# *Pearson Physics* Level 20
# Unit I Kinematics: Chapter 1
# Solutions

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## Skills Practice

**1.** scale: 26.0 m : 3.05 cm (north/south side of rink)
scale: 60.0 m : 7.05 cm (east/west side of rink)

**(a) position from north side of rink:**
player 1: 0.55 cm = 4.7 m [S]
player 2: 0.75 cm = 6.4 m [S]
player 3: 2.45 cm = 20.9 m [S]
player 4: 2.60 cm = 22.2 m [S]
player 5: 2.20 cm = 18.8 m [S]

**position from south side of rink:**
player 1: 2.50 cm = 21.3 m [N]
player 2: 2.30 cm = 19.6 m [N]
player 3: 0.55 cm = 4.7 m [N]
player 4: 0.40 cm = 3.4 m [N]
player 5: 0.90 cm = 7.7 m [N]

**(b) position from east side of rink:**
player 1: 5.00 cm = 42.6 m [W]
player 2: 3.70 cm = 31.5 m [W]
player 3: 2.15 cm = 18.3 m [W]
player 4: 3.80 cm = 32.3 m [W]
player 5: 6.85 cm = 58.3 m [W]

**position from west side of rink:**
player 1: 2.00 cm = 17.0 m [E]
player 2: 3.30 cm = 28.1 m [E]
player 3: 4.90 cm = 41.7 m [E]
player 4: 3.20 cm = 27.2 m [E]
player 5: 0.20 cm = 1.7 m [E]

**(c)** 2.0 cm = 17.0 m [S]

## Example 1.1 Practice Problems

**1.** ***Given***

$\vec{d}_1 = 40.0 \text{ m [N]}$

$\vec{d}_2 = 20.0 \text{ m [N]}$

$\vec{d}_3 = 100.0 \text{ m [N]}$

***Required***

displacement ($\Delta\vec{d}$)

***Analysis and Solution***

Since the sprinter moves north continuously, the distances can be added together.

$$\begin{aligned}\Delta\vec{d} &= 40.0 \text{ m [N]} + 20.0 \text{ m [N]} + 100.0 \text{ m [N]}\\ &= 160.0 \text{ m [N]}\end{aligned}$$

***Paraphrase***

Sprinter's displacement is 160.0 m [N].

**2.** ***Given***

$\vec{d}_1 = 0.75 \text{ m [right]}$

$\vec{d}_2 = 3.50 \text{ m [left]}$

***Required***

displacement ($\Delta\vec{d}$)

 

***Analysis and Solution***
Use vector addition, but change signs since directions are opposite.

$$\Delta\vec{d} = 0.75 \text{ m [right]} + 3.50 \text{ m [left]}$$
$$= -0.75 \text{ m [left]} + 3.50 \text{ m [left]}$$
$$= 2.75 \text{ m [left]}$$

***Paraphrase***
Player's displacement is 2.75 m [left].

3. ***Given***
$\vec{d}_1 = 0.85 \text{ m [back]}$

$\vec{d}_2 = -0.85 \text{ m [forth]}$

***Required***
distance ( $\Delta d$ )
displacement ( $\Delta\vec{d}$ )

***Analysis and Solution***
The bricklayer's hand moves 1.70 m back and forth four times, so $\Delta d = 4(d_1 + d_2)$.

$$\Delta d = 4(0.85 \text{ m} + 0.85 \text{ m})$$
$$= 6.80 \text{ m}$$

Since the player starts and finishes in the same spot, displacement is zero.
$\Delta\vec{d} = 0 \text{ m}$

***Paraphrase***
Total distance is 6.80 m. Total displacement is zero.

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## 1.1 Check and Reflect

**Knowledge**

**1.** Two categories of terms that describe motion are scalar quantities and vector quantities. Scalar quantities include distance, time, and speed. Vector quantities include position, displacement, velocity, and acceleration.

**2.** Distance is the length of path taken to travel between two points. Displacement is the change in position: how far and in which direction an object is situated after it has travelled from its original starting or reference point. Distance is a scalar quantity, represented by $\Delta d$. Displacement is a vector quantity, represented by $\Delta\vec{d}$. Distance may be the same as displacement for straight line motion in one direction, but will be different from displacement when the motion is along any path for which the direction of motion changes.

**3.** A reference point determines the direction for vector quantities. A reference point is necessary to calculate displacement and measure position.

 

**Applications**

**4. (a)–(d)**


**(e)** From Greg to Hannah, the displacement is
7.5 m [right] + 4.5 m [right] + 1.0 m [right] = 13.0 m [right].

**5.** ***Given***

$\Delta \vec{d} = 50.0 \text{ km [W]}$

$\vec{d}_{\text{i}} = 5.0 \text{ km [E]}$

***Required***

final position ($\vec{d}_{\text{f}}$)

***Analysis and Solution***

Use the equation $\Delta \vec{d} = \vec{d}_{\text{f}} - \vec{d}_{\text{i}}$.

$$\Delta \vec{d} = \vec{d}_{\text{f}} - \vec{d}_{\text{i}}$$

$$\vec{d}_{\text{f}} = \Delta \vec{d} + \vec{d}_{\text{i}}$$

$$\begin{aligned}\vec{d}_{\text{f}} &= 50.0 \text{ km [W]} + 5.0 \text{ km [E]} \\ &= 50.0 \text{ km [W]} + -5.0 \text{ km [W]} \\ &= 45.0 \text{ km [W]}\end{aligned}$$

***Paraphrase***

The person's final position is 45.0 km [W].

**6.** ***Given***

$\vec{d}_1 = 3.0 \text{ m [left]}$

$\vec{d}_2 = (3.0 \text{ m } + 5.0 \text{ m}) \text{ [right]}$

***Required***

distance ($\Delta d$)

displacement ($\Delta \vec{d}$)

***Analysis and Solution***

Use $\Delta d = d_1 + d_2$

$$\Delta \vec{d} = \vec{d}_1 + \vec{d}_2$$

$$\begin{aligned}\Delta d &= 3.0 \text{ m} + (3.0 + 5.0) \text{ m} \\ &= 11.0 \text{ m}\end{aligned}$$

$$\begin{aligned}\Delta \vec{d} &= 3.0 \text{ m [left] } + (3.0 \text{ m } + 5.0 \text{ m})\text{[right]} \\ &= -3.0 \text{ m [right] } + 8.0 \text{ m[right]} \\ &= +5.0 \text{ m [right]}\end{aligned}$$

 

***Paraphrase***

The ball travels a distance of 11.0 m. Its displacement is 5.0 m [right].

**7.** $\Delta\vec{d}_{\text{groom}} = 0.50 \text{ m [right]}$

$\Delta\vec{d}_{\text{best man}} = 0.75 \text{ m [left]}$

$$\begin{aligned}\Delta\vec{d}_{\text{maid of honour}} &= 0.50 \text{ m [right]} + 0.75 \text{ m [right]}\\ &= 1.25 \text{ m [right]}\end{aligned}$$

$$\begin{aligned}\Delta\vec{d}_{\text{flower girl}} &= 0.75 \text{ m [left]} + 0.75 \text{ m [left]}\\ &= 1.50 \text{ m [left]}\end{aligned}$$

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## Concept Check

**(a)** On a ticker tape at rest, all the dots would be placed on top of each other at a single point. The slope of the position-time graph in Figure 1.14 is zero.

**(b)** A position-time graph for an object travelling at a constant velocity is a straight line. Its slope is positive (tilted to the left) for positive velocity, negative (tilted to the right) for negative velocity, and zero (horizontal) for an object at rest. In each case, change in position remains constant for equal time intervals.

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## Concept Check

The velocity of the ball can be positive with the hole at the origin if the slope of the graph is positive. The axis is labelled right and the initial position of the ball is –5.0 m. This means the ball is 5.0 m LEFT of the origin. The graph slopes up from -5.0 m to zero and hence has a positive slope.

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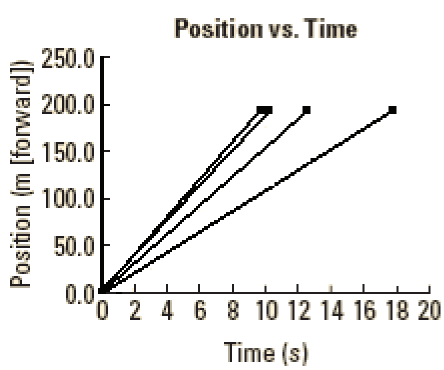
## Example 1.2 Practice Problems

**1.(a)**



**(b)** Elk: $\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$

$$= \frac{200 \text{ m [forward]}}{10.0 \text{ s}}$$

$$= 20.0 \text{ m/s [forward]}$$

Coyote: $\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$

$$= \frac{200 \text{ m [forward]}}{10.4 \text{ s}}$$

$$= 19.2 \text{ m/s [forward]}$$

Grizzly Bear: $\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$

$$= \frac{200 \text{ m [forward]}}{18.0 \text{ s}}$$

$$= 11.1 \text{ m/s [forward]}$$

Moose: $\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$

$$= \frac{200 \text{ m [forward]}}{12.9 \text{ s}}$$

$$= 15.5 \text{ m/s [forward]}$$

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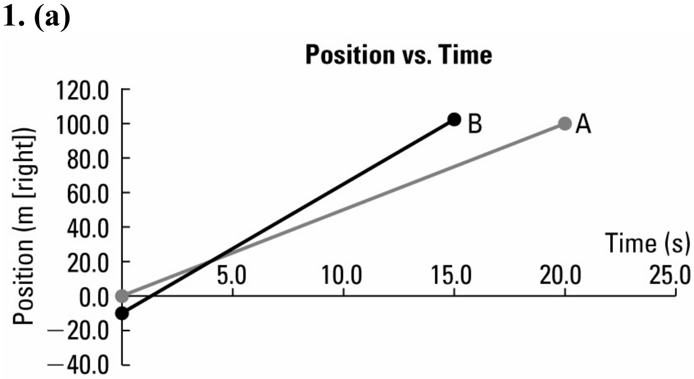
### Concept Check

The position-time graph showing the motion of two objects approaching each other would consist of two converging lines.

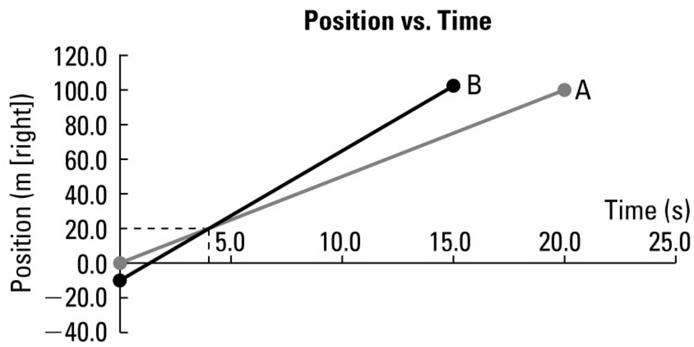
### Example 1.3 Practice Problems

**1. (a)**



**(b)**




From the graph, B catches up with A at $t$ = 4.0 s. B's position at this time is 20.0 m [right]. Because B started 10.0 m to the left of A, B's displacement is 20.0 m [right] + 10.0 m [right] = 30.0 m [right].

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## Example 1.4 Practice Problem

**1.** ***Given***

Consider right to be positive.

$\Delta\vec{d}_A = 100.0\text{ m [right]} = +100.0\text{ m} \quad \Delta t_A = 15.0\text{ s}$

$\Delta\vec{d}_B = 100.0\text{ m [right]} = +100.0\text{ m} \quad \Delta t_B = 10.0\text{ s}$

***Required***

velocities of A and B $(\vec{v}_A, \vec{v}_B)$

***Analysis and Solution***

The velocities of each rollerblader are given by $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$.

$$\begin{aligned}\vec{v}_A &= \frac{\Delta\vec{d}_A}{\Delta t_A}\\ &= \frac{+100.0\text{ m}}{15.0\text{ s}}\\ &= +6.67\text{ m/s}\\ &= 6.67\text{ m/s [right]}\end{aligned}$$

$$\begin{aligned}\vec{v}_B &= \frac{\Delta\vec{d}_B}{\Delta t_B}\\ &= \frac{+100.0\text{ m}}{10.0\text{ s}}\\ &= +10.0\text{ m/s}\\ &= 10.0\text{ m/s [right]}\end{aligned}$$

 

***Paraphrase***
The velocity of rollerblader A is 6.67 m/s [right] and the velocity of rollerblader B is 10.0 m/s [right].

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## 1.2 Check and Reflect

**Knowledge**

**1.** The quantities of motion that remain the same over equal time intervals for an object at rest are position (the object does not move), displacement (since the object does not move, the change in position is always zero), velocity (velocity is zero), and acceleration (acceleration is zero) — although acceleration is not dealt with until after p. 23.

**2.** For an object travelling at a constant velocity, displacement is the same over equal time intervals.

**3.** The faster the ticker tape, the fewer dots there are, and the steeper the graph is. Therefore: **(i)** D **(ii)** C **(iii)** A **(iv)** B

**4.** ***Given***

$v_A = 3.0$ m/s $v_B = 1.5$ m/s $d_{B_i} = 20.0$ m $\Delta t = 20.0$ s

***Required***

distance between A and B and who is ahead at 20.0 s

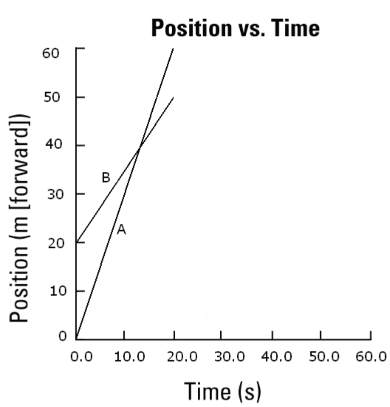
***Analysis and Solution***

$$v_A = \frac{d_A}{t} \qquad v_B = \frac{d_B}{t}$$

$$\begin{aligned} d_A &= v_A t & d_B &= v_B t \\ &= (3.0\text{ m/s})(20.0\text{ s}) & &= (1.5\text{ m/s})(20.0\text{ s}) \\ &= 60\text{ m} & &= 30\text{ m} \end{aligned}$$

But, in total, B is 30 m + 20.0 m away from the origin. Therefore, $d_B = 50$ m.

The distance between A and B is 60 m – 50 m = 10 m, and A is ahead.




***Paraphrase***

A is ahead of B by 10 m.

**5.** ***Given***

$\vec{d}_1 = 16\text{ km [E]} \quad \vec{d}_2 = 23\text{ km [W]}$

***Required***

final position ($\vec{d}_\text{f}$)

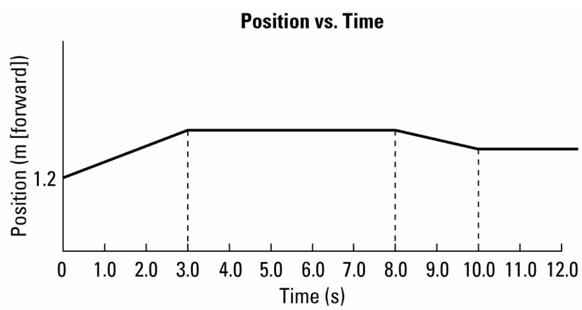
***Analysis and Solution***

$$\begin{aligned}\vec{d}_\text{f} &= \vec{d}_1 + \vec{d}_2 \\ &= 16\text{ km [E]} + 23\text{ km [W]} \\ &= 16\text{ km [E]} + (-23\text{ km [E]}) \\ &= 16\text{ km [E]} - 23\text{ km [E]} \\ &= -7\text{ km [E]} \\ &= 7\text{ km [W]}\end{aligned}$$

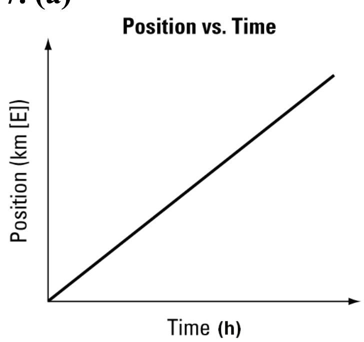
***Paraphrase***

The camper's final position with respect to the camp site is 7 km [W].

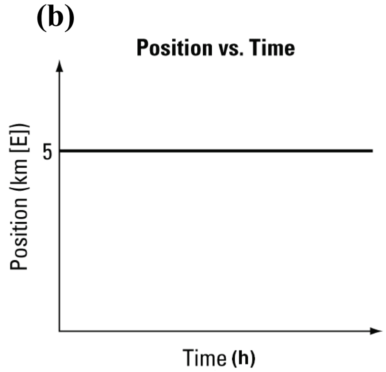
**6.**




**7. (a)**

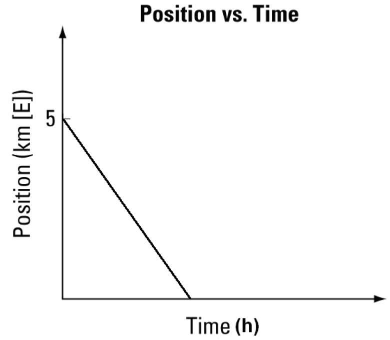



**(b)**



**(c)**




## Applications

**8.** ***Given***

$\vec{v}_A = 5.0$ m/s [right]

$\vec{v}_B = 4.5$ m/s [right]

***Required***

displacement ( $\Delta\vec{d}_{AB}$ )

***Analysis and Solution***

Determine the displacement of both children.

Equation for child A: $y_A = 5.0\Delta t$

Equation for child B: $y_B = 4.5\Delta t$

Find the difference between results. Since Child A pedals faster, Child A should be farther away from the initial starting position.

$$\begin{aligned} y_A - y_B &= 5.0\Delta t - 4.5\Delta t \\ &= 0.5\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{right}] \times 5.0\ \cancel{\text{s}} \\ &= 2.5\ \text{m [right]} \end{aligned}$$

***Paraphrase and Verify***

Child A will be 2.5 m farther right after 5.0 s. Check: Child A travels 25 m and Child B travels 22.5 m.

**9.** ***Given***

$v_A = 5.0$ m/min

$v_B = 9.0$ cm/s = 5.4 m/min (converted from 9.0 cm/s $\rightarrow$ 0.09 m/s $\times$ 60 s/min)

$\Delta t = 3.0$ min

***Required***

Which insect is ahead and by how much after 3.0 min

***Analysis and Solution***

After 3.0 min, A has travelled 5.0 m/min $\times$ 3.0 min = 15.0 m, and B has travelled 5.4 m/min $\times$ 3.0 min = 16.2 m. So the distance between A and B is 1.2 m. Insect B is ahead.

***Paraphrase***

Insect B is ahead by 1.2 m.

**10.** A: The object is moving west with a constant speed.

B: The object is stationary.

C: The object is moving east with a constant speed, slower than in A.

**11.** ***Given***

Choose east to be positive and the mosquito's initial position be the reference point ($\vec{d}_{\text{m}_\text{i}} = 0 \text{ m [E]}$).

$\vec{v}_m = 2.4 \text{ km/h [E]}$ $\vec{v}_y = 2.0 \text{ m/s [W]}$

$\vec{d}_{y_\text{i}} = 35.0 \text{ m [E]}$ (you are 35.0 m east of the mosquito at start)

***Required***

time ($\Delta t$) at point of collision

distance you travelled before mosquito hit you

***Analysis and Solution***

First, convert 2.4 km/h to m/s.

$$v_\text{m} = 2.4 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}}$$
$$= 0.667 \text{ m/s}$$

Position of mosquito at point of collision,

$$\vec{d}_{\text{m}_\text{f}} = \vec{d}_{\text{m}_\text{i}} + \vec{v}_\text{m}\Delta t$$
$$= 0.667\Delta t \text{ m [E]}$$

Your position at point of collision,

$$\vec{d}_{\text{y}_\text{f}} = \vec{d}_{\text{y}_\text{i}} + \vec{v}_\text{y}\Delta t$$
$$= 35.0 \text{ m [E]} + 2.0\Delta t \text{ m [W]}$$

Since $\vec{d}_{\text{m}_\text{f}}$ and $\vec{d}_{\text{y}_\text{f}}$ are the same position,

$$0.667\Delta t \text{ m [E]} = 35.0 \text{ m [E]} + 2.0\Delta t \text{ m [W]}$$
$$0.667\Delta t = 35.0 - 2.0\Delta t$$
$$2.667\Delta t = 35.0$$
$$\Delta t = \frac{35.0}{2.667} \text{ s}$$
$$= 13.1 \text{ s}$$

Distance you travelled before the mosquito hit you,

$$v_\text{y}\Delta t = 2.0 \text{ m/s} \times 13.1 \text{ s}$$
$$= 26 \text{ m}$$

***Paraphrase and Verify***

The mosquito will hit you at 13 s, when you have travelled 26 m toward the mosquito. Check: Mosquito travels $0.667 \text{ m/s} \times 13.1 \text{ s} = 8.75 \text{ m}$ in 13.1 s; $8.75 \text{ m} + 26.2 \text{ m} = 35.0 \text{ m}$, the original separation.

**12.** ***Given***

you: $\vec{v} = 2.25 \text{ m/s [N]}$ $\vec{d}_\text{i} = 0 \text{ m}$

friend: $\vec{v} = 2.0 \text{ m/s [N]}$ $\vec{d}_\text{i} = 5.0 \text{ m [N]}$

***Required***

time ($\Delta t$)

displacement ($\Delta\vec{d}$)

***Analysis and Solution***

Equation for you: $y_A = (2.25 \text{ m/s [N]})\ \Delta t$

Equation for friend: $y_B = (2.0 \text{ m/s [N]})\ \Delta t + 5.0 \text{ m [N]}$

At intersection, $y_A = y_B = \vec{d}_f$

$(2.25 \text{ m/s [N]})\ \Delta t = (2.0 \text{ m/s [N]})\Delta t + 5.0 \text{ m [N]}$

$(0.25 \text{ m/s [N]})\ \Delta t = 5.0 \text{ m [N]}$

$\Delta t = 20 \text{ s}$

$y_A = (2.25 \text{ m/s [N]})(20 \text{ s})$

$= 45 \text{ m [N]}$

***Paraphrase and Verify***

It takes 20 s to close the gap. Your displacement is 45 m [N].

Check: $y_B = (2.0 \text{ m/s [N]})(20 \text{ s}) + 5.0 \text{ m [N]} = 45 \text{ m [N]}$

**13.** ***Given***

$\vec{v}_A = 35 \text{ km/h [W]}$ $\vec{p}_A = 300 \text{ m [E]}$ (reference point: traffic light) $\vec{v}_B = 40 \text{ km/h [E]}$

***Required***

times for: • vehicles to pass each other
• vehicle A to pass traffic light
• vehicle B to pass traffic light

***Analysis and Solution***

$v_A = 35 \frac{\text{km}}{\text{h}} \text{[W]} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}}$

$= 9.72 \text{ m/s [W]}$

$d_A = 300 \text{ m [E]}$

$= -300 \text{ m [W]}$

Equation for vehicle A: $y_A = 9.72\Delta t - 300$

$v_B = 40 \frac{\text{km}}{\text{h}} \text{[E]} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}}$

$= -11.1 \text{ m/s [W]}$

$d_B = 450 \text{ m [W]} - 300 \text{ m [W]}$

$= 150 \text{ m [W]}$

Equation for vehicle B: $y_B = -11.1\Delta t + 150$

• Vehicles pass when $y_A = y_B$.

• Vehicle A passes traffic light when $y_A = 0$.

• Vehicle B passes traffic light when $y_B = 0$.

$9.72\Delta t - 300 = -11.1\Delta t + 150$

$20.8\Delta t = 450$

$\Delta t = 22 \text{ s}$

$9.72\Delta t - 300 = 0$

$9.72\Delta t = 300$

$\Delta t = 31 \text{ s}$

$$-11.1\Delta t + 150 = 0$$
$$11.1\Delta t = 150$$
$$\Delta t = 14 \text{ s}$$

***Paraphrase***

• The vehicles pass after 22 s.
• Vehicle A passes the traffic light after 31 s.
• Vehicle B passes the traffic light after 14 s.

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### Concept Check

**(a)** The slope of a position-time graph represents velocity.
**(b)** The slope of a velocity-time graph represents acceleration.

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### Concept Check

The lower ticker tape in Figure 1.25 represents accelerated motion because the spaces between the dots are changing—the dots are successively farther apart showing increasing displacement in equal time intervals. The speed is increasing.

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### Concept Check

The position-time graph for an object undergoing negative acceleration in the positive direction is a parabola that curves down to the right. The ticker tape of the motion of an object that is slowing down would consist of a series of dots that get closer and closer together.

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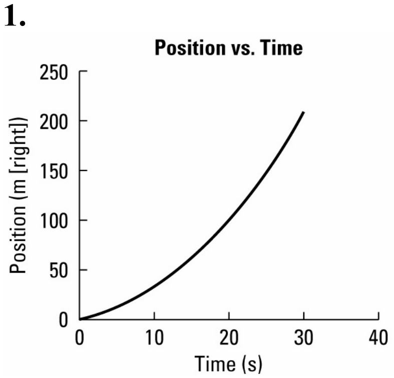
### Example 1.5 Practice Problems

**1.**




**2.** Acceleration is the slope of the graph.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$$
$$= \frac{0 \text{ m/s} - 10 \text{ m/s}}{10 \text{ s} - 0 \text{ s}}$$
$$= -1.0 \text{ m/s}^2 [\text{N}]$$

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### Concept Check

**(a)** For a cyclist coming to a stop at a red light, her velocity is positive and her acceleration is negative (in opposite directions). For the space shuttle taking off, its velocity and acceleration are both positive (in the same direction).
**(b)** An object can have a negative acceleration and be speeding up if its velocity is increasing in the negative direction. When velocity and acceleration are in the same direction, an object speeds up.
**(c)** If the positive slopes of the tangents along the curve increase, then the object is speeding up. Similarly, if the negative slopes of the tangents along the curve become more negative (decrease), then the object is speeding up in the negative direction. If the positive slopes decrease or the negative slopes become less negative (increase), then the object is slowing down.

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### 1.3 Check and Reflect

**Applications**

**1. (a)** $\vec{a} = \frac{2.80 \text{ m/s [forward]} - 0.00 \text{ m/s [forward]}}{0.50 \text{ s} - 0.00 \text{ s}} = 5.6 \text{ m/s}^2 \text{ [forward]}$

**(b)** $\vec{a} = \frac{9.80 \text{ m/s [forward]} - 2.80 \text{ m/s [forward]}}{3.00 \text{ s} - 0.50 \text{ s}} = 2.8 \text{ m/s}^2 \text{ [forward]}$

**(c)** $\vec{a} = \frac{11.60 \text{ m/s [forward]} - 11.30 \text{ m/s [forward]}}{6.00 \text{ s} - 5.00 \text{ s}} = 0.30 \text{ m/s}^2 \text{ [forward]}$

**(d)** Velocity is increasing whereas acceleration is decreasing.

**2.** The object is accelerating (speeding up) to the left.

**3. (i)** A **(ii)** B **(iii)** C **(iv)** D

**Extensions**

**4.**

At time 2.0 s, slope = $\frac{\Delta \vec{d}}{\Delta t} = \frac{12 \text{ m [forward]} - 0.0 \text{ m [forward]}}{4.0 \text{ s} - 0.8 \text{ s}} = 3.8 \text{ m/s [forward]}$

At time 4.0 s, slope = $\frac{\Delta \vec{d}}{\Delta t} = \frac{24 \text{ m [forward]} - 3 \text{ m [forward]}}{5.0 \text{ s} - 2.0 \text{ s}} = 7.0 \text{ m/s [forward]}$

At time 6.0 s, slope = 0.0 m/s [forward]

At time 8.0 s, slope = $\frac{\Delta \vec{d}}{\Delta t} = \frac{9 \text{ m [forward]} - 33 \text{ m [forward]}}{9.2 \text{ s} - 6.0 \text{ s}} = -7.5 \text{ m/s [forward]}$

 

| Time (s) | Velocity (m/s [forward]) |
|---|---|
| 2.0 | 3.8 |
| 4.0 | 7.0 |
| 6.0 | 0.0 |
| 8.0 | −7.5 |

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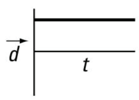
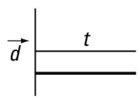
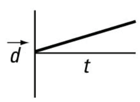
### Concept Check

**1. (a)** 

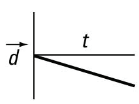
The object is stopped at a positive position.



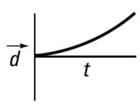
The object is stopped at a negative position.

**(b)** 

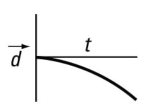
The object is travelling at a constant velocity in the positive direction.



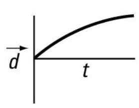
The object is travelling at a constant velocity in the negative direction.

**(c)** 

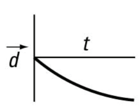
The object is speeding up while moving in the positive direction.



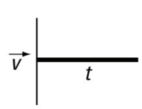
The object is speeding up while moving in the negative direction.



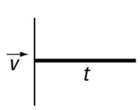
The object is slowing down while moving in the positive direction.



The object is slowing down while moving in the negative direction.

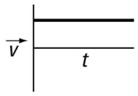
**2. (a)** 

The slope of the position-time graph is zero, so the velocity-time graph is along the time axis.

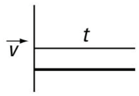


The slope of the position-time graph is zero, so the velocity-time graph is along the time axis.

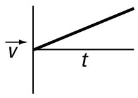
 

**(b)** 

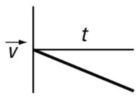

The slope of the position-time graph is positive, so the velocity-time graph is a horizontal line above the time axis indicating a constant velocity in the positive direction.



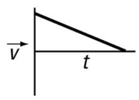

The slope of the position-time graph is negative, so the velocity-time graph is a horizontal line below the time axis indicating a constant velocity in the negative direction.

**(c)** 

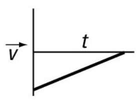

The slope of the position-time graph increases in the positive direction, so the velocity-time graph is a straight line with a positive slope above the time axis.




The slope of the position-time graph increases in the negative direction, so the velocity-time graph is a straight line with a negative slope below the time axis.




The slope of the position-time graph decreases in the positive direction, so the velocity-time graph is a straight line with a negative slope above the time axis.

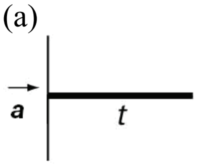



The slope of the position-time graph decreases in the negative direction, so the velocity-time graph is a straight line with a positive slope below the time axis.

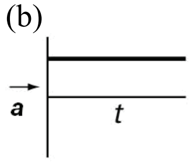
### Concept Check

The acceleration-time graphs encountered thus far are all (a) either a zero line (along the time axis), meaning no change in speed or constant motion, or (b) a horizontal line either above or (c) below the time axis. These last two cases represent situations where the object is either speeding up or slowing down, depending on the direction of velocity.

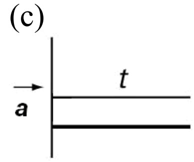
(a)




(b)




(c)

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### Example 1.6 Practice Problems

**1.** $\Delta\vec{d} = \text{area under graph}$

$$= 2.2\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{N}] \times 10\ \cancel{\text{s}}$$

$$= 22\ \text{m}\ [\text{N}]$$

 

$\vec{a} = \text{slope of curve}$

$= 0 \text{ m/s}^2 \text{ [N]}$

**2.** $\Delta\vec{d} = \text{area under graph} = \frac{1}{2}\left(-20 \ \frac{\text{m}}{\not{\text{s}}} \ \text{[E]}\right)(10 \ \not{\text{s}})$

$= -100 \text{ m [E] or } 100 \text{ m [W]}$

$= -1.0\times10^2 \text{ m [E] or } 1.0\times10^2 \text{ m [W]}$

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### Concept Check

The ball's net displacement is zero because the sum of the areas under the velocity-time graph is zero. That is, the ball returns to the position from which it was thrown.

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### Example 1.7 Practice Problems

**1.** ***Given***

Consider east to be positive.

$\Delta\vec{d}_1$ = 10.0 m [E] = 10.0 m    $\Delta t_1$ = 2.0 s

$\Delta\vec{d}_2$ = 5.0 m [E] = 5.0 m    $\Delta t_2$ = 1.5 s

$\Delta\vec{d}_3$ = 30.0 m [W] = –30.0 m    $\Delta t_3$ = 5.0 s

***Required***

average velocity ($\vec{v}_{\text{ave}}$)

***Analysis and Solution***

The total displacement is:

$\Delta\vec{d}$ = 10.0 m + 5.0 m + (–30.0 m)

= –15.0 m

The total time is:

$\Delta t$ = 2.0 s + 1.5 s + 5.0 s

= 8.5 s

$$\vec{v}_{\text{ave}} = \frac{\Delta\vec{d}}{\Delta t}$$

$$= \frac{-15.0 \text{ m}}{8.5 \text{ s}}$$

$$= -1.8 \text{ m/s}$$

$$= 1.8 \text{ m/s [W]}$$

***Paraphrase***

The person's average velocity is 1.8 m/s [W].

 

**2.** ***Given***

Consider forward to be positive.

$\Delta\vec{d}_A$ = 100 m [forward] = +100 m    $\Delta t_A$ = 9.84 s

$\Delta\vec{d}_B$ = 200 m [forward] = +200 m    $\Delta t_B$ = 19.32 s

$\Delta\vec{d}_C$ = 400 m [forward] = +400 m    $\Delta t_C$ = 1.90 min

***Required***

average velocity ($\vec{v}_{ave}$)

***Analysis and Solution***

The total displacement is:

$$\begin{aligned}\Delta\vec{d} &= +100 \text{ m} + (+200 \text{ m}) + (+400 \text{ m})\\ &= +700 \text{ m}\end{aligned}$$

The total time is:

$$\begin{aligned}\Delta t &= 9.84 \text{ s} + 19.32 \text{ s} + \left(1.90 \cancel{\text{min}} \times \frac{60 \text{ s}}{1 \cancel{\text{min}}}\right)\\ &= 9.84 \text{ s} + 19.32 \text{ s} + 114.00 \text{ s}\\ &= 143.16 \text{ s}\end{aligned}$$

$$\begin{aligned}\vec{v}_{ave} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+700 \text{ m}}{143.16 \text{ s}}\\ &= +4.89 \text{ m/s}\\ &= 4.89 \text{ m/s [forward]}\end{aligned}$$

$$\begin{aligned}\vec{v}_A &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+100 \text{ m}}{9.84 \text{ s}}\\ &= +10.2 \text{ m/s}\\ &= 10.2 \text{ m/s [forward]}\end{aligned}$$

$$\begin{aligned}\vec{v}_B &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+200 \text{ m}}{19.32 \text{ s}}\\ &= +10.4 \text{ m/s}\\ &= 10.4 \text{ m/s [forward]}\end{aligned}$$

$$\begin{aligned}\vec{v}_C &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+400 \text{ m}}{114.00 \text{ s}}\\ &= +3.51 \text{ m/s}\\ &= 3.51 \text{ m/s [forward]}\end{aligned}$$

***Paraphrase***

The average velocity of all three runners is 4.89 m/s [forward]. Person A's average velocity is 10.2 m/s [forward] (faster than the average velocity). Person B's average velocity is 10.4 m/s [forward] (faster than the average velocity). Person C's average velocity is 3.51 m/s [forward] (slower than the average velocity).

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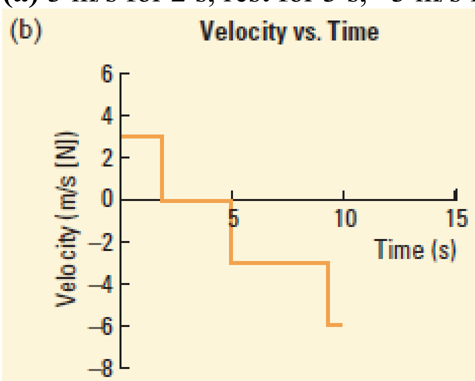
## Example 1.8 Practice Problems

**1. (a)** 3 m/s for 2 s, rest for 3 s, –3 m/s for 4 s, –6 m/s for 1 s




**(c)** $\Delta\vec{d} = \vec{d}_{\text{f}} - \vec{d}_{\text{i}}$

$= -12\text{ m} - 0\text{ m}$

$= -12\text{ m}$

**(d)** The object is stopped when the velocity-time graph is along the time axis, between 2–5 s.

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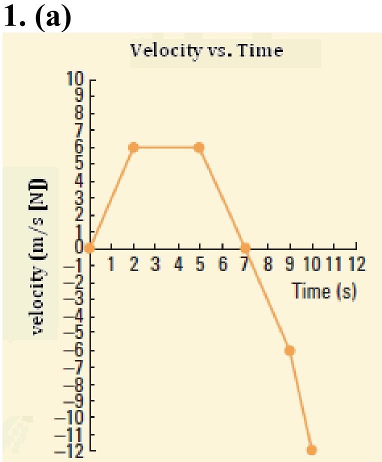
## Example 1.9 Practice Problems

**1. (a)**




Displacement is the area under the velocity-time graph.
Consider north to be positive.

0–2 s:

$$A = \frac{1}{2}bh$$

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}(2\text{ s})(+6\text{ m/s})\\ &= +6\text{ m}\\ &= 6\text{ m [N]}\end{aligned}$$

2–5 s:

$$A = lw$$

$$\begin{aligned}\Delta\vec{d} &= (+6\text{ m/s})(3\text{ s})\\ &= +18\text{ m}\\ &= 18\text{ m [N]}\end{aligned}$$

5–7 s:

$$A = \frac{1}{2}bh$$

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}(2\text{ s})(+6\text{ m/s})\\ &= +6\text{ m}\\ &= 6\text{ m [N]}\end{aligned}$$

7–9 s:

$$A = \frac{1}{2}bh$$

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}(2\text{ s})(-6\text{ m/s})\\ &= -6\text{ m}\\ &= 6\text{ m [S]} \quad \text{or } -6\text{ m [N]}\end{aligned}$$

9–10 s:

$$A = lw + \frac{1}{2}bh$$

$$\begin{aligned}\Delta\vec{d} &= (-6\text{ m/s})(10\text{ s} - 9\text{ s}) + \frac{1}{2}(10\text{ s} - 9\text{ s})(-12\text{ m/s} - (-6\text{ m/s}))\\ &= -6\text{ m} + (-3\text{ m})\\ &= -9\text{ m}\\ &= 9\text{ m [S]} \quad \text{or } -9\text{ m [N]}\end{aligned}$$

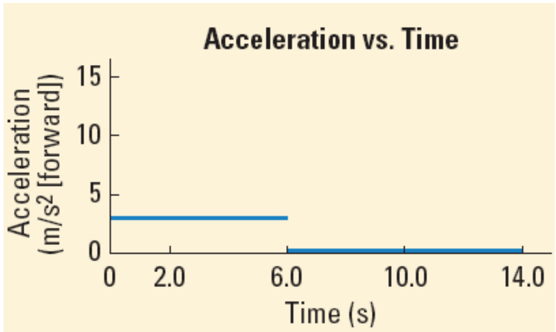
**(b)** $$\begin{aligned}\Delta\vec{d} &= +6\text{ m} + (+18\text{ m}) + (+6\text{ m}) + (-6\text{ m}) + (-9\text{ m})\\ &= +15\text{ m}\\ &= 15\text{ m [N]}\end{aligned}$$

**(c)** $$\begin{aligned}\vec{v}_{\text{ave}} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+15\text{ m}}{10\text{ s}}\\ &= +1.5\text{ m/s}\\ &= 1.5\text{ m/s [N]}\end{aligned}$$

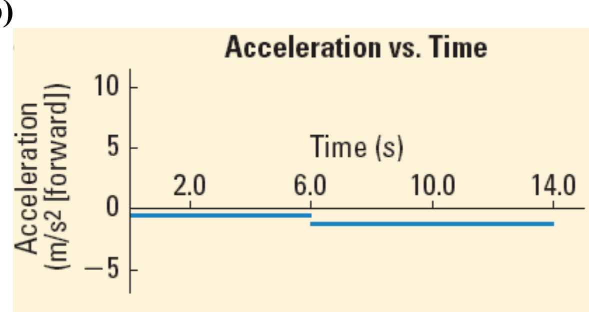
 

### Example 1.10 Practice Problems

**1. (a)**




**(b)**



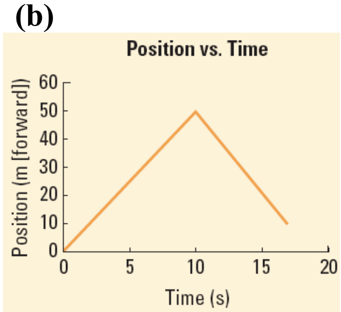



### Example 1.11 Practice Problems

1. **(a)** The object travels with uniform motion, changes direction at 10 s, and travels with uniform motion. The object travels forward at 5 m/s for 10 s, then backward at 5 m/s for 8 s. Consider forward to be positive.

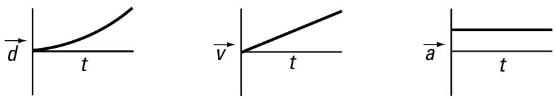
$$\begin{aligned}\Delta\vec{d} &= \Delta\vec{d}_1 + \Delta\vec{d}_2 \\ &= \vec{v}_1\Delta t_1 + \vec{v}_2\Delta t_2 \\ &= \left(+5\ \frac{\text{m}}{\cancel{\text{s}}}\right)(10\ \cancel{\text{s}}) + \left(-5\ \frac{\text{m}}{\cancel{\text{s}}}\right)(8\ \cancel{\text{s}}) \\ &= +50\text{ m} + (-40\text{ m}) \\ &= +10\text{ m} \\ &= 10\text{ m [forward]}\end{aligned}$$

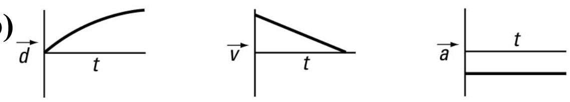
**(b)**

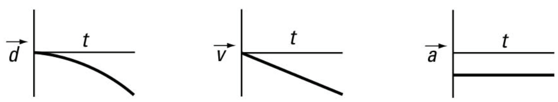


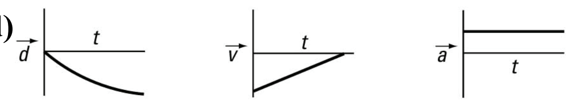

 

## Concept Check

**(a)**



**(b)**



**(c)**



**(d)**



## 1.4 Check and Reflect

**Knowledge**

**1.** Spaces between dots on a ticker tape for uniform motion are equal. On a ticker tape for accelerated motion, the spaces between dots are unequal or different for equal time intervals. (One would have to do some measuring and calculating to determine if the object is uniformly accelerated.)

**2.** For an object undergoing uniform motion, the object experiences equal displacement during equal time intervals and its velocity remains constant. For an object undergoing uniformly accelerated motion, the object experiences an equal change in velocity in equal time intervals.

**3.** The slope of a position-time graph gives velocity.

**4.** A position-time graph for an object undergoing uniform motion is a straight line (linear): horizontal for objects at rest, and with a positive or negative slope for objects moving at a constant rate. Accelerated motion is represented by a curve (section of a parabola) on a position-time graph.

**5.** The slope of a velocity-time graph gives acceleration.

**6.** The object would be undergoing uniform acceleration.

**7.** Consider east to be positive.

$$\begin{aligned}\Delta\vec{d} &= \text{area under graph}\\ &= lw + \frac{1}{2}bh\\ &= \left(5.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{E}]\right)\left(10.0\ \cancel{\text{s}}\right) + \frac{1}{2}\left(5.0\ \cancel{\text{s}}\right)\left(10.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{E}]\right)\\ &= 50\text{ m [E]} + 25\text{ m [E]}\\ &= 75\text{ m [E]}\end{aligned}$$

**8.** Consider up to be positive.

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_1\Delta t_1 + \vec{v}_2\Delta t_2 + \vec{v}_3\Delta t_3 \\ &= (+4.0\ \text{km}/\not{s})(5.0\ \not{s} - 0.0\ \not{s}) + (+2.0\ \text{km}/\not{s})(7.0\ \not{s} - 5.0\ \not{s}) + (+4.0\ \text{km}/\not{s})(10.0\ \not{s} - 7.0\ \not{s}) \\ &= (+20\ \text{km}) + (+4.0\ \text{km}) + (+12\ \text{km}) \\ &= +36\ \text{km} \\ &= 36\ \text{km [up]}\end{aligned}$$

**9.** The velocity-time graph for an object undergoing negative acceleration is a line sloping down to the right above or below the time axis. It represents a slowing down motion above the time axis and a speeding up motion (in the negative direction) below the time axis.

**10.** The area under a velocity-time graph gives displacement.

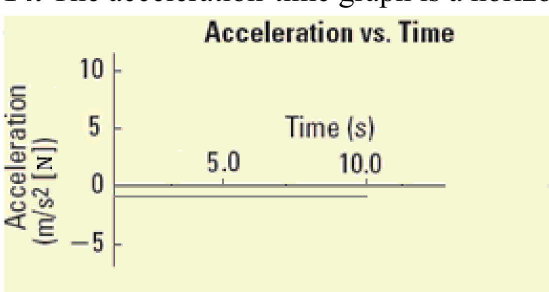
**11.** Since an object undergoing uniform motion does not experience a change in velocity, the velocity-time graph is a horizontal line (slope of zero) either at zero (object at rest), or above or below the time axis. A velocity-time graph for an object undergoing uniformly accelerated motion is a line with a positive or negative slope.

**12.** Assuming the forward direction is positive, an acceleration-time graph for an object that is slowing down in the forward direction is a horizontal line below the time axis.

**13.** Consider east to be positive.

$$\begin{aligned}\vec{a} &= \frac{\Delta\vec{v}}{\Delta t} \\ &= \frac{+100\ \text{m/s} - (-50\ \text{m/s})}{10.0\ \text{s}} \\ &= \frac{+150\ \text{m/s}}{10.0\ \text{s}} \\ &= +15\ \text{m/s}^2 \\ &= 15\ \text{m/s}^2\ \text{[E]}\end{aligned}$$

**14.** The acceleration-time graph is a horizontal line at $-1\ \text{m/s}^2$ [N].




**Applications**

**15.** Consider west to be positive.

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}(\vec{v}_\text{f} + \vec{v}_\text{i})\Delta t \\ +200\ \text{m} &= \frac{1}{2}(+30.0\ \text{m/s} + (+20.0\ \text{m/s}))\Delta t \\ +200\ \text{m} &= (+25.0\ \text{m/s})\Delta t \\ \Delta t &= 8.00\ \text{s}\end{aligned}$$

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$= \frac{+30.0 \text{ m/s} - (+20.0 \text{ m/s})}{8.00 \text{ s}}$$
$$= +1.25 \text{ m/s}^2$$
$$= 1.25 \text{ m/s}^2 \text{ [W]}$$

**16. (a)** ***Given***

Consider north to be positive.

$\vec{v}_1 = 70 \text{ km/h [N]} = +70 \text{ km/h} \quad \Delta t_1 = 75 \text{ min}$

$\vec{v}_2 = 90 \text{ km/h [N]} = +90 \text{ km/h} \quad \Delta t_2 = 96 \text{ min}$

***Required***

average velocity ($\vec{v}_{ave}$)

***Analysis and Solution***

Average velocity is a vector quantity. Determine the total displacement vector.

$$\Delta\vec{d} = \Delta\vec{d}_1 + \Delta\vec{d}_2$$
$$= \vec{v}_1\Delta t_1 + \vec{v}_2\Delta t_2$$
$$= \left(+70 \frac{\text{km}}{\cancel{\text{h}}} \times 75 \cancel{\text{min}} \times \frac{1 \cancel{\text{h}}}{60 \cancel{\text{min}}}\right) + \left(+90 \frac{\text{km}}{\cancel{\text{h}}} \times 96 \cancel{\text{min}} \times \frac{1 \cancel{\text{h}}}{60 \cancel{\text{min}}}\right)$$
$$= +232 \text{ km}$$

Determine the total time.

$$\Delta t = \Delta t_1 + \Delta t_2$$
$$= (75 + 96) \cancel{\text{min}} \times \frac{1 \text{ h}}{60 \cancel{\text{min}}}$$
$$= 2.85 \text{ h}$$

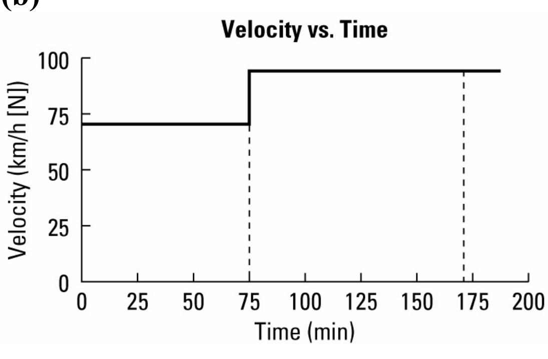
Calculate the average velocity.

$$\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$$
$$= \frac{+232 \text{ km}}{2.85 \text{ h}}$$
$$= +81 \text{ km/h}$$
$$= 81 \text{ km/h [N]}$$

***Paraphrase***

The average velocity is 81 km/h [N].

**(b)**



$$\begin{aligned}\Delta\vec{d} &= \Delta\vec{d}_1 + \Delta\vec{d}_2 \\ &= lw + lw \\ &= \vec{v}_1\Delta t_1 + \vec{v}_2\Delta t_2 \\ &= \left(70\ \frac{\text{km}}{\cancel{\text{h}}}\ [\text{N}] \times 75\ \cancel{\text{min}} \times \frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right) + \left(90\ \frac{\text{km}}{\cancel{\text{h}}}\ [\text{N}] \times 96\ \cancel{\text{min}} \times \frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right) \\ &= 232\ \text{km [N]}\end{aligned}$$

The total time is

$$171\ \cancel{\text{min}} \times \frac{1\ \text{h}}{60\ \cancel{\text{min}}} = 2.85\ \text{h}$$

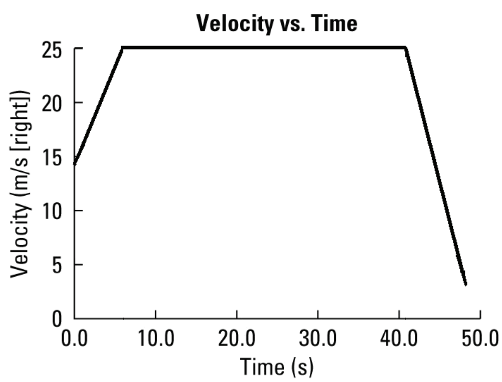
Therefore, the average velocity is

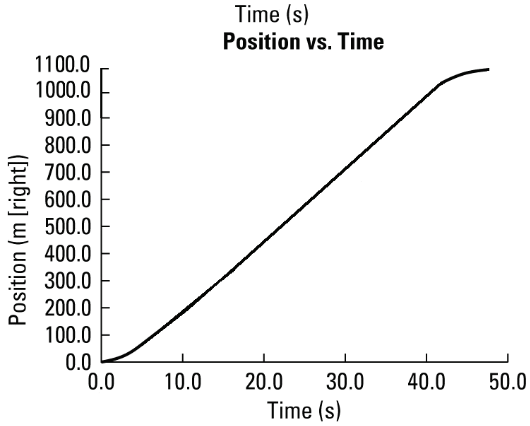
$$\begin{aligned}\vec{v}_{\text{ave}} &= \frac{\Delta\vec{d}}{\Delta t} \\ &= \frac{232\ \text{km [N]}}{2.85\ \text{h}} \\ &= 81\ \text{km/h [N]}\end{aligned}$$

**17.** Acceleration is the slope of the velocity-time graph. Consider right to be positive.

$$\begin{aligned}\vec{a} &= \frac{\Delta\vec{v}}{\Delta t} \\ &= \frac{+12.0\ \text{m/s} - (+2.0\ \text{m/s})}{30.0\ \text{s}} \\ &= +0.33\ \text{m/s}^2 \\ &= 0.33\ \text{m/s}^2\ [\text{right}]\end{aligned}$$

**18.**



**Extension**

**19.** 0.0 s to 2.0 s: sharp acceleration [E]
2.0 s to 6.0 s: gentle acceleration [E]
6.0 s to 10.0 s: uniform motion [E]
10.0 s to 11.0 s: sharp deceleration, to momentary stop
11.0 s to 12.0 s: sharp acceleration [W]
12.0 s to 15.0 s: medium acceleration [W]
15.0 s to 18.0 s: gentle deceleration [E]
18.0 s to 24.0 s: uniform motion [W]
24.0 s to 27.0 s: medium acceleration [E] to momentary stop
27.0 s to 30.0 s: medium acceleration [E]

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## Concept Check

| Graph Type | Reading the Graph | Slope | Area |
|---|---|---|---|
| **position-time** | position | velocity | — |
| **velocity-time** | velocity | acceleration | displacement |
| **acceleration-time** | acceleration | jerk | change in velocity |

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## Example 1.12 Practice Problems

**1.** ***Given***

Consider east to be positive.

$\vec{v}_{\text{i}}$ = 6.0 m/s [E] = +6.0 m/s

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

$\vec{v}_{\text{f}}$ = 36.0 m/s [E] = +36.0 m/s

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Rearrange the equation $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$. Since you are dividing by a vector, use the scalar form of the equation.

$$\begin{aligned}\Delta t &= \frac{\Delta v}{a} \\ &= \frac{36.0 \text{ m/s} - 6.0 \text{ m/s}}{4.0 \text{ m/s}^2} \\ &= 7.5 \text{ s}\end{aligned}$$

***Paraphrase***

It will take the motorcycle 7.5 s to reach a final velocity of 36.0 m/s [E].

 

**2.** ***Given***

Consider north to be positive.

$\vec{v}_{\text{i}}$ = 20 km/h [N] = $20\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{3600\ \text{s}} \times \frac{1000\ \text{m}}{1\ \text{km}} = +5.6\ \text{m/s}$

$\vec{a}$ = 1.5 m/s$^2$ [N] = +1.5 m/s$^2$

$\Delta t$ = 9.3 s

***Required***

maximum velocity ($\vec{v}_{\text{f}}$)

***Analysis and Solution***

Use the equation $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$.

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

$$\begin{aligned}\vec{v}_{\text{f}} &= \vec{a}\Delta t + \vec{v}_{\text{i}} \\ &= (+1.5\ \text{m/s}^2)(9.3\ \text{s}) + (+5.6\ \text{m/s}) \\ &= +19.55\ \frac{\text{m}}{\text{s}} \times \frac{1\ \text{km}}{1000\ \text{m}} \times \frac{3600\ \text{s}}{1\ \text{h}} \\ &= +70\ \text{km/h} \\ &= 70\ \text{km/h [N]}\end{aligned}$$

***Paraphrase***

The maximum velocity of the elk is 70 km/h [N].

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## Example 1.13 Practice Problems

**1.** ***Given***

Consider south to be positive.

$\vec{v}_{\text{i}}$ = 16 m/s [S] = +16 m/s

$\vec{v}_{\text{f}}$ = 4.0 m/s [S] = +4.0 m/s

$\Delta t$ = 4.0 s

***Required***

displacement ($\Delta \vec{d}$)

***Analysis and Solution***

Use the equation $\Delta \vec{d} = \frac{1}{2}(\vec{v}_{\text{i}} + \vec{v}_{\text{f}})\Delta t$.

$$\begin{aligned}\Delta \vec{d} &= \frac{1}{2}(+16\ \text{m/s} + (+4.0\ \text{m/s}))(4.0\ \text{s}) \\ &= +40\ \text{m} \\ &= 40\ \text{m [S]}\end{aligned}$$

***Paraphrase***

The hound's displacement is 40 m [S].

 

**2.** ***Given***

Consider uphill to be positive.

$\vec{v}_i$ = 3.0 m/s [uphill] = +3.0 m/s

$\vec{v}_f$ = 9.0 m/s [downhill] = –9.0 m/s

$\Delta t$ = 4.0 s

***Required***

displacement ( $\Delta\vec{d}$ )

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \frac{1}{2}(\vec{v}_i + \vec{v}_f)\Delta t$.

$$\Delta\vec{d} = \frac{1}{2}(+3.0 \text{ m/s} + (-9.0 \text{ m/s}))(4.0 \text{ s})$$
$$= -12 \text{ m}$$

***Paraphrase***

The ball's displacement is –12 m or 12 m [downhill].

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## Example 1.14 Practice Problems

**1.** ***Given***

Consider down to be positive.

$\vec{v}_i$ = 3.0 m/s [down] = +3.0 m/s

$\vec{a}$ = 4.0 m/s$^2$ [down] = +4.0 m/s$^2$

$\Delta t$ = 5.0 s

***Required***

displacement ( $\Delta\vec{d}$ )

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$.

$$\Delta\vec{d} = (+3.0 \text{ m/s})(5.0 \text{ s}) + \frac{1}{2}(+4.0 \text{ m/s}^2)(5.0 \text{ s})^2$$
$$= +65 \text{ m}$$
$$= 65 \text{ m [down]}$$

***Paraphrase***

The skier's displacement after 5.0 s is 65 m [down].

**2.** ***Given***

Consider forward to be positive.

$$\vec{v}_i = 100 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} = +27.8 \text{ m/s}$$

$\vec{a}$ = –0.80 m/s$^2$

$\Delta t$ = 1.0 min = 60 s

***Required***

distance ( $\Delta d$ )

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$.

$$\Delta\vec{d} = (+27.8 \text{ m/s})(60 \text{ s}) + \frac{1}{2}(-0.80 \text{ m/s}^2)(60 \text{ s})^2$$
$$= +227 \text{ m}$$
$$\Delta d = 2.3\times10^2 \text{ m}$$

***Paraphrase***

The motorcycle travels $2.3\times10^2$ m.

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## Example 1.15 Practice Problems

**1.** ***Given***

Consider forward to be positive.

$\Delta\vec{d}$ = +150 m

$\vec{v}_{\text{f}}$ = 0

$\vec{a}$ = –15 m/s$^2$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_{\text{f}}\Delta t - \frac{1}{2}\vec{a}(\Delta t)^2$ to solve for time.

$$+150 \text{ m} = (0)(\Delta t) - \frac{1}{2}(-15 \text{ m/s}^2)(\Delta t)^2$$
$$\Delta t = \sqrt{\frac{150 \text{ m}}{7.5 \text{ m/s}^2}}$$
$$= 4.5 \text{ s}$$

***Paraphrase***

The plane stops after 4.5 s.

**2.** ***Given***

Consider north to be positive.

$\Delta t$ = 6.2 s

$\vec{v}_{\text{f}}$ = 160 km/h [N] $\times\frac{1 \text{ h}}{3600 \text{ s}}\times\frac{1000 \text{ m}}{1 \text{ km}} = +44.4 \text{ m/s}$

$\Delta\vec{d}$ = 220 m [N] = +220 m

***Required***

acceleration ( $\vec{a}$ )

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_{\text{f}}\Delta t - \frac{1}{2}\vec{a}(\Delta t)^2$ .

 

$$\vec{a} = \frac{2(\vec{v}_f \Delta t - \Delta \vec{d})}{(\Delta t)^2}$$
$$= \frac{2((+44.4 \text{ m/s})(6.2 \text{ s}) - (+220 \text{ m}))}{(6.2 \text{ s})^2}$$
$$= +2.9 \text{ m/s}^2$$
$$= 2.9 \text{ m/s}^2 \text{ [N]}$$

***Paraphrase***

The Corvette's acceleration is 2.9 m/s$^2$ [N].

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### Example 1.16 Practice Problems

**1.** ***Given***

$\vec{v}_i = 70$ m/s [forward]

$\Delta t = 29$ s

$\vec{v}_f = 0$ m/s

***Required***

**(a)** acceleration ($\vec{a}$)

**(b)** distance ($\Delta d$)

***Analysis and Solution***

**(a)** Use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$. Since the jetliner comes to a halt, final velocity is zero.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$= \frac{0 \text{ m/s} - 70 \text{ m/s [forward]}}{29 \text{ s}}$$
$$= -2.41 \text{ m/s}^2 \text{ [forward]}$$

**(b)** Use the equation $v_f^2 = v_i^2 + 2a\Delta d$.

$$v_f^2 = v_i^2 + 2a\Delta d$$
$$\Delta d = \frac{v_f^2 - v_i^2}{2a}$$
$$= \frac{(0 \text{ m/s})^2 - (70 \text{ m/s})^2}{2(-2.41 \text{ m/s}^2)}$$
$$= 1015 \text{ m}$$
$$= 1.0 \text{ km}$$

***Paraphrase***

(a) The jet's acceleration is −2.4 m/s$^2$ [forward].

(b) The runway length is 1.0 km.

 

**2.** ***Given***

$v_i = 50$ km/h

$v_f = 100$ km/h

$a = 3.8$ m/s$^2$

***Required***

distance ( $\Delta d$ )

***Analysis and Solution***

Convert initial and final velocities to m/s. Then use the equation $v_f^2 = v_i^2 + 2a\Delta d$ to find the on-ramp length.

$$50\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} = 13.89\ \text{m/s}$$

$$100\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} = 27.78\ \text{m/s}$$

$$v_f^2 = v_i^2 + 2a\Delta d$$

$$\begin{aligned} \Delta d &= \frac{v_f^2 - v_i^2}{2a} \\ &= \frac{(27.78\ \text{m/s})^2 - (13.89\ \text{m/s})^2}{2(3.8\ \text{m/s}^2)} \\ &= 76\ \text{m} \end{aligned}$$

***Paraphrase***

The minimum length of the on-ramp is 76 m.

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## 1.5 Check and Reflect

**Applications**

**1.** ***Given***

Consider forward to be positive.

$\Delta t = 3.0$ s

$\vec{a} = 1.0$ cm/s$^2$ [forward] $= +1.0$ cm/s$^2$

$\vec{v}_i = 5.0$ cm/s [forward] $= +5.0$ cm/s

***Required***

displacement ( $\Delta\vec{d}$ )

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\left(\Delta t\right)^2$.

$$\begin{aligned} \Delta\vec{d} &= (+5.0\ \text{cm/s})(3.0\ \text{s}) + \frac{1}{2}(+1.0\ \text{cm/s}^2)(3.0\ \text{s})^2 \\ &= +20\ \text{cm} \\ &= 20\ \text{cm [forward]} \end{aligned}$$

***Paraphrase***

The robot will travel 20 cm [forward].

 

**2.** ***Given***

Consider right to be positive.

$\vec{v}_{\rm i} = 10 \text{ m/s [right]} = +10 \text{ m/s}$

$\vec{v}_{\rm f} = 20 \text{ m/s [right]} = +20 \text{ m/s}$

$\Delta t = 5.0 \text{ s}$

***Required***

displacement ( $\Delta \vec{d}$ )

***Analysis and Solution***

Since you do not know the acceleration, use the equation $\Delta \vec{d} = \frac{1}{2}(\vec{v}_{\rm i} + \vec{v}_{\rm f})\Delta t$.

$$\begin{aligned}\Delta \vec{d} &= \frac{1}{2}(+10 \text{ m/s} + (+20 \text{ m/s}))(5.0 \text{ s}) \\ &= +75 \text{ m} \\ &= 75 \text{ m [right]}\end{aligned}$$

***Paraphrase***

The logging truck moves 75 m [right].

**3.** ***Given***

$v_{\rm i} = 0 \text{ m/s}$

$a = 3.75 \text{ m/s}^2$

$\Delta t = 5.65 \text{ s}$

***Required***

distance ( $\Delta d$ )

***Analysis and Solution***

Apply the equation $\Delta d = v_{\rm i}\Delta t + \frac{1}{2}a\Delta t^2$, where $v_{\rm i} = 0$.

$$\begin{aligned}\Delta d &= 0 + \frac{1}{2}(3.75 \text{ m/s}^2)(5.65 \text{ s})^2 \\ &= 59.9 \text{ m}\end{aligned}$$

***Paraphrase***

The car will travel 59.9 m.

**4.** ***Given***

Consider forward to be positive.

$\vec{v}_{\rm i} = 0 \text{ m/s}$

$\Delta t = 2.75 \times 10^{-3} \text{ s}$

$\vec{v}_{\rm f} = 460 \text{ m/s [forward]} = +460 \text{ m/s}$

***Required***

acceleration ( $\vec{a}$ )

***Analysis and Solution***

Use the equation $\vec{a} = \frac{\vec{v}_{\rm f} - \vec{v}_{\rm i}}{\Delta t}$.

$$\begin{aligned}\vec{a} &= \frac{+460 \text{ m/s} - 0 \text{ m/s}}{2.75 \times 10^{-3} \text{ s}} \\ &= +1.67 \times 10^5 \text{ m/s}^2 \\ &= 1.67 \times 10^5 \text{ m/s}^2 \text{ [forward]}\end{aligned}$$

 

***Paraphrase***
The bullet's acceleration is $1.67 \times 10^5$ m/s$^2$ [forward].

5. ***Given***
$a = 42.5$ m/s$^2$
$v_i = 0$ m/s
$\Delta d = 2.6$ km $= 2600$ m
***Required***
time ($\Delta t$)
***Analysis and Solution***
Apply the equation $\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$, where $v_i = 0$.
$$\Delta d = \frac{1}{2} a \Delta t^2$$
$$\begin{aligned} \Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(2600 \text{ m})}{42.5 \frac{\text{m}}{\text{s}^2}}} \\ &= 11 \text{ s} \end{aligned}$$
***Paraphrase***
It takes the aircraft 11 s to travel down the runway.

6. ***Given***
$v_i = 14.0$ m/s
$v_f = 0$ m/s
$\Delta t = 5.60$ s
***Required***
distance ($\Delta d$)
***Analysis and Solution***
Since acceleration is uniform, use the equation $\Delta d = \frac{1}{2}(v_i + v_f)\Delta t$.
$$\begin{aligned} \Delta d &= \frac{1}{2}(14.0 \text{ m/s} + 0 \text{ m/s})(5.60 \text{ s}) \\ &= 39.2 \text{ m} \end{aligned}$$
***Paraphrase***
The skidding distance is 39.2 m.

7. ***Given***
$\Delta d = 150$ m
$v_i = 50$ km/h
$v_f = 30$ km/h
***Required***
magnitude of acceleration ($a$)
***Analysis and Solution***
Convert initial and final speeds to m/s. Use the equation $v_f^2 = v_i^2 + 2a\Delta d$.

 

$30\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} = 8.33\ \text{m/s}$

$50\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} = 13.89\ \text{m/s}$

$$v_f^2 = v_i^2 + 2a\Delta d$$

$$\begin{aligned} a &= \frac{v_f^2 - v_i^2}{2\Delta d} \\ &= \frac{(8.33\ \text{m/s})^2 - (13.89\ \text{m/s})^2}{2(150\ \text{m})} \\ &= -0.41\ \text{m/s}^2 \end{aligned}$$

***Paraphrase***

The magnitude of the car's acceleration is $0.41\ \text{m/s}^2$.

**8.** ***Given***

$\Delta\vec{d} = 1.3$ km [forward] = 1300 m [forward]

$\vec{v}_i = 90$ km/h [forward]

$\vec{v}_f = 0$ m/s

***Required***

acceleration ($\vec{a}$)

***Analysis and Solution***

Convert km/h to m/s.

$90\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} = 25\ \text{m/s}$

Then use the equation $v_f^2 = v_i^2 + 2a\Delta d$.

$$\begin{aligned} a &= \frac{v_f^2 - v_i^2}{2\Delta d} \\ &= \frac{0 - (25\ \text{m/s})^2}{2(1300\ \text{m})} \\ &= -0.24\ \text{m/s}^2 \end{aligned}$$

***Paraphrase***

The train's acceleration is $-0.24\ \text{m/s}^2$ [forward].

**9.** ***Given***

Consider west to be positive.

$\vec{v}_i = 0$ m/s

$\Delta t = 2.00$ s

$\Delta\vec{d} = 150$ m [W] $= +150$ m

***Required***

acceleration ($\vec{a}$)

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i = 0$.

 

$$\vec{a} = \frac{2\left(\Delta\vec{d} - \vec{v}_i\Delta t\right)}{\left(\Delta t\right)^2}$$
$$= \frac{2\left(+150 \text{ m} - 0\right)}{(2.00 \text{ s})^2}$$
$$= +75.0 \text{ m/s}^2$$
$$= 75.0 \text{ m/s}^2 \text{ [W]}$$

***Paraphrase***

The rocket's acceleration is $75.0 \text{ m/s}^2$ [W].

**10.** ***Given***

$v_i = 0 \text{ m/s}$

$v_f = 241 \text{ km/h}$

$\Delta d = 96.0 \text{ m}$

***Required***

magnitude of acceleration ($a$)

***Analysis and Solution***

Convert km/h to m/s.

$$241 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 66.94 \text{ m/s}$$

Use the equation $v_f{}^2 = v_i{}^2 + 2a\Delta d$, where $v_i = 0$.

$$a = \frac{v_f{}^2 - v_i{}^2}{2\Delta d}$$
$$= \frac{(66.94 \text{ m/s})^2 - 0 \text{ m/s}}{2(96.0 \text{ m})}$$
$$= 23.3 \text{ m/s}^2$$

***Paraphrase***

The jet's acceleration has a magnitude of $23.3 \text{ m/s}^2$.

**11.** ***Given***

Consider south to be positive.

$\vec{v}_i = 0 \text{ m/s}$

$\Delta\vec{d} = 350.0 \text{ m [S]} = +350.0 \text{ m}$

$\Delta t = 14.1 \text{ s}$

***Required***

acceleration ($\vec{a}$)

***Analysis and Solution***

Apply the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\left(\Delta t\right)^2$, where $\vec{v}_i = 0$.

 

$$\Delta\vec{d} = \frac{1}{2}\vec{a}(\Delta t)^2$$

$$\vec{a} = \frac{2\Delta\vec{d}}{(\Delta t)^2}$$

$$= \frac{2(+350.0\text{ m})}{(14.1\text{ s})^2}$$

$$= +3.52\text{ m/s}^2$$

$$= 3.52\text{ m/s}^2\text{ [S]}$$

***Paraphrase***

The motorcycle's acceleration is $3.52\text{ m/s}^2$ [S].

**12.** ***Given***

$\Delta d = 39.0\text{ m}$

$v_f = 0\text{ m/s}$

$v_i = 97.0\text{ km/h}$

***Required***

magnitude of acceleration ($a$)

***Analysis and Solution***

Use the equation $v_f^2 = v_i^2 + 2a\Delta d$, where $v_f = 0$.

$$97.0\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\text{ s}} = 26.94\text{ m/s}$$

$$v_f^2 = v_i^2 + 2a\Delta d$$

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

$$= \frac{0 - (26.94\text{ m/s})^2}{2(39.0\text{ m})}$$

$$= -9.31\text{ m/s}^2$$

***Paraphrase***

The magnitude of the car's acceleration is $9.31\text{ m/s}^2$.

**13.** ***Given***

$\vec{a} = -49\text{ m/s}^2$ [forward]

$$v_i = 110\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\text{ s}} = 30.56\text{ m/s}$$

$v_f = 0$

***Required***

distance ($\Delta d$)

***Analysis and Solution***

Use the equation $v_f^2 = v_i^2 + 2a\Delta d$.

 

$$\Delta d = \frac{v_f^2 - v_i^2}{2a}$$
$$= \frac{0 - (30.56 \text{ m/s})^2}{2(-49 \text{ m/s}^2)}$$
$$= 9.5 \text{ m}$$

***Paraphrase***

The minimum stopping distance must be 9.5 m.

**14.** ***Given***

Consider north to be positive.

$\vec{v}_i = 9.0 \text{ m/s [N]} = +9.0 \text{ m/s}$

$\Delta\vec{d} = 1.54 \text{ km [N]} = +1540 \text{ m}$

$\Delta t = 2.0 \text{ min} = 120 \text{ s}$

***Required***

acceleration ($\vec{a}$)

***Analysis and Solution***

Rearrange the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$ to solve for acceleration.

$$\vec{a} = \frac{2\left(\Delta\vec{d} - \vec{v}_i\Delta t\right)}{(\Delta t)^2}$$
$$= \frac{2\left(+1540 \text{ m} - \left(+9.0 \frac{\text{m}}{\cancel{\text{s}}}\right)(120 \cancel{\text{s}})\right)}{(120 \text{ s})^2}$$
$$= +0.064 \text{ m/s}^2$$
$$= 0.064 \text{ m/s}^2 \text{ [N]}$$

***Paraphrase***

The submarine's acceleration is 0.064 m/s$^2$ [N].

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## Example 1.17 Practice Problems

**1.** ***Given***

Consider down to be positive.

$\Delta t = 0.750 \text{ s}$

$\Delta\vec{d} = 4.80 \text{ m [down]} = +4.80 \text{ m}$

$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$

***Required***

initial velocity ($\vec{v}_i$)

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$.

$$\vec{v}_i = \frac{\Delta\vec{d} - \frac{1}{2}\vec{a}(\Delta t)^2}{\Delta t}$$
$$= \frac{+4.80 \text{ m} - \frac{1}{2}\left(+9.81 \ \frac{\text{m}}{\text{s}^2}\right)(0.750 \text{ s})^2}{0.750 \text{ s}}$$
$$= +2.72 \text{ m/s}$$
$$= 2.72 \text{ m/s [down]}$$

***Paraphrase***

The rock's initial velocity is 2.72 m/s [down].

**2.** ***Given***

Consider down to be positive.

$\vec{v}_i = 2.0 \text{ m/s [down]} = +2.0 \text{ m/s}$

$\Delta\vec{d} = 1.75 \text{ m [down]} = +1.75 \text{ m}$

$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Determine the final velocity using the equation $v_f^2 = v_i^2 + 2a\Delta d$ .

$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$
$$= \sqrt{\left(2.0 \ \frac{\text{m}}{\text{s}}\right)^2 + 2\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(1.75 \text{ m})}$$
$$= 6.19 \text{ m/s}$$

Determine the time using $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$ . Use the scalar form of the equation because you are dividing by a vector.

$$a = \frac{\Delta v}{\Delta t}$$
$$\Delta t = \frac{v_f - v_i}{a}$$
$$= \frac{6.19 \text{ m/s} - (2.0 \text{ m/s})}{9.81 \text{ m/s}^2}$$
$$= 0.43 \text{ s}$$

***Paraphrase***

The football is in the air for 0.43 s.

**3.** ***Given***

Choose down to be positive.

$\vec{a} = 2.00 \text{ m/s}^2 \text{ [up]} = -2.00 \text{ m/s}^2$

$\vec{v}_i = 4.00 \text{ m/s [down]} = +4.00 \text{ m/s}$

$\Delta t = 1.80 \text{ s}$

***Required***

final velocity ( $\vec{v}_f$ )

distance ( $\Delta d$ )

***Analysis and Solution***

Use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ to find final velocity.

$$\begin{aligned}\vec{v}_f &= \vec{v}_i + \vec{a}\Delta t \\ &= +4.00\ \frac{\text{m}}{\text{s}} + \left(-2.00\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(1.80\ \cancel{\text{s}}) \\ &= +0.400\ \text{m/s} \\ &= 0.400\ \text{m/s [down]}\end{aligned}$$

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}\left(\Delta t\right)^2$ to find the distance $(\Delta d)$.

$$\begin{aligned}\Delta\vec{d} &= \left(+4.00\ \frac{\text{m}}{\cancel{\text{s}}}\right)(1.80\ \cancel{\text{s}}) + \frac{1}{2}\left(-2.00\ \frac{\text{m}}{\text{s}^2}\right)(1.80\ \text{s})^2 \\ &= +3.96\ \text{m}\end{aligned}$$

$\Delta d = 3.96$ m

***Paraphrase***

The final velocity is 0.400 m/s [down] and the elevator travels 3.96 m.



## Example 1.18 Practice Problem

**1.** ***Given***

Choose down to be positive.

$\Delta\vec{d}$ = 27 m [down] = +27 m

$\vec{a} = 9.81\ \text{m/s}^2\ \text{[down]} = +9.81\ \text{m/s}^2$

$\vec{v}_i = 0$ m/s

***Required***

final speed ( $v_f$ )

***Analysis and Solution***

Determine the final speed using the equation $v_f^{\ 2} = v_i^{\ 2} + 2a\Delta d$ .

$$\begin{aligned}v_f &= \sqrt{v_i^{\ 2} + 2a\Delta d} \\ &= \sqrt{0 + 2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(27\ \text{m})} \\ &= 23\ \text{m/s}\end{aligned}$$

***Paraphrase***

The final speed of the riders before they start slowing down is 23 m/s.

## Example 1.19 Practice Problems

**1. (a)** ***Given***

Choose down to be positive.

$\Delta\vec{d}$ = 20.0 m [down] = +20.0 m

$\vec{a} = 9.81\ \text{m/s}^2\ [\text{down}] = +9.81\ \text{m/s}^2$

$\vec{v}_\text{i} = 0\ \text{m/s}$

***Required***

final velocity ( $\vec{v}_\text{f}$ )

***Analysis and Solution***

Determine the final velocity using the equation $v_\text{f}^2 = v_\text{i}^2 + 2a\Delta d$.

$$\begin{aligned} v_\text{f} &= \sqrt{v_\text{i}^2 + 2a\Delta d} \\ &= \sqrt{0 + 2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(20.0\ \text{m})} \\ &= 19.81\ \text{m/s} \\ &= 19.8\ \text{m/s} \end{aligned}$$

***Paraphrase***

The pebble hits the ground with a velocity of 19.8 m/s [down].

**(b)** ***Given***

Choose down to be positive.

$\Delta\vec{d}$ = 20.0 m [down] = +20.0 m

$\vec{a} = 9.81\ \text{m/s}^2\ [\text{down}] = +9.81\ \text{m/s}^2$

$\vec{v}_\text{i} = 0\ \text{m/s}$

$\vec{v}_\text{f}$ = 19.8 m/s [down]

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Determine the time using $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$. Use the scalar form of the equation because you are dividing by a vector.

$$a = \frac{\Delta v}{\Delta t}$$

$$\begin{aligned} \Delta t &= \frac{v_\text{f} - v_\text{i}}{a} \\ &= \frac{19.81\ \text{m/s} - 0\ \text{m/s}}{9.81\ \text{m/s}^2} \\ &= 2.02\ \text{s} \end{aligned}$$

***Paraphrase***

The pebble hits the ground after 2.02 s.

## Student Book page 61

### Concept Check

**(a)** The speed of an object at the launch level is the same at the moment it is thrown upwards and at the moment it arrives back to this level.
Since an object thrown upward experiences uniformly accelerated motion due to gravity, it undergoes equal changes in velocity over equal time intervals according to the equation $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$. It therefore makes sense that the time taken to reach maximum height is the same time required to fall back down to the launch level.

**(b)** According to the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, the length of time a projectile is in the air depends on the acceleration due to gravity and on the initial velocity of the object. This answer is surprising because it is counterintuitive: It is a common misconception that an object's mass affects how long it spends in the air.

## Student Book page 62

### Concept Check

The slope of the velocity-time graph for vertical projectile motion should be –9.81 m/s$^2$, where [up] is positive.

## Student Book page 63

### 1.6 Check and Reflect

**Knowledge**

**1.** A projectile is any object thrown, dropped, or fired into the air.

**2.** The height ($\Delta d$) from which an object is dropped determines how long it will take to reach the ground.

**Applications**

**3.** ***Given***

Choose down to be positive.

$\Delta t = 3.838 \text{ s} \quad \vec{v}_i = 0$

$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$

***Required***

height ($\Delta d$)

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0.

$$\begin{aligned}\Delta\vec{d} &= 0 + \frac{1}{2}(+9.81 \text{ m/s}^2)(3.838 \text{ s})^2 \\ &= +72.3 \text{ m} \\ &= 72.3 \text{ m [down]}\end{aligned}$$

***Paraphrase***

The muffin falls from a height of 72.3 m.

**4.** ***Given***

Choose down to be positive.

$\vec{v}_i = 0$ m/s

$\Delta t = 0.56$ s

$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$

***Required***

height ( $\Delta d$ )

***Analysis and Solution***

Use the equation $\Delta \vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i = 0$.

$$
\begin{aligned}
&= 0 + \frac{1}{2}(+9.81 \text{ m/s}^2)(0.56 \text{ s})^2 \\
&= +1.5 \text{ m} \\
&= 1.5 \text{ m [down]}
\end{aligned}
$$

***Paraphrase***

The toys are being dropped from a height of 1.5 m.

**5.** ***Given***

Consider down to be positive.

$\Delta t = 1.575$ s

$\Delta \vec{d} = 2.00 \text{ m [down]} = +2.00 \text{ m}$

$\vec{v}_i = 0$ m/s

***Required***

acceleration ( $\vec{a}$ )

***Analysis and Solution***

Use the equation $\Delta \vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i = 0$.

$$
\begin{aligned}
\Delta \vec{d} &= \frac{1}{2}\vec{a}(\Delta t)^2 \\
\vec{a} &= \frac{2\Delta \vec{d}}{(\Delta t)^2} \\
&= \frac{2(+2.00 \text{ m})}{(1.575 \text{ s})^2} \\
&= +1.61 \text{ m/s}^2 \\
&= 1.61 \text{ m/s}^2 \text{ [down]}
\end{aligned}
$$

***Paraphrase***

The acceleration due to gravity on the Moon is 1.61 m/s$^2$ [down].

**6.** ***Given***

Consider down to be positive.

$\vec{v}_i = 5.0 \text{ m/s [up]} = -5.0 \text{ m/s}$

$\vec{d}_i = 1.50 \text{ m [up]} = -1.50 \text{ m}$

$\vec{v}_f = 0$ m/s

$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$

***Required***
maximum height ( $\Delta d$ )
***Analysis and Solution***
At the instant the ball reaches maximum height, its velocity is zero. The maximum height reached by the ball is the height it reaches from the initial impulse plus the height from which it was launched. Use the equation $v_f{}^2 = v_i{}^2 + 2a\Delta d$ and substitute scalar quantities.

$$v_f{}^2 = v_i{}^2 + 2a\Delta d$$

$$\begin{aligned}\Delta d &= \frac{v_f{}^2 - v_i{}^2}{2a} \\ &= \frac{0 - (-5.0 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)} \\ &= 1.27 \text{ m}\end{aligned}$$

The ball's height from the floor is $1.50 \text{ m} + 1.27 \text{ m} = 2.8 \text{ m}$.
***Paraphrase***
The basketball reaches a maximum height of 2.8 m.

**7.** ***Given***
Choose down to be positive.
$\vec{v}_i = 0 \text{ m/s}$
$\Delta t = 2.6 \text{ s}$
$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$
***Required***
final velocity ( $\vec{v}_f$ )
distance ( $\Delta d$ )
***Analysis and Solution***
Because the student drops from rest, initial velocity is zero. For final velocity, use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

$$\begin{aligned}\vec{v}_f &= \vec{v}_i + \vec{a}\Delta t \\ &= 0 \text{ m/s} + (+9.81 \text{ m/s}^2)(2.6 \text{ s}) \\ &= +25.5 \text{ m/s} \\ &= 25.5 \text{ m/s [down]}\end{aligned}$$

For distance, use the equation $\Delta d = \frac{1}{2}(v_i + v_f)\Delta t$.

$$\begin{aligned}\Delta d &= \frac{1}{2}(v_i + v_f)\Delta t \\ &= \frac{1}{2}(0 \text{ m/s} + 25.5 \text{ m/s})(2.6 \text{ s}) \\ &= 33 \text{ m}\end{aligned}$$

***Paraphrase***
The student falls 33 m and the student's final velocity is 26 m/s [down].

**8.** ***Given***

Choose down to be positive.

$\Delta\vec{d} = 1.75\text{ m [down]} = +1.75\text{ m}$

$\vec{a} = 24.8\text{ m/s}^2\text{ [down]} = +24.8\text{ m/s}^2$

$\vec{v}_i = 0$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i = 0$. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta d = \frac{1}{2}a(\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$

$$= \sqrt{\frac{2(1.75\ \cancel{\text{m}})}{24.8\ \frac{\cancel{\text{m}}}{\text{s}^2}}}$$

$$= 0.376\text{ s}$$

***Paraphrase***

The tennis ball takes 0.376 s to drop 1.75 m on Jupiter.

**9.** ***Given***

Choose down to be positive.

$\Delta t = 6.25\text{ s}$

$\vec{a} = 9.81\text{ m/s}^2\text{ [down]} = +9.81\text{ m/s}^2$

***Required***

distance ( $\Delta d$ )

***Analysis and Solution***

The ball takes $\frac{6.25\text{ s}}{2} = 3.125\text{ s}$ to reach its maximum height. At maximum height, $\vec{v}_i = 0$. To find maximum height, use the equation $\Delta d = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$.

$$\Delta d = 0 + \frac{1}{2}(9.81\text{ m/s}^2)(3.125\text{ s})^2$$

$$= 47.9\text{ m}$$

***Paraphrase***

The baseball reaches a maximum height of 47.9 m.

**10.** ***Given***

Choose down to be positive.

$\Delta\vec{d} = 3.0\text{ m [down]} = +3.0\text{ m}$

$\vec{a} = 9.81\text{ m/s}^2\text{ [down]} = +9.81\text{ m/s}^2$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

The kangaroo's time in the air is $2\Delta t$. Find time using the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0 from maximum height. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta d = \frac{1}{2}a(\Delta t)^2$$

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(3.0\ \cancel{\text{m}})}{9.81\ \frac{\cancel{\text{m}}}{\text{s}^2}}} \\ &= 0.78\ \text{s}\end{aligned}$$

Since this time is the time taken to fall from maximum height, the kangaroo's total time in the air is $2 \times 0.78\ \text{s} = 1.6\ \text{s}$.

***Paraphrase***

The kangaroo is in the air for 1.6 s.

**11.** ***Given***

Choose down to be positive.

$\Delta\vec{d} = 190\ \text{m [down]} = +190\ \text{m}$

$\vec{a} = 9.81\ \text{m/s}^2\ \text{[down]} = +9.81\ \text{m/s}^2$

$\vec{v}_i = 0\ \text{m/s}$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Find the time using the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0 from maximum height. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta d = \frac{1}{2}a(\Delta t)^2$$

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(190\ \cancel{\text{m}})}{9.81\ \frac{\cancel{\text{m}}}{\text{s}^2}}} \\ &= 6.22\ \text{s}\end{aligned}$$

***Paraphrase***

The penny takes 6.22 s to fall 190 m.

**12.** ***Given***

Choose down to be positive.

$\Delta t = 2.75\ \text{s}$

$\Delta\vec{d}_i = 1.30\ \text{m [up]} = -1.30\ \text{m}$

$\vec{a} = 9.81\ \text{m/s}^2\ \text{[down]} = +9.81\ \text{m/s}^2$

***Required***
maximum height ( $\Delta d$ )
***Analysis and Solution***
The ball takes $\frac{2.75\text{ s}}{2} = 1.375\text{ s}$ to reach its maximum height. Find height using the equation $\Delta d = v_i \Delta t + \frac{1}{2}a(\Delta t)^2$, where $v_i$ = 0 from maximum height.

$$\Delta d = 0 + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.375\text{ s})^2$$
$$= 9.27\text{ m}$$

Total height, from ground, is 9.27 m + 1.30 m = 10.57 m = 10.6 m
***Paraphrase***
The coin reaches a maximum height of 10.6 m.

**13.** ***Given***
Choose down to be positive.

$\Delta\vec{d} = 10\text{ m [down]} = +10\text{ m}$

$\vec{a} = 9.81\text{ m/s}^2\text{ [down]} = +9.81\text{ m/s}^2$

$\vec{v}_i = 0\text{ m/s}$

***Required***
time ( $\Delta t$ )
***Analysis and Solution***
Use the equation $\Delta\vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$
$$= \sqrt{\frac{2(10\ \cancel{\text{m}})}{9.81\ \frac{\cancel{\text{m}}}{\text{s}^2}}}$$
$$= 1.4\text{ s}$$

***Paraphrase***
The diver takes 1.4 s to reach the water's surface.

**14.** ***Given***

$h_{\text{building}} = 5.0\text{ m}$

$v_{\text{walking}} = 2.75\text{ m/s}$

$h_{\text{catch}} = 1.25\text{ m}$

***Required***
distance ( $\Delta d$ )
***Analysis and Solution***
If the person catches his keys directly below where they are dropped, the amount of time the keys have to fall is the same amount of time the person has to walk to catch them. To find the time taken for the keys to fall, use the equation $\Delta\vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0.

To find $\Delta t$, use the scalar form of the equation because you are dividing by a vector.

$$\Delta t = \sqrt{\frac{2\Delta d_{\text{vertical}}}{a}}$$

$$= \sqrt{\frac{2(5.0\ \text{m} - 1.25\ \text{m})}{9.81\ \frac{\text{m}}{\text{s}^2}}}$$

$$= 0.87\ \text{s}$$

To find the distance the person needs to walk to catch his keys, use the equation $v = \frac{\Delta d}{\Delta t}$.

$$\Delta d_{\text{horizontal}} = v_{\text{horizontal}}\Delta t$$

$$= \left(2.75\ \frac{\text{m}}{\text{s}}\right)(0.87\ \text{s})$$

$$= 2.4\ \text{m}$$

***Paraphrase***

The person is 2.4 m away.

**Extensions**

**15.** ***Given***

Choose up to be positive.

$\Delta t = 50\ \text{s}$

$\vec{v}_{\text{i}} = 0$

$\vec{v}_{\text{f}} = 200\ \text{m/s [up]} = +200\ \text{m/s}$

$\vec{a} = 9.81\ \text{m/s}^2\ \text{[down]} = -9.81\ \text{m/s}^2$

***Required***

**(a)** acceleration ($\vec{a}$)

**(b)** height at which fuel runs out ($\Delta d_{\text{fuel}}$)

**(c)** explanation for height gain

**(d)** maximum height ($\Delta d_{\text{max}}$)

***Analysis and Solution***

**(a)** To find acceleration, assume the rocket launches from an initial velocity of zero. Use the equation $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$.

$$\vec{a} = \frac{+200\ \text{m/s} - 0}{50\ \text{s}}$$

$$= +4.0\ \text{m/s}^2$$

$$= 4.0\ \text{m/s}^2\ \text{[up]}$$

**(b)** Determine the distance travelled upward using the equation $\Delta d = v_{\text{i}}\Delta t + \frac{1}{2}a(\Delta t)^2$.

$$\Delta d_{\text{fuel}} = 0 + \frac{1}{2}(4.0\ \text{m/s}^2)(50\ \text{s})^2$$

$$= 5.0 \times 10^3\ \text{m}$$

**(c)** As soon as the rocket's fuel runs out, its upward acceleration suddenly changes to the downward acceleration due to gravity. At this moment, the rocket is moving upward with a velocity it gained due to the thrust of its engines. This is the initial velocity for this last leg of the flight without further thrust. The rocket will continue to rise until its upward velocity is reduced to zero by the (downward) acceleration due to gravity. At maximum height,

$\vec{v}_f = 0$ m/s, $\vec{v}_i = 200$ m/s [up] $= +200$ m/s

Using $\vec{v}_f = \vec{v}_i + \vec{a}\Delta t$,

$0 = 200 - 9.81\Delta t$

Therefore, $\Delta t = \dfrac{200 \text{ m/s}}{9.81 \text{ m/s}^2} = 20.39 \text{ s} = 20 \text{ s}$

The rocket contines to gain height for 20 s.

**(d)** To determine how far the rocket will travel once it runs out of fuel, use the equation $v_f^{\,2} = v_i^{\,2} + 2a\Delta d$ , where $v_f$ (at maximum height) equals zero.

$$\Delta d_{max} = \Delta d_{fuel} + \Delta d_{top}$$

$$v_f^{\,2} = v_i^{\,2} + 2a\Delta d$$

$$\Delta d_{top} = \frac{v_f^{\,2} - v_i^{\,2}}{2a}$$

$$= \frac{0 - (200 \text{ m/s})^2}{2(-9.81 \text{ m/s}^2)}$$

$$= 2039 \text{ m}$$

$$\Delta d_{max} = 5000 \text{ m} + 2039 \text{ m}$$

$$= 7039 \text{ m}$$

$$= 7.0 \times 10^3 \text{ m}$$

***Paraphrase***

(a) The rocket's acceleration during fuel burning is 4.0 m/s$^2$ [up].

(b) At the end of 50 s, the rocket has reached a height of $5.0 \times 10^3$ m.

(d) The rocket's maximum height is $7.0 \times 10^3$ m.

**16.** ***Given***

Choose down to be positive.

$\Delta\vec{d} = 60.0$ m [down] $= +60.0$ m

$\Delta t = 0.850$ s

$\vec{a} = 9.81$ m/s$^2$ [down] $= +9.81$ m/s$^2$

***Required***

initial velocity of second ball ( $\vec{v}_{i_2}$ )

***Analysis and Solution***

Determine how long the first ball takes to hit the ground. Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta d = v_i \Delta t + \frac{1}{2}a(\Delta t)^2$$

$$\begin{aligned}\Delta t_1 &= \sqrt{\frac{2\Delta d}{a}}\\ &= \sqrt{\frac{2(60.0\ \text{m})}{9.81\ \frac{\text{m}}{\text{s}^2}}}\\ &= 3.497\ \text{s}\end{aligned}$$

The second ball has 0.850 s less to cover the same distance.

$$\begin{aligned}\Delta t_2 &= 3.497\ \text{s} - 0.850\ \text{s}\\ &= 2.647\ \text{s}\end{aligned}$$

Use the equation $\Delta \vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$ to determine the initial velocity of the second ball.

$$\begin{aligned}\vec{v}_i &= \frac{\Delta \vec{d} - \frac{1}{2}\vec{a}(\Delta t)^2}{\Delta t}\\ &= \frac{+60.0\ \text{m} - \frac{1}{2}\left(+9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.647\ \text{s})^2}{2.647\ \text{s}}\\ &= +9.68\ \text{m/s}\\ &= 9.68\ \text{m/s [down]}\end{aligned}$$

***Paraphrase***

The initial velocity of the second ball was 9.68 m/s [down].

**Student Book pages 65–67**

## Chapter 1 Review

**Knowledge**

**1.** Vector quantities have magnitude and direction. They must be added by vector addition–special tip-to-tail procedure. Scalar quantities have magnitude only.
Scalar quantity: a mass of 10 kg
Vector quantity: a displacement of 10 m [N]

**2.**

| Time (s) | Position (cm [right]) |
|---|---|
| 0.0 | 0.0 |
| 1.0 | 1.0 |
| 2.0 | 2.0 |
| 3.0 | 3.0 |
| 4.0 | 4.0 |
| 5.0 | 5.0 |
| 6.0 | 6.0 |

**3.** **(a)** $\vec{v} = \frac{0\ \text{m [forward]} - 10\ \text{m [forward]}}{10\ \text{s} - 0\ \text{s}} = -1.0\ \text{m/s [forward] or } 1.0\ \text{m/s [backward]}$

**(b)** $\vec{v} = \frac{-20\ \text{m [right]} - 0\ \text{m [right]}}{10\ \text{min} - 0\ \text{min}} = -2.0\ \text{m/min [right]}$

**(c)** $\vec{v} = \dfrac{0 \text{ m [forward]} - (-25 \text{ m [forward]})}{15 \text{ s} - 0 \text{ s}} = 1.7 \text{ m/s [forward]}$

**4.** ***Given***

$\Delta t = 15.0 \text{ min}$

$\vec{v} = 30.0 \text{ m/s [W]}$

***Required***

displacement ( $\Delta\vec{d}$ )

***Analysis and Solution***

Use the equation $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$ and convert 15.0 min into seconds.

$$\begin{aligned}\Delta\vec{d} &= 30.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{W}] \times 15.0\ \cancel{\text{min}} \times \frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}} \\ &= 27\,000 \text{ m [W]} \\ &= 27.0 \text{ km [W]}\end{aligned}$$

***Paraphrase***

The vehicle's displacement is $27.0 \text{ km [W]}$.

**5.** ***Given***

$v = 5.0 \text{ km/h}$

$\Delta d = 3.50 \text{ km}$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Use the equation $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$.

$$\Delta d = v\Delta t$$

$$\begin{aligned}\Delta t &= \frac{\Delta d}{v} \\ &= \frac{3.50 \text{ km}}{5.0 \text{ km/h}} \\ &= 0.70\ \cancel{\text{h}} \times \frac{60 \text{ min}}{1\ \cancel{\text{h}}} \\ &= 42 \text{ min}\end{aligned}$$

***Paraphrase and Verify***

The cross-country skier will take 42 min. Check: $(0.70 \text{ h})(5.0 \text{ km/h}) = 3.5 \text{ km}$

**6.**

$$\begin{aligned}v_{\text{ave}} &= \frac{\Delta d}{\Delta t} \\ &= \frac{25.0 \text{ m} + 50.0 \text{ m}}{20.0 \text{ s}} \\ &= 3.75 \text{ m/s}\end{aligned}$$

$$\begin{aligned}\vec{v}_{\text{ave}} &= \frac{\Delta\vec{d}}{\Delta t} \\ &= \frac{-25.0 \text{ m [right]}}{20.0 \text{ s}} \\ &= -1.25 \text{ m/s [right] or } 1.25 \text{ m/s [left]}\end{aligned}$$

$\Delta\vec{d} = 25.0 \text{ m [right]} + (-50.0 \text{ m [right]})$
$= -25.0 \text{ m [right] or } 25.0 \text{ m [left]}$

**7.** A person standing still could have the same average velocity as someone running around a circular track if the runner starts and finishes at the same point, ensuring total displacement is zero. Average speed would be different since the stationary person will have no change in distance, while the runner will have covered a certain distance in the same amount of time.

**8.** If an object is in the air for 5.6 s, it reaches maximum height in half the time, or $\frac{5.6 \text{ s}}{2} = 2.8 \text{ s}$.

**9.** An object is in the air for twice the amount of time it takes to reach maximum height, or $2 \times 3.5 \text{ s} = 7.0 \text{ s}$, provided it lands at the same height from which it was launched.

**10.** The initial vertical velocity for an object dropped from rest is zero.

**Applications**

**11.** ***Given***

$v = 0.77 \text{ m/s}$

$\Delta d = 150 \text{ m}$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Use the equation $v = \frac{\Delta d}{\Delta t}$.

$$\Delta t = \frac{\Delta d}{v} = \frac{150 \text{ m}}{0.77 \text{ m/s}} = 1.9 \times 10^2 \text{ s}$$

***Paraphrase***

The diver takes $1.9 \times 10^2 \text{ s}$ to travel 150 m.

**12.** ***Given***

$\Delta\vec{d} = 42 \text{ km [W]}$

$\Delta t = 8.0 \text{ h}$

***Required***

average velocity ( $\vec{v}_{\text{ave}}$ )

***Analysis and Solution***

Use the equation $\vec{v}_{\text{ave}} = \frac{\Delta\vec{d}}{\Delta t}$.

$$\vec{v}_{\text{ave}} = \frac{42 \text{ km [W]}}{8.0 \text{ h}} = 5.25 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \text{ [W]} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} = 1.5 \text{ m/s [W]}$$

***Paraphrase***

Terry Fox's average velocity was 1.5 m/s [W].

**13.** The point of intersection on a position-time graph shows the time and location where two objects meet. The point of intersection on a velocity-time graph shows when two objects have the same velocity.

**14.** ***Given***

Consider north to be positive.

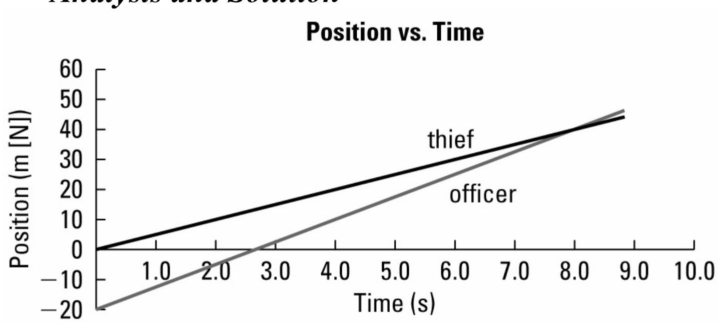
$\vec{v}_{\text{thief}} = 5.0 \text{ m/s [N]} = +5.0 \text{ m/s} \quad \vec{d}_{\text{thief}_1} = 0 \text{ m}$

$\vec{v}_{\text{officer}} = 7.5 \text{ m/s [N]} = +7.5 \text{ m/s} \quad \vec{d}_{\text{officer}_1} = 20 \text{ m [S]} = -20 \text{ m}$

***Required***

distance ( $\Delta d_{\text{officer}}$ )

***Analysis and Solution***




From the graph, the police officer catches up with the thief after about 8.0 s.

Equation for thief: $y_{\text{A}} = 5.0\Delta t$

Equation for officer: $y_{\text{B}} = 7.5\Delta t - 20$

At the point of intersection, the time is

$$\begin{aligned} y_{\text{A}} &= y_{\text{B}} \\ 5.0\Delta t &= 7.5\Delta t - 20 \\ 20 &= 2.5\Delta t \\ \Delta t &= 8.0 \text{ s} \end{aligned}$$

Displacement is:

$$\begin{aligned} \Delta\vec{d}_{\text{officer}} &= \vec{d}_{\text{officer}_2} - \vec{d}_{\text{officer}_1} \\ &= y_{\text{B}} - (-20 \text{ m}) \\ &= (+7.5 \text{ m/s})(8.0 \text{ s}) - 20 \text{ m} - (-20 \text{ m}) \\ &= +60 \text{ m} \\ &= 60 \text{ m [N]} \end{aligned}$$

***Paraphrase and Verify***

The police officer will run 60 m before catching the thief.

Check: Distance run in 8.0 s at 7.5 m/s is 60 m.

**15.** ***Given***

$v_{\text{i}} = 1200 \text{ m/s}$

$v_{\text{f}} = 0 \text{ m/s}$

$\Delta d = 1.0 \text{ cm} = 0.010 \text{ m}$

***Required***

magnitude of acceleration ($a$)

***Analysis and Solution***

The bullet comes to rest within the vest, so $v_{\text{f}} = 0$. Use the equation $v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$ .

$$v_f^2 = v_i^2 + 2a\Delta d$$

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

$$= \frac{0 - (1200 \text{ m/s})^2}{2(0.010 \text{ m})}$$

$$= -7.2 \times 10^7 \text{ m/s}^2$$

***Paraphrase***

The magnitude of the bullet's acceleration is $7.2 \times 10^7$ m/s$^2$.

**16.** ***Given***

$\vec{v} = 35$ km/h [forward]

$\Delta t = 30 \text{ min} = 0.50$ h

***Required***

distance ( $\Delta d$ )

***Analysis and Solution***

Determine the area under the graph after 0.50 h.

$$\Delta\vec{d} = \left(35 \ \frac{\text{km}}{\cancel{\text{h}}} \ [\text{forward}]\right)(0.50 \ \cancel{\text{h}})$$

$$= 18 \text{ km [forward]}$$

***Paraphrase***

The elk will travel 18 km.

**17.** ***Given***

$\Delta t = 2.50$ min

$v = 829$ km/h

***Required***

distance ( $\Delta d$ )

***Analysis and Solution***

Use the equation $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$.

$$\Delta d = v\Delta t$$

$$= 829 \ \frac{\text{km}}{\cancel{\text{h}}} \times 2.50 \ \cancel{\text{min}} \times \frac{1 \ \cancel{\text{h}}}{60 \ \cancel{\text{min}}}$$

$$= 34.5 \text{ km}$$

***Paraphrase***

The speedboat will travel 34.5 km.

**18.** ***Given***

$\Delta d = 300$ km

$\Delta t_{\text{stagecoach}} = 24$ h

$\Delta t_{\text{airliner}} = 20$ min

***Required***

speed factor $\left(\dfrac{v_{\text{airliner}}}{v_{\text{stagecoach}}}\right)$

***Analysis and Solution***

Determine the average speed of the stagecoach and airliner and then compare the two speeds.

Stagecoach:

$$v = \frac{\Delta d}{\Delta t}$$
$$= \frac{300 \text{ km}}{24 \text{ h}}$$
$$= 12.5 \text{ km/h}$$

Airliner:

$$v = \frac{\Delta d}{\Delta t}$$
$$= \frac{300 \text{ km}}{20 \not{\text{min}} \times \frac{1 \text{ h}}{60 \not{\text{min}}}}$$
$$= 900 \text{ km/h}$$
$$\frac{900 \text{ km/h}}{12.5 \text{ km/h}} = 72$$

***Paraphrase***

The airliner is 72 times faster than the stagecoach.

**19.** ***Given***

$d_{\text{i}} = 22\,647 \text{ km}$

$d_{\text{f}} = 23\,209 \text{ km}$

$\Delta t = 5.0 \text{ h}$

***Required***

average speed ( $v_{\text{ave}}$ )

***Analysis and Solution***

Determine the distance by subtracting the two odometer readings. Use the equation $v = \frac{\Delta d}{\Delta t}$.

$$v_{\text{ave}} = \frac{\Delta d}{\Delta t}$$
$$= \frac{23\,209 \text{ km} - 22\,647 \text{ km}}{5.0 \text{ h}}$$
$$= 1.1 \times 10^2 \text{ km/h}$$
$$= 1.1 \times 10^2 \frac{\not{\text{km}}}{\not{\text{h}}} \times \frac{1000 \text{ m}}{1 \not{\text{km}}} \times \frac{1 \not{\text{h}}}{3600 \text{ s}}$$
$$= 31 \text{ m/s}$$

***Paraphrase***

The car's average speed was $1.1 \times 10^2$ km/h, which equals 31 m/s.

**20. *Given***

Choose downhill to be positive.

$\Delta\vec{d} = 90.0 \text{ m [downhill]} = +90.0 \text{ m}$

$\Delta t = 8.00 \text{ s}$

$\vec{v}_\text{i} = 0 \text{ m/s}$

***Required***

acceleration ( $\vec{a}$ )

final velocity ( $\vec{v}_\text{f}$ )

***Analysis and Solution***

Find final velocity using the equation $\Delta\vec{d} = \frac{1}{2}(\vec{v}_\text{i} + \vec{v}_\text{f})\Delta t$, where $\vec{v}_\text{i} = 0$.

$$\begin{aligned}\vec{v}_\text{f} &= \frac{2\Delta\vec{d}}{\Delta t} - \vec{v}_\text{i}\\ &= \frac{2(+90.0 \text{ m})}{8.00 \text{ s}} - 0\\ &= +22.5 \text{ m/s}\\ &= 22.5 \text{ m/s [downhill]}\end{aligned}$$

Find acceleration using the equation $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$.

$$\begin{aligned}\vec{a} &= \frac{+22.5 \text{ m/s} - 0 \text{ m/s}}{8.00 \text{ s}}\\ &= +2.81 \text{ m/s}^2\\ &= 2.81 \text{ m/s}^2 \text{ [downhill]}\end{aligned}$$

***Paraphrase***

The motorcycle's velocity at 8.00 s is $22.5 \text{ m/s [downhill]}$. Its acceleration is $2.81 \text{ m/s}^2 \text{ [downhill]}$.

**21. *Given***

Choose north to be positive.

$\Delta t = 4.0 \text{ s}$

$\Delta\vec{d} = 30.0 \text{ m [N]} = +30.0 \text{ m}$

$\vec{v}_\text{i} = 5.0 \text{ m/s [N]} = +5.0 \text{ m/s}$

***Required***

acceleration ( $\vec{a}$ )

final velocity ( $\vec{v}_\text{f}$ )

***Analysis and Solution***

First determine the acceleration of the cyclist using the equation $\Delta\vec{d} = \vec{v}_\text{i}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$.

$$\vec{a} = \frac{2\left(\Delta\vec{d} - \vec{v}_i\Delta t\right)}{(\Delta t)^2}$$

$$= \frac{2\left[+30.0 \text{ m} - \left(+5.0 \ \frac{\text{m}}{\cancel{\text{s}}}\right)\left(4.0 \ \cancel{\text{s}}\right)\right]}{(4.0 \text{ s})^2}$$

$$= +1.25 \text{ m/s}^2$$

$$= 1.25 \text{ m/s}^2 \text{ [N]}$$

Calculate final velocity using $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

$$\vec{v}_f = \vec{v}_i + \vec{a}\Delta t$$

$$= +5.0 \ \frac{\text{m}}{\text{s}} + \left(+1.25 \ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)\left(4.0 \ \cancel{\text{s}}\right)$$

$$= +10 \text{ m/s}$$

$$= 10 \text{ m/s [N]}$$

***Paraphrase***

At the other end of the bridge, the cyclist's acceleration was $1.3 \text{ m/s}^2$ [N] and her final velocity was 10 m/s [N].

**22.** ***Given***

Consider south to be positive.

$\vec{v}_i = 10.0 \text{ m/s [S]} = +10.0 \text{ m/s}$

$\Delta\vec{d} = 720 \text{ m [S]} = +720 \text{ m}$

$\Delta t = 45.0 \text{ s}$

***Required***

average velocity ($\vec{v}_{ave}$)

final velocity ($\vec{v}_f$)

acceleration ($\vec{a}$)

***Analysis and Solution***

Use $\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$ to find average velocity.

$$\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$$

$$= \frac{+720 \text{ m}}{45.0 \text{ s}}$$

$$= +16.0 \text{ m/s}$$

$$= 16.0 \text{ m/s [S]}$$

Use $\Delta\vec{v}_{ave} = \frac{(\vec{v}_f + \vec{v}_i)}{2}$ to find final velocity.

$$\vec{v}_f = 2\Delta\vec{v}_{ave} - \vec{v}_i$$

$$= 2(+16.0 \text{ m/s}) - (+10.0 \text{ m/s})$$

$$= +22.0 \text{ m/s}$$

$$= 22.0 \text{ m/s [S]}$$

Use $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ to find acceleration.

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \\ &= \frac{+22.0 \text{ m/s} - (+10.0 \text{ m/s})}{45.0 \text{ s}} \\ &= +0.267 \text{ m/s}^2 \\ &= 0.267 \text{ m/s}^2 \text{ [S]}\end{aligned}$$

***Paraphrase***

The object has an average velocity of 16.0 m/s [S], a final velocity of 22.0 m/s [S], and an acceleration of $0.267 \text{ m/s}^2$ [S].

**23. *Given***

$$\Delta t_1 + \Delta t_2 = 65 \text{ s}$$

$$\Delta d_1 = \frac{2.88 \text{ km}}{2} = 1.44 \text{ km} = 1440 \text{ m}$$

$$\Delta d_2 = 1440 \text{ m}$$

$$v_1 = 60 \text{ m/s}$$

***Required***

speed ($v_2$)

***Analysis and Solution***

Determine the amount of time the car takes to complete the first half-lap using the equation $v = \frac{\Delta d}{\Delta t}$.

$$\begin{aligned}\Delta t_1 &= \frac{\Delta d_1}{v_1} \\ &= \frac{1440 \text{ m}}{60 \text{ m/s}} \\ &= 24 \text{ s}\end{aligned}$$

Determine the speed for the second half-lap by dividing the distance by the remaining time.

$$\begin{aligned}v_2 &= \frac{\Delta d_2}{\Delta t} \\ &= \frac{1440 \text{ m}}{65 \text{ s} - 24 \text{ s}} \\ &= 35 \text{ m/s}\end{aligned}$$

***Paraphrase***

The car's speed for the second half-lap must be 35 m/s.

**24. *Given***

$$v_{car} = 19.4 \text{ m/s}$$

$$v_{police_i} = 0 \text{ m/s}$$

$$a_{police} = 3.2 \text{ m/s}^2$$

***Required***
time ( $\Delta t$ )
final speed ( $v_{\text{police}_\text{f}}$ )

***Analysis and Solution***
Use the given data to write motion equations for the cars.
equation for car: $y_\text{A} = 19.4\Delta t$

equation for police car: $y_\text{B} = \frac{1}{2}3.2\Delta t^2$

$$y_\text{B} = 1.6\Delta t^2$$

At the point of intersection, time is

$$\begin{aligned} y_\text{A} &= y_\text{B} \\ 19.4\Delta t &= 1.6\Delta t^2 \\ \Delta t &= 0 \text{ s or } 12.1 \text{ s} \end{aligned}$$

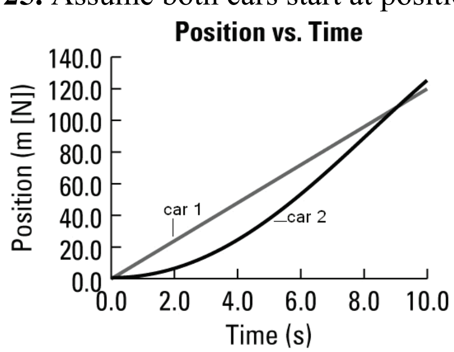
Take the second solution: 12.1 s

Use the equation $a = \frac{v_\text{f} - v_\text{i}}{\Delta t}$ to find the final speed of the police car.

$$\begin{aligned} v_\text{f} &= v_\text{i} + a\Delta t \\ &= 0 + \left(3.2 \ \frac{\text{m}}{\text{s}^{\not 2}}\right)(12.1 \ \not\text{s}) \\ &= 39 \text{ m/s} \end{aligned}$$

***Paraphrase***
It takes the police car 12 s to catch the motorist. The police car's final speed is 39 m/s. The scenario is likely to happen on a straight part of a highway, and less likely in a high-speed chase within city limits.

**25.** Assume both cars start at position 0.0 m [N] and time 0.0 s.




The cars pass one another at time $\Delta t$ where they have travelled the same displacement. Determine the displacement by calculating the area under the given velocity-time graph for each car.

For car 1 at $\Delta t$, $\Delta\vec{d}_1 = \left(12.0 \ \frac{\text{m}}{\text{s}} \text{ [N]}\right)\Delta t$

For car 2 at $\Delta t$, $\Delta\vec{d}_2 = \frac{1}{2}(6.0 \text{ s})\left(18.0 \ \frac{\text{m}}{\text{s}} \text{ [N]}\right) + (18.0 \ \frac{\text{m}}{\text{s}} \text{ [N]})(\Delta t - 6.0 \text{ s})$

Since $\Delta\vec{d}_1 = \Delta\vec{d}_2$, it follows that

$$(12.0 \text{ m/s})\Delta t = \frac{1}{2}(6.0 \text{ s})(18.0 \text{ m/s}) + (18.0 \text{ m/s})(\Delta t - 6.0 \text{ s})$$
$$(12.0 \text{ m/s})\Delta t = 54 \text{ m} + (18.0 \text{ m/s})\Delta t - 108 \text{ m}$$
$$(6.0 \text{ m/s})\Delta t = 54 \text{ m}$$
$$\Delta t = 9.0 \text{ s}$$

The two cars pass one another at 9.0 s.

$$\begin{aligned}\Delta \vec{d}_1 &= (12.0 \text{ m/s [N]})\Delta t \\ &= 12.0 \text{ m/s [N]} \times 9.0 \text{ s} \\ &= 108 \text{ m [N]} \\ &= 1.1 \times 10^2 \text{ m [N]}\end{aligned}$$

The cars pass one another at position $1.1 \times 10^2$ m [N].

**26.** Choose right to be positive.

$$\begin{aligned}\Delta \vec{d} &= \left(-4.0 \ \frac{\text{km}}{\cancel{\text{h}}} \text{ [right]}\right)\left(5.0 \ \cancel{\text{h}}\right) \\ &= -20 \text{ km [right]} \\ &= 20 \text{ km [left]}\end{aligned}$$

$\vec{a} = 0$ m/s$^2$ because the velocity-time graph is a horizontal line.

**27.** ***Given***

Consider forward to be positive.

$$\vec{a} = 9.85 \text{ m/s}^2 \text{ [forward]} = +9.85 \text{ m/s}^2$$
$$\vec{v}_\text{i} = 0 \text{ m/s}$$
$$\Delta \vec{d} = 402 \text{ m [forward]} = +402 \text{ m}$$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Use the equation $\Delta \vec{d} = \vec{v}_\text{i}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_\text{i} = 0$. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta d = v_\text{i}\Delta t + \frac{1}{2}a(\Delta t)^2$$
$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(402 \text{ m})}{9.85 \text{ m/s}^2}} \\ &= 9.03 \text{ s}\end{aligned}$$

***Paraphrase***

The fire truck takes 9.03 s to travel 402 m.

**28.** ***Given***

Consider forward to be positive.

$$\vec{v}_\text{i} = 25.0 \text{ m/s [forward]} = +25.0 \text{ m/s}$$
$$\vec{a} = -3.75 \text{ m/s}^2 \text{ [forward]} = -3.75 \text{ m/s}^2$$
$$\Delta \vec{d} = 95.0 \text{ m [forward]} = +95.0 \text{ m}$$

***Required***
reaction time ( $\Delta t$ )
***Analysis and Solution***
Find the displacement during braking (less than 95.0 m [forward]) using the equation $v_f{}^2 = v_i{}^2 + 2a\Delta d$, where $v_f = 0$.
Reaction time is time for the motion phase before braking begins.
The distance travelled while braking is

$$\begin{aligned} v_f{}^2 &= v_i{}^2 + 2a\Delta d \\ \Delta d &= \frac{v_f{}^2 - v_i{}^2}{2a} \\ &= \frac{0 - (25.0 \text{ m/s})^2}{2(-3.75 \text{ m/s}^2)} \\ &= 83.33 \text{ m} \end{aligned}$$

The driver must react while travelling a maximum distance of
95.0 m – 83.33 m = 11.67 m.
Maximum reaction time is:

$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ \Delta t &= \frac{\Delta d}{v} \\ &= \frac{11.67 \text{ m}}{25.0 \frac{\text{m}}{\text{s}}} \\ &= 0.467 \text{ s} \end{aligned}$$

***Paraphrase***
The driver has 0.467 s to react in order to avoid hitting the obstacle.

**29.** ***Given***

$\Delta d = 1.10 \text{ km} = 1100 \text{ m}$
$v_i = 110.0 \text{ km/h}$
$v_f = 60.0 \text{ km/h}$

***Required***
magnitude of acceleration ($a$)
***Analysis and Solution***
Convert km/h to m/s.

$$60.0 \ \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 16.67 \text{ m/s}$$

$$110 \ \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 30.56 \text{ m/s}$$

Use the equation $v_f{}^2 = v_i{}^2 + 2a\Delta d$ to calculate the magnitude of acceleration.

$$a = \frac{v_f^2 - v_i^2}{2\Delta d}$$
$$= \frac{(16.67 \text{ m/s})^2 - (30.56 \text{ m/s})^2}{2(1100 \text{ m})}$$
$$= -0.298 \text{ m/s}^2$$

***Paraphrase***

The magnitude of the vehicle's acceleration is $0.298 \text{ m/s}^2$.

**30.** ***Given***

$\Delta\vec{d} = 3.2 \text{ km [E]}$

$t_i = 4:45 \text{ p.m.}$

$t_f = 4:53 \text{ p.m.}$

$\Delta t = 8.0 \text{ min}$

***Required***

average velocity ($\vec{v}_{ave}$)

***Analysis and Solution***

Convert $\Delta t$ to hours.

$$\Delta t = 8.0 \cancel{\text{min}} \times \frac{1 \text{ h}}{60 \cancel{\text{min}}} = 0.133 \text{ h}$$

Find $\vec{v}_{ave}$ using $\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$.

$$\vec{v}_{ave} = \frac{3.2 \text{ km [E]}}{0.133 \text{ h}}$$
$$= 24 \text{ km/h [E]}$$

***Paraphrase***

The CTrain's average velocity is 24 km/h [E].

**31.** The truck

- accelerates at 5.0 m/s$^2$ [forward] for 3.0 s, achieving a velocity of 15.0 m/s [forward]
- travels with a constant velocity of 15.0 m/s [forward] for 2.0 s
- accelerates at −3.0 m/s$^2$ [forward] for 1.0 s
- accelerates at 3.0 m/s$^2$ [forward] for 1.0 s
- travels with a constant velocity of 15.0 m/s [forward] for 1.0 s
- accelerates at −5.0 m/s$^2$ [forward] for 1.0 s
- comes to a complete stop in 1.0 s with an acceleration of −10.0 m/s$^2$ [forward]

The truck is at rest at 0.0 s and at 10.0 s.

The truck travels with constant velocity from 3.0 s to 5.0 s and from 7.0 s to 8.0 s.

The greatest magnitude of acceleration is from 9.0 s to 10.0 s.

The greatest positive acceleration is from 0.0 s to 3.0 s.

**32.** ***Given***

Consider west to be positive.

$\vec{v}_i = 17.5 \text{ m/s [W]}$

$\vec{v}_f = 45.2 \text{ m/s [W]}$

$\Delta t = 2.47 \text{ s}$

***Required***

acceleration ( $\vec{a}$ )

***Analysis and Solution***

Use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

$$\begin{aligned}\vec{a} &= \frac{+45.2 \text{ m/s} - (+17.5 \text{ m/s})}{2.47 \text{ s}} \\ &= +11.2 \text{ m/s}^2 \\ &= 11.2 \text{ m/s}^2 \text{ [W]}\end{aligned}$$

***Paraphrase and Verify***

The racecar's acceleration is $11.2 \text{ m/s}^2$ [W].

Check:

$$\begin{aligned}v_f &= v_i + a\Delta t \\ &= 17.5 \text{ m/s} + (11.2 \text{ m/s}^2)(2.47\text{s}) \\ &= 45.2 \text{ m/s}\end{aligned}$$

**33.** ***Given***

Consider west to be positive.

$\vec{v}_i = 80$ km/h [W] $= +80$ km/h

$\vec{v}_f = 0$ m/s

$\Delta\vec{d} = 76.0$ m [W] $= +76.0$ m

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Convert km/h to m/s.

$$80 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} = 22.2 \text{ m/s}$$

Use the equation $\Delta\vec{d} = \frac{1}{2}(\vec{v}_f + \vec{v}_i)\Delta t$. Use the scalar form of the equation because you are dividing by vectors.

$$\begin{aligned}\Delta t &= \frac{2\Delta d}{v_f + v_i} \\ &= \frac{2\left(76.0 \cancel{\text{m}}\right)}{22.2 \frac{\cancel{\text{m}}}{\text{s}}} \\ &= 6.8 \text{ s}\end{aligned}$$

***Paraphrase***

It will take the vehicle 6.8 s to come to a complete stop.

**34.** ***Given***

Choose up to be positive.

$\vec{v}_i = 0$ m/s

$\vec{a} = 39.24 \text{ m/s}^2$ [up] $= +39.24 \text{ m/s}^2$

$\Delta\vec{d} = 27.0$ m [up] $= +27.0$ m

***Required***
time ( $\Delta t$ )
***Analysis and Solution***
Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta d = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$

$$= \sqrt{\frac{2(27.0\ \cancel{\text{m}})}{39.24\ \frac{\cancel{\text{m}}}{\text{s}^2}}}$$

$$= 1.17\ \text{s}$$

***Paraphrase***
The Slingshot propels riders up to a height of 27.0 m in 1.17 s.

**35.** ***Given***
Choose down to be positive.

$\vec{v}_i = 0$ m/s

$\vec{a} = 9.81\ \text{m/s}^2$ [down] $= +9.81\ \text{m/s}^2$

$\vec{v}_f = 55$ km/h [down] $= +55$ km/h

***Required***
height ( $\Delta d$ )
***Analysis and Solution***
Convert km/h to m/s.

$$55\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} = 15.3\ \text{m/s}$$

Since the diver started from rest, initial vertical velocity is zero.
To find the height, use the equation $v_f^2 = v_i^2 + 2a\Delta d$.

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

$$= \frac{(15.3\ \text{m/s})^2 - 0}{2\left(9.81\ \text{m/s}^2\right)}$$

$$= 12\ \text{m}$$

***Paraphrase***
The diver started from a height of 12 m.

**36.** ***Given***
Choose down to be positive.

$\vec{v}_i = 0$ m/s

$\vec{v}_f = 13.5$ m/s [down] $= +13.5$ m/s

$\vec{a} = 9.81\ \text{m/s}^2$ [down] $= +9.81\ \text{m/s}^2$

***Required***
height ( $\Delta d$ )

***Analysis and Solution***

Use the equation $v_f^2 = v_i^2 + 2a\Delta d$, where $v_i$ = 0.

$$\Delta d = \frac{v_f^2 - v_i^2}{2a}$$
$$= \frac{(13.5 \text{ m/s})^2 - 0}{2(9.81 \text{ m/s}^2)}$$
$$= 9.29 \text{ m}$$

***Paraphrase***

The greatest height from which the performer can fall is 9.29 m.

**37.** ***Given***

Choose down to be positive.

$\Delta\vec{d} = 8.52 \text{ m [down]} = +8.52 \text{ m}$

$\vec{v}_i = 0 \text{ m/s}$

$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$

***Required***

time ( $\Delta t$ )

***Analysis and Solution***

Since the bolt falls from rest, initial vertical velocity is zero. Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta d = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$$
$$\Delta t = \sqrt{\frac{2\Delta d}{a}}$$
$$= \sqrt{\frac{2(8.52 \cancel{\text{m}})}{9.81 \frac{\cancel{\text{m}}}{\text{s}^2}}}$$
$$= 1.32 \text{ s}$$

***Paraphrase***

The bolt takes 1.32 s to fall to the ground.

**38.** ***Given***

Choose down to be positive.

$\Delta t = 1.76 \text{ s}$

$\vec{v}_i = 0 \text{ m/s}$

$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$

***Required***

height ( $\Delta d$ )

final speed ( $v_f$ )

***Analysis and Solution***

Since the weathervane falls from rest, initial velocity is zero. Use the equation $\Delta d = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$ to find the height.

$$\Delta d = 0 + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.76\ \text{s})^2$$
$$= 15.2\ \text{m}$$

Calculate final speed using the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

$$\vec{v}_f = \vec{v}_i + \vec{a}\Delta t$$
$$= 0\ \text{m/s} + \left(+9.81\ \frac{\text{m}}{\text{s}^{\not 2}}\right)(1.76\ \not{\text{s}})$$
$$= +17.3\ \text{m/s}$$
$$= 17.3\ \text{m/s [down]}$$

***Paraphrase***

The weathervane fell from a height of 15.2 m and was travelling at 17.3 m/s just before impact.

**39.** ***Given***

Choose down to be positive.

$$\Delta\vec{d} = 24.91\ \text{m [down]} - 5.0\ \text{m [down]} = 19.91\ \text{m [down]} = +19.91\ \text{m}$$
$$\vec{v}_i = 0\ \text{m/s}$$
$$\vec{a} = 9.81\ \text{m/s}^2\ \text{[down]} = +9.81\ \text{m/s}^2$$

***Required***

final speed ( $v_f$ )

time ( $\Delta t$ )

***Analysis and Solution***

Use the equation $v_f^2 = v_i^2 + 2a\Delta d$ to find final speed.

$$v_f = \sqrt{v_i^2 + 2a\Delta d}$$
$$= \sqrt{0 + 2\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(19.91\ \text{m})}$$
$$= 19.76\ \text{m/s}$$
$$= 20\ \text{m/s}$$

Use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ to find the time interval. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta t = \frac{v_f - v_i}{a}$$
$$= \frac{19.76\ \text{m/s} - 0}{9.81\ \text{m/s}^2}$$
$$= 2.0\ \text{s}$$

***Paraphrase***

The Lego piece will be travelling at a speed of 20 m/s when it reaches 5.0 m above the ground and will take 2.0 s to get there.

**Extension**

**40.** A design engineer must consider the initial and final speeds of the cars leaving the expressway, the initial and final speeds of the cars entering the expressway, the shape of the land (downward slope, upward slope, or curve), stopping and following distances, and the maximum safe acceleration of the vehicles travelling through the weave zone.