Pearson Physics Level 20
Unit I Kinematics: Chapter 1
Solutions

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Skills Practice

1. scale: 26.0 m : 3.10 cm (north/south side of rink)
scale: 60.0 m : 7.00 cm (east/west side of rink)

(a) position from north side of rink:
player 1: 0.50 cm = 4.2 m [S]
player 2: 0.75 cm = 6.3 m [S]
player 3: 2.45 cm = 20.5 m [S]
player 4: 2.60 cm = 21.8 m [S]
player 5: 2.20 cm = 18.5 m [S]

position from south side of rink:
player 1: 2.50 cm = 21.0 m [N]
player 2: 2.30 cm = 19.3 m [N]
player 3: 0.55 cm = 4.6 m [N]
player 4: 0.40 cm = 3.4 m [N]
player 5: 0.90 cm = 7.5 m [N]

(b) position from east side of rink:
player 1: 5.00 cm = 42.9 m [W]
player 2: 3.70 cm = 31.7 m [W]
player 3: 2.15 cm = 18.4 m [W]
player 4: 3.80 cm = 32.6 m [W]
player 5: 6.85 cm = 58.7 m [W]

position from west side of rink:
player 1: 2.00 cm = 17.1 m [E]
player 2: 3.30 cm = 28.3 m [E]
player 3: 4.85 cm = 41.6 m [E]
player 4: 3.20 cm = 27.4 m [E]
player 5: 0.20 cm = 1.7 m [E]

(c), (d) 2.0 cm = 16.8 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***

$\vec{d}_1 = 0.750 \text{ m [right]}$

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

Required
displacement ($\Delta\vec{d}$)
Analysis and Solution
Use vector addition but change signs since directions are opposite.

$$\begin{aligned}\Delta\vec{d} &= 0.750 \text{ m [right]} + 3.50 \text{ m [left]}\\ &= -0.750 \text{ m [left]} + 3.50 \text{ m [left]}\\ &= 2.75 \text{ m [left]}\end{aligned}$$

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

3. ***Given***
$\vec{d}_1 = 0.85$ m [back]
$\vec{d}_2 = -0.85$ m [forth]
Required
distance (Δd)
displacement ($\Delta\vec{d}$)
Analysis and Solution
The bricklayer's hand moves 1.70 m back and forth four times, so $\Delta d = 4(d_1 + d_2)$.

$$\begin{aligned}\Delta d &= 4(0.85 \text{ m} + 0.85 \text{ m})\\ &= 6.80 \text{ m}\end{aligned}$$

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 path taken to travel between two points. Displacement is the change in position: how far and in which direction an object has travelled from its original starting or reference point. Distance is a scalar quantity, represented by Δd and measured in metres. Displacement is a vector quantity, represented by $\Delta\vec{d}$ and also measured in metres.

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***

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

$\vec{d}_i = 5.0$ km [E]

Required

final position ($\vec{d}_f$)

Analysis and Solution

Use the equation $\Delta\vec{d} = \vec{d}_f - \vec{d}_i$.

$\Delta\vec{d} = \vec{d}_f - \vec{d}_i$

$\vec{d}_f = \Delta\vec{d} + \vec{d}_i$

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

Paraphrase

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

6. ***Given***

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

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

Required

distance (Δd)

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) A ticker tape at rest has a single dot (really lots of repeated dots). The slope of the position-time graph is zero.

(b) A position-time graph for an object travelling at a constant velocity can either be a straight line with a positive slope, a straight line with a negative slope, or a horizontal line 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 would be positive with the hole at the origin if the slope was positive and the ball started from the left: –5.0 m from the origin. The graph would be the mirror image in the *x*-axis of the graph in Figure 1.15(b).

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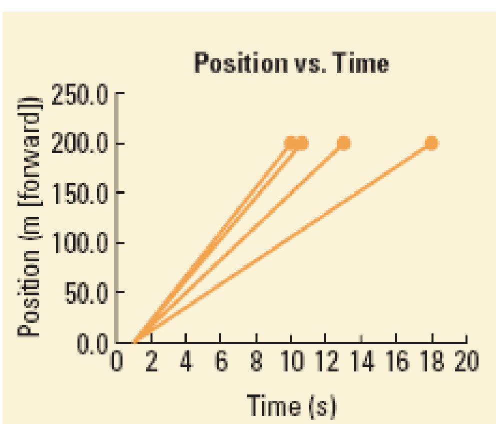
Example 1.2 Practice Problems

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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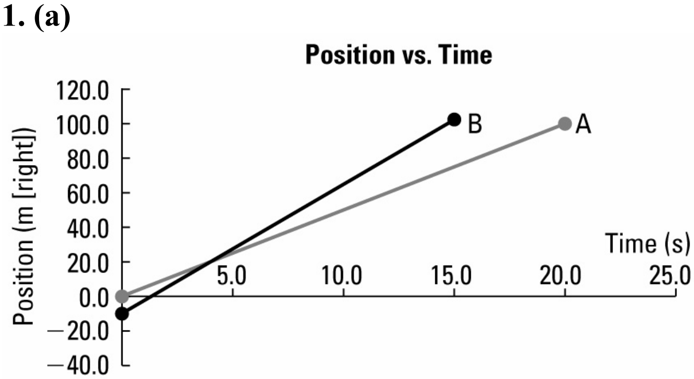
Concept Check

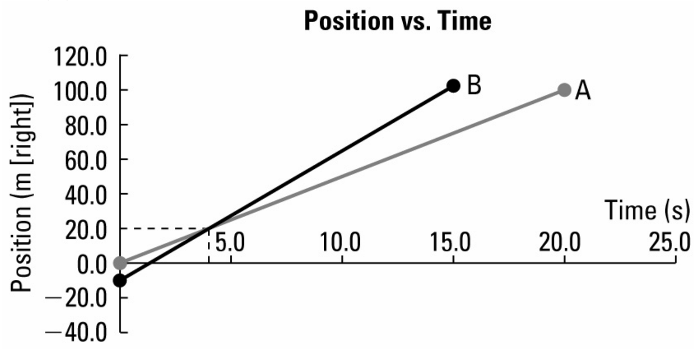
The graphs of two objects approaching each other would consist of two converging lines.

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.

$\Delta\vec{d}_A = 100 \text{ m [right]} = +100 \text{ m}$ $\qquad \Delta t_A = 20.0 \text{ s}$

$\Delta\vec{d}_B = 112.5 \text{ m [right]} = +112.5 \text{ m}$ $\qquad \Delta t_B = 15.0 \text{ s}$

Required

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

Analysis and Solution

Even though B starts 10.0 m to the left of A, B's total displacement is still 112.5 m [right].

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

$$\begin{aligned}\vec{v}_A &= \frac{\Delta\vec{d}_A}{\Delta t_A} \\ &= \frac{+100 \text{ m}}{20.0 \text{ s}} \\ &= +5.00 \text{ m/s} \\ &= 5.00 \text{ m/s [right]}\end{aligned}$$

$$\begin{aligned}\vec{v}_B &= \frac{\Delta\vec{d}_B}{\Delta t_B} \\ &= \frac{+112.5 \text{ m}}{15.0 \text{ s}} \\ &= +7.50 \text{ m/s} \\ &= 7.50 \text{ m/s [right]}\end{aligned}$$

Paraphrase
The velocity of rollerblader A is 5.00 m/s [right] and the velocity of rollerblader B is 7.50 m/s [right].

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1.2 Check and Reflect

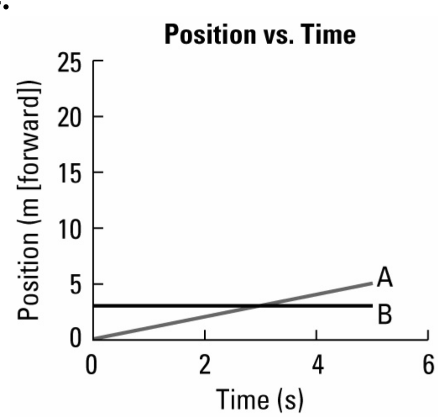
Knowledge

1. The quantities of motion that remain the same over equal time intervals 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).

2. For objects undergoing uniform motion, displacement, velocity, and acceleration remain constant. Position changes, but the change in position (the displacement) is constant over equal 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.



5. ***Given***

$\vec{d}_1 = 16$ km [E]

$\vec{d}_2 = 23$ km [W]

Required

final position ($\vec{d}_f$)

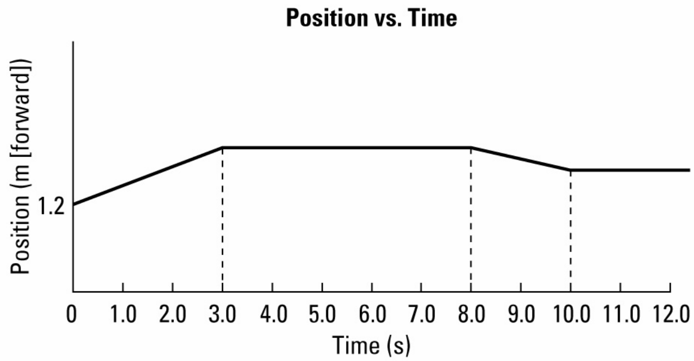
Analysis and Solution

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

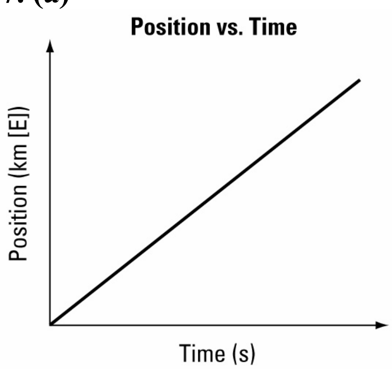
Paraphrase

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

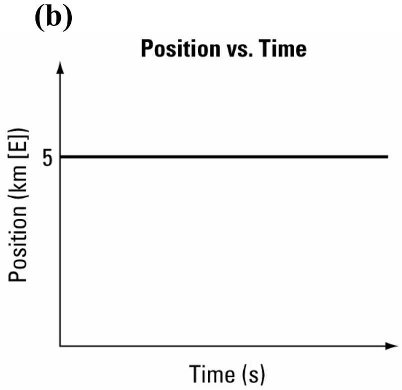
6.


Position vs. Time
Position (m [forward])
1.2
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
Time (s)

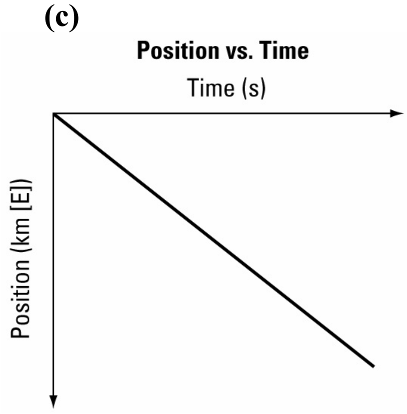
7. (a)


Position vs. Time
Position (km [E])
Time (s)

(b)


Position vs. Time
Position (km [E])
5
Time (s)

(c)


Position vs. Time
Time (s)
Position (km [E])

Applications

8. ***Given***

$\vec{v}_{\text{A}} = 5.0$ m/s [right]

$\vec{v}_{\text{B}} = 4.5$ m/s [right]

Required

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

Analysis and Solution

Determine the displacement of both children.

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

Equation for child B: $y_{\text{B}} = 4.5\Delta t$

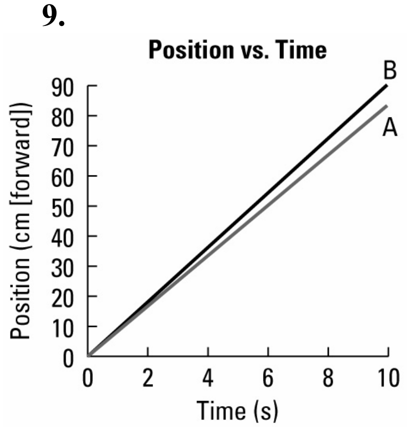
Find the difference of the results. Since Child A pedals faster, Child A should be farther away from the initial starting position.

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

Paraphrase and Verify

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

9.



The graph for insect B has the steeper slope, so insect B moves faster.

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***

$\vec{v}_m = -2.4$ km/h (toward you, so negative)

$\vec{v}_y = 2.0$ m/s

$d_{m_1} = 35.0$ m

$d_{y_1} = 0$ m

Required

time (Δt)

position (d_{m_2}, d_{y_2})

Analysis and Solution
Using graphical analysis will help you to visualize the point of intersection.
Convert km/h to m/s.

$$d_y = \vec{v}_y \Delta t$$
$$= (2.0 \text{ m/s})\Delta t$$
$$d_m = \vec{v}_m \Delta t + 35.0 \text{ m}$$
$$= \left(-2.4 \ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \ \cancel{\text{km}}} \times \frac{1 \ \cancel{\text{h}}}{3600 \text{ s}}\right)\Delta t + 35.0 \text{ m}$$
$$= (-0.667 \text{ m/s})\Delta t + 35.0 \text{ m}$$

Create equations for the two motions:

$$\Delta d_{y_1} = \Delta d_{m_1}$$
$$(2.0 \text{ m/s})\Delta t = (-0.667 \text{ m/s})\Delta t + 35.0 \text{ m}$$
$$(2.667 \text{ m/s})\Delta t = 35.0 \text{ m}$$
$$\Delta t = 13.1 \text{ s}$$
$$\Delta d_{y_1} = \left(2.0 \ \frac{\text{m}}{\cancel{\text{s}}}\right)(13.1 \ \cancel{\text{s}})$$
$$= 26 \text{ m}$$

Paraphrase and Verify
The mosquito will hit you at 13 s, when you have travelled 26 m toward the mosquito. Check: Mosquito travels $0.667 \text{ m/s} \times 13.1 \text{ s} = 8.8 \text{ m}$ in 13 s; $8.8 \text{ m} + 26.2 \text{ m} = 35 \text{ m}$, 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 (Δt)
displacement ($\Delta \vec{d}$)

Analysis and Solution
Equation for you: $y_\text{A} = (2.25 \text{ m/s [N]}) \ \Delta t$
Equation for friend: $y_\text{B} = (2.0 \text{ m/s [N]}) \ \Delta t + 5.0 \text{ m [N]}$
At intersection, $y_\text{A} = y_\text{B} = \vec{d}_\text{f}$

$$(2.25 \text{ m/s [N]}) \ \Delta t = (2.0 \text{ m/s [N]})\Delta t + 5.0 \text{ m [N]}$$
$$(0.25 \text{ m/s [N]}) \ \Delta t = 5.0 \text{ m [N]}$$
$$\Delta t = 20 \text{ s}$$
$$y_\text{A} = (2.25 \text{ m/s [N]})(20 \text{ s})$$
$$= 45 \text{ m [N]}$$

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

Check:

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

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

13. ***Given***

$\vec{v}_A = 35 \text{ km/h [W]}$

$\vec{p}_A = 300 \text{ m [E]}$

$\vec{v}_B = 40 \text{ km/h [E]}$

Required

times for:

- vehicles to pass each other
- vehicle A to pass traffic light
- vehicle B to pass traffic light

Analysis and Solution

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

$$= 9.7 \text{ m/s [W]}$$

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

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

Equation for vehicle A: $y_A = 9.7\Delta t - 300$

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

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

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

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

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 $y_B = 0$.

$$9.7\Delta t - 300 = -11.1\Delta t + 150$$

$$20.8\Delta t = 450$$

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

$$9.7\Delta t - 300 = 0$$

$$9.7\Delta t = 300$$

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

$$-11.1\Delta t + 150 = 0$$

$$11.1\Delta t = 150$$

$$\Delta t = 14 \text{ s}$$

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 is equal to velocity.
(b) The slope of a velocity-time graph is equal to 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—increasing in this case.

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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 an object slowing down would consist of a series of dots that get closer and closer together.

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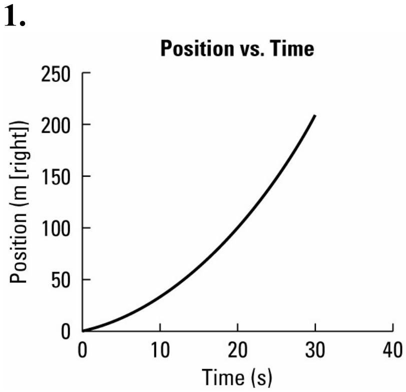
Example 1.5 Practice Problems

1.



2. Acceleration is the slope of the graph.

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

3. $\Delta\vec{d}$ = area under graph

$$\begin{aligned}&= \frac{1}{2}\left(-20 \frac{\text{m}}{\cancel{\text{s}}} \text{ [E]}\right)\left(10 \cancel{\text{s}}\right)\\ &= -100 \text{ m [E] or } 100 \text{ m [W]}\end{aligned}$$

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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.
(c) If the slopes of the tangents along the curve increase, then the object is speeding up. If the slopes of the tangents along the curve decrease (approach zero), then the object is slowing down.

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1.3 Check and Reflect

Applications

1. (a) $\vec{a} = \dfrac{2.80 \text{ m/s [forward]} - 0}{0.50 \text{ s} - 0} = 5.6 \text{ m/s}^2 \text{ [forward]}$

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

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

(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

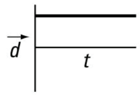
Extensions

4.

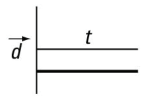
Time (s)	**Velocity (m/s [forward])**
0.0	1
2.0	4
4.0	8
6.0	0
8.0	−9

Concept Check

1. (a)

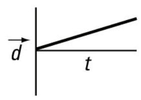


The object is stopped in the positive direction.

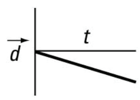


The object is stopped in the negative direction.

(b)

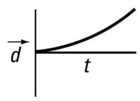


The object is travelling at a constant velocity in the positive direction.

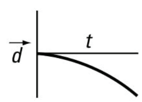


The object is travelling at a constant velocity in the negative direction.

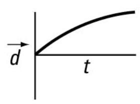
(c)



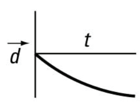
The object is speeding up in the positive direction.



The object is speeding up in the negative direction.

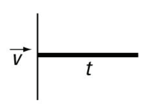


The object is slowing down in the positive direction.

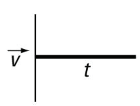


The object is slowing down in the negative direction.

2. (a)

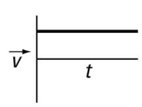


The slope of the position-time graph is zero, so the velocity-time graph is along the time axis.

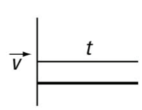


The slope of the position-time graph is zero, so the velocity-time graph is along the time axis.

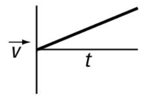
(b)



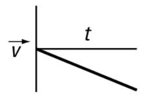
The slope of the position-time graph is positive, so the velocity-time graph is a horizontal line above the time axis.



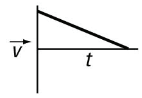
The slope of the position-time graph is negative, moving away from the time axis, so the velocity-time graph is a horizontal line below the time axis.

(c) 

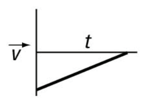
The slope of the position-time graph increases in the positive direction, so the velocity-time graph is a straight line with positive slope above the time axis.



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

Concept Check

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

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Example 1.6 Practice Problems

1. (a) $\Delta\vec{d} = \text{area under graph}$

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

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

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

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

(b) $\Delta\vec{d} = \text{area under curve}$

$$= \left(6\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forward}] \times 6\ \cancel{\text{s}}\right) + \left(-6\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{forward}] \times 6\ \cancel{\text{s}}\right)$$

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

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

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

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Concept Check

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

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Example 1.7 Practice Problems

1. ***Given***

Consider west to be positive.

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

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

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

Required

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

Analysis and Solution

The total displacement is:

$$\begin{aligned}\Delta\vec{d} &= -10.0 \text{ m} + (-5.0 \text{ m}) + (+30.0 \text{ m})\\ &= +15.0 \text{ m}\end{aligned}$$

The total time is:

$$\begin{aligned}\Delta t &= 2.0 \text{ s} + 1.5 \text{ s} + 5.0 \text{ s}\\ &= 8.5 \text{ s}\end{aligned}$$

$$\begin{aligned}\vec{v}_{\text{ave}} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+15.0 \text{ m}}{8.5 \text{ s}}\\ &= +1.8 \text{ m/s}\\ &= 1.8 \text{ m/s [W]}\end{aligned}$$

Paraphrase

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

2. ***Given***

Consider forward to be positive.

$\Delta\vec{d}_{\text{DB}} = 100 \text{ m [forward]} = +100 \text{ m}$ $\quad$ $\Delta t_{\text{DB}} = 9.84 \text{ s}$

$\Delta\vec{d}_{\text{MJ}} = 200 \text{ m [forward]} = +200 \text{ m}$ $\quad$ $\Delta t_{\text{MJ}} = 19.32 \text{ s}$

$\Delta\vec{d}_{\text{s}} = 400 \text{ m [forward]} = +400 \text{ m}$ $\quad$ $\Delta t_{\text{s}} = 1.90 \text{ min}$

Required

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

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:

$$\Delta t = 9.84\text{ s} + 19.32\text{ s} + \left(1.90\ \cancel{\text{min}} \times \frac{60\text{ s}}{1\ \cancel{\text{min}}}\right)$$
$$= 9.84\text{ s} + 19.32\text{ s} + 114\text{ s}$$
$$= 143.16\text{ s}$$

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

$$\vec{v}_{\text{DB}} = \frac{\Delta \vec{d}}{\Delta t}$$
$$= \frac{+100\text{ m}}{9.84\text{ s}}$$
$$= +10.2\text{ m/s}$$
$$= 10.2\text{ m/s [forward]}$$

$$\vec{v}_{\text{MJ}} = \frac{\Delta \vec{d}}{\Delta t}$$
$$= \frac{+200\text{ m}}{19.32\text{ s}}$$
$$= +10.4\text{ m/s}$$
$$= 10.4\text{ m/s [forward]}$$

$$\vec{v}_{\text{s}} = \frac{\Delta \vec{d}}{\Delta t}$$
$$= \frac{+400\text{ m}}{114\text{ s}}$$
$$= +3.51\text{ m/s}$$
$$= 3.51\text{ m/s [forward]}$$

Paraphrase

The average velocity of all three runners is 4.89 m/s [forward]. Donovan Bailey's average velocity is 10.2 m/s [forward]. Michael Johnson's average velocity is 10.4 m/s [forward]. The student's average velocity is 3.51 m/s [forward].

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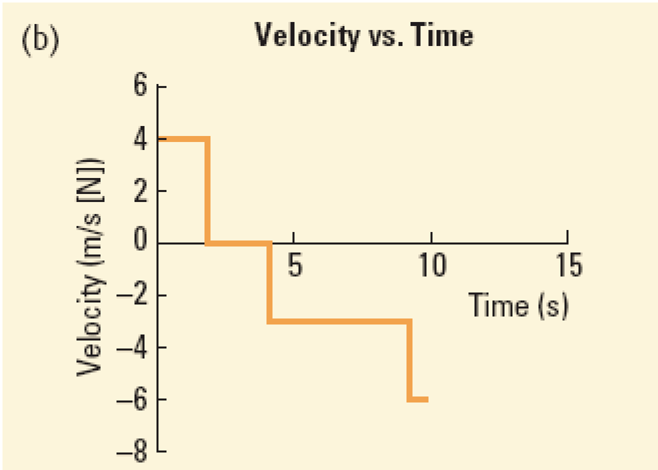
Example 1.8 Practice Problems

1. (a) 4.0 m/s for 2.0 s, rest for 2.0 s, –2.8 m/s for 5.0 s, –6.0 m/s for 1.0 s



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

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

$= -12\text{ m}$

(d) All the sections of the velocity-time graph are horizontal, so the acceleration in each section is zero.

(e) The object is stopped when the velocity-time graph is along the time axis, between 2–4 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:

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

$$\Delta\vec{d} = \frac{1}{2}(2\text{ s})(+8\text{ m/s})$$

$$= +8\text{ m}$$

$$= 8\text{ m [N]}$$

2–4 s:

$$A = lw$$

$$\Delta\vec{d} = (4\text{ s} - 2\text{ s})(+8\text{ m/s})$$

$$= +16\text{ m}$$

$$= 16\text{ m [N]}$$

4–7 s:

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

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}(7\text{ s} - 4\text{ s})(+8\text{ m/s})\\ &= +12\text{ m}\\ &= 12\text{ m [N]}\end{aligned}$$

7–9 s:

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

$$\begin{aligned}\Delta\vec{d} &= \frac{1}{2}(9\text{ s} - 7\text{ s})(-6\text{ m/s})\\ &= -6\text{ m}\\ &= 6\text{ m [S]} \quad \text{or } -6\text{ m [N]}\end{aligned}$$

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) $$\begin{aligned}\Delta\vec{d} &= +8\text{ m} + (+16\text{ m}) + (+12\text{ m}) + (-6\text{ m}) + (-9\text{ m})\\ &= +21\text{ m}\\ &= 21\text{ m [N]}\end{aligned}$$

(c) $$\begin{aligned}\vec{v}_{\text{ave}} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{+21\text{ m}}{10\text{ s}}\\ &= +2.1\text{ m/s}\\ &= 2.1\text{ m/s [N]}\end{aligned}$$

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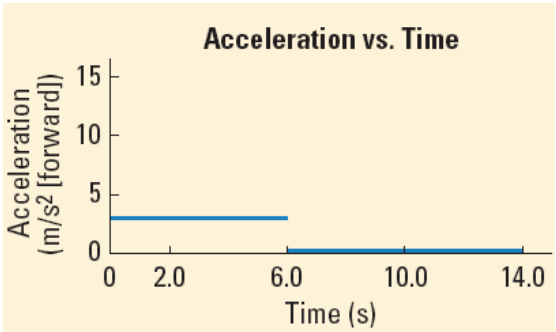
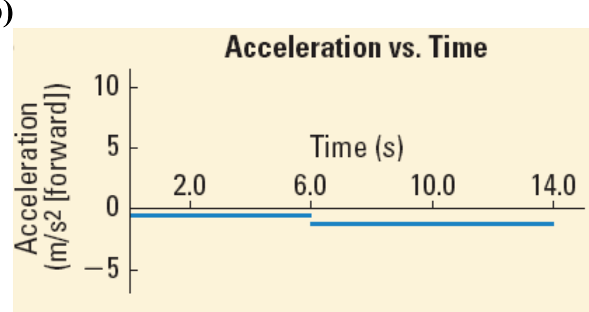
Example 1.10 Practice Problems

1. (a)



(b)



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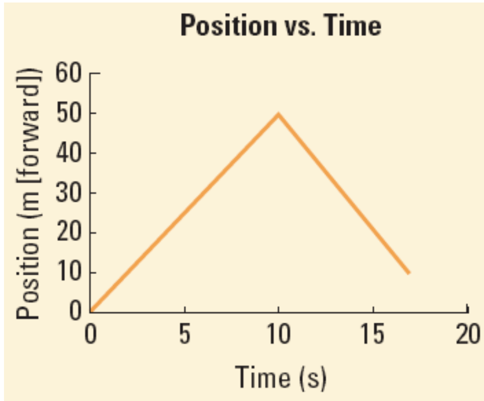
Example 1.11 Practice Problems

1. (a) The object travels forward at 5.0 m/s for 10 s, then backward at 5.0 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)



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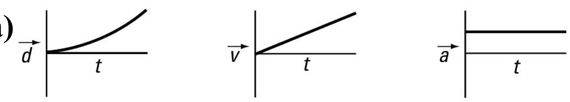
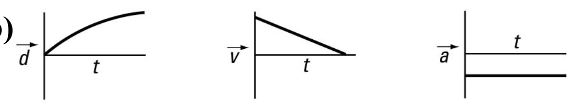
Concept Check

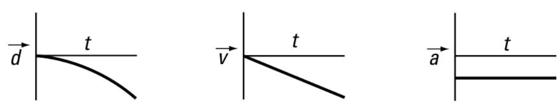
(a)



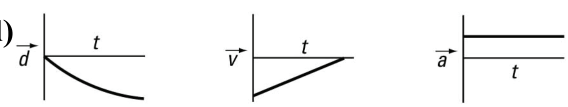
(b)



(c)



(d)



1.4 Check and Reflect

Knowledge

1. Area under a velocity-time graph gives displacement.

2. The velocity-time graph for an object undergoing negative acceleration is a straight line with negative slope above the time axis or a straight line with positive slope below the time axis.

3. A velocity-time graph with non-zero slope represents an object that is accelerating.

4. An acceleration-time graph for an object that is slowing down in the forward direction is a horizontal line below the time axis.

5. For an object undergoing uniform motion, the object experiences equal displacement during equal time intervals, and its velocity remains constant. For an object undergoing accelerated motion, the object experiences a changing displacement for equal time intervals, and velocity changes—either decreases or increases.

6. A position-time graph for an object undergoing uniform motion is a straight line: 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 on a position-time graph.

7. Consider east to be positive.

$$\begin{aligned}\Delta\vec{d} &= \text{area under graph}\\ &= \left(+5.0\ \frac{\text{m}}{\cancel{\text{s}}}\right)(5.0\ \cancel{\text{s}}) + \frac{1}{2}\left(+5.0\ \frac{\text{m}}{\text{s}} + \left(+15.0\ \frac{\text{m}}{\text{s}}\right)\right)(5.0\ \text{s})\\ &= +75\ \text{m/s}\\ &= 75\ \text{m/s [E]}\end{aligned}$$

8. Consider up to be positive.

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_1\Delta t_1 + \vec{v}_2\Delta t_2 + \vec{v}_3\Delta t_3\\ &= (+4.0\ \text{m/s})(5.0\ \text{s} - 0\ \text{s}) + (+2.0\ \text{m/s})(7.0\ \text{s} - 5.0\ \text{s}) + (+4.0\ \text{m/s})(10\ \text{s} - 7.0\ \text{s})\\ &= +20\ \text{m} + (+4.0\ \text{m}) + (+12\ \text{m})\\ &= +36\ \text{m}\\ &= 36\ \text{m [up]}\end{aligned}$$

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

10. 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.

11. Consider east to be positive.

$$\begin{aligned}\vec{a} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{+100\ \text{m/s} - (-50\ \text{m/s})}{10.0\ \text{s}}\\ &= \frac{+150\ \text{m/s}}{10.0\ \text{s}}\\ &= +15.0\ \text{m/s}^2\\ &= 15.0\ \text{m/s}^2\ \text{[E]}\end{aligned}$$

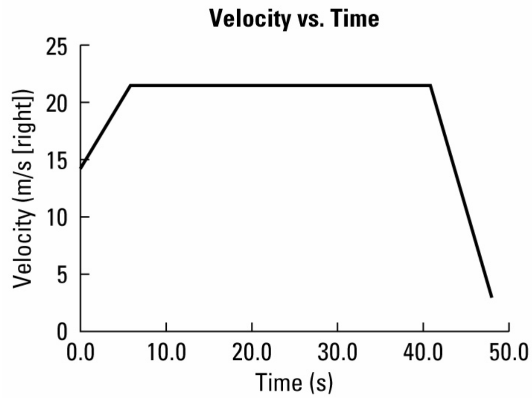
12. The acceleration-time graph is a horizontal line at $-1\ \text{m/s}^2$ [N].

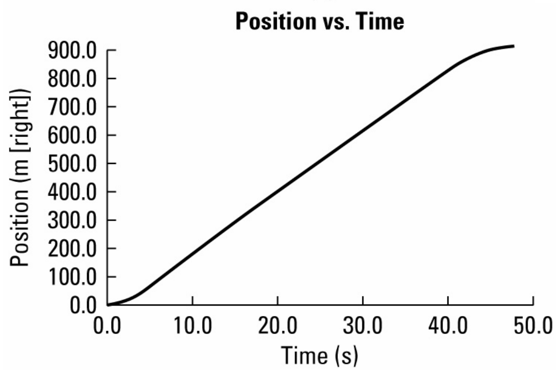
13. The slope of a position-time graph gives velocity.

14. The slope of a velocity-time graph gives acceleration.

Applications

15.





16. Consider west to be positive.

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

$$+200\text{ m} = \frac{1}{2}(+20.0\text{ m/s} + (+30.0\text{ m/s}))\Delta t$$

$$+200\text{ m} = (+25.0\text{ m/s})\Delta t$$

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

$$\vec{a} = \frac{\vec{v}_1 - \vec{v}_2}{\Delta t}$$

$$= \frac{+30.0\text{ m/s} - (+20.0\text{ m/s})}{8.00\text{ s}}$$

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

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

17. (a) ***Given***

Consider north to be positive.

$\vec{v}_1 = 70$ km/h [N] = +70 km/h

$\Delta t_1 = 75$ min

$\vec{v}_2 = 90$ km/h [N] = +90 km/h

$\Delta t_2 = 96$ min

Required

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

Analysis and Solution

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

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

Determine the total time.

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

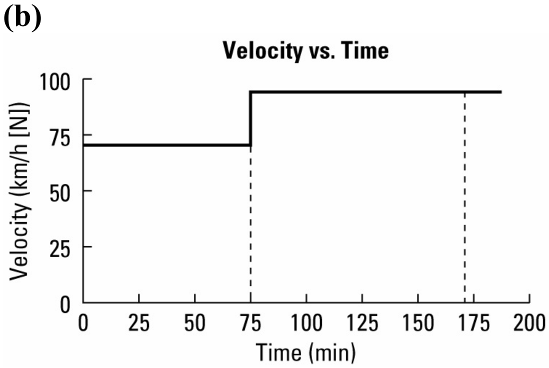
Calculate average velocity.

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

Paraphrase

Average velocity is 81 km/h [N].

(b)



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

$$\begin{aligned}\vec{a} &= \frac{\Delta\vec{v}}{\Delta t}\\ &= \frac{+12.0\text{ m/s} - (+2.0\text{ m/s})}{30.0\text{ s}}\\ &= +0.333\text{ m/s}^2\\ &= 0.333\text{ m/s}^2\text{ [right]}\end{aligned}$$

Extension

19. 0 s to 2 s: sharp acceleration [E]
2 s to 6 s: gentle acceleration [E]
6 s to 10 s: uniform motion [E]
10 s to 11 s: sharp deceleration, to stop
11 s to 12 s: sharp acceleration [W]
12 s to 15 s: medium acceleration [W]

15 s to 18 s: gentle deceleration [E]
18 s to 24 s: uniform motion [W]
24 s to 27 s: medium acceleration [E] to momentary stop
27 s to 30 s: medium acceleration [E]

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Concept Check

	Reading the Graph	Slope	Area
position-time	position	velocity	—
velocity-time	velocity	acceleration	displacement
acceleration-time	acceleration	jerk	velocity

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Example 1.12 Practice Problems

1. ***Given***

Consider east to be positive.

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

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

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

Required

time (Δt)

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.

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

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

Δt = 9.3 s

Required

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

Analysis and Solution

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

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

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

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.

$\vec{v}_i$ = 16 m/s [S] = +16 m/s

$\vec{v}_f$ = 4.0 m/s [S] = +4.0 m/s

Δt = 4.0 s

Required

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

Analysis and Solution

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

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

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

Δt = 4.0 s

Required

position ($\vec{d}_i$)

Analysis and Solution

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

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

Paraphrase

The ball is released from a position 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

Δt = 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.

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

$\vec{a}$ = –0.80 m/s^2

Δt = 1.0 min = 60 s

Required

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

Analysis and Solution

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

$$\Delta\vec{d} = (+27.8 \text{ m/s})(60 \text{ s}) + \frac{1}{2}(-0.80 \text{ m/s}^2)(60 \text{ s})^2$$
$$= +228 \text{ m}$$
$$= 228 \text{ m [forward]}$$

Paraphrase

The motorcycle travels 228 m.

Example 1.15 Practice Problems

1. ***Given***

Consider forward to be positive.

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

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

$\vec{a} = -15 \text{ m/s}^2$

Required

time (Δt)

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.

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

$$\begin{aligned}\Delta t &= \sqrt{\frac{150 \text{ m}}{7.5 \text{ m/s}^2}} \\ &= 4.5 \text{ s}\end{aligned}$$

Paraphrase

The plane stops after 4.5 s.

2. ***Given***

Consider north to be positive.

$\Delta t = 6.2 \text{ s}$

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

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

Required

acceleration ($\vec{a}$)

Analysis and Solution

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

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

Paraphrase

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

Example 1.16 Practice Problems

1. ***Given***

$\vec{v}_\mathrm{i} = 70\ \mathrm{m/s}$ [forward]

$\Delta t = 29\ \mathrm{s}$

$\vec{v}_\mathrm{f} = 0\ \mathrm{m/s}$

Required

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

(b) distance (Δd)

Analysis and Solution

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

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_\mathrm{f} - \vec{v}_\mathrm{i}}{\Delta t}\\ &= \frac{0\ \mathrm{m/s} - 70\ \mathrm{m/s\ [forward]}}{29\ \mathrm{s}}\\ &= -2.4\ \mathrm{m/s^2}\ \mathrm{[forward]}\end{aligned}$$

(b) Use the equation $v_\mathrm{f}^2 = v_\mathrm{i}^2 + 2a\Delta d$.

$$\begin{aligned}v_\mathrm{f}^2 &= v_\mathrm{i}^2 + 2a\Delta d\\ \Delta d &= \frac{v_\mathrm{f}^2 - v_\mathrm{i}^2}{2a}\\ &= \frac{(0\ \mathrm{m/s})^2 - (70\ \mathrm{m/s})^2}{2(-2.4\ \mathrm{m/s^2})}\\ &= 1021\ \mathrm{m}\\ &= 1.0\ \mathrm{km}\end{aligned}$$

Paraphrase

(a) The jet's acceleration is $-2.4\ \mathrm{m/s^2}$ [forward].

(b) The minimum runway length is 1.0 km.

2. ***Given***

$v_\mathrm{i} = 50\ \mathrm{km/h}$

$v_\mathrm{f} = 100\ \mathrm{km/h}$

$a = 3.8\ \mathrm{m/s^2}$

Required

distance (Δd)

Analysis and Solution

Convert initial and final velocities to m/s. Then use the equation $v_\mathrm{f}^2 = v_\mathrm{i}^2 + 2a\Delta d$ to find the on-ramp length.

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

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

$$_{\text{f}}{}^2 = v_{\text{i}}^2 + 2a\Delta d$$

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

Paraphrase

The minimum length of the ramp is 76 m.

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1.5 Check and Reflect

Applications

1. ***Given***

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

$\vec{v}_{\text{i}} = 90$ km/h [forward]

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

Required

acceleration ($\vec{a}$)

Analysis and Solution

Convert km/h to m/s and km to m.

The use the equation $v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$.

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

Paraphrase

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

2. ***Given***

$\Delta d = 2.6$ km or 2600 m

$a = 42.5\ \text{m/s}^2$

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

Required

time (Δt)

Analysis and Solution

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

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

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

$$= \sqrt{\frac{2(2600\ \cancel{\text{m}})}{42.5\ \frac{\cancel{\text{m}}}{\text{s}^2}}}$$

$$= 11\ \text{s}$$

Paraphrase

The plane takes 11 s to travel down the runway.

3. ***Given***

Consider forward to be positive.

$\Delta t = 3.0\ \text{s}$

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

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

Required

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

Analysis and Solution

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

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

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

Paraphrase

The robot travels 20 cm [forward].

4. ***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.

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

$$= \frac{2\left(+1540 \text{ m} - \left(+9.0 \ \frac{\text{m}}{\cancel{\text{s}}}\right)\left(120 \ \cancel{\text{s}}\right)\right)}{(120 \text{ s})^2}$$

$$= +0.064 \text{ m/s}^2$$

$$= 0.064 \text{ m/s}^2 \text{ [N]}$$

Paraphrase

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

5. ***Given***

Consider west to be positive.

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

$\Delta t = 2.00 \text{ s}$

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

Required

acceleration ($\vec{a}$)

Analysis and Solution

Use 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.

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

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

$$= \frac{2\left(+150 \text{ m} - 0\right)}{(2.00 \text{ s})^2}$$

$$= +75.0 \text{ m/s}^2$$

$$= 75.0 \text{ m/s}^2 \text{ [W]}$$

Paraphrase

The jet's acceleration is 75.0 m/s^2 [W].

6. ***Given***

$v_i = 14.0 \text{ m/s}$

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

$\Delta t = 2.80 \text{ s}$

Required

distance (Δd)

Analysis and Solution

Since acceleration is uniform, use the equation $\Delta d = \frac{1}{2}\left(v_i + v_f\right)\Delta t$.

$$\Delta d = \frac{1}{2}(v_i + v_f)\Delta t$$
$$= \frac{1}{2}(14.0 \text{ m/s} + 0 \text{ m/s})(2.80 \text{ s})$$
$$= 19.6 \text{ m}$$

Paraphrase

The cyclist skids for 19.6 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 $v_f^2 = v_i^2 + 2a\Delta d$.

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

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

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

Paraphrase

The magnitude of the car's acceleration is -0.41 m/s^2.

8. ***Given***

$v_i = 0$ m/s

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

$\Delta t = 5.65$ s

Required

distance (Δd)

Analysis and Solution

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

$$\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t^2$$
$$= 0 + \frac{1}{2}(3.75 \text{ m/s}^2)(5.65 \text{ s})^2$$
$$= 59.9 \text{ m}$$

Paraphrase

Car travels 59.9 m.

9. ***Given***

Consider south to be positive.

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

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_\text{i}\Delta t + \frac{1}{2}\vec{a}\left(\Delta t\right)^2 \\ \vec{a} &= \frac{2\Delta\vec{d}}{\left(\Delta t\right)^2} \\ &= \frac{2\left(+350.0 \text{ m}\right)}{(14.1 \text{ s})^2} \\ &= +3.52 \text{ m/s}^2 \\ &= 3.52 \text{ m/s}^2 \text{ [S]}\end{aligned}$$

Paraphrase

Motorcycle's acceleration is 3.52 m/s^2 [S] .

10. ***Given***

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

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

$v_\text{i} = 97.0 \text{ km/h}$

Required

magnitude of acceleration (a)

Analysis and Solution

Use the equation $v_\text{f}{}^2 = v_\text{i}{}^2 + 2a\Delta d$, where $v_\text{f} = 0$.

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

$$\begin{aligned}v_\text{f}{}^2 &= v_\text{i}{}^2 + 2a\Delta d \\ a &= \frac{v_\text{f}{}^2 - v_\text{i}{}^2}{2\Delta d} \\ &= \frac{0 - (26.94 \text{ m/s})^2}{2(39.0 \text{ m})} \\ &= -9.30 \text{ m/s}^2\end{aligned}$$

Paraphrase

The acceleration has a magnitude of 9.30 m/s^2 .

11. ***Given***

$v_{\mathrm{i}} = 0\ \mathrm{m/s}$

$v_{\mathrm{f}} = 241\ \mathrm{km/h}$

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

Required

magnitude of acceleration (a)

Analysis and Solution

Convert km/h to m/s.

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

Use the equation $v_{\mathrm{f}}^2 = v_{\mathrm{i}}^2 + 2a\Delta d$, where $v_{\mathrm{i}} = 0$.

$$\begin{aligned} v_{\mathrm{f}}^2 &= v_{\mathrm{i}}^2 + 2a\Delta d \\ a &= \frac{v_{\mathrm{f}}^2 - v_{\mathrm{i}}^2}{2\Delta d} \\ &= \frac{(66.94\ \mathrm{m/s})^2 - 0\ \mathrm{m/s}}{2(96.0\ \mathrm{m})} \\ &= 23.3\ \mathrm{m/s^2} \end{aligned}$$

Paraphrase

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

12. ***Given***

Consider right to be positive.

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

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

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

Required

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

Analysis and Solution

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

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

Paraphrase

The logging truck moves 75 m [right].

13. ***Given***

Consider forward to be positive.

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

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

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

Required
acceleration ($\vec{a}$)
Analysis and Solution
Use the equation $\vec{a} = \dfrac{\vec{v}_\mathrm{f} - \vec{v}_\mathrm{i}}{\Delta t}$.

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

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

14. ***Given***
$\vec{a}$ = –49 $\mathrm{m/s^2}$ [forward]
$v_\mathrm{i} = 110\ \dfrac{\cancel{\mathrm{km}}}{\cancel{\mathrm{h}}} \times \dfrac{1000\ \mathrm{m}}{1\ \cancel{\mathrm{km}}} \times \dfrac{1\ \cancel{\mathrm{h}}}{3600\ \mathrm{s}} = 30.56\ \mathrm{m/s}$
$v_\mathrm{f} = 0$
Required
distance (Δd)
Analysis and Solution
Use the equation ${v_\mathrm{f}}^2 = {v_\mathrm{i}}^2 + 2a\Delta d$.

$$\begin{aligned}\Delta d &= \frac{{v_\mathrm{f}}^2 - {v_\mathrm{i}}^2}{2a}\\ &= \frac{0 - (30.56\ \mathrm{m/s})^2}{2(-49\ \mathrm{m/s^2})}\\ &= 9.5\ \mathrm{m}\end{aligned}$$

Paraphrase
The minimum stopping distance must be 9.5 m.

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Example 1.17 Practice Problems

1. ***Given***
Consider down to be positive.
Δt = 0.750 s
$\Delta\vec{d}$ = 4.80 m [down] = +4.80 m
$\vec{a}$ = 9.81 $\mathrm{m/s^2}$ [down] = +9.81 $\mathrm{m/s^2}$
Required
initial velocity ($\vec{v}_\mathrm{i}$)
Analysis and Solution
Use the equation $\Delta\vec{d} = \vec{v}_\mathrm{i}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$.

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

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 (Δt)

Analysis and Solution

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

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

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 ($\vec{v}_f$)
displacement ($\Delta\vec{d}$)
Analysis and Solution
Use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$ to find final velocity.

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

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

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

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

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

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Example 1.18 Practice Problem

1. ***Given***
Choose down to be positive.
$\Delta\vec{d}$ = 27 m [down] = +27 m
$\vec{a} = 9.81\ \text{m/s}^2\ \text{[down]} = +9.81\ \text{m/s}^2$
$\vec{v}_i = 0\ \text{m/s}$
Required
final speed (v)
Analysis and Solution
Determine the final speed using the equation $v_f{}^2 = v_i{}^2 + 2a\Delta d$.

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

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.

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

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

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

Required

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

Analysis and Solution

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

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

Paraphrase

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

(b) ***Given***

Choose down to be positive.

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

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

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

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

Required

time (Δt)

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.

$$\begin{aligned} a &= \frac{\Delta v}{\Delta t} \\ \Delta t &= \frac{v_\text{f} - v_\text{i}}{a} \\ &= \frac{19.8 \text{ m/s} - 0 \text{ m/s}}{9.81 \text{ m/s}^2} \\ &= 2.02 \text{ s} \end{aligned}$$

Paraphrase

The pebble hits the ground after 2.02 s.

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Concept Check

(a) 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

(a) The defining equation for a ball thrown straight up is $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$.

(b) The value of the slope of the velocity-time graph in Figure 1.67(b) should be $-9.81\ \text{m/s}^2$.

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1.6 Check and Reflect

Knowledge

1. The height from which an object is dropped determines how long it will take to reach the ground.

2. A projectile is any object thrown into the air.

Applications

3. ***Given***

Consider down to be positive.

$\Delta t = 1.575\ \text{s}$

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

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

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 $\vec{v}_i = 0$.

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

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

Paraphrase

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

4. ***Given***

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

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

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

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

Required

maximum height (Δd)

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 $v_\text{f}{}^2 = v_\text{i}{}^2 + 2a\Delta d$ and substitute scalar quantities.

$$v_\text{f}{}^2 = v_\text{i}{}^2 + 2a\Delta d$$

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

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.

5. ***Given***

Choose down to be positive.

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

$\Delta t = 2.6\text{ s}$

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

Required

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

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

Analysis and Solution

Because the student drops from rest, initial velocity is zero. For final velocity, use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

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

For displacement, use the equation $\Delta\vec{d} = \frac{1}{2}(\vec{v}_i + \vec{v}_f)\Delta t$ since motion is uniformly accelerated.

$$\begin{aligned}
\Delta\vec{d} &= \frac{1}{2}(\vec{v}_i + \vec{v}_f)\Delta t \\
&= \frac{1}{2}(0 \text{ m/s} + (+25.5 \text{ m/s}))(2.6 \text{ s}) \\
&= +33 \text{ m} \\
&= 33 \text{ m [down]}
\end{aligned}$$

Paraphrase

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

6. ***Given***

Choose down to be positive.

$$\begin{aligned}
\Delta\vec{d} &= 1.75 \text{ m [down]} = +1.75 \text{ m} \\
\vec{a} &= 26.2 \text{ m/s}^2 \text{ [down]} = +26.2 \text{ m/s}^2 \\
\vec{v}_i &= 0
\end{aligned}$$

Required

time (Δt)

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.

$$\begin{aligned}
\Delta d &= v_i\Delta t + \frac{1}{2}a(\Delta t)^2 \\
\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\
&= \sqrt{\frac{2(1.75 \cancel{\text{m}})}{26.2 \frac{\cancel{\text{m}}}{\text{s}^2}}} \\
&= 0.365 \text{ s}
\end{aligned}$$

Paraphrase

The tennis ball takes 0.365 s to drop 1.75 m on Jupiter.

7. ***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 (Δd)

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.

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2 \\ &= 0 + \frac{1}{2}(+9.81 \text{ m/s}^2)(0.56 \text{ s})^2 \\ &= +1.5 \text{ m} \\ &= 1.5 \text{ [down]}\end{aligned}$$

Paraphrase

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

8. ***Given***

Choose down to be positive.

$\Delta t = 6.25$ s

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

Required

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

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

$$\begin{aligned}\Delta d &= 0 + \frac{1}{2}(+9.81 \text{ m/s}^2)(3.125 \text{ s})^2 \\ &= +47.9 \text{ m} \\ &= 47.9 \text{ m [down]}\end{aligned}$$

Paraphrase

The baseball reaches a maximum height of 47.9 m.

9. ***Given***

Choose down to be positive.

$\Delta t = 3.838$ s

$\vec{v}_i = 0$

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

Required

height (Δd)

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.

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

Paraphrase

The muffin falls from a height of 72.3 m.

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 (Δt)

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.

$$\begin{aligned}\Delta d &= \frac{1}{2}a(\Delta t)^2 \\ \Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(3.0\ \cancel{\text{m}})}{9.81\ \frac{\cancel{\text{m}}}{\text{s}^2}}} \\ &= 0.78\ \text{s}\end{aligned}$$

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 (Δt)

Analysis and Solution

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.

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

Paraphrase

The penny takes 6.22 s to fall 190 m.

12. ***Given***

Choose down to be positive.

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

$\Delta d_i = 1.30\ \text{m [up]} = -1.30\ \text{m}$

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

Required

maximum height (Δd)

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 $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_i$ = 0 from maximum height.

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2 \\ &= 0 + \frac{1}{2}\left(+9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.375\ \text{s})^2 \\ &= +9.27\ \text{m} \\ &= 9.27\ \text{m [down]}\end{aligned}$$

Paraphrase

The coin reaches a maximum height of 9.27 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 (Δt)

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.

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

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 (Δd)

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 $\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$, where $\vec{v}_{\text{i}}$ = 0.

To find Δt, use the scalar form of the equation because you are dividing by a vector.

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d_{\text{vertical}}}{a}} \\ &= \sqrt{\frac{2(5.0\ \cancel{\text{m}} - 1.25\ \cancel{\text{m}})}{9.81\ \frac{\cancel{\text{m}}}{\text{s}^2}}} \\ &= 0.87\ \text{s}\end{aligned}$$

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

$$\begin{aligned}\Delta d_{\text{horizontal}} &= v_{\text{horizontal}}\Delta t \\ &= \left(2.75\ \frac{\text{m}}{\cancel{\text{s}}}\right)(0.87\ \cancel{\text{s}}) \\ &= 2.4\ \text{m}\end{aligned}$$

Paraphrase

The person is 2.4 m away.

15. ***Given***

Choose down to be positive.

$\vec{v}_{\text{f}} = 201 \text{ km/h [down]}$

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

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

Required

distance (Δd)

time (Δt)

Analysis and Solution

Convert km/h to m/s.

$$201 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} = 55.83 \text{ m/s}$$

Since acceleration is uniform, use the equation $\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$ to find the time interval.

Use the scalar form of the equation because you are dividing by a vector.

$$a = \frac{v_{\text{f}} - v_{\text{i}}}{\Delta t}$$

$$\begin{aligned} \Delta t &= \frac{v_{\text{f}} - v_{\text{i}}}{a} \\ &= \frac{55.83 \frac{\cancel{\text{m}}}{\cancel{\text{s}}} - 0}{9.81 \frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}} \\ &= 5.691 \text{ s} \end{aligned}$$

Then use the equation $\Delta \vec{d} = \vec{v}_{\text{i}} \Delta t + \frac{1}{2} \vec{a} \left(\Delta t \right)^2$ to find distance.

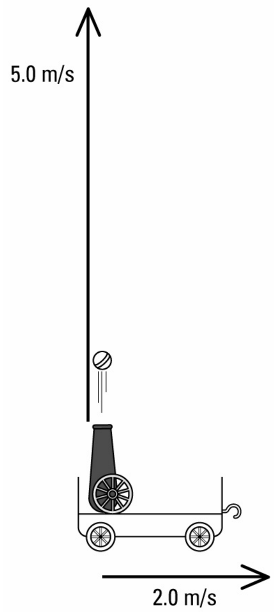
$$\begin{aligned} \Delta \vec{d} &= 0 + \frac{1}{2} \left(+9.81 \frac{\text{m}}{\text{s}^2} \right) (5.691 \text{ s})^2 \\ &= +159 \text{ m} \\ &= 159 \text{ m [down]} \end{aligned}$$

Paraphrase

The parachuter falls 159 m in 5.69 s before reaching terminal velocity.

Extensions

16.



Given

$\vec{v}_{\mathrm{h}} = 2.0$ m/s [right]

$\vec{v}_{\mathrm{v}} = 5.0$ m/s [up]

Required

resultant initial velocity ($\vec{v}_{\mathrm{r}}$)

Analysis and Solution

To find the magnitude of the velocity, use the Pythagorean theorem. Use the tangent function to find the direction.

$$\begin{aligned} v_{\mathrm{r}} &= \sqrt{(v_{\mathrm{h}})^2 + (v_{\mathrm{v}})^2} \\ &= \sqrt{(2.0 \text{ m/s})^2 + (5.0 \text{ m/s})^2} \\ &= 5.4 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \tan\theta &= \frac{v_{\mathrm{v}}}{v_{\mathrm{h}}} \\ &= \frac{5.0 \cancel{\text{ m/s}}}{2.0 \cancel{\text{ m/s}}} \\ &= 2.5 \\ \theta &= \tan^{-1}(2.5) \\ &= 68° \end{aligned}$$

Paraphrase

To an observer on the ground, the ball has an initial velocity of 5.4 m/s [68°].

17. ***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 (Δd_{fuel})

(c) explanation for height gain

(d) maximum height (Δd_{max})

Analysis and Solution

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

$$\begin{aligned}\vec{a} &= \frac{\Delta \vec{v}}{\Delta t} \\ &= \frac{+200\ \text{m/s} - 0}{50\ \text{s}} \\ &= +4.0\ \text{m/s}^2 \\ &= 4.0\ \text{m/s}^2\ \text{[up]}\end{aligned}$$

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

$$\begin{aligned}\Delta \vec{d}_{\text{fuel}} &= \vec{v}_{\text{i}} \Delta t + \frac{1}{2} \vec{a} (\Delta t)^2 \\ &= 0 + \frac{1}{2}(+4.0\ \text{m/s}^2)(50\ \text{s})^2 \\ &= +5.0 \times 10^3\ \text{m} \\ &= 5.0 \times 10^3\ \text{m [up]}\end{aligned}$$

(c) The rocket continues to rise because its initial velocity during the final leg of its trip is that provided by the rocket's engines. The rocket will continue to rise until the rocket's upward velocity is greater than the acceleration due to gravity.

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

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

$$v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$$

$$\begin{aligned}\Delta d_{\text{top}} &= \frac{v_{\text{f}}^2 - v_{\text{i}}^2}{2a} \\ &= \frac{0 - (200\ \text{m/s})^2}{2(-9.81\ \text{m/s}^2)} \\ &= 2039\ \text{m}\end{aligned}$$

$$\begin{aligned}\Delta d_{max} &= 5000 \text{ m} + 2039 \text{ m}\\ &= 7039 \text{ m}\\ &= 7.0\times10^3 \text{ m}\end{aligned}$$

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 5.0×10^3 m.

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

18. ***Given***

Choose down to be positive.

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

$\Delta t = 0.850 \text{ s}$

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

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 is 9.68 m/s [down].

Chapter 1 Review

Knowledge

1. Vector quantities include direction. They must be added by vector addition.
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)** $\vec{v} = \dfrac{10\text{ m [forward]}}{10\text{ s}} = 1.0\text{ m/s [forward]}$

(b) $\vec{v} = \dfrac{-20\text{ m [right]}}{10\ \cancel{\text{min}}} \times \dfrac{1\ \cancel{\text{min}}}{60\text{ s}} = -0.033\text{ m/s [right]} = 0.033\text{ m/s [left]}$

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

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

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 km [W].

5. ***Given***

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

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

Required

time (Δt)

Analysis and Solution

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

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

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

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

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

7. A person standing still will 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 $\dfrac{5.6\text{ s}}{2} = 2.8\text{ s}$.

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***

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

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

Required

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

Analysis and Solution

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

$$\begin{aligned}\vec{v}_{\text{ave}} &= \frac{42\text{ km [W]}}{8.0\text{ h}} \\ &= 5.3\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}}\ [\text{W}] \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\text{ s}} \\ &= 1.5\text{ m/s [W]}\end{aligned}$$

Paraphrase

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

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

13. ***Given***

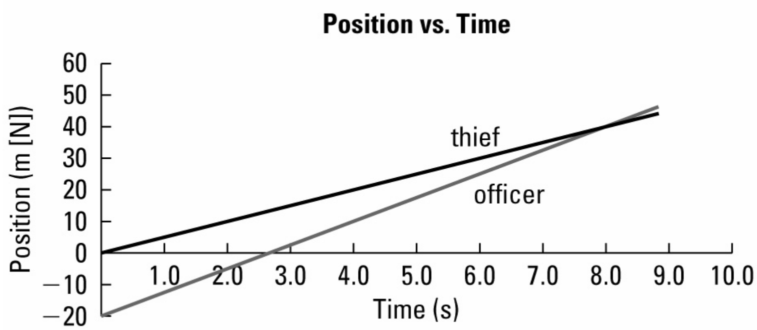
Consider north to be positive.

$$\begin{aligned}\vec{v}_{\text{thief}} &= 5.0\text{ m/s [N]} = +5.0\text{ m/s} \\ \vec{d}_{\text{thief}_\text{i}} &= 0\text{ m} \\ \vec{v}_{\text{officer}} &= 7.5\text{ m/s [N]} = +7.5\text{ m/s} \\ \vec{d}_{\text{officer}_\text{i}} &= 20\text{ m [S]} = -20\text{ m}\end{aligned}$$

Required

displacement ($\Delta\vec{d}_{\text{officer}}$)

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 [N] before catching the thief. Check: Distance run in 8.0 s at 7.5 m/s is 60 m.

14. ***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 $v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$.

$$\begin{aligned}v_{\text{f}}^2 &= v_{\text{i}}^2 + 2a\Delta d\\ a &= \frac{v_{\text{f}}^2 - v_{\text{i}}^2}{2\Delta d}\\ &= \frac{0 - (1200 \text{ m/s})^2}{2(0.010 \text{ m})}\\ &= -7.2\times10^7 \text{ m/s}^2\end{aligned}$$

Paraphrase

The magnitude of the bullet's acceleration is $7.2\times10^7 \text{ m/s}^2$.

15. ***Given***

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

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

Required

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

Analysis and Solution

Determine the area under the graph after 0.50 h.

$$\begin{aligned}\Delta\vec{d} &= \left(35 \ \frac{\text{km}}{\cancel{\text{h}}} \text{ [forward]}\right)(0.50 \ \cancel{\text{h}})\\ &= 18 \text{ km [forward]}\end{aligned}$$

Paraphrase

The elk will travel 18 km [forward].

16. ***Given***

$\Delta t = 2.50 \text{ min}$

$v = 829 \text{ km/h}$

Required

distance (Δd)

Analysis and Solution

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

$$\begin{aligned}\Delta d &= v\Delta t \\ &= 829 \ \frac{\text{km}}{\cancel{\text{h}}} \times 2.50 \ \cancel{\text{min}} \times \frac{1 \ \cancel{\text{h}}}{60 \ \cancel{\text{min}}} \\ &= 34.5 \text{ km}\end{aligned}$$

Paraphrase

The speedboat will travel 34.5 km.

17. ***Given***

$\Delta d = 300 \text{ km}$

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

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

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:

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

Airliner:

$$\begin{aligned}v &= \frac{\Delta d}{\Delta t} \\ &= \frac{300 \text{ km}}{20 \ \cancel{\text{min}} \times \dfrac{1 \text{ h}}{60 \ \cancel{\text{min}}}} \\ &= 900 \text{ km/h}\end{aligned}$$

$$\frac{900 \text{ km/h}}{12.5 \text{ km/h}} = 72$$

Paraphrase

The airliner is 72 times faster than the stagecoach.

18. ***Given***

$d_i = 22\ 647$ km

$d_f = 23\ 209$ km

$\Delta t = 5.0$ h

Required

average speed (v_{ave})

Analysis and Solution

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

$$\begin{aligned} v_{ave} &= \frac{\Delta d}{\Delta t} \\ &= \frac{23\ 209\ \text{km} - 22\ 647\ \text{km}}{5.0\ \text{h}} \\ &= 1.1 \times 10^2\ \text{km/h} \\ &= 1.1 \times 10^2\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\ \text{m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\ \text{s}} \\ &= 31\ \text{m/s} \end{aligned}$$

Paraphrase

The car's average speed was 1.1×10^2 km/h or 31 m/s.

19. ***Given***

Choose downhill to be positive.

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

$\Delta t = 8.00$ s

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

Required

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

acceleration ($\vec{a}$)

Analysis and Solution

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

$$\begin{aligned} \Delta \vec{d} &= \frac{1}{2}(\vec{v}_f + \vec{v}_i)\Delta t \\ \vec{v}_f &= \frac{2\Delta \vec{d}}{\Delta t} - \vec{v}_i \\ &= \frac{2(+90.0\ \text{m})}{8.00\ \text{s}} - 0 \\ &= +22.5\ \text{m/s} \\ &= 22.5\ \text{m/s [downhill]} \end{aligned}$$

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

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

Paraphrase

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

20. ***Given***

Choose north to be positive.

$$\begin{aligned}\Delta t &= 4.0 \text{ s}\\ \Delta\vec{d} &= 30.0 \text{ m [N]} = +30.0 \text{ m}\\ \vec{v}_{\text{i}} &= 5.0 \text{ m/s [N]} = +5.0 \text{ m/s}\end{aligned}$$

Required

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

Analysis and Solution

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

$$\begin{aligned}\Delta\vec{d} &= \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2\\ \vec{a} &= \frac{2\left(\Delta\vec{d} - \vec{v}_{\text{i}}\Delta t\right)}{(\Delta t)^2}\\ &= \frac{2\left[+30.0 \text{ m} - \left(+5.0 \ \frac{\text{m}}{\cancel{\text{s}}}\right)\left(4.0 \ \cancel{\text{s}}\right)\right]}{(4.0 \text{ s})^2}\\ &= +1.25 \text{ m/s}^2\\ &= 1.25 \text{ m/s}^2 \text{ [N]}\end{aligned}$$

Calculate final velocity using $\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$.

$$\begin{aligned}\vec{v}_{\text{f}} &= \vec{v}_{\text{i}} + \vec{a}\Delta t\\ &= +5.0 \ \frac{\text{m}}{\text{s}} + \left(+1.25 \ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)\left(4.0 \ \cancel{\text{s}}\right)\\ &= +10 \text{ m/s}\\ &= 10 \text{ m/s [N]}\end{aligned}$$

Paraphrase

At the second traffic light, the cyclist's acceleration was $1.3 \text{ m/s}^2 \text{ [N]}$ and her final velocity was 10 m/s [N].

21. ***Given***

$v = 0.77$ m/s

$\Delta d = 150$ m

Required

time (Δt)

Analysis and Solution

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

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

Paraphrase

The diver takes 1.9×10^2 s to travel 150 m.

22. ***Given***

Consider south to be positive.

$\vec{v}_\mathrm{i} = 10.0$ m/s [S] $= +10.0$ m/s

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

$\Delta t = 45.0$ s

Required

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

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

acceleration ($\vec{a}$)

Analysis and Solution

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

$$\begin{aligned}\vec{v}_\mathrm{ave} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{+720 \text{ m}}{45.0 \text{ s}} \\ &= +16.0 \text{ m/s} \\ &= 16.0 \text{ m/s [S]}\end{aligned}$$

Use $\Delta \vec{v}_\mathrm{ave} = \dfrac{(\vec{v}_\mathrm{f} + \vec{v}_\mathrm{i})}{2}$ to find final velocity.

$$\begin{aligned}\vec{v}_\mathrm{f} &= 2\Delta \vec{v}_\mathrm{ave} - \vec{v}_\mathrm{i} \\ &= 2(+16.0 \text{ m/s}) - (+10.0 \text{ m/s}) \\ &= +22.0 \text{ m/s} \\ &= 22.0 \text{ m/s [S]}\end{aligned}$$

Use $\vec{a} = \dfrac{\vec{v}_\mathrm{f} - \vec{v}_\mathrm{i}}{\Delta t}$ to find acceleration.

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

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 $0.267 \text{ m/s}^2 \text{ [S]}$.

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 $v = \dfrac{\Delta d}{\Delta t}$.

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

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

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

Paraphrase

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

24. ***Given***

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

$v_{\text{police}_i} = 0 \text{ m/s}$

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

Required
time (Δt)
final speed ($v_{\text{police}_\text{f}}$)
Analysis and Solution
Use the given data to write motion equations for the cars.
equation for car: $y_A = 19.4\Delta t$

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

$$y_B = 1.6\Delta t^2$$

At the point of intersection, time is

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

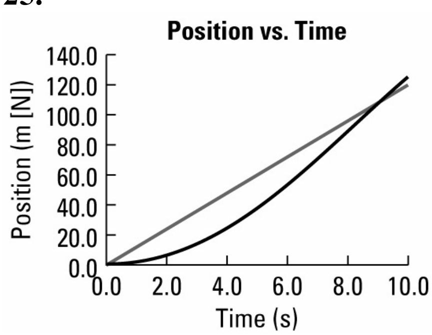
Take the second solution: 12.1 s

Use the equation $a = \frac{v_f - v_i}{\Delta t}$ to find the final speed of the police car.

$$\begin{aligned} a &= \frac{v_f - v_i}{\Delta t} \\ v_f &= v_i + a\Delta t \\ &= 0 + \left(3.2 \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(12.1 \cancel{\text{s}}) \\ &= 39 \text{ m/s} \end{aligned}$$

Paraphrase
It takes the police car 12.1 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.



To find the displacement of each car when car 2 stops accelerating, find the area under the velocity-time graph. After 6.0 s, car 2's displacement is

$$\begin{aligned} \Delta\vec{d} &= \frac{1}{2}(6.0 \cancel{\text{s}})\left(18.0 \frac{\text{m}}{\cancel{\text{s}}} \text{ [N]}\right) \\ &= 54 \text{ m [N]} \end{aligned}$$

After 6.0 s, car 1's displacement is

$$\Delta\vec{d} = (6.0\ \cancel{\text{s}})\left(12.0\ \frac{\text{m}}{\cancel{\text{s}}}\ [\text{N}]\right)$$
$$= 72\text{ m [N]}$$

Let $\Delta t = \text{time} - 6.0\text{ s}$.

equation for car 1: $\Delta d_1 = (12.0\text{ m/s})\Delta t + 72\text{ m}$

equation for car 2: $\Delta d_2 = (18.0\text{ m/s})\Delta t + 54\text{ m}$

At the point of intersection, the time is

$$\begin{aligned}\Delta d_1 &= \Delta d_2 \\ (12.0\text{ m/s})\Delta t + 72\text{ m} &= (18.0\text{ m/s})\Delta t + 54\text{ m} \\ 18\text{ m} &= (6.0\text{ m/s})\Delta t \\ \Delta t &= 3.0\text{ s}\end{aligned}$$

At the point of intersection, the displacement is

$$\begin{aligned}\Delta d_1 &= (12.0\text{ m/s})\Delta t + 72\text{ m} \\ &= (12.0\text{ m/s})(3.0\text{ s}) + 72\text{ m} \\ &= 108\text{ m}\end{aligned}$$

Car 2 passes car 1 at 3.0 s + 6.0 s = 9.0 s. They have travelled 108 m [N].

26. Choose right to be positive.

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

$\vec{a} = 0\text{ m/s}^2$ 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 (Δt)

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.

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

Paraphrase
The fire truck takes 9.03 s to travel 402 m.

28. ***Given***
Consider forward to be positive.

$$\vec{v}_i = 25.0 \text{ m/s [forward]} = +25.0 \text{ m/s}$$

$$\vec{a} = -3.75 \text{ m/s}^2 \text{ [forward]} = -3.75 \text{ m/s}^2$$

$$\Delta\vec{d} = 95.0 \text{ m [forward]} = +95.0 \text{ m}$$

Required
reaction time (Δt)

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

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

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

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

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

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

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.

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

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

Use the equation $v_\text{f}^2 = v_\text{i}^2 + 2a\Delta d$ to calculate the magnitude of acceleration.

$$\begin{aligned} a &= \frac{v_\text{f}^2 - v_\text{i}^2}{2\Delta d} \\ &= \frac{(16.67\ \text{m/s})^2 - (30.56\ \text{m/s})^2}{2(1100\ \text{m})} \\ &= -0.298\ \text{m/s}^2 \end{aligned}$$

Paraphrase

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

30. ***Given***

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

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

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

$\Delta t = 8\ \text{min}$

Required

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

Analysis and Solution

Convert Δt to hours.

$$\Delta t = 8\ \cancel{\text{min}} \times \frac{1\ \text{h}}{60\ \cancel{\text{min}}} = 0.13\ \text{h}$$

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

$$\begin{aligned} \vec{v}_\text{ave} &= \frac{3.2\ \text{km [E]}}{0.13\ \text{h}} \\ &= 25\ \text{km/h [E]} \end{aligned}$$

Paraphrase

The CTrain's average velocity is 25 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 m/s^2 [forward]

The truck is at rest at 0 s and at 10 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 $\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \\ &= \frac{+45.2 \text{ m/s} - (+17.5 \text{ m/s})}{2.47 \text{ s}} \\ &= +11.2 \text{ m/s}^2 \\ &= 11.2 \text{ m/s}^2 \text{ [W]}\end{aligned}$$

Paraphrase and Verify

The racecar's acceleration is 11.2 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.

$\vec{v}_i = 80 \text{ km/h [W]} = +80 \text{ km/h}$

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

$\Delta\vec{d} = 76.0 \text{ m [W]} = +76.0 \text{ m}$

Required

time (Δt)

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.

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

$\vec{a} = 39.24 \text{ m/s}^2 \text{ [up]} = +39.24 \text{ m/s}^2$

$\Delta\vec{d} = 27.0 \text{ m [up]} = +27.0 \text{ m}$

Required
time (Δt)

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.

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

$$\begin{aligned}\Delta t &= \sqrt{\frac{2\Delta d}{a}} \\ &= \sqrt{\frac{2(27.0 \cancel{\text{m}})}{39.24 \frac{\cancel{\text{m}}}{\text{s}^2}}} \\ &= 1.17 \text{ s}\end{aligned}$$

Paraphrase
The Slingshot propels riders up to a height of 27.0 m in 1.17 s.

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

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

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

$\vec{v}_f = 55 \text{ km/h [down]} = +55 \text{ km/h}$

Required
height (Δd)

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

$$\Delta d = \frac{v_f^2 - v_i^2}{2a}$$
$$= \frac{(15.3\text{ m/s})^2 - 0}{2(9.81\text{ m/s}^2)}$$
$$= \frac{233\ \frac{\text{m}^{\cancel{2}}}{\cancel{\text{s}^2}}}{19.6\ \frac{\cancel{\text{m}}}{\cancel{\text{s}^2}}}$$
$$= 11.9\text{ m}$$

Paraphrase

The diver started from a height of 11.9 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

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

Required

height (Δd)

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 a performer can fall is 9.29 m.

37. ***Given***

Choose down to be positive.

$\Delta\vec{d} = 8.52$ m [down] $= +8.52$ m

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

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

Required

time (Δt)

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 (Δd)

final speed (v_f)

Analysis and Solution

Since the weathervane falls from rest, initial velocity is zero. Use the equation $\Delta\vec{d} = \vec{v}_i\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$ to find the height.

$$\Delta\vec{d} = 0 + \frac{1}{2}\left(+9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.76\ \text{s})^2$$

$$= +15.2\ \text{m}$$

$$= 15.2\ \text{m [down]}$$

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

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

$$= 0\ \text{m/s} + \left(+9.81\ \frac{\text{m}}{\text{s}^{\cancel{2}}}\right)(1.76\ \cancel{\text{s}})$$

$$= +17.3\ \text{m/s}$$

$$= 17.3\ \text{m/s [down]}$$

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.

$$\Delta\vec{d} = 24.91 \text{ m [down]} - 5.0 \text{ m [down]}$$
$$= 19.91 \text{ m [down]}$$
$$= +19.91 \text{ m}$$
$$\vec{v}_{\text{i}} = 0 \text{ m/s}$$
$$\vec{a} = 9.81 \text{ m/s}^2 \text{ [down]} = +9.81 \text{ m/s}^2$$

Required

final speed (v_{f})

time (Δt)

Analysis and Solution

Use the equation $v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$ to find final speed.

$$v_{\text{f}} = \sqrt{v_{\text{i}}^2 + 2a\Delta d}$$
$$= \sqrt{0 + 2\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(19.91 \text{ m})}$$
$$= 19.76 \text{ m/s}$$

Use the equation $\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$ to find the time interval. Use the scalar form of the equation because you are dividing by a vector.

$$\Delta t = \frac{v_{\text{f}} - v_{\text{i}}}{a}$$
$$= \frac{19.76 \text{ m/s} - 0}{9.81 \text{ m/s}^2}$$
$$= 2.0 \text{ s}$$

Paraphrase

The Lego piece will take 2.0 s to fall 19.91 m and be travelling with a speed of 20 m/s before impact.

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.

