Sketch position versus time graphs for the following motions. Include a numerical scale on both axes with units that are reasonable for this motion. Some numerical information is given in the problems. You may have to make reasonable estimates for other quantities.

a) A student walks to the bus stop, waits for the bus, then rides to campus. Assume that all the motion is along a straight street.

b) A student walks slowly to the bus stop, realizes he forgot his paper that is due and quickly walks home to get it.
c) Quarterback Bill throws the ball to the right at a speed of 15m/s. It is intercepted 45m away by Carlos, who is running to the left at 7.5m/s. Carlos carries the ball 60m to score. Let x = 0m be the point where Bill throws the ball. Draw the graph for the football.

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Questions 7, 8, 9, 11, 15, 16, 17

Q2.7 Yes. If the velocity of the particle is nonzero, the particle is in motion. If the acceleration is zero, the velocity of the particle is unchanging, or is a constant.

Q2.8 Yes. If you drop a doughnut from rest \( v = 0 \), then its acceleration is not zero. A common misconception is that immediately after the doughnut is released, both the velocity and acceleration are zero. If the acceleration were zero, then the velocity would not change, leaving the doughnut floating at rest in mid-air.

Q2.9 No: Car A might have greater acceleration than B, but they might both have zero acceleration, or otherwise equal accelerations; or the driver of B might have tramped hard on the gas pedal in the recent past.

Q2.11 East

(a) Accelerating East  (b) Braking East  (c) Cruising

(d) Braking West  (e) Accelerating West  (f) Cruising

(g) Stopped but starting to move East

(h) Stopped but starting to move West

Q2.15 They are the same. After the first ball reaches its apex and falls back downward past the student, it will have a downward velocity equal to \( v_2 \). This velocity is the same as the velocity of the second ball, so after they fall through equal heights their impact speeds will also be the same.
Q2.16 \(\text{With } h = \frac{1}{2}gt^2,\)

(a) \(0.5h = \frac{1}{2}g(0.707)^2.\) The time is later than 0.5t.

(b) The distance fallen is \(0.25h = \frac{1}{2}g(0.5t)^2.\) The elevation is 0.75h, greater than 0.5h.

Q2.17 Above. Your ball has zero initial speed and smaller average speed during the time of flight to the passing point.

Problems 3, 5

(Please show steps in the problems and the rationale when you answer questions. Simply saying “Yes” or “No” or writing down the final answer is not sufficient).

P2.3

(a) \(\bar{v} = \frac{\Delta x}{\Delta t} = \frac{10 \text{ m}}{2 \text{ s}} = \boxed{5 \text{ m/s}}\)

(b) \(\bar{v} = \frac{5 \text{ m}}{4 \text{ s}} = \boxed{1.25 \text{ m/s}}\)

(c) \(\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{5 \text{ m} - 10 \text{ m}}{4 \text{ s} - 2 \text{ s}} = \boxed{-2.5 \text{ m/s}}\)

(d) \(\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{-5 \text{ m} - 5 \text{ m}}{7 \text{ s} - 4 \text{ s}} = \boxed{-3.3 \text{ m/s}}\)

(e) \(\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{0 - 0}{8 - 0} = \boxed{0 \text{ m/s}}\)

P2.5

(a) Let \(d\) represent the distance between A and B. Let \(t_1\) be the time for which the walker has the higher speed in \(5.00 \text{ m/s} = \frac{d}{t_1}\). Let \(t_2\) represent the longer time for the return trip in \(-3.00 \text{ m/s} = \frac{d}{t_2}\). Then the times are \(t_1 = \frac{d}{(5.00 \text{ m/s})}\) and \(t_2 = \frac{d}{(3.00 \text{ m/s})}\). The average speed is:

\[
\bar{v} = \frac{\text{Total distance}}{\text{Total time}} = \frac{d}{5.00 \text{ m/s}} + \frac{d}{3.00 \text{ m/s}} = \frac{2d}{(5.00 \text{ m/s})(3.00 \text{ m/s})} = \frac{2d}{(8.00 \text{ m/s})(5.00 \text{ m/s})}\]

\[
\bar{v} = \boxed{3.75 \text{ m/s}}
\]

\[
\bar{v} = \boxed{3.75 \text{ m/s}}
\]
(b) She starts and finishes at the same point A. With total displacement = 0, average velocity = \[ 0 \].

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**Problems 7, 12, 14, 17, 24, 27, 29, 37**

**P2.7**

(a) at \( t_1 = 1.5 \text{ s} \), \( x_1 = 8.0 \text{ m} \) (Point A)

at \( t_2 = 4.0 \text{ s} \), \( x_2 = 2.0 \text{ m} \) (Point B)

\[
\bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{(2.0 - 8.0) \text{ m}}{(4 - 1.5) \text{ s}} = \frac{-6.0 \text{ m}}{2.5 \text{ s}} = -2.4 \text{ m/s}
\]

(b) The slope of the tangent line is found from points C and D. \( t_c = 1.0 \text{ s}, x_c = 9.5 \text{ m} \) and \( t_d = 3.5 \text{ s}, x_d = 0 \).

\[
\bar{v} = -3.8 \text{ m/s}.
\]

(c) The velocity is zero when \( x \) is a minimum. This is at \( t = 4 \text{ s} \).

**P2.12**

(a) Acceleration is constant over the first ten seconds, so at the end,

\[
v_f = v_i + at = 0 + \left( \frac{2.00 \text{ m}}{10.0 \text{ s}} \right)^2(10.0 \text{ s}) = 20.0 \text{ m/s}.
\]

Then \( a = 0 \) so \( v \) is constant from \( t = 10.0 \text{ s} \) to \( t = 15.0 \text{ s} \). And over the last five seconds the velocity changes to

\[
v_f = v_i + at = 20.0 \text{ m/s} + \left( \frac{3.00 \text{ m}}{5.00 \text{ s}} \right)(5.00 \text{ s}) = 5.00 \text{ m/s}.
\]

(b) In the first ten seconds,

\[
x_f = x_i + v_i t + \frac{1}{2} at^2 = 0 + 0 + \frac{1}{2} \left( \frac{2.00 \text{ m}}{10.0 \text{ s}} \right)^2(10.0 \text{ s})^2 = 100 \text{ m}.
\]

Over the next five seconds the position changes to

\[
x_f = x_i + v_i t + \frac{1}{2} at^2 = 100 \text{ m} + \left( \frac{2.00 \text{ m}}{5.00 \text{ s}} \right)(5.00 \text{ s}) + 0 = 200 \text{ m}.
\]

And at \( t = 20.0 \text{ s} \),

\[
x_f = x_i + v_i t + \frac{1}{2} at^2 = 200 \text{ m} + \left( \frac{2.00 \text{ m}}{5.00 \text{ s}} \right)(5.00 \text{ s}) + \frac{1}{2} \left( \frac{-3.00 \text{ m}}{5.00 \text{ s}} \right)^2(5.00 \text{ s})^2 = 262 \text{ m}.
\]
P2.14  (a) Acceleration is the slope of the graph of $v$ vs $t$.

For $0 < t < 5.00 \text{ s}$, $a = 0$.
For $15.0 \text{ s} < t < 20.0 \text{ s}$, $a = 0$.
For $5.0 \text{ s} < t < 15.0 \text{ s}$, $a = \frac{v_f - v_i}{t_f - t_i}$.

$$a = \frac{8.00 - (-8.00)}{15.0 - 5.00} = 1.60 \text{ m/s}^2$$

We can plot $a(t)$ as shown.

(b) $a = \frac{v_f - v_i}{t_f - t_i}$

(i) For $5.00 \text{ s} < t < 15.0 \text{ s}$, $t_i = 5.00 \text{ s}$, $v_i = -8.00 \text{ m/s}$

$$v_f = 8.00 \text{ m/s}$$

$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{8.00 - (-8.00)}{15.0 - 5.00} = 1.60 \text{ m/s}^2$$

(ii) $t_i = 0$, $v_i = -8.00 \text{ m/s}$, $t_f = 20.0 \text{ s}$, $v_f = 8.00 \text{ m/s}$

$$a = \frac{v_f - v_i}{t_f - t_i} = \frac{8.00 - (-8.00)}{20.0 - 0} = 0.800 \text{ m/s}^2$$

P2.17  (a) $a = \frac{\Delta v}{\Delta t} = \frac{8.00 \text{ m/s}}{6.00 \text{ s}} = 1.3 \text{ m/s}^2$

(b) Maximum positive acceleration is at $t = 3 \text{ s}$, and is approximately $2 \text{ m/s}^2$.

(c) $a = 0$, at $t = 6 \text{ s}$, and also for $t > 10 \text{ s}$.

(d) Maximum negative acceleration is at $t = 8 \text{ s}$, and is approximately $-1.5 \text{ m/s}^2$. 
P2.24  
(a) Total displacement = area under the \((v, t)\) curve from  
\(t = 0\) to 50 s.  
\[
\Delta x = \frac{1}{2} (50 \text{ m/s})(15 \text{ s}) + (50 \text{ m/s})(40 - 15) \text{ s} \\
+ \frac{1}{2} (50 \text{ m/s})(10 \text{ s}) \\
\Delta x = 1875 \text{ m}
\]

(b) From \(t = 10\) s to \(t = 40\) s, displacement is  
\[
\Delta x = \frac{1}{2} (50 \text{ m/s} + 33 \text{ m/s})(5 \text{ s}) + (50 \text{ m/s})(25 \text{ s}) = 1457 \text{ m}
\]

(c)  
\(0 \leq t \leq 15\) s: \(a_i = \frac{\Delta v}{\Delta t} = \frac{(50 - 0) \text{ m/s}}{15 \text{ s} - 0} = \frac{33 \text{ m/s}^2}{15 \text{ s}}\)

15 s < \(t < 40\) s: \(a_i = 0\)

40 s ≤ \(t \leq 50\) s: \(a_i = \frac{\Delta v}{\Delta t} = \frac{(0 - 50) \text{ m/s}}{50 \text{ s} - 40 \text{ s}} = \frac{-5 \text{ m/s}^2}{10 \text{ s}}\)

(d)  
(i) \(x_1 = 0 + \frac{1}{2} \frac{a_i}{a} t^2 = \frac{1}{2} (3.3 \text{ m/s}^2) t^2\) or \(x_1 = (1.67 \text{ m/s}^2) t^2\)

(ii) \(x_2 = \frac{1}{2} (15 \text{ s}) [50 \text{ m/s} - 0] + (50 \text{ m/s})(t - 15 \text{ s})\) or \(x_2 = (50 \text{ m/s}) t - 375 \text{ m}\)

(iii) For 40 s ≤ \(t \leq 50\) s,  
\[
x_3 = \left[\text{area under } v \text{ vs } t \right] \text{ from } t = 0 \text{ to } 40 \text{ s} + \frac{1}{2} a_i (t - 40 \text{ s})^2 + (50 \text{ m/s})(t - 40 \text{ s})
\]

or  
\[
x_3 = 375 \text{ m} + 1250 \text{ m} + \frac{1}{2} (-5.0 \text{ m/s}^2)(t - 40 \text{ s})^2 + (50 \text{ m/s})(t - 40 \text{ s})
\]

which reduces to  
\[
x_3 = (250 \text{ m/s}) t - (2.5 \text{ m/s}^2) t^2 - 4375 \text{ m}.
\]

(e) \(\bar{v} = \frac{\text{total displacement}}{\text{total elapsed time}} = \frac{1875 \text{ m}}{50 \text{ s}} = 37.5 \text{ m/s}\)

P2.27  
(a) \(v_i = 100 \text{ m/s}, a = -5.00 \text{ m/s}^2, v_f = v_i + at \) so \(0 = 100 - 5t, v_f^2 = v_i^2 + 2a(x_f - x_i)\)

so \(0 = (100)^2 - 2(5.00)\left(x_f - 0\right). \) Thus \(x_f = 1000 \text{ m}\) and \(t = 20 \text{ s}\).
At this acceleration the plane would overshoot the runway: \( \text{No} \).

**P2.29** In the simultaneous equations:

\[
\begin{align*}
\left\{ \begin{array}{l}
\frac{1}{2}v_{xf} + \frac{1}{2}a x f = v_{xi} + a t \\
x_f - x_i = \frac{1}{2}(v_{xf} + v_{xi}) t
\end{array} \right. \\
\text{we have} \quad \left\{ \begin{array}{l}
v_{xf} = v_{xi} - \frac{1}{2}\left(5.60 \text{ m/s}^2\right)(4.20 \text{ s}) \\
62.4 \text{ m} = \frac{1}{2}(v_{xf} + v_{xi})(4.20 \text{ s})
\end{array} \right.
\]

So substituting for \( v_{xi} \) gives \( 62.4 \text{ m} = \frac{1}{2}v_{xf} + \left(5.60 \text{ m/s}^2\right)(4.20 \text{ s}) + v_{xf}(4.20 \text{ s}) \)

\[ 14.9 \text{ m/s} = \frac{1}{2}(v_{xf} + \frac{1}{2}(5.60 \text{ m/s}^2))(4.20 \text{ s}) \] Thus

\[ v_{xf} = \boxed{3.10 \text{ m/s}}. \]

**P2.37** (a) Take initial and final points at top and bottom of the incline. If the ball starts from rest,

\[ v_i = 0, \quad a = 0.500 \text{ m/s}^2, \quad x_f - x_i = 9.00 \text{ m}. \]

Then

\[ v_f^2 = v_i^2 + 2a(x_f - x_i) = 0^2 + 2\left(0.500 \text{ m/s}^2\right)(9.00 \text{ m}) \]

\[ v_f = \boxed{3.00 \text{ m/s}}. \]

(b) \[ x_f - x_i = v_i t + \frac{1}{2}a t^2 \]

\[ 9.00 = 0 + \frac{1}{2}(0.500 \text{ m/s}^2)t^2 \]

\[ t = \boxed{6.00 \text{ s}} \]

(c) Take initial and final points at the bottom of the planes and the top of the second plane, respectively:

\[ v_i = 3.00 \text{ m/s}, \quad v_f = 0, \quad x_f - x_i = 15.00 \text{ m}. \]

\[ v_f^2 = v_i^2 + 2a(x_f - x_i) \quad \text{gives} \]

\[ a = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{[0 - (3.00 \text{ m/s})^2]}{2(15.0 \text{ m})} = -0.300 \text{ m/s}^2. \]

(d) Take the initial point at the bottom of the planes and the final point 8.00 m along the second: \( v_i = 3.00 \text{ m/s}, \quad x_f - x_i = 8.00 \text{ m}, \quad a = -0.300 \text{ m/s}^2 \)

\[ v_f^2 = v_i^2 + 2a(x_f - x_i) = (3.00 \text{ m/s})^2 + 2(-0.300 \text{ m/s}^2)(8.00 \text{ m}) = 4.20 \text{ m}^2/\text{s}^2 \]

\[ v_f = \boxed{2.05 \text{ m/s}}. \]
Problems 45, 47, 62, 69, 70

*P2.45  (a) From $\Delta y = v_y t + \frac{1}{2} a t^2$ with $v_y = 0$, we have

$$t = \sqrt{\frac{2(\Delta y)}{a}} = \sqrt{\frac{2(-23 m)}{-9.80 \text{ m/s}^2}} = 2.17 \text{ s}.$$

(b) The final velocity is $v_f = 0 + (-9.80 \text{ m/s}^2)(2.17 \text{ s}) = -21.2 \text{ m/s}.$

(c) The time taken for the sound of the impact to reach the spectator is

$$t_{\text{sound}} = \frac{\Delta y}{v_{\text{sound}}} = \frac{23 \text{ m}}{340 \text{ m/s}} = 6.76 \times 10^{-2} \text{ s},$$

so the total elapsed time is $t_{\text{total}} = 2.17 \text{ s} + 6.76 \times 10^{-2} \text{ s} = 2.23 \text{ s}.$

P2.47  (a) $v_f = v_i - gt$: $v_f = 0$ when $t = 3.00 \text{ s}$, $g = 9.80 \text{ m/s}^2$. Therefore,

$$v_i = gt = (9.80 \text{ m/s}^2)(3.00 \text{ s}) = 29.4 \text{ m/s}.$$

(b) $y_f - y_i = \frac{1}{2} (v_f + v_i) t$

$$y_f - y_i = \frac{1}{2} (29.4 \text{ m/s})(3.00 \text{ s}) = 44.1 \text{ m}.$$

P2.62  Let point 0 be at ground level and point 1 be at the end of the engine burn. Let point 2 be the highest point the rocket reaches and point 3 be just before impact. The data in the table are found for each phase of the rocket’s motion.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Equation</th>
<th>Time (s)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0 to 1)</td>
<td>$v_x^2 - (80.0)^2 = 2(4.00)(1000)$</td>
<td>$t = 10.0 \text{ s}$</td>
<td>$v_x = 120 \text{ m/s}$</td>
</tr>
<tr>
<td>(1 to 2)</td>
<td>$0 - (120)^2 = 2(-9.80)(x_f - x_i)$</td>
<td>$t = 12.2 \text{ s}$</td>
<td>$x_f - x_i = 735 \text{ m}$</td>
</tr>
<tr>
<td>(2 to 3)</td>
<td>$v_x^2 = 0 = 2(-9.80)(-1.735)$</td>
<td>$t = 18.8 \text{ s}$</td>
<td>$v_x = -184 = (-9.80) t$</td>
</tr>
</tbody>
</table>
(a) \[ t_{\text{total}} = 10 + 12.2 + 18.8 = 41.0 \text{ s} \]

(b) \[ \left( x_f - x_i \right)_{\text{total}} = 1.73 \text{ km} \]

(c) \[ v_{\text{final}} = -184 \text{ m/s} \]

<table>
<thead>
<tr>
<th></th>
<th>( t )</th>
<th>( x )</th>
<th>( v )</th>
<th>( a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Launch</td>
<td>0.0</td>
<td>0</td>
<td>+4.00</td>
</tr>
<tr>
<td>#1</td>
<td>End Thrust</td>
<td>10.0</td>
<td>1000</td>
<td>120</td>
</tr>
<tr>
<td>#2</td>
<td>Rise Upwards</td>
<td>22.2</td>
<td>1735</td>
<td>0</td>
</tr>
<tr>
<td>#3</td>
<td>Fall to Earth</td>
<td>41.0</td>
<td>0</td>
<td>−184</td>
</tr>
</tbody>
</table>

P2.69 (a) \[ y_f = v_\perp t + \frac{1}{2} a t^2 = 50 D = 2.00 t + \frac{1}{2} (9.80) t^2, \]
\[ 4.90 t^2 + 2.00 t - 50 D = 0 \]
\[ t = \frac{-2.00 + \sqrt{2.00^2 - 4(4.90)(-50D)}}{2(4.90)} \]

Only the positive root is physically meaningful:
\[ t = \boxed{3.00 \text{ s}} \] after the first stone is thrown.

(b) \[ y_f = v_\perp t + \frac{1}{2} a t^2 \] and \[ t = 3.00 - 1.00 = 2.00 \text{ s} \]

<table>
<thead>
<tr>
<th></th>
<th>( \perp )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>15.3 m/s downward</td>
</tr>
<tr>
<td>2</td>
<td>31.4 m/s downward</td>
</tr>
<tr>
<td>3</td>
<td>34.8 m/s downward</td>
</tr>
</tbody>
</table>

P2.70 (a) \[ d = \frac{1}{2} (9.80) t_1^2 \]
\[ t_1 + t_2 = 2.40 \]
\[ 4.90 t_1^2 - 359.5 t_2 + 28.22 = 0 \]
\[ t_2 = \frac{359.5 \pm \sqrt{359.5^2 - 4(4.90)(28.22)}}{9.80} \]
\[ t_2 = \frac{359.5 \pm 358.75}{9.80} = 0.0765 \text{ s} \]
\[ \text{so} \quad d = 336 t_2 = 26.4 \text{ m} \]

(b) Ignoring the sound travel time, \[ d = \frac{1}{2} (9.80)(2.40)^2 = 28.2 \text{ m} \], an error of 6.82%.