2-4 A top-gun pilot, practicing radar avoidance maneuvers, is manually flying horizontally at 1300 km/h, just 35 m above the level ground. Suddenly, the plane encounters terrain that slopes gently upward at 4.3°, an amount difficult to detect visually (Fig. 2-16).

How much time does the pilot have to make a correction to avoid flying into the ground?

\[ \theta = 4.3^\circ \quad h = 35 \text{ m} \]

\[ v = 1300 \text{ km/h} \]

\[ \text{given} \]

Plane will travel a distance, \( x \), before it strikes ground.

Note... right triangle

\[ h = x \tan \theta \]

So, plane travels distance,

\[ x = \frac{h}{\tan \theta} = \frac{35 \text{ m}}{\tan 4.3^\circ} = 35 \text{ m} \]

\[ x = 465 \text{ m} = 0.465 \text{ km} \]

Since it travels with constant speed, \( v \)

\[ x = vt \]

the time it takes is

\[ t = \frac{x}{v} = \frac{0.465 \text{ km}}{1300 \text{ km/h}} = 0.00358 \text{ hr} \]

or

\[ t = 0.00358 \text{ hr} \times \frac{3600 \text{ sec}}{1 \text{ hr}} = 1.29 \text{ s} \]
2-32 Figure 2-21 depicts the motion of a particle moving along an x axis with a constant acceleration. What are the magnitude and direction of the particle's acceleration?

**Prob 2-32**

Particle travels at constant acceleration, \( a \), so

\[
x = x_0 + v_0t + \frac{1}{2}at^2
\]

We know \( x \) and \( t \) for 3 cases (points on graph):

<table>
<thead>
<tr>
<th>( t ) (sec)</th>
<th>( x ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-2.0</td>
</tr>
<tr>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>6.0</td>
</tr>
</tbody>
</table>

First equation:

\[
x_0 = -2.0 \text{ m}
\]

2nd + 3rd:

\[
v_0 + \frac{1}{2}a = +2.0 \Rightarrow v_0 + \frac{1}{2}a = +2.0
\]

\[
2v_0 + 2a = +8.0 \Rightarrow v_0 + a = +4.0
\]

Subtract \( \frac{1}{2}a = 2.0 \Rightarrow a = 4.0 \text{ m/s}^2 \)

So

\[
v_0 = +4.0 - a = +4.0 - 4.0 = 0.0
\]

\[
v_0 = 0.0 \text{ m/s}
\]
2-38 When a high-speed passenger train traveling at 161 km/h rounds a bend, the engineer is shocked to see that a locomotive has improperly entered onto the track from a siding and is a distance $D=676$ m ahead (Fig. 2-22). The locomotive is moving at 29.0 km/h. The engineer of the high-speed train immediately applies the brakes.

(a) What must be the magnitude of the resulting constant deceleration if a collision is to be just avoided?

(b) Assume that the engineer is at $x=0$ when, at $t=0$, he first spots the locomotive. Sketch the $x(t)$ curves representing the locomotive and high-speed train for the situations in which a collision is just avoided and is not quite avoided.

\[\begin{align*}
    v_t &= v_i - at \\
    x_t &= 0 + v_i t - \frac{1}{2} a t^2 \\
    v_L &= v_L \\
    x_L &= D + v_L t \\

    \text{The conditions for no collision (just gentle tap) are} \quad \left\{ \begin{array}{c}
    x_t = x_L \\
    v_t = v_L
    \end{array} \right. \\

    \text{This occurs at time} \quad t = \frac{t}{a} = \frac{v_i - v_L}{a} \\

    \text{so} \quad a = \frac{1}{2} \left( \frac{v_i - v_L}{D} \right)^2 \\

    a = \frac{1}{2} \times \frac{(182)^2}{676} \times \frac{10^9}{10^3 m^2} = 0.994 \, \text{m/s}^2 \\

    t = \frac{v_i - v_L}{a} = \frac{182}{0.994} \times \frac{10^5}{3600} = 37.9 \, \text{s} \\

    \text{(see graph)}
\end{align*}\]
2-52 A model rocket fired vertically from the ground ascends with a constant vertical acceleration of 4.00 m/s$^2$ for 6.00 s. Its fuel is then exhausted, so it continues upward as a free-fall particle and then falls back down.

(a) What is the maximum altitude reached?

(b) What is the total time elapsed from takeoff until the rocket strikes the ground?
2-64 A parachutist bails out and freely falls 50 m. Then the parachute opens, and thereafter she decelerates at 2.0 m/s². She reaches the ground with a speed of 3.0 m/s.
(a) How long is the parachutist in the air?
(b) At what height does the fall begin?

(a) time to get to \( y = d_1 \)

\[ t_1 = \sqrt{\frac{2d_1}{g}} = \sqrt{\frac{2(50 \text{ m})}{9.8 \text{ m/s}^2}} \]

\[ t_1 = 3.19 \text{ sec} \]

Its vertical speed at \( t_1 \) is

\[ v_1 = gt_1 = (9.8 \text{ m/s}^2)(3.19 \text{ s}) \]

\[ v_1 = 31.3 \text{ m/s} \]

The parachutist thereafter loses speed at the rate \( a_2 \).

\[ v = v_1 + a_2t \]

\[ v = v_1 \]

\[ v = v_2 \]

At time \( t_2 \),

\[ v_2 = v + a_2t_2 \]

\[ t_2 = \frac{v_2 - v_1}{a_2} = \frac{3.0 - 31.3}{-2.0} \]

\[ t_2 = 14.2 \text{ sec} \]

So, the total time is

\[ T = t_1 + t_2 = 3.2 + 14.2 \]

\[ T = 17.4 \text{ sec} \]

(b) The parachutist falls additional distance

\[ d_2 = v_1 t_2 + \frac{1}{2} a_2 t_2^2 \]

\[ d_2 = (31.3)(14.2) + \left(\frac{1}{2}\right)(-2.0)(14.2)^2 \]

\[ d_2 = 243 \text{ m} \]

So, total distance she falls is

\[ D = d_1 + d_2 = 50 + 243 = 293 \text{ meters} \]

So, \( D = 293 \text{ meters} \) above ground

is where she started.
Rock faults are ruptures along which opposite faces of rock have slid past each other. In Fig. 3-28, points A and B coincided before the rock in the foreground slid down to the right. The net displacement is along the plane of the fault. The horizontal component of AB is the strike-slip AC. The component of AB that is directly down the plane of the fault is the dip-slip AD.

(a) What is the magnitude of the net displacement if the strike-slip is 22.0 m and the dip-slip is 17.0 m?

(b) If the plane of the fault is inclined 52.0° to the horizontal, what is the vertical component of AB?

$$
\begin{align*}
AC &= 22.0 \text{ m} \\
AB &= 17.0 \text{ m} \\
AB &= \sqrt{AC^2 + AD^2} = \sqrt{(17)^2 + (22)^2} \\
&= 27.8 \text{ m}
\end{align*}
$$

(b) Note that AC is in the horizontal plane. But AD has both vertical and horizontal components.

Looking into the fault plane from the front

$$
\begin{align*}
(AB)_{\text{vert}} &= (AD)_{\text{vert}} \\
&= AD \sin 52^\circ \\
&= (17.0) (0.788) \\
&= 13.4 \text{ m}
\end{align*}
$$
3 - 24 Find the sum of the following four vectors in (a) unit-vector notation, and as (b) a magnitude and (c) an angle relative to +x.

\[ \vec{P} : 10.0 \text{ m, at } 25^\circ \text{ counterclockwise from } +x \]
\[ \vec{Q} : 12.0 \text{ m, at } 10.0^\circ \text{ counterclockwise from } +y \]
\[ \vec{R} : 8.00 \text{ m, at } 20.0^\circ \text{ clockwise from } -y \]
\[ \vec{S} : 9.00 \text{ m, at } 40.0^\circ \text{ counterclockwise from } -y \]

\[ \vec{P} = 10.0 \begin{bmatrix} \cos 25^\circ \hat{i} + \sin 25^\circ \hat{j} \end{bmatrix} = 9.06 \hat{i} + 4.23 \hat{j} \]
\[ \vec{Q} = 12.0 \begin{bmatrix} -\sin 10^\circ \hat{i} + \cos 10^\circ \hat{j} \end{bmatrix} = -2.08 \hat{i} + 11.82 \hat{j} \]
\[ \vec{R} = 8.0 \begin{bmatrix} \sin 20^\circ \hat{i} + \cos 20^\circ \hat{j} \end{bmatrix} = -2.74 \hat{i} - 7.52 \hat{j} \]
\[ \vec{S} = 9.0 \begin{bmatrix} \sin 40^\circ \hat{i} + \cos 40^\circ \hat{j} \end{bmatrix} = 5.79 \hat{i} - 6.89 \hat{j} \]

(a) \[ \vec{R}' : \text{Resultant } = \vec{P} + \vec{Q} + \vec{R} + \vec{S} = 10.0 \hat{i} + 1.6 \hat{j} \text{ meter} \]

(b) \[ |\vec{R}'| = \sqrt{(10.0)^2 + (1.6)^2} = 10.1 \text{ m} \]
\[ \tan \phi = \frac{1.6}{10.0} = 0.16 \Rightarrow \phi = 9.1^\circ \]
4-19 A baseball leaves a pitcher’s hand horizontally at a speed of 161 km/h. The distance to the batter is 18.3 m. (Ignore the effect of air resistance.)

(a) How long does the ball take to travel the first half of that distance?
(b) The second half?
(c) How far does the ball fall freely during the first half?
(d) During the second half?
(e) Why aren’t the quantities in (c) and (d) equal?

\[ v_x = (161 \text{ km/h}) \]

\[ v_y = 0 \]

\[ t = \frac{x}{v_x} = \frac{9.15 \text{ m}}{44.7 \text{ m/s}} = 0.205 \text{ sec} \]

\[ t_2 = 0.205 \text{ sec} \]

\[ v_y = -\frac{1}{2} gt^2 \]

\[ v_y = -\frac{1}{2} (9.8 \text{ m/s}^2)(0.205)^2 = -0.205 \text{ m} \]

\[ t_1 = 0.820 \text{ m} \]

\[ y_2 = y_1 - y = -0.820 - (0.205) = -0.615 \text{ m} \] (which is 3 times \( y_1 \))
4 - 30 Two seconds after being projected from ground level, a projectile is displaced 40 m horizontally and 53 m vertically above its point of projection. What are the
(a) horizontal and
(b) vertical components of the initial velocity of the projectile?
(c) At the instant the projectile achieves its maximum height above ground level, how far is it displaced horizontally from its point of projection?

\[
\begin{align*}
\text{(a)} & \quad \text{At } t = 2 \text{ sec,} \\
& \quad 40 \text{ m} = V_{ox} (2) \\
& \quad 53 \text{ m} = V_{oy} (2) - \frac{1}{2} (9.8) (4) \\
& \quad V_{ox} = 20 \text{ m/s} \\
& \quad V_{oy} = 36 \text{ m/s} \\
\text{(b)} & \quad \text{The highest point occurs for } V_y = 0 \quad \text{where } V_y = V_{oy} - gt \\
& \quad \text{and horizontal position is} \\
& \quad x_m = \frac{V_{ox} V_{oy}}{2} \\
& \quad x_m = \frac{(36 \text{ m/s})(20 \text{ m/s})}{9.8 \text{ m/s}^2} = 74 \text{ meters}
\end{align*}
\]