3.73: a) The acceleration is given as \( g \) at an angle of 53.1° to the horizontal. This is a 3-4-5 triangle, and thus, \( a_x = (3/5)g \) and \( a_y = (4/5)g \) during the "boost" phase of the flight. Hence this portion of the flight is a straight line at an angle of 53.1° to the horizontal. After time \( T \), the rocket is in free flight, the acceleration is \( a_x = 0 \) and \( a_y = g \), and the familiar equations of projectile motion apply. During the rising phase of the flight, the trajectory is the familiar parabola.

b) During the boost phase, the velocities are: \( v_x = (3/5)gt \) and \( v_y = (4/5)gt \), both straight lines. After \( t = T \), the velocities are \( v_x = (3/5)gT \), a horizontal line, and \( v_y = (4/5)gT - g(t-T) \), a negatively sloping line which crosses the axis at the time of the maximum height.

c) To find the maximum height of the rocket, set \( v_y = 0 \), and solve for \( t \), where \( t = 0 \) when the engines are cut off, use this time in the familiar equation for \( y \). Thus, using \( t = (4/5)T \) and \( y_{\text{max}} = y_0 + v_{0y}t - \frac{1}{2}gt^2 \), \( y_{\text{max}} = \frac{2}{5}gT^2 + \frac{4}{5}gT \left(\frac{4}{5}T\right) - \frac{1}{2}g \left(\frac{4}{5}T\right)^2 \), \( y_{\text{max}} = \frac{2}{5}gT^2 + \frac{16}{25}gT^2 - \frac{8}{25}gT^2 \). Combining terms, \( y_{\text{max}} = \frac{18}{25}gT^2 \).

d) To find the total horizontal distance, break the problem into three parts: The boost phase, the rise to maximum, and the fall back to earth. The fall time back to earth can be found from the answer to part (c), \( (18/25)gT^2 = (1/2)gt^2 \), or \( t = (6/5)T \). Then, multiplying these times and the velocity, \( x = \frac{3}{10}gT^2 + \left(\frac{3}{5}gT\right) \left(\frac{4}{5}T\right) + \left(\frac{3}{5}gT\right) \left(\frac{6}{5}T\right) \), or \( x = \frac{3}{10}gT^2 + \frac{12}{25}gT^2 + \frac{18}{25}gT^2 \). Combining terms gives \( x = \frac{3}{2}gT^2 \).
3.16:  

a) Solving Eq. (3.18) with $y = 0$, $y_0 = 0.75$ m gives $t = 0.391$ s.

b) Assuming a horizontal tabletop, $v_{0y} = 0$, and from Eq. (3.16), $v_{0x} = (x - x_0)/t = 3.58$ m/s.

c) On striking the floor, $v_y = -gt = -\sqrt{2gy_0} = -3.83$ m/s, and so the ball has a velocity of magnitude 5.24 m/s, directed $46.9^\circ$ below the horizontal.

Although not asked for in the problem, this $y$ vs. $x$ graph shows the trajectory of the tennis ball as viewed from the side.
3.26: a) horizontal motion: \( x - x_0 = v_{0x} t \) so \( t = \frac{60.0 \text{ m}}{(v_0 \cos 43.0^\circ)} \)
vertical motion (take \(+y\) to be upward):
\[
y - y_0 = v_{0y} t + \frac{1}{2} a_y t^2 \text{ gives } 25.0 \text{ m} = (v_0 \sin 43.0^\circ) t + \frac{1}{2} (-9.80 \text{ m/s}^2) t^2
\]
Solving these two simultaneous equations for \(v_0\) and \(t\) gives \(v_0 = 3.26 \text{ m/s}\) and \(t = 2.51 \text{ s}\).

b) \(v_y\) when shell reaches cliff:
\[
v_y = v_{0y} + a_y t = (32.6 \text{ m/s}) \sin 43.0^\circ - (9.80 \text{ m/s}^2)(2.51 \text{ s}) = -2.4 \text{ m/s}
\]

The shell is traveling downward when it reaches the cliff, so it lands right at the edge of the cliff.

3.27: Take \(+y\) to be upward.

Use the vertical motion to find the time it takes the suitcase to reach the ground:

\[
v_{0y} = v_0 \sin 23^\circ, \quad a_y = -9.80 \text{ m/s}^2, \quad y - y_0 = -114 \text{ m}, \quad t = ?
\]

\[
y - y_0 = v_{0y} t + \frac{1}{2} a_y t^2 \text{ gives } t = 9.60 \text{ s}
\]

The distance the suitcase travels horizontally is \(x - x_0 = v_{0x} = (v_0 \cos 23.0^\circ) t = 795 \text{ m}\)

3.35: b) No. Only in a circle would \(a_{\text{rad}}\) point to the center (See planetary motion in Chapter 12).

c) Where the car is farthest from the center of the ellipse.

3.36: Repeated use of Eq. (3.33) gives a) 5.0 = m/s to the right, b) 16.0 m/s to the left, and c) 13.0 = m/s to the left.

3.37: a) The speed relative to the ground is \(1.5 \text{ m/s} + 1.0 \text{ m/s} = 2.5 \text{ m/s}\), and the time is \(35.0 \text{ m} / 2.5 \text{ m/s} = 14.0 \text{ s}\) b) The speed relative to the ground is 0.5 m/s, and the time is 70 s.

3.38: The walker moves a total distance of 3.0 km at a speed of 4.0 km/h, and takes a time of three fourths of an hour (45.0 min). The boat’s speed relative to the shore is 6.8 km/h downstream and 1.2 km/h upstream, so the total time the rower takes is
\[
\frac{1.5 \text{ km}}{6.8 \text{ km/h}} + \frac{1.5 \text{ km}}{1.2 \text{ km/h}} = 1.47 \text{ hr} = 88 \text{ min}.
\]
3.45:  a) The $a_x = 0$ and $a_y = -2\beta$, so the velocity and the acceleration will be perpendicular only when $v_y = 0$, which occurs at $t = 0$.

b) The speed is $v = (\alpha^2 + 4\beta^2t^2)^{1/2}$, $dv/dt = 0$ at $t = 0$. (See part d below.)

c) $r$ and $v$ are perpendicular when their dot product is 0: 

\[
(\alpha t)(\alpha) + (15.0 \text{ m} - \beta t^2) \times (-2\beta t) = \alpha^2 t - (30.0 \text{ m})\beta t + 2\beta^2 t^3 = 0.
\]

Solve this for $t$: 

\[
t = \pm \sqrt{\frac{(30.0 \text{ m})(0.500 \text{ m/s}^2)-(1.2 \text{ m/s})^2}{2(0.500 \text{ m/s}^2)^2}} = +5.208 \text{ s, and 0 s, at which times the student is at (6.25 m, 1.44 m) and (0 m, 15.0 m), respectively.}
\]

d) At $t = 5.208 \text{ s}$, the student is 6.41 m from the origin, at an angle of $13^\circ$ from the $x$-axis. A plot of $d(t) = (x(t)^2+y(t)^2)^{1/2}$ shows the minimum distance of 6.41 m at 5.208 s:

![Graph showing d(t) vs t](image)

e) In the $x$-$y$ plane the student’s path is:

![Graph showing y(t) vs x(t)](image)

3.54: In terms of the range $R$ and the time $t$ that the balloon is in the air, the car’s original distance is $d = R + v_{\text{car}}t$. The time $t$ can be expressed in terms of the range and the horizontal component of velocity, $t = \frac{R}{v_0\cos\alpha_0}$, so $d = R \left( 1 + \frac{v_{\text{car}}}{v_0\cos\alpha_0} \right)$. Using $R = v_0^2\sin2\alpha_0/g$ and the given values yields $d = 29.5 \text{ m}$. 
b) \[ \vec{v} = \alpha \hat{i} - 2\beta t \hat{j} = (2.4 \text{ m/s}) \hat{i} - [(2.4 \text{ m/s}^2)t] \hat{j} \]

\[ \vec{a} = -2\beta \hat{j} = (-2.4 \text{ m/s}^2) \hat{j}. \]

c) At \( t = 2.0 \text{ s} \), the velocity is \( \vec{v} = (2.4 \text{ m/s}) \hat{i} - (4.8 \text{ m/s}) \hat{j} \); the magnitude is \( \sqrt{(2.4 \text{ m/s})^2 + (-4.8 \text{ m/s})^2} = 5.4 \text{ m/s} \), and the direction is \( \arctan\left(\frac{-4.8}{2.4}\right) = -63^\circ \). The acceleration is constant, with magnitude 2.4 m/s\(^2\) in the \(-y\)-direction. d) The velocity vector has a component parallel to the acceleration, so the bird is speeding up. The bird is turning toward the \(-y\)-direction, which would be to the bird’s right (taking the \(+z\)-direction to be vertical).