Pearson Physics Level 20
Unit I Kinematics: Unit I Review
Solutions

Student Book pages 118–121

Vocabulary

1. **acceleration:** a vector quantity representing the change in velocity (magnitude and/or direction) per unit time
   acceleration due to gravity: downward acceleration experienced by objects near Earth's surface; 9.81 m/s^2 [down]
   air velocity: an object's velocity relative to still air
   at rest: not moving, stationary
   Cartesian method: a direction convention where the positive *x*-axis is at 0^o and angles are measured by moving counter-clockwise about the origin
   collinear: along the same straight line, either in the same or in opposite directions
   components: perpendicular parts into which a vector can be separated
   displacement: a vector quantity representing change in position
   distance: a scalar quantity representing the path taken to travel between two points
   ground velocity: velocity relative to an observer on the ground
   instantaneous velocity: an object's velocity at a moment in time
   kinematics: branch of mechanics that describes motion
   navigator method: a direction convention where 0^o can be north, south, east, or west, and the angle, between 0^o and 90^o, is between two adjacent cardinal directions, e.g., north of east or west of south
   non-collinear: not along a straight line
   non-uniform motion: accelerated motion; change in velocity
   origin: a reference point
   position: a vector quantity representing an object's location relative to a reference point
   projectile: an object thrown into the air
   projectile motion: motion in a vertical plane
   range: the distance a projectile travels horizontally over level ground
   relative motion: motion measured with respect to an observer
   resultant vector: a vector drawn from the tail of the first vector to the tip of the last vector
   scalar quantity: a measurement that has magnitude only
   tangent: a straight line that touches a curved-line graph at only one point
   trajectory: the parabolic motion of a projectile
   uniform motion: constant velocity (motion or rest)
   uniformly accelerated motion: constant change in velocity per unit time
   vector quantity: a measurement that has both magnitude and direction
   velocity: a vector quantity representing displacement divided by time elapsed
   wind velocity: velocity of the wind relative to the ground

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Knowledge

Chapter 1

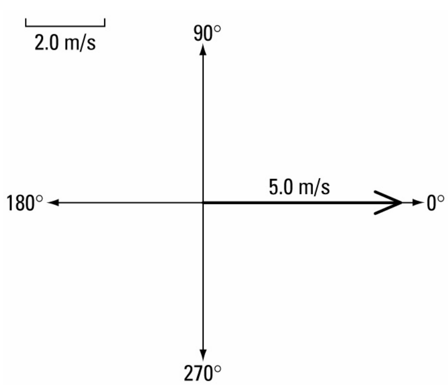
2. Scalar quantities remain constant regardless of where they are measured and contain magnitude only. Vector quantities have magnitude and direction and can change depending on their location or reference point from which they are measured.

Chapter 2

3. (a) $d_x = (5.0 \text{ m})(\cos 90°)$
$= 0 \text{ m}$
$d_y = (5.0 \text{ m})(\sin 90°)$
$= 5.0 \text{ m}$

(b) $v_x = (16.0 \text{ m/s})(\cos 20°)$
$= 15.0 \text{ m/s}$
$v_y = (16.0 \text{ m/s})(\sin 20°)$
$= 5.47 \text{ m/s}$

4. (a)



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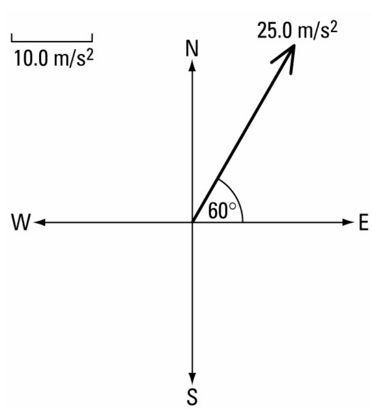

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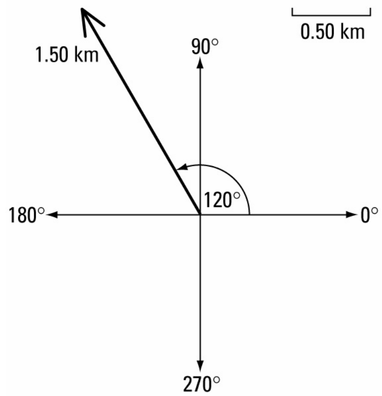


5. vector measures 2.8 cm, at a 30° angle
$\therefore \vec{R}$ = 9.8 km [30° S of E]

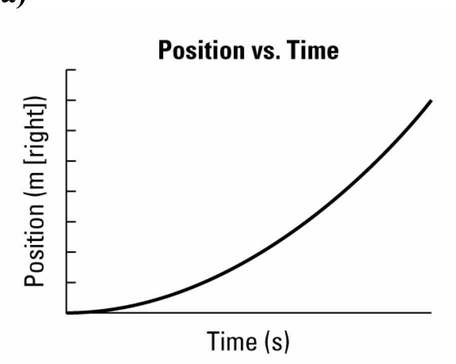
Applications

6. $\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$

$= \frac{27.0 \text{ m [W]}}{10.0 \text{ s}}$

$= 2.70 \text{ m/s [W]}$

7. (a)



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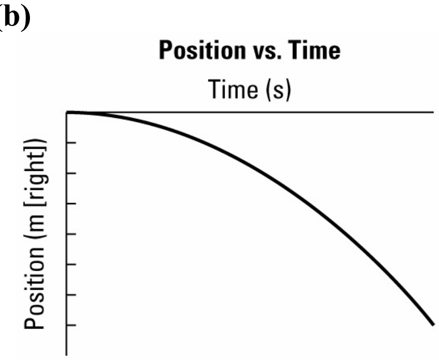

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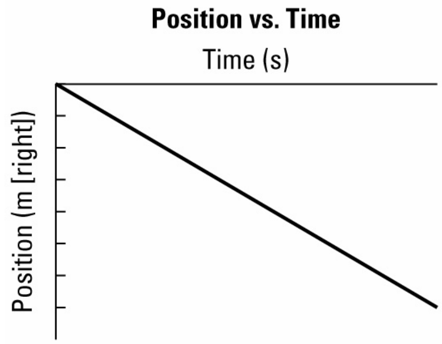

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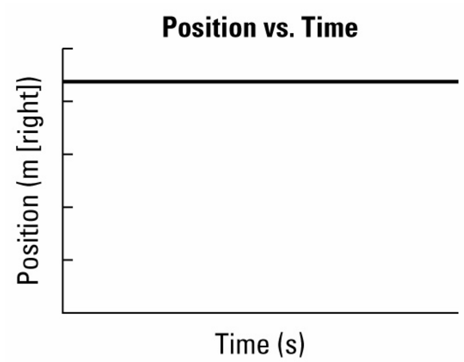

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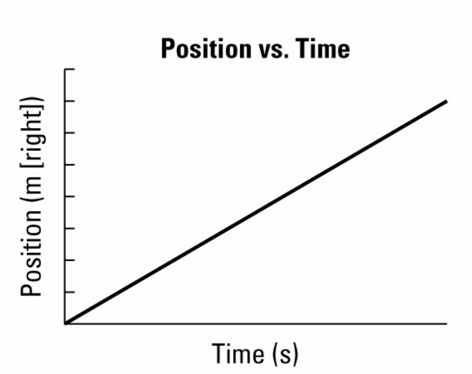

8. ***Given***

$\vec{v} = 107$ km/h [30°]

Required

time (Δt)

range (Δd_x)

maximum height (Δd_y)

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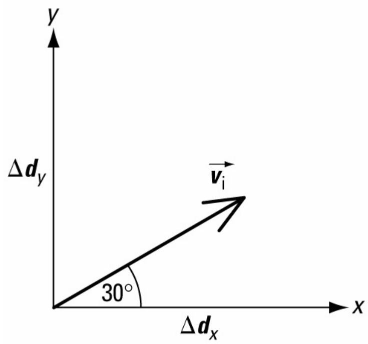
Analysis and Solution



Choose up and forward to be positive.
First convert km/h to m/s.

$$107\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\text{ s}} = 29.72\text{ m/s}$$

Then find the components of the puck's velocity.

$$\begin{aligned} v_x &= (29.72\text{ m/s})(\cos 30°) \\ &= 25.74\text{ m/s} \end{aligned}$$

$$\begin{aligned} v_y &= (29.72\text{ m/s})(\sin 30°) \\ &= 14.86\text{ m/s} \end{aligned}$$

Use the equation $a = \frac{v_f - v_i}{\Delta t}$ to find the time interval.

$$a_y = \frac{v_{f_y} - v_{i_y}}{\Delta t}$$

$$\begin{aligned} \Delta t &= \frac{v_{f_y} - v_{i_y}}{a_y} \\ &= \frac{-14.86\text{ m/s} - (14.86\text{ m/s})}{-9.81\text{ m/s}^2} \\ &= \frac{-29.72\ \frac{\cancel{\text{m}}}{\cancel{\text{s}}}}{-9.81\ \frac{\cancel{\text{m}}}{\text{s}^{\cancel{2}}}} \\ &= 3.03\text{ s} \end{aligned}$$

Substitute into the uniform motion equation to find the range.

$$\begin{aligned} \Delta d_x &= v_x \Delta t \\ &= \left(25.74\ \frac{\text{m}}{\cancel{\text{s}}}\right)(3.03\ \cancel{\text{s}}) \\ &= 78\text{ m} \end{aligned}$$

To find maximum height, use the equation $\Delta d_y = v_{i_y}\Delta t + \frac{1}{2}a_y(\Delta t)^2$, where v_{i_y} at maximum height equals zero. Substitute one-half of the time interval.

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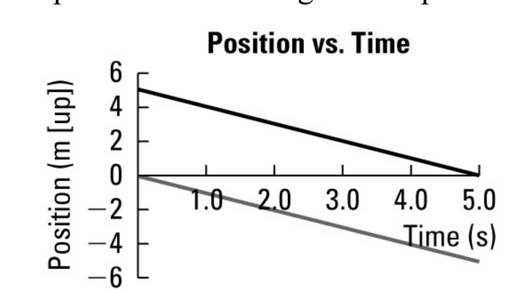
$$\Delta d_y = v_{i_y}\Delta t + \frac{1}{2}a_y(\Delta t)^2$$
$$= 0 + \frac{1}{2}\left(-9.81\ \frac{\text{m}}{\text{s}^2}\right)\left(\frac{3.03}{2}\ \text{s}\right)^2$$
$$= -11\ \text{m}$$

Since up and forward are positive, the negative sign means that motion is downward.

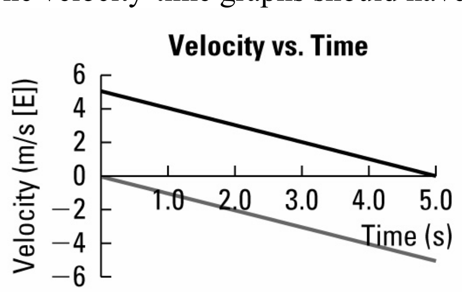
Paraphrase

The hockey puck will remain airborne for 3.0 s, travel 78 m horizontally, and reach a maximum height of 11 m.

9. Graphs should have negative slope.



10. The velocity-time graphs should have a negative slope.



11. Object A has the steepest slope and, therefore, the greatest velocity.

12. (a)

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

(b)

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

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(c)

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

$$\vec{v}_\text{i} + \vec{v}_\text{f} = \frac{2\Delta\vec{d}}{\Delta t}$$

$$\vec{v}_\text{i} = \frac{2\Delta\vec{d}}{\Delta t} - \vec{v}_\text{f}$$

13. ***Given***

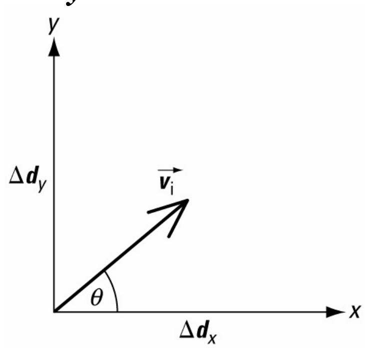
$\Delta d_x = 83.2\text{ m}$

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

Required

initial speed (v_i)

Analysis and Solution



Choose up and forward to be positive.

First, determine horizontal velocity using the equation $\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$.

$$\begin{aligned} v_x &= \frac{\Delta d_x}{\Delta t} \\ &= \frac{83.2\text{ m}}{5.0\text{ s}} \\ &= 16.6\text{ m/s} \end{aligned}$$

Use the equation $\vec{a} = \frac{\vec{v}_\text{f} - \vec{v}_\text{i}}{\Delta t}$ to calculate initial vertical velocity, where v_{f_y} at maximum height equals zero and the time is half the time the football is in the air.

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

$$\begin{aligned} v_{\text{i}_y} &= v_{\text{f}_y} - a_y\Delta t \\ &= 0 - \left(-9.81\ \frac{\text{m}}{\text{s}^{\not 2}}\right)\left(\frac{5.0}{2}\ \not\text{s}\right) \\ &= 24.5\text{ m/s} \end{aligned}$$

Use the Pythagorean theorem to determine initial speed.

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$$v_i = \sqrt{(v_x)^2 + (v_{i_y})^2}$$
$$= \sqrt{(16.6 \text{ m/s})^2 + (24.5 \text{ m/s})^2}$$
$$= 30 \text{ m/s}$$

Paraphrase

The football's initial speed is 30 m/s.

14. ***Given***

$\Delta d = 48 \text{ km}$

$$\Delta t = 90 \text{ min} \times \frac{1 \text{ h}}{60 \text{ min}} = 1.5 \text{ h}$$

Required

speed (v)

Analysis and Solution

$$v = \frac{\Delta d}{\Delta t}$$
$$= \frac{48 \text{ km}}{1.5 \text{ h}}$$
$$= 32 \text{ km/h}$$

Paraphrase

The raven's speed is 32 km/h.

15. The object accelerates from rest to a velocity of 8.0 m/s [E] in 4.0 s, maintains a constant velocity for 2.0 s, and then accelerates to a complete stop at 8.0 s.

16. (a) $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

$$\Delta \vec{v} = \vec{a}\Delta t$$
$$= \left(3.0 \ \frac{\text{m}}{\text{s}^{\not{2}}} \ [90°]\right)(10.0 \ \not{\text{s}})$$
$$= 30 \text{ m/s } [90°]$$

(b) $\Delta \vec{v} = \vec{v}_f - \vec{v}_i$

$$\vec{v}_f = \vec{v}_i + \Delta \vec{v}$$
$$= 10 \text{ m/s } [90°] + 30 \text{ m/s } [90°]$$
$$= 40 \text{ m/s } [90°]$$

17. ***Given***

$v = 13.4$ m/s

$$\Delta t = 15.0 \ \not{\text{min}} \times \frac{60 \text{ s}}{1 \ \not{\text{min}}} = 900 \text{ s}$$

Required

distance (Δd)

Analysis and Solution

$$\Delta d = v\Delta t$$
$$= \left(13.4 \ \frac{\text{m}}{\not{\text{s}}}\right)(900 \ \not{\text{s}})$$
$$= 12060 \text{ m}$$
$$= 12.1 \text{ km}$$

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Paraphrase

The crow can fly 12.1 km in 15.0 min.

18. If the measured displacement is 0.8 cm, the displacement from Valleyview to Grande Prairie is $0.8 \not{\text{cm}} \times \frac{118 \text{ km}}{1 \not{\text{cm}}} = 94.4 \text{ km}$.

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

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

$$= \frac{94.4 \not{\text{km}}}{100 \frac{\not{\text{km}}}{\text{h}}}$$

$$= 0.944 \text{ h}$$

It will take the car 0.944 h to travel from Valleyview to Grande Prairie.

19. ***Given***

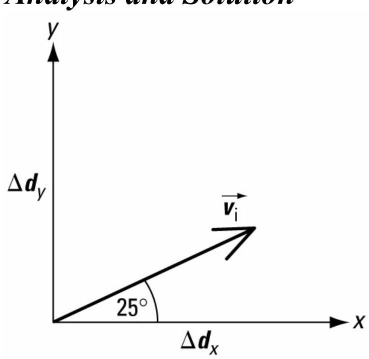
$$\vec{v} = 30 \text{ m/s } [25°]$$

$$d_{\text{i}_{\text{outfielder}}} = 85.0 \text{ m}$$

Required

outfielder's speed ($v_{\text{outfielder}}$)

Analysis and Solution



Choose up and forward to be positive.

$$v_x = (30 \text{ m/s})(\cos 25°)$$

$$= 27.2 \text{ m/s}$$

$$v_y = (30 \text{ m/s})(\sin 25°)$$

$$= 12.7 \text{ m/s}$$

Calculate the time the ball is in the air.

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

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

$$= \frac{-12.7 \text{ m/s} - (12.7 \text{ m/s})}{-9.81 \text{ m/s}^2}$$

$$= 2.59 \text{ s}$$

Calculate how far the ball will travel horizontally.

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$$\Delta d_x = v_x \Delta t$$
$$= \left(27.2\ \frac{\text{m}}{\cancel{\text{s}}}\right)(2.59\ \cancel{\text{s}})$$
$$= 70.4\ \text{m}$$

Subtract this distance from the distance of the outfielder to determine how far the outfielder must run to catch the ball.

$$\Delta d_{\text{outfielder}} = 85.0\ \text{m} - 70.4\ \text{m}$$
$$= 14.6\ \text{m}$$

Divide the distance the outfielder must cover by the amount of time the ball is in the air to determine the outfielder's speed.

$$v_{\text{outfielder}} = \frac{\Delta d_{\text{outfielder}}}{\Delta t}$$
$$= \frac{14.6\ \text{m}}{2.59\ \text{s}}$$
$$= 5.6\ \text{m/s}$$

Paraphrase

The outfielder must run with a speed of 5.6 m/s to catch the ball.

20. ***Given***

$\Delta d = 51.51\ \text{m}$

$v_{\text{i}} = 113\ \text{km/h}$

$v_{\text{f}} = 0$

Required

magnitude of acceleration (a)

Analysis and Solution

Convert speed from km/h to m/s. Since the final speed is zero and the distance is known, use the equation $v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$.

$$113\ \frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}} = 31.39\ \text{m/s}$$

$$v_{\text{f}}^2 = v_{\text{i}}^2 + 2a\Delta d$$
$$a = \frac{v_{\text{f}}^2 - v_{\text{i}}^2}{2\Delta d}$$
$$= \frac{0 - (31.39\ \text{m/s})^2}{2(51.51\ \text{m})}$$
$$= -9.56\ \text{m/s}^2$$

The negative sign means that the jeep is slowing down.

Paraphrase

The magnitude of the jeep's acceleration is 9.56 m/s^2.

21. ***Given***

$\vec{v}_{\text{air}} = 785\ \text{km/h [S]}$

$\vec{v}_{\text{wind}} = 55\ \text{km/h [22° S of W]}$

Required

ground velocity ($\vec{v}_{\text{ground}}$)

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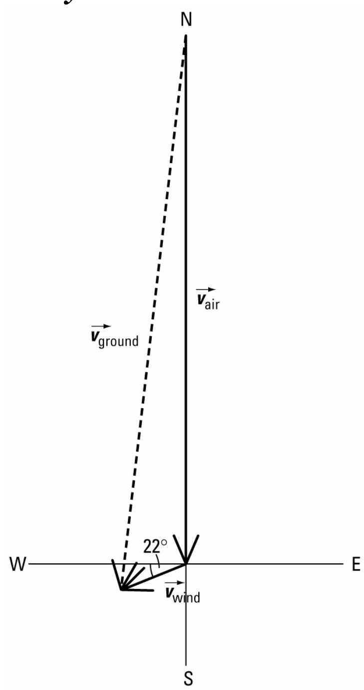
Analysis and Solution



Resolve wind velocity into its *x* and *y* components.

$$
\begin{aligned}
v_{\text{wind}_x} &= -v_{\text{wind}} \cos\theta \\
&= -(55 \text{ km/h})(\cos 22°) \\
&= -51.0 \text{ km/h} \\
v_{\text{wind}_y} &= -v_{\text{wind}} \sin\theta \\
&= -(55 \text{ km/h})(\sin 22°) \\
&= -20.6 \text{ km/h} \\
v_{\text{air}_x} &= 0 \\
v_{\text{air}_y} &= -785 \text{ km/h}
\end{aligned}
$$

Perform vector addition and then use tangent function to determine the direction.

$$
\begin{aligned}
\vec{v}_{\text{ground}} &= \vec{v}_{\text{air}} + \vec{v}_{\text{wind}} \\
v_{\text{ground}_x} &= v_{\text{air}_x} + v_{\text{wind}_x} \\
&= 0 + (-51.0 \text{ km/h}) \\
&= -51.0 \text{ km/h} \\
v_{\text{ground}_y} &= v_{\text{air}_y} + v_{\text{wind}_y} \\
&= -785 \text{ km/h} + (-20.6 \text{ km/h}) \\
&= -805.6 \text{ km/h} \\
v_{\text{ground}} &= \sqrt{\left(v_{\text{ground}_x}\right)^2 + \left(v_{\text{ground}_y}\right)^2} \\
&= \sqrt{(-51.0 \text{ km/h})^2 + (-805.6 \text{ km/h})^2} \\
&= 8.1 \times 10^2 \text{ km/h}
\end{aligned}
$$

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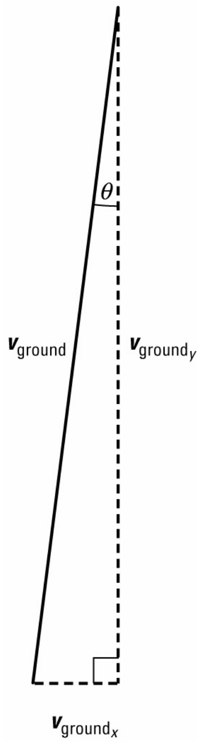

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$
$$= \frac{51.0\ \cancel{\text{km/h}}}{805.6\ \cancel{\text{km/h}}}$$
$$= 0.0633$$
$$\theta = \tan^{-1}(0.0633)$$
$$= 3.6°$$

From the diagram, this angle is 3.6° W of S.

Paraphrase

The aircraft has a ground velocity of 8.1×10^2 km/h [3.6° W of S].

22. ***Given***

$v_i = 11.0$ m/s

$\Delta d = 350$ m

$\Delta t = 3.00$ s

Required

magnitude of acceleration (a)

Analysis and Solution

Since initial velocity and time are known, use the equation $\Delta d = v_i \Delta t + \frac{1}{2}a(\Delta t)^2$.

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

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

$$= \frac{2\left[350 \text{ m} - \left(11.0 \ \frac{\text{m}}{\cancel{\text{s}}}\right)(3.00 \ \cancel{\text{s}})\right]}{(3.00 \text{ s})^2}$$

$$= 70.4 \text{ m/s}^2$$

Paraphrase

The magnitude of the object's acceleration is 70.4 m/s^2.

23. ***Given***

$\Delta d_y = 24 \text{ m}$

Required

time (Δt)

Analysis and Solution

Choose down to be positive. Use the equation $\Delta d_y = v_{i_y} \Delta t + \frac{1}{2} a_y (\Delta t)^2$, where $v_{i_y} = 0$.

$$\Delta d_y = v_{i_y} \Delta t + \frac{1}{2} a_y (\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$

$$= \sqrt{\frac{2(24 \ \cancel{\text{m}})}{9.81 \ \frac{\cancel{\text{m}}}{\text{s}^2}}}$$

$$= 2.2 \text{ s}$$

Paraphrase

The pedestrian has 2.2 s to get out of the way.

24. ***Given***

$\vec{v}_i = 15 \text{ m/s } [32°]$

$\Delta d_y = 65.0 \text{ m}$

Required

range (Δd_x)

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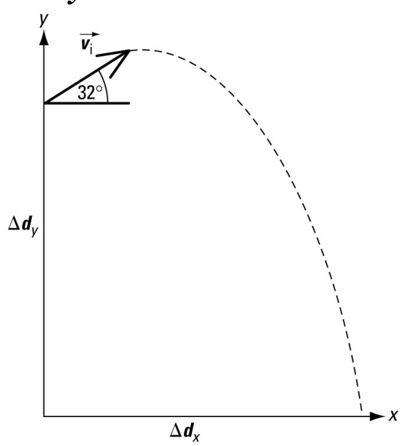
Analysis and Solution



Choose up and forward to be positive. Find the components of the initial velocity.

$$v_{i_x} = (15 \text{ m/s})(\cos 32°)$$
$$= 12.7 \text{ m/s}$$
$$v_{i_y} = (15 \text{ m/s})(\sin 32°)$$
$$= 7.95 \text{ m/s}$$

Solve for the time going up and then down separately, where v_y = 0 at maximum height.

For time going up, use the equation $\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$.

$$a_y = \frac{v_{f_y} - v_{i_y}}{\Delta t}$$
$$\Delta t = \frac{v_{f_y} - v_{i_y}}{a_y}$$
$$= \frac{0 - 7.95 \text{ m/s}}{-9.81 \text{ m/s}^2}$$
$$= 0.810 \text{ s}$$

Solve for maximum height with respect to the top of the building using the equation $v_f^2 = v_i^2 + 2a\Delta d$.

$$\Delta d_y = \frac{v_{f_y}^{\,2} - v_{i_y}^{\,2}}{2a_y}$$
$$= \frac{0 - (7.95 \text{ m/s})^2}{2(-9.81 \text{ m/s}^2)}$$
$$= 3.22 \text{ m}$$

Since the building is 65.0 m high, the object falls a total distance of
Δd_y = 3.22 m + 65.0 m = 68.22 m

Solve for time to fall all the way to the ground using the equation
$\Delta d_y = v_{i_y}\Delta t + \frac{1}{2}a_y(\Delta t)^2$. From maximum height, v_{i_y} = 0.

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$$\Delta d_y = \frac{1}{2}a_y(\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2\Delta d_y}{a_y}}$$

$$= \sqrt{\frac{2(-68.22\text{ m})}{-9.81\text{ m/s}^2}}$$

$$= 3.73\text{ s}$$

Add the two times together to find the total time in the air.

$$\Delta t = 0.810\text{ s} + 3.73\text{ s}$$

$$= 4.54\text{ s}$$

Then solve for the range.

$$\Delta d_x = v_x \Delta t$$

$$= \left(12.7\ \frac{\text{m}}{\cancel{\text{s}}}\right)(4.54\ \cancel{\text{s}})$$

$$= 58\text{ m}$$

Paraphrase

The object lands 58 m from the base of the building.

25. (a) The friend on the travelator moves at a speed of 4.0 km/h + 3.0 km/h = 7.0 km/h. Convert km/h to m/s.

$$7.0\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\text{ s}} = 1.94\text{ m/s}$$

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

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

$$= \frac{100\ \cancel{\text{m}}}{1.94\ \frac{\cancel{\text{m}}}{\text{s}}}$$

$$= 51.5\text{ s}$$

It will take 52 s to reach the end of the travelator.

(b) ***Given***

$$v_{\text{i}} = 4.0\ \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1000\text{ m}}{1\ \cancel{\text{km}}} \times \frac{1\ \cancel{\text{h}}}{3600\text{ s}} = 1.11\text{ m/s}$$

$$\Delta d = 100\text{ m}$$

$$\Delta t = 51.5\text{ s}$$

Required

magnitude of acceleration (a)

Analysis and Solution

The pedestrian who's not on the travelator has the same amount of time to cover the same distance.

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

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

$$= \frac{2\left[100\ \text{m} - \left(1.11\ \frac{\text{m}}{\not{\text{s}}}\right)(51.5\ \not{\text{s}})\right]}{(51.5\ \text{s})^2}$$

$$= 0.032\ \text{m/s}^2$$

Paraphrase

The pedestrian must have an acceleration of magnitude 0.032 m/s^2 to keep up with his friend.

26. ***Given***

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

$\vec{v}_\text{i} = 2.50$ m/s [forward]

$\vec{v}_\text{f} = 7.75$ m/s [forward]

Required

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

Analysis and Solution

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

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

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

$$= \frac{(7.75\ \text{m/s})^2 - (2.50\ \text{m/s})^2}{2(2.00\ \text{m/s}^2)}$$

$$= 13.5\ \text{m}$$

Paraphrase

The vehicle travelled a displacement of 13.5 m [forward].

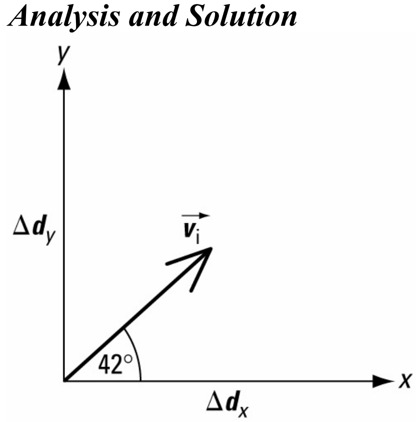
27. ***Given***

$\vec{v} = 25.0$ m/s [42°]

Required

range (Δd_x)

Analysis and Solution



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Choose up and forward to be positive.
Resolve the velocity vector into its x and y components.

$$v_x = (25.0 \text{ m/s})(\cos 42°)$$
$$= 18.6 \text{ m/s}$$
$$v_y = (25.0 \text{ m/s})(\sin 42°)$$
$$= 16.7 \text{ m/s}$$

Determine how long the object is in the air using the equation $a = \frac{v_f - v_i}{\Delta t}$.

$$a_y = \frac{v_{f_y} - v_{i_y}}{\Delta t}$$
$$\Delta t = \frac{v_{f_y} - v_{i_y}}{a_y}$$
$$= \frac{-16.7 \text{ m/s} - (16.7 \text{ m/s})}{-9.81 \text{ m/s}^2}$$
$$= 3.40 \text{ s}$$

To determine how far it will travel horizontally, use the equation $\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$.

$$\Delta d_x = v_x \Delta t$$
$$= \left(18.6 \frac{\text{m}}{\cancel{\text{s}}}\right)(3.40 \cancel{\text{s}})$$
$$= 63 \text{ m}$$

Paraphrase

The object will travel 63 m horizontally.

28. ***Given***

$$\vec{v}_1 = 110 \text{ km/h [W]}$$
$$\Delta t_1 = 80 \cancel{\text{min}} \times \frac{1 \text{ h}}{60 \cancel{\text{min}}} = 1.33 \text{ h}$$
$$\vec{v}_2 = 90 \text{ km/h [W]}$$
$$\Delta t_2 = 100 \cancel{\text{min}} \times \frac{1 \text{ h}}{60 \cancel{\text{min}}} = 1.67 \text{ h}$$

Required

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

Analysis and Solution

Find the displacement travelled at each velocity and then divide by the total time.

$$\vec{v}_{\text{ave}} = \frac{\Delta \vec{d}_1 + \Delta \vec{d}_2}{\Delta t_1 + \Delta t_2}$$
$$= \frac{\vec{v}_1 \Delta t_1 + \vec{v}_2 \Delta t_2}{\Delta t_1 + \Delta t_2}$$
$$= \frac{\left(110 \frac{\text{km}}{\cancel{\text{h}}} \text{ [W]}\right)(1.33 \cancel{\text{h}}) + \left(90 \frac{\text{km}}{\cancel{\text{h}}} \text{ [W]}\right)(1.67 \cancel{\text{h}})}{1.33 \text{ h} + 1.67 \text{ h}}$$
$$= 99 \text{ km/h [W]}$$

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Paraphrase

The average velocity of the truck was 99 km/h [W].

29. ***Given***

$\vec{v}_i = 15.0 \text{ m/s [S]}$

$\vec{v}_f = 35.0 \text{ m/s [S]}$

$\Delta t = 6.0 \text{ s}$

Required

distance (Δd)

Analysis and Solution

Since the object accelerates uniformly, use the equation $\Delta d = \frac{1}{2}(v_f + v_i)\Delta t$.

Since the directions of the velocity vectors are the same and you are asked to find a scalar quantity, directions may be omitted from the calculation.

$$\begin{aligned}\Delta d &= \frac{1}{2}(v_f + v_i)\Delta t \\ &= \frac{1}{2}(35.0 \text{ m/s} + 15.0 \text{ m/s})(6.0 \text{ s}) \\ &= \left(25 \frac{\text{m}}{\cancel{\text{s}}}\right)(6.0 \cancel{\text{s}}) \\ &= 150 \text{ m}\end{aligned}$$

Paraphrase

The vehicle travels 1.5×10^2 m.

30.
$$\begin{aligned}m_{t=5.0 \text{ s}} &= \frac{\Delta y}{\Delta x} \\ \vec{v} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{10.0 \text{ m [210°]} - 0.0 \text{ m}}{10.0 \text{ s} - 2.0 \text{ s}} \\ &= \frac{10.0 \text{ m [210°]}}{8.0 \text{ s}} \\ &= 1.2 \text{ m/s [210°]}\end{aligned}$$

$$\begin{aligned}m_{t=10.0 \text{ s}} &= \frac{\Delta y}{\Delta x} \\ \vec{v} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{40.0 \text{ m [210°]} - 0.0 \text{ m}}{15.0 \text{ s} - 6.0 \text{ s}} \\ &= \frac{40.0 \text{ m [210°]}}{9.0 \text{ s}} \\ &= 4.4 \text{ m/s [210°]}\end{aligned}$$

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$$m_{t=15.0\text{ s}} = \frac{\Delta y}{\Delta x}$$

$$\begin{aligned}\vec{v} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{60.0\text{ m [210°]} - 40.0\text{ m [210°]}}{16.0\text{ s} - 13.0\text{ s}} \\ &= \frac{20.0\text{ m [210°]}}{3.0\text{ s}} \\ &= 6.7\text{ m/s [210°]}\end{aligned}$$

31. ***Given***

$\vec{v}_{\text{boat}} = 215$ km/h [N]

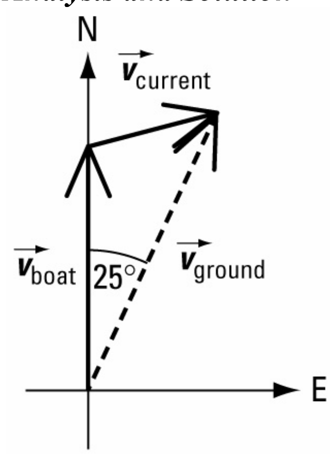
$\Delta \vec{d} = 877$ km [25° E of N]

$\Delta t = 3.5$ h

Required

current's velocity ($\vec{v}_{\text{current}}$)

Analysis and Solution



Calculate the boat's ground velocity.

$$\begin{aligned}\vec{v}_{\text{ground}} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{877\text{ km [25° E of N]}}{3.5\text{ h}} \\ &= 250.6\text{ km/h [25° E of N]}\end{aligned}$$

Resolve the ground velocity into its *x* and *y* components.

$$\begin{aligned}v_{\text{ground}_x} &= v_{\text{ground}} \sin\theta \\ &= (250.6\text{ km/h})(\sin 25°) \\ &= 105.9\text{ km/h}\end{aligned}$$

$$\begin{aligned}v_{\text{ground}_y} &= v_{\text{ground}} \cos\theta \\ &= (250.6\text{ km/h})(\cos 25°) \\ &= 227.1\text{ km/h}\end{aligned}$$

$$v_{\text{boat}_x} = 0$$

$$v_{\text{boat}_y} = 215\text{ km/h}$$

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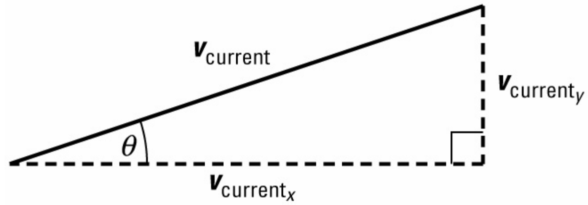
Use trigonometry and the Pythagorean theorem to solve for the current's velocity.



$$\vec{v}_{\text{ground}} = \vec{v}_{\text{boat}} + \vec{v}_{\text{current}}$$

$$\vec{v}_{\text{current}} = \vec{v}_{\text{ground}} - \vec{v}_{\text{boat}}$$

$$\begin{aligned} v_{\text{current}_x} &= v_{\text{ground}_x} - v_{\text{boat}_x} \\ &= 105.9 \text{ km/h} - 0 \\ &= 105.9 \text{ km/h} \end{aligned}$$

$$\begin{aligned} v_{\text{current}_y} &= v_{\text{ground}_y} - v_{\text{boat}_y} \\ &= 227.1 \text{ km/h} - 215 \text{ km/h} \\ &= 12.1 \text{ km/h} \end{aligned}$$

$$\begin{aligned} v_{\text{current}} &= \sqrt{\left(v_{\text{current}_x}\right)^2 + \left(v_{\text{current}_y}\right)^2} \\ &= \sqrt{(105.9 \text{ km/h})^2 + (12.1 \text{ km/h})^2} \\ &= 1.1 \times 10^2 \text{ km/h} \end{aligned}$$

$$\begin{aligned} \tan\theta &= \frac{\text{opposite}}{\text{adjacent}} \\ &= \frac{12.1 \ \cancel{\text{km/h}}}{105.9 \ \cancel{\text{km/h}}} \\ &= 0.114 \\ \theta &= \tan^{-1}(0.114) \\ &= 6.5° \end{aligned}$$

From the diagram, the direction is [6.5° N of E].

Paraphrase

The current's velocity is 1.1×10^2 km/h [6.5° N of E].

32. ***Given***

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

$\Delta d = 50.0$ m

$\Delta t = 2.75$ s

Required

magnitude of acceleration (a)

Analysis and Solution

Since the object starts from rest, initial velocity is zero. Use the equation $\Delta d = v_{\text{i}}\Delta t + \frac{1}{2}a\left(\Delta t\right)^2$.

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$$\Delta d = 0 + \frac{1}{2}a(\Delta t)^2$$

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

$$= \frac{2(50.0 \text{ m})}{(2.75 \text{ s})^2}$$

$$= 13.2 \text{ m/s}^2$$

Paraphrase

The magnitude of the object's acceleration is 13.2 m/s^2.

33. $30.0 \frac{\cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{1 \cancel{\text{h}}}{3600 \text{ s}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} = 8.33 \text{ m/s}$

$\Delta\vec{d}$ = area under velocity-time graph

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

$$= \frac{1}{2}\left(8.33 \frac{\text{m}}{\cancel{\text{s}}} [\text{N}]\right)(30.0 \cancel{\text{s}})$$

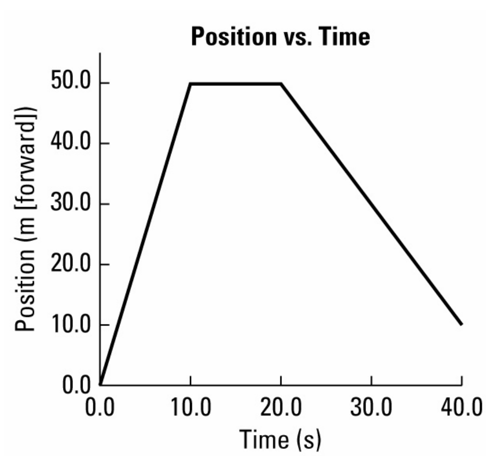
$$+ \left(8.33 \frac{\text{m}}{\cancel{\text{s}}} [\text{N}]\right)(60.0 \cancel{\text{s}} - 30.0 \cancel{\text{s}})$$

$$= 125 \text{ m [N]} + 250 \text{ m [N]}$$

$$= 375 \text{ m [N]}$$

The blue jay travels 375 m [N] in 60.0 s.

34.



35. ***Given***

$\vec{v} = 18.0 \text{ m/s } [20°]$

Required

height (Δd_y)

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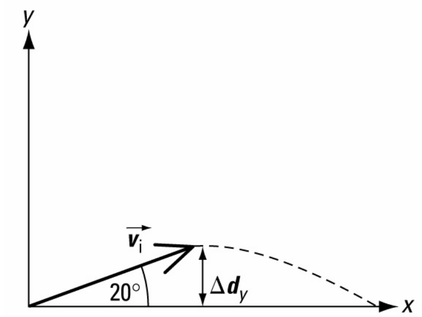
Analysis and Solution



Choose up and forward to be positive.
Determine the vertical component of the projectile's velocity.

$$\begin{aligned} v_y &= v \sin\theta \\ &= (18.0 \text{ m/s})(\sin 20°) \\ &= 6.156 \text{ m/s} \end{aligned}$$

To solve for maximum height, use the equation $v_f^2 = v_i^2 + 2a\Delta d$, where v_f at maximum height equals zero.

$$v_{f_y}{}^2 = v_{i_y}{}^2 + 2a_y\Delta d_y$$

$$\begin{aligned} \Delta d_y &= \frac{v_{f_y}{}^2 - v_{i_y}{}^2}{2a_y} \\ &= \frac{0 - (6.156 \text{ m/s})^2}{2(-9.81 \text{ m/s}^2)} \\ &= 1.9 \text{ m} \end{aligned}$$

Paraphrase

The projectile reaches a height of 1.9 m.

36. (a) $\Delta d^2 = d_1^2 + d_2^2$

$$\begin{aligned} \Delta d &= \sqrt{(500 \text{ m})^2 + (500 \text{ m})^2} \\ &= 707 \text{ m} \end{aligned}$$

$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{500}{500}\right) \\ &= 45° \end{aligned}$$

Becky's position is 707 m [45°].

(b) Becky must walk 3 blocks and a bit to get to school—500 m + 500 m + 500 m +100 m = 1600 m.

37. ***Given***

$\Delta t = 15 \cancel{\text{min}} \times \frac{60 \text{ s}}{1 \cancel{\text{min}}} = 900 \text{ s}$

$\vec{d}_i = 350 \text{ m [N]}$

$\vec{d}_f = 1.75 \cancel{\text{km}} \text{ [N]} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} = 1.75 \times 10^3 \text{ m [N]}$

Required

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

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Analysis and Solution

Average velocity equals total displacement divided by total time.

$$\Delta\vec{d} = \vec{d}_f - \vec{d}_i$$
$$= 1.75 \times 10^3 \text{ m [N]} - 350 \text{ m [N]}$$
$$= 1400 \text{ m [N]}$$

$$\vec{v}_{ave} = \frac{\Delta\vec{d}}{\Delta t}$$
$$= \frac{1400 \text{ m [N]}}{900 \text{ s}}$$
$$= 1.56 \text{ m/s [N]}$$

Paraphrase

The wildlife biologist's average velocity is 1.56 m/s [N].

38. *Given*

$\vec{d}_1 = 500$ m [N]

$\vec{d}_2 = 200$ m [E]

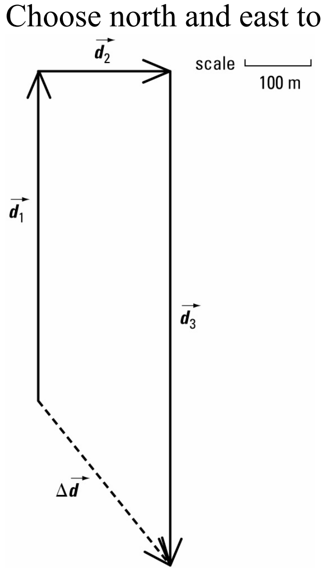
$\vec{d}_3 = 750$ m [S]

Required

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

Analysis and Solution

Choose north and east to be positive.



$$\Delta\vec{d} = 500 \text{ m [N]} + 200 \text{ m [E]} + 750 \text{ m [S]}$$

$$\Delta d_y = 500 \text{ m [N]} + 750 \text{ m [S]}$$
$$= 500 \text{ m [N]} + (-750 \text{ m [N]})$$
$$= 500 \text{ m [N]} - 750 \text{ m [N]}$$
$$= -250 \text{ m [N]}$$
$$= 250 \text{ m [S]}$$

$$\Delta d_x = 200 \text{ m [E]}$$

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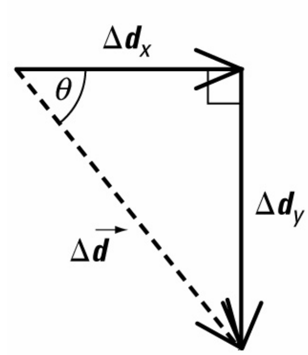

$$
\begin{aligned}
\Delta d &= \sqrt{(\Delta d_x)^2 + (\Delta d_y)^2} \\
&= \sqrt{(250\text{ m})^2 + (200\text{ m})^2} \\
&= 320\text{ m}
\end{aligned}
$$

$$
\begin{aligned}
\theta &= \tan^{-1}\left(\frac{\text{opposite}}{\text{adjacent}}\right) \\
&= \tan^{-1}\left(\frac{250\ \cancel{\text{m}}}{200\ \cancel{\text{m}}}\right) \\
&= 51.3^\circ
\end{aligned}
$$

From the diagram, this angle is S of E.

Paraphrase

The bus' displacement is 320 m [51.3° S of E].

39. **(a)** ii, uniformly accelerated motion
(b) iv, uniformly accelerated motion
(c) ii, uniformly accelerated motion
(d) iii, at rest
(e) iii, at rest
(f) i, uniform motion

40. ***Given***

$v_i = 0$

$v_f = 26.9$ m/s

$\Delta t = 4.50$ s

Required

magnitude of acceleration (a)

Analysis and Solution

Since the car starts from rest, initial velocity is zero.

$$
\begin{aligned}
a &= \frac{\Delta v}{\Delta t} \\
&= \frac{26.9\text{ m/s} - 0\text{ m/s}}{4.50\text{ s}} \\
&= 5.98\text{ m/s}^2
\end{aligned}
$$

Paraphrase

The magnitude of the jeep's acceleration is 5.98 m/s^2.

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Extensions

41. ***Given***

$\Delta t = 1.47\text{ s}$

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

Required

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

(b) height (Δd_y)

Analysis and Solution

Choose down to be positive.

(a) For final vertical velocity, use the equation $\vec{a} = \dfrac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$.

$$\begin{aligned}\vec{v}_{\text{f}} &= \vec{v}_{\text{i}} + \vec{a}\Delta t \\ &= 0 + \left(+9.81\ \frac{\text{m}}{\text{s}^{\not 2}}\right)(1.47\ \not\text{s}) \\ &= +14.4\text{ m/s} \\ &= 14.4\text{ m/s [down]}\end{aligned}$$

(b) For the height the penny falls, use the equation $\Delta\vec{d} = \vec{v}_{\text{i}}\Delta t + \frac{1}{2}\vec{a}\left(\Delta t\right)^2$.

$$\begin{aligned}\Delta d_y &= v_{\text{i}_y}\Delta t + \frac{1}{2}a_y\left(\Delta t\right)^2 \\ &= 0 + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.47\text{ s})^2 \\ &= 10.6\text{ m}\end{aligned}$$

Paraphrase

(a) The penny has a final vertical velocity of 14.4 m/s [down].

(b) The distance from the top of the well to the water's surface is 10.6 m.

42. ***Given***

$\vec{v}_{\text{balloon}} = 3.25\text{ m/s [up]}$

$\Delta t = 8.75\text{ s}$

Required

(a) initial height of balloon (Δd_{i})

(b) final height of balloon (Δd_{f})

(c) final velocity of sandbag ($v_{\text{f}_{\text{sandbag}}}$)

Analysis and Solution

Choose down to be positive.

(a) The height of the balloon at the time the sandbag is dropped is the distance the sandbag drops, which can be calculated using the equation $\Delta d_{\text{i}} = v_{\text{i}}\Delta t + \frac{1}{2}a\left(\Delta t\right)^2$.

$$\begin{aligned}\Delta d_{\text{i}} &= v_{\text{i}}\Delta t + \frac{1}{2}a\left(\Delta t\right)^2 \\ &= \left(-3.25\ \frac{\text{m}}{\text{s}}\right)(8.75\text{ s}) + \frac{1}{2}\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(8.75\text{ s})^2 \\ &= 347\text{ m}\end{aligned}$$

(b) After the sandbag is dropped, the balloon continues to rise at the constant rate of 3.25 m/s. Use the uniform motion equation.

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$$\Delta d_{8.75\text{ s}} = \left(3.25\ \frac{\text{m}}{\text{s}}\right)(8.75\text{ s})$$
$$= 28.44\text{ m}$$
$$\Delta d_{\text{f}} = \Delta d_{\text{i}} + \Delta d_{8.75\text{ s}}$$
$$= 347\text{ m} + 28.44\text{ m}$$
$$= 375\text{ m}$$

(c) Find the final velocity of the sandbag by using the accelerated motion equation $\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$.

$$a_y = \frac{v_{\text{f}_y} - v_{\text{i}_y}}{\Delta t}$$
$$v_{\text{f}_y} = v_{\text{i}_y} + a_y \Delta t$$
$$= -3.25\ \frac{\text{m}}{\text{s}} + \left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(8.75\text{ s})$$
$$= 82.6\text{ m/s}$$

Paraphrase

(a) The sandbag dropped from a height of 347 m.
(b) The balloon's height when the sandbag hits the ground is 375 m.
(c) The sandbag has a velocity of 82.6 m/s [down] before it hits the ground.

43. ***Given***

$\Delta d_x = 20.0\text{ m}$

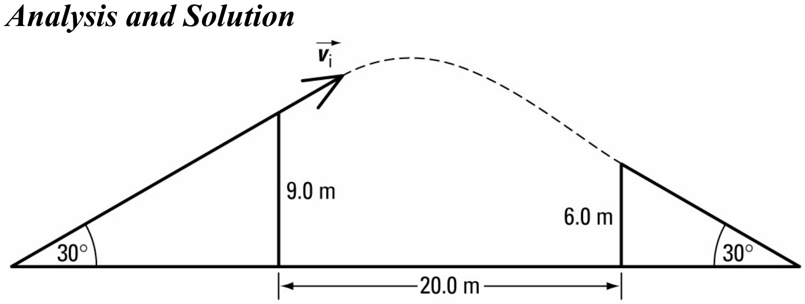
$\Delta d_y = 3.0\text{ m}$

$\theta = 30°$

Required

minimum initial velocity ($\vec{v}_{\text{i}}$)

Analysis and Solution



Choose down to be positive.
The minimum horizontal distance is 20.0 m and the minimum vertical distance is 3.0 m.

$$v_x = v_i \cos 30°$$
$$v_{i_y} = -v_i \sin 30°$$
$$\Delta d_x = v_x \Delta t$$
$$\Delta t = \frac{20.0 \text{ m}}{v_x}$$
$$= \frac{20.0 \text{ m}}{v_i \cos 30°}$$

Substitute the components of the initial velocity into the equation $\Delta d_y = v_{i_y} \Delta t + \frac{1}{2} a_y (\Delta t)^2$ to solve for the magnitude of the initial velocity.

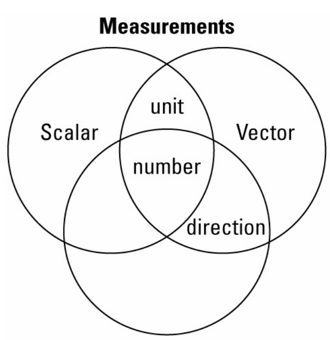
$$\Delta d_y = v_{i_y} \Delta t + \frac{1}{2} a_y (\Delta t)^2$$
$$3.0 \text{ m} = -(v_i \sin 30°)\left(\frac{20.0 \text{ m}}{v_i \cos 30°}\right) + \frac{1}{2}(9.81 \text{ m/s}^2)\left(\frac{20.0 \text{ m}}{v_i \cos 30°}\right)^2$$
$$= -(\tan 30°)(20.0 \text{ m}) + \frac{1}{2}(9.81 \text{ m/s}^2)\left(\frac{20.0 \text{ m}}{v_i \cos 30°}\right)^2$$
$$14.547 = \frac{2616}{v_i^2}$$
$$v_i = 13 \text{ m/s}$$

Paraphrase

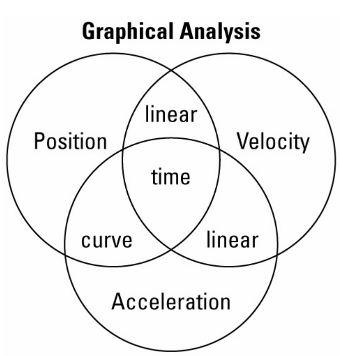
The minimum initial velocity for a successful jump is 13 m/s [30°].

Skills Practice

44.



45.



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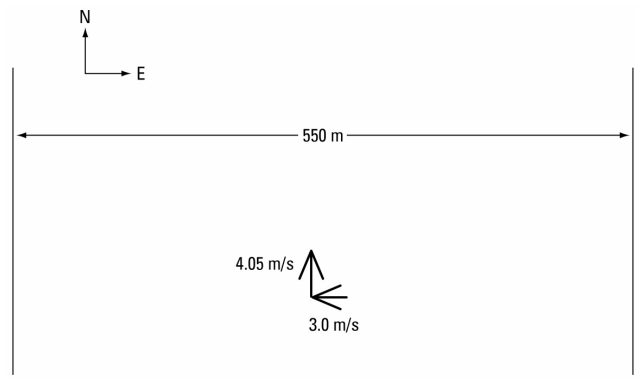
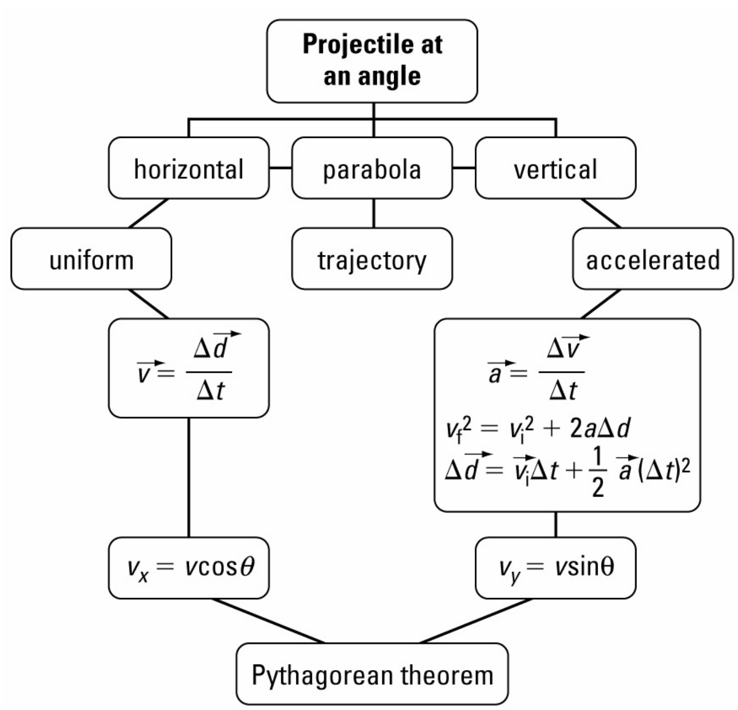
46.



47. Your choice of instruments depends on availability and experimental conditions. A radar gun will give moment-to-moment measures of the velocity of an object and may be used outdoors. Probeware and motion sensors may only be for use indoors and may have limited range of motion. Radar guns can track an object but lack the graphing capabilities of other equipment.

48. Student answers should be similar to 1-7 Inquiry Lab: Determining the Magnitude of the Acceleration due to Gravity, substituting an inclined plane for straight vertical motion.

49.



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50. Velocity-time graphs describe the motion of an object. If the velocity-time graph is along the time axis, the object is at rest. If the velocity-time graph is a horizontal line that is not on the time axis, the object is travelling at a constant rate. Both types of graphs represent uniform motion with zero acceleration. If the velocity-time graph has a non-zero slope, the object is experiencing uniformly accelerated motion. The area under a velocity-time graph represents the displacement of the object for a particular time interval.

Self-assessment

Students' answers in this section will vary greatly depending on their experiences, depth of understanding, and the depth of the research that they do into each of the topics.

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