N]}}{12 \text{ s}} \\ \vec{a}_{av} &= 0.67 \text{ m/s}^2 \text{ [N]} \end{aligned}$$

Statement: The car's average acceleration is 0.67 m/s^2 [N].

3. Given: $\vec{v}_i = 25$ m/s [W]; $\vec{v}_f = 29$ m/s [E]; $\Delta t = 0.25$ s

Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

Solution: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$\begin{aligned} &= \frac{29 \text{ m/s [E]} - 25 \text{ m/s [W]}}{0.25 \text{ s}} \\ &= \frac{29 \text{ m/s [E]} + 25 \text{ m/s [E]}}{0.25 \text{ s}} \\ &= \frac{54 \text{ m/s [E]}}{0.25 \text{ s}} \\ \vec{a}_{av} &= 220 \text{ m/s}^2 \text{ [E]} \end{aligned}$$

Statement: The squash ball's average acceleration is 220 m/s^2 [E] or $2.2 \times 10^2 \text{ m/s}^2$ [E].

Tutorial 2 Practice, page 25

1. Given: $\vec{v}_i = 3.2$ m/s [W]; $\vec{v}_f = 5.8$ m/s [W]; $\vec{a}_{av} = 1.23 \text{ m/s}^2$ [W]

Required: Δt

Analysis: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$\Delta t = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}_{av}}$$

Solution: $\Delta t = \dfrac{\vec{v}_f - \vec{v}_i}{\vec{a}_{av}}$

$$\begin{aligned} &= \frac{5.8 \text{ m/s [W]} - 3.2 \text{ m/s [W]}}{1.23 \text{ m/s}^2 \text{ [W]}} \\ &= \frac{2.6 \dfrac{\cancel{\text{m}}}{\cancel{\text{s}}} \text{ [W]}}{1.23 \dfrac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}} \text{ [W]}} \\ \Delta t &= 2.1 \text{ s} \end{aligned}$$

Statement: The radio-controlled car's acceleration will take 2.1 s.

2. Given: $\vec{v}_f = 17$ m/s [W]; $\vec{a}_{av} = 2.4 \text{ m/s}^2$ [W]; $\Delta t = 6.2$ s

Required: $\vec{v}_i$

Analysis: $\vec{a}_{av} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$

$$\begin{aligned} \vec{a}_{av}\,\Delta t &= \vec{v}_f - \vec{v}_i \\ \vec{v}_i &= \vec{v}_f - \vec{a}_{av}\,\Delta t \end{aligned}$$

Solution:

$$\begin{aligned} \vec{v}_i &= \vec{v}_f - \vec{a}_{av}\,\Delta t \\ &= 17 \text{ m/s [W]} - \left(2.4 \frac{\text{m}}{\text{s}^{\cancel{2}}} \text{ [W]}\right)\left(6.2 \text{ s}\right) \\ &= 17 \text{ m/s [W]} - 14.88 \text{ m/s [W] (two extra digits carried)} \\ \vec{v}_i &= 2.1 \text{ m/s [W]} \end{aligned}$$

Statement: The initial velocity of the speedboat was 2.1 m/s [W].

Tutorial 3 Practice, page 26

1. (a) Given: $b = 4.0$ s; $h = 8.0$ m/s [S]

Required: $\Delta \vec{d}$

Analysis: $\Delta \vec{d} = A_{triangle}$

Solution:

$$\begin{aligned}\Delta\vec{d} &= A_{\text{triangle}}\\ &= \frac{1}{2}bh\\ &= \frac{1}{2}(4.0\ \cancel{\text{s}})\left(8.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{S}]\right)\\ \Delta\vec{d} &= 16\ \text{m [S]}\end{aligned}$$

Statement: The object has travelled 16 m [S] after 4.0 s.

(b) Given: b = 5.0 s; h = 10.0 m/s [S]; l = 2.5 s; w = 10.0 m/s [S]

Required: $\Delta\vec{d}$

Analysis: $\Delta\vec{d} = A_{\text{triangle}} + A_{\text{rectangle}}$

Solution:

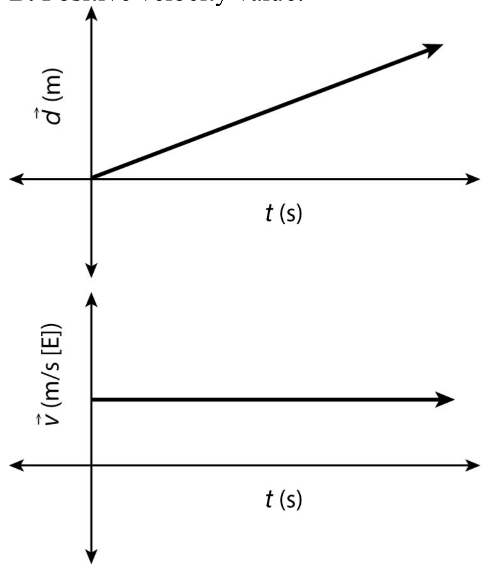
$$\begin{aligned}\Delta\vec{d} &= A_{\text{triangle}} + A_{\text{rectangle}}\\ &= \frac{1}{2}bh + lw\\ &= \frac{1}{2}(5.0\ \cancel{\text{s}})\left(10.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{S}]\right) + (2.5\ \cancel{\text{s}})\left(10.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{S}]\right)\\ &= 25.0\ \text{m [S]} + 25.0\ \text{m [S]}\\ \Delta\vec{d} &= 50\ \text{m [S]}\end{aligned}$$

Statement: The object has travelled 50 m [S] after 7.5 s.

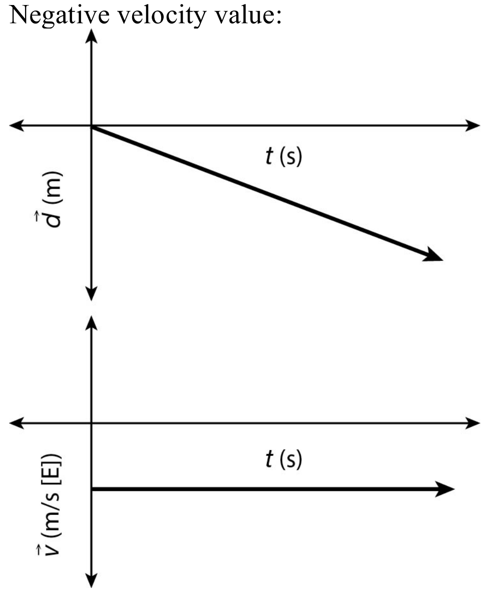
Mini Investigation: Motion Simulations, page 27

A. Positive velocity value: The position–time graph will be a straight line starting at the origin with a positive slope. The velocity–time graph will be a horizontal line with positive value.
Negative velocity value: The position–time graph will be a straight line starting at the origin with a negative slope. The velocity–time graph will be a horizontal line with negative value.
Negative initial position, positive velocity value: The position–time graph will be a straight line starting below the x-axis with a positive slope. The velocity–time graph will be a horizontal line with positive value.
Negative initial position, negative velocity value: The position–time graph will be a straight line starting below the x-axis with a negative slope. The velocity–time graph will be a horizontal line with negative value.

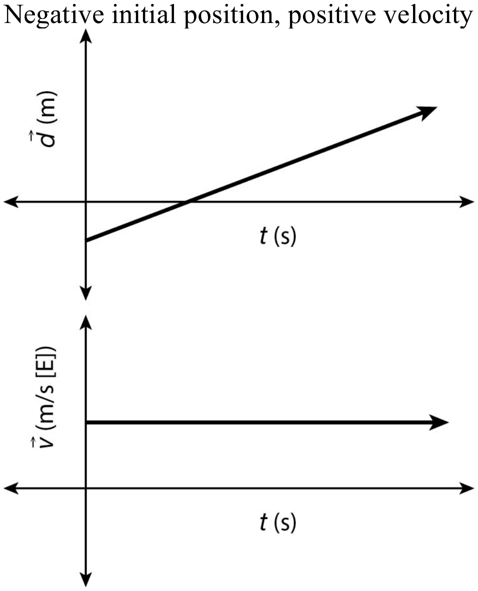
B. Positive velocity value:



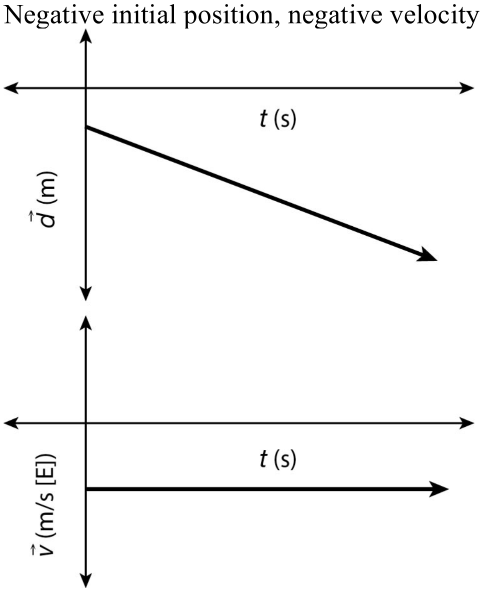
Negative velocity value:



Negative initial position, positive velocity value:



Negative initial position, negative velocity value:



C. Differences are due to the difficulty in using the mouse to mimic constant velocity.

Tutorial 4 Practice, page 29

1. (a) Given: t = 1.0 s; position–time graph

Required: $\vec{v}_{\text{inst}}$

Analysis: $\vec{v}_{\text{inst}}$ is equal to the slope, m, of the tangent to the curve at t = 1.0 s, so $m = \dfrac{\Delta\vec{d}}{\Delta t}$.

By placing a ruler along the curve in Figure 6 at t = 1.0 s, I can picture the tangent. The tangent has a rise of 4.0 m [E] over a run of 2.0 s.

Solution:
$$m = \frac{\Delta\vec{d}}{\Delta t}$$
$$m = \frac{4.0\text{ m [E]}}{2.0\text{ s}}$$
$$\vec{v}_{\text{inst}} = 2.0\text{ m/s [E]}$$

Statement: The instantaneous velocity of the object at 1.0 s is 2.0 m/s [E].

(b) Given: t = 3.0 s; position–time graph

Required: $\vec{v}_{\text{inst}}$

Analysis: $\vec{v}_{\text{inst}}$ is equal to the slope, m, of the tangent to the curve at t = 3.0 s, so $m = \dfrac{\Delta\vec{d}}{\Delta t}$.

By placing a ruler along the curve in Figure 6 at t = 3.0 s, I can picture the tangent. The tangent has a rise of 12.0 m [E] over a run of 2.0 s.

Solution:
$$m = \frac{\Delta\vec{d}}{\Delta t}$$
$$m = \frac{12.0\text{ m [E]}}{2.0\text{ s}}$$
$$\vec{v}_{\text{inst}} = 6.0\text{ m/s [E]}$$

Statement: The instantaneous velocity of the object at 3.0 s is 6.0 m/s [E].

(c) At t = 1.0 s, $\vec{v}_{\text{inst}}$ is 2.0 m/s [E], at t = 2.0 s, $\vec{v}_{\text{inst}}$ is 4.0 m/s [E], and at t = 3.0 s, $\vec{v}_{\text{inst}}$ is 6.0 m/s [E]. Since the increase in the instantaneous velocity is constant (2.0 m/s [E] every second), it is possible that the object is moving with constant acceleration.

2. (a) Given: t = 5.0 s; position–time graph

Required: $\vec{v}_{\text{inst}}$

Analysis: $\vec{v}_{\text{inst}}$ is equal to the slope, m, of the tangent to the curve at t = 5.0 s, so $m = \dfrac{\Delta\vec{d}}{\Delta t}$.

By placing a ruler along the curve in Figure 7 at t = 5.0 s, I can picture the tangent. The tangent has a rise of 150 m [E] over a run of 5.0 s.

Solution:
$$m = \frac{\Delta\vec{d}}{\Delta t}$$
$$= \frac{150\text{ m [E]}}{5.0\text{ s}}$$
$$\vec{v}_{\text{inst}} = 30\text{ m/s [E]}$$

Statement: The instantaneous velocity of the object at 5.0 s is 30 m/s [E].

(b) Given: $\vec{d}_1 = 0.0$ m [E]; $\vec{d}_2 = 300.0$ m [E];
$t_1 = 0.0$ s; $t_2 = 10.0$ s
Required: $\vec{v}_{av}$

Analysis: $\vec{v}_{av} = \dfrac{\Delta\vec{d}}{\Delta t}$

$\vec{v}_{av} = \dfrac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$

Solution: $\vec{v}_{av} = \dfrac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$

$= \dfrac{300 \text{ m [E]} - 0.0 \text{ m [E]}}{10.0 \text{ s} - 0.0 \text{ s}}$

$\vec{v}_{av} = 30$ m/s [E]

Statement: The average velocity of the object over the time interval from 0.0 s to 10.0 s is 30 m/s [E].

(c) When an object is accelerating uniformly (constant acceleration), the average velocity over an interval of time equals the instantaneous velocity of the midpoint in that interval of time.

Section 1.3 Questions, page 30

1. Answers may vary. Sample answer:
An accelerating object may exhibit increasing velocity, such as a horse accelerating from a slow trot to a gallop.
An accelerating object may exhibit decreasing velocity, such as a cyclist who slows down while riding up a steep road.
An accelerating object may come to a complete stop, such as a car travelling east that accelerates west until it stops.

2. Answers may vary. Sample answer:
To determine the acceleration of an object from a velocity-time graph, divide the velocity by the time at a given point.

3. Answers may vary. Sample answer:
To determine the displacement of an object from a velocity–time graph, calculate the area under the graph from the initial time to the final time. The area is equal to the displacement between those two times.

4. (a) Given: $\Delta\vec{v} = 28$ m/s [E]; $\Delta t = 7.0$ s
Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

$= \dfrac{28 \text{ m/s [E]}}{7.0 \text{ s}}$

$\vec{a}_{av} = 4.0 \text{ m/s}^2$ [E]

Statement: The average acceleration described by the graph is 4.0 m/s^2 [E].

(b) Given: $\Delta\vec{v} = 24.5$ m/s [E]; $\Delta t = 7.0$ s
Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

$= \dfrac{24.5 \text{ m/s [E]}}{7.0 \text{ s}}$

$\vec{a}_{av} = 3.5 \text{ m/s}^2$ [E]

Statement: The average acceleration described by the graph is 3.5 m/s^2 [E].

(c) Given: $\Delta\vec{v} = 2.1$ m/s [E]; $\Delta t = 7.0$ s
Required: $\vec{a}_{av}$

Analysis: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution: $\vec{a}_{av} = \dfrac{\Delta\vec{v}}{\Delta t}$

$= \dfrac{2.1 \text{ m/s [E]}}{7.0 \text{ s}}$

$\vec{a}_{av} = 0.30 \text{ m/s}^2$ [E]

Statement: The average acceleration described by the graph is 0.30 m/s^2 [E].

5. Answers may vary. Sample answer:
What you said about the constant speed of the object isn't right. Even though the speed is still the same, the direction has changed from north to south. That means that the velocity has changed, so there must have been an acceleration in the direction of south.

6. (a) In the first segment, the object accelerates from 0.0 m/s to 6.0 m/s [W] in the first 4.0 s. In the second segment, the object continues at a constant velocity of 6.0 m/s [W] for 3.0 s. In the third segment, the object accelerates east so the velocity changes from 60.0 m/s [W] to 0.0 m/s in the final 3.0 s.

(b) For the first segment:
Given: $\Delta\vec{v}$ = 6.0 m/s [W]; Δt = 4.0 s
Required: $\vec{a}_{\text{av}}$

Analysis: $\vec{a}_{\text{av}} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{a}_{\text{av}} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{6.0\text{ m/s [W]}}{4.0\text{ s}}\\ \vec{a}_{\text{av}} &= 1.5\text{ m/s}^2\text{ [W]}\end{aligned}$$

Statement: The average acceleration in the first segment of the graph is 1.5 m/s^2 [W].

For the second segment:
Given: $\Delta\vec{v}$ = 0.0 m/s; Δt = 3.0 s
Required: $\vec{a}_{\text{av}}$

Analysis: $\vec{a}_{\text{av}} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{a}_{\text{av}} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{0.0\text{ m/s}}{4.0\text{ s}}\\ \vec{a}_{\text{av}} &= 0.0\text{ m/s}^2\end{aligned}$$

Statement: The average acceleration in the second segment of the graph is 0.0 m/s^2.

For the third segment:
Given: $\Delta\vec{v}$ = –6.0 m/s [W]; Δt = 3.0 s
Required: $\vec{a}_{\text{av}}$

Analysis: $\vec{a}_{\text{av}} = \dfrac{\Delta\vec{v}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{a}_{\text{av}} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{-6.0\text{ m/s [W]}}{3.0\text{ s}}\\ &= \frac{6.0\text{ m/s [E]}}{3.0\text{ s}}\\ \vec{a}_{\text{av}} &= 2.0\text{ m/s}^2\text{ [E]}\end{aligned}$$

Statement: The average acceleration in the third segment of the graph is 2.0 m/s^2 [E].

(c) Given: b_1 = 4.0 s; b_2 = 3.0 s; h = 6.0 m/s [W]; l = 3.0 s
Required: $\Delta\vec{d}$
Analysis: $\Delta\vec{d} = A_{\text{triangle 1}} + A_{\text{rectangle}} + A_{\text{triangle 2}}$

Solution:
$$\begin{aligned}\Delta\vec{d} &= A_{\text{triangle 1}} + A_{\text{rectangle}} + A_{\text{triangle 2}}\\ &= \frac{1}{2}b_1h + lh + \frac{1}{2}b_2h\\ &= \frac{1}{2}(4.0\ \cancel{\text{s}})\left(6.0\ \frac{\text{m}}{\cancel{\text{s}}}\text{ [W]}\right) + (3.0\ \cancel{\text{s}})\left(6.0\ \frac{\text{m}}{\cancel{\text{s}}}\text{ [W]}\right)\\ &\quad + \frac{1}{2}(3.0\ \cancel{\text{s}})\left(6.0\ \frac{\text{m}}{\cancel{\text{s}}}\text{ [W]}\right)\\ &= 12\text{ m [W]} + 18\text{ m [W]} + 9\text{ m [W]}\\ \Delta\vec{d} &= 39\text{ m [W]}\end{aligned}$$

Statement: The object has travelled 39 m [W] after 10.0 s.

7. Given: $\vec{v}_{\text{i}}$ = 2.0 m/s [W]; $\vec{v}_{\text{f}}$ = 4.5 m/s [W]; Δt = 1.9 s
Required: $\vec{a}_{\text{av}}$

Analysis: $\vec{a}_{\text{av}} = \dfrac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$

Solution:
$$\begin{aligned}\vec{a}_{\text{av}} &= \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}\\ &= \frac{4.5\text{ m/s [W]} - 2.0\text{ m/s [W]}}{1.9\text{ s}}\\ &= \frac{2.5\text{ m/s [W]}}{1.9\text{ s}}\\ \vec{a}_{\text{av}} &= 1.3\text{ m/s}^2\text{ [W]}\end{aligned}$$

Statement: The average acceleration of the car is 1.3 m/s^2 [W].

8. Given: $\vec{v}_{\text{i}}$ = 0.68 m/s [N]; $\vec{v}_{\text{f}}$ = 0.89 m/s [N]; $\vec{a}_{\text{av}}$ = 0.53 m/s^2 [N]
Required: Δt

Analysis:
$$\begin{aligned}\vec{a}_{\text{av}} &= \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}\\ \Delta t &= \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\vec{a}_{\text{av}}}\end{aligned}$$

Solution:
$$\begin{aligned}\Delta t &= \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\vec{a}_{\text{av}}}\\ &= \frac{0.89\text{ m/s [N]} - 0.68\text{ m/s [N]}}{0.53\text{ m/s}^2\text{ [N]}}\\ &= \frac{0.21\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}\text{ [N]}}{0.53\ \frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}\text{ [N]}}\\ \Delta t &= 0.40\text{ s}\end{aligned}$$

Statement: It will take 0.40 s to increase the bicycle's velocity.

9. (a) Given: $\vec{v}_\text{f} = 0.0$ m/s; $\vec{a}_\text{av} = 2.90$ m/s^2 [S]; $\Delta t = 5.72$ s
Required: $\vec{v}_\text{i}$

Analysis:
$$\vec{a}_\text{av} = \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}$$
$$\vec{a}_\text{av}\,\Delta t = \vec{v}_\text{f} - \vec{v}_\text{i}$$
$$\vec{v}_\text{i} = \vec{v}_\text{f} - \vec{a}_\text{av}\,\Delta t$$

Solution:
$$\begin{aligned}\vec{v}_\text{i} &= \vec{v}_\text{f} - \vec{a}_\text{av}\,\Delta t\\ &= 0.0\text{ m/s} - \left(2.90\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\ [\text{S}]\right)\left(5.72\ \cancel{\text{s}}\right)\\ &= 0.0\text{ m/s} - 16.6\text{ m/s [S]}\\ \vec{v}_\text{i} &= 16.6\text{ m/s [N]}\end{aligned}$$

Statement: The initial velocity of the car was 16.6 m/s [N].

(b) To decrease the velocity, the driver must accelerate in the opposite direction. In this example, to stop going north, the driver accelerated south.

10. Given: $\vec{v}_\text{i} = 6.0$ m/s [E]; $\vec{v}_\text{f} = 7.3$ m/s [W]; $\Delta t = 0.094$ s
Required: $\vec{a}_\text{av}$

Analysis:
$$\vec{a}_\text{av} = \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}$$

Solution:
$$\begin{aligned}\vec{a}_\text{av} &= \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}\\ &= \frac{7.3\text{ m/s [W]} - 6.0\text{ m/s [E]}}{0.094\text{ s}}\\ &= \frac{7.3\text{ m/s [W]} + 6.0\text{ m/s [W]}}{0.094\text{ s}}\\ &= \frac{13.3\text{ m/s [W]}}{0.094\text{ s}}\\ \vec{a}_\text{av} &= 140\text{ m/s}^2\text{ [W]}\end{aligned}$$

Statement: The average acceleration of the tennis ball is 140 m/s^2 [W] or 1.4×10^2 m/s^2 [W].

11. (a) Given: $t = 6.0$ s; position–time graph
Required: $\vec{v}_\text{inst}$

Analysis: $\vec{v}_\text{inst}$ is equal to the slope, m, of the tangent to the curve at $t = 6.0$ s, so $m = \dfrac{\Delta\vec{d}}{\Delta t}$.

By placing a ruler along the curve in Figure 9 at $t = 6.0$ s, I can picture the tangent. The tangent has a rise of 120 m [E] over a run of 5.0 s.

Solution:
$$\begin{aligned}m &= \frac{\Delta\vec{d}}{\Delta t}\\ m &= \frac{120\text{ m [E]}}{5.0\text{ s}}\\ \vec{v}_\text{inst} &= 24\text{ m/s [E]}\end{aligned}$$

Statement: The instantaneous velocity of the object at 6.0 s is 24 m/s [E].

(b) Given: $\vec{d}_1 = 0.0$ m; $\vec{d}_2 = 200$ m; $t_1 = 0.0$ s; $t_2 = 10.0$ s
Required: $\vec{v}_\text{av}$

Analysis:
$$\vec{v}_\text{av} = \frac{\Delta\vec{d}}{\Delta t}$$
$$\vec{v}_\text{av} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$$

Solution:
$$\begin{aligned}\vec{v}_\text{av} &= \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}\\ &= \frac{200\text{ m [W]} - 0.0\text{ m [W]}}{10.0\text{ s} - 0.0\text{ s}}\\ \vec{v}_\text{av} &= 20\text{ m/s [W]}\end{aligned}$$

Statement: The average velocity of the object over the time interval from 0.0 s to 10.0 s is 20 m/s [W].