3.16. **IDENTIFY:** The football moves in projectile motion.
**SET UP:** Let $+y$ be upward. $a_x = 0, a_y = -g$. At the highest point in the trajectory, $v_y = 0$.

**EXECUTE:**
(a) $v_y = v_{0y} + at$. The time $t$ is $\frac{v_{0y}}{g} = \frac{16.0 \text{ m/s}}{9.8 \text{ m/s}^2} = 1.63 \text{ s}$.
(b) Different constant acceleration equations give different expressions but the same numerical result:
\[ \frac{1}{2} g t^2 = \frac{1}{2} v_{0y}^2 - \frac{v_{0y}^2}{2g} = 13.1 \text{ m}. \]
(c) Regardless of how the algebra is done, the time will be twice that found in part (a), or 3.27 s.
(d) $a_x = 0$, so $x - x_0 = v_{0x}t = (20.0 \text{ m/s})(3.27 \text{ s}) = 65.3 \text{ m}$.
(e) The graphs are sketched in the figure below.

**EVALUATE:** When the football returns to its original level, $v_x = 20.0 \text{ m/s}$ and $v_y = -16.0 \text{ m/s}$.

3.32. **IDENTIFY:** Each planet moves in a circular orbit and therefore has acceleration $a_{rad} = v^2 / R$.
**SET UP:** The radius of the earth’s orbit is $r = 1.50 \times 10^{11} \text{ m}$ and its orbital period is $T = 365 \text{ days} = 3.16 \times 10^7 \text{ s}$. For Mercury, $r = 5.79 \times 10^{10} \text{ m}$ and $T = 88.0 \text{ days} = 7.60 \times 10^6 \text{ s}$.

**EXECUTE:**
(a) $v = \frac{2\pi r}{T} = 2.98 \times 10^4 \text{ m/s}$
(b) $a_{rad} = \frac{v^2}{r} = 5.91 \times 10^3 \text{ m/s}^2$.
(c) If you repeat parts (a) and (b) for the motion of the planet Mercury, you will get $v = 4.79 \times 10^4 \text{ m/s}$, and $a_{rad} = 3.96 \times 10^2 \text{ m/s}^2$.
**EVALUATE:** Mercury has a larger orbital velocity and a larger radial acceleration than earth.

3.36. **IDENTIFY:** The relative velocities are $\vec{v}_{SF}$, the velocity of the scooter relative to the flatcar, $\vec{v}_{SG}$, the scooter relative to the ground and $\vec{v}_{FG}$, the flatcar relative to the ground. $\vec{v}_{SG} = \vec{v}_{SF} + \vec{v}_{FG}$. Carry out the vector addition by drawing a vector addition diagram.
**SET UP:** $\vec{v}_{SF} = \vec{v}_{SG} - \vec{v}_{FG}$. $\vec{v}_{FG}$ is to the right, so $-\vec{v}_{FG}$ is to the left.

**EXECUTE:** In each case the vector addition diagram gives
(a) $5.0 \text{ m/s}$ to the right
(b) $16.0 \text{ m/s}$ to the left
(c) $13.0 \text{ m/s}$ to the left.

**EVALUATE:** The scooter has the largest speed relative to the ground when it is moving to the right relative to the flatcar, since in that case the two velocities $\vec{v}_{SF}$ and $\vec{v}_{FG}$ are in the same direction and their magnitudes add.
4.6. **IDENTIFY:** Add the two forces using components.

**SET UP:** \( F_x = F \cos \theta \), \( F_y = F \sin \theta \), where \( \theta \) is the angle \( \vec{F} \) makes with the +x axis.

**EXECUTE:** (a) \( F_{x_1} + F_{x_2} = (9.00 \text{ N}) \cos 120^\circ + (6.00 \text{ N}) \cos 233.1^\circ = -8.10 \text{ N} \)

\( F_{y_1} + F_{y_2} = (9.00 \text{ N}) \sin 120^\circ + (6.00 \text{ N}) \sin 233.1^\circ = +3.00 \text{ N} \).

(b) \( R = \sqrt{R_x^2 + R_y^2} = \sqrt{(8.10 \text{ N})^2 + (3.00 \text{ N})^2} = 8.64 \text{ N} \).

**EVALUATE:** Since \( F_x < 0 \) and \( F_y > 0 \), \( \vec{F} \) is in the second quadrant.

4.12. **IDENTIFY:** Apply \( \sum \vec{F} = m \vec{a} \). Then use a constant acceleration equation to relate the kinematic quantities.

**SET UP:** Let +x be in the direction of the force.

**EXECUTE:** (a) \( a_x = \frac{F_x}{m} = \frac{140 \text{ N}}{32.5 \text{ kg}} = 4.31 \text{ m/s}^2 \).

(b) \( x - x_0 = v_{0x} t + \frac{1}{2} a_x t^2 \). With \( v_{0x} = 0 \), \( x = \frac{1}{2} a_x t^2 = 215 \text{ m} \).

(c) \( v_y = v_{0y} + a_y t \). With \( v_{0y} = 0 \), \( v_y = a_y t = 2 x / t = 43.0 \text{ m/s} \).

**EVALUATE:** The acceleration connects the motion to the forces.

4.18. **IDENTIFY:** Apply \( \sum \vec{F} = m \vec{a} \).

**SET UP:** \( m = \frac{w}{g} = \frac{71.2 \text{ N}}{9.80 \text{ m/s}^2} = 7.27 \text{ kg} \).

**EXECUTE:** \( a = \frac{F}{m} = \frac{160 \text{ N}}{7.27 \text{ kg}} = 22.0 \text{ m/s}^2 \).

**EVALUATE:** The weight of the ball is a vertical force and doesn’t affect the horizontal acceleration. However, the weight is used to calculate the mass.

4.25. **IDENTIFY:** Apply Newton’s second law to the earth.

**SET UP:** The force of gravity that the earth exerts on her is her weight, \( w = mg = (45 \text{ kg})(9.8 \text{ m/s}^2) = 441 \text{ N} \). By Newton’s 3rd law, she exerts an equal and opposite force on the earth.

Apply \( \sum \vec{F} = m \vec{a} \) to the earth, with \( |\sum \vec{F}| = w = 441 \text{ N} \), but must use the mass of the earth for \( m \).

**EXECUTE:** \( a = \frac{w}{m} = \frac{441 \text{ N}}{6.0 \times 10^{24} \text{ kg}} = 7.4 \times 10^{-23} \text{ m/s}^2 \).

**EVALUATE:** This is much smaller than her acceleration of 9.8 m/s². The force she exerts on the earth equals in magnitude the force the earth exerts on her, but the acceleration the force produces depends on the mass of the object and her mass is much less than the mass of the earth.

4.31. **IDENTIFY:** Identify the forces on the chair. The floor exerts a normal force and a friction force.

**SET UP:** Let +y be upward and let +x be in the direction of the motion of the chair.

**EXECUTE:** (a) The free-body diagram for the chair is given in the figure below.

(b) For the chair, \( a_y = 0 \) so \( \sum F_y = ma_y \) gives \( n - mg - F \sin 37^\circ = 0 \) and \( n = 142 \text{ N} \).

**EVALUATE:** \( n \) is larger than the weight because \( \vec{F} \) has a downward component.