12. ***REASONING AND SOLUTION***

a. The x component of velocity is

$$v_x = v_{0x} + a_x t = 5480 \text{ m/s} + \left(1.20 \text{ m/s}^2\right)(842 \text{ s}) = \boxed{6490 \text{ m/s}}$$

b. For the y component

$$v_y = v_{0y} + a_y t = 0 \text{ m/s} + \left(8.40 \text{ m/s}^2\right)(842 \text{ s}) = \boxed{7070 \text{ m/s}}$$

13. ***REASONING AND SOLUTION*** Use the information concerning the x motion to find the time of flight of the ball

$$x = v_{ox}t \quad \text{or} \quad t = x/v_{ox} = (19.6\text{ m})/(28.0\text{ m/s}) = 0.700\text{ s}$$

The motion in the y direction is therefore subject to

$$y = v_{oy}t - (1/2)gt^2 = 0 - (1/2)(9.80\text{ m/s}^2)(0.700\text{ s})^2 = -2.40\text{ m}$$

The height of the tennis ball is $\boxed{2.40\text{ m}}$.

14. ***REASONING*** The vertical component of the ball's velocity $\mathbf{v_0}$ changes as the ball approaches the opposing player. It changes due to the acceleration of gravity. However, the horizontal component does not change, assuming that air resistance can be neglected. Hence, the horizontal component of the ball's velocity when the opposing player fields the ball is the same as it was initially.

SOLUTION Using trigonometry, we find that the horizontal component is

$$v_x = v_0 \cos\theta = (15\ \text{m/s})\cos 55° = \boxed{8.6\ \text{m/s}}$$

15. **SSM** ***REASONING*** The time that the ball spends in the air is determined by its vertical motion. The time required for the ball to reach the lake can be found by solving Equation 3.5b for t. The motion of the golf ball is characterized by constant velocity in the x direction and accelerated motion (due to gravity) in the y direction. Thus, the x component of the velocity of the golf ball is constant, and the y component of the velocity at any time t can be found from Equation 3.3b. Once the x and y components of the velocity are known for a particular time t, the speed can be obtained from $v = \sqrt{v_x^2 + v_y^2}$.

SOLUTION

a. Since the ball rolls off the cliff horizontally, $v_{0y} = 0$. If the origin is chosen at top of the cliff and upward is assumed to be the positive direction, then the vertical component of the ball's displacement is $y = -15.5$ m. Thus, Equation 3.5b gives

$$t = \sqrt{\frac{2y}{a_y}} = \sqrt{\frac{2(-15.5\text{ m})}{(-9.80\text{ m/s}^2)}} = \boxed{1.78\text{ s}}$$

b. Since there is no acceleration in the x direction, $v_x = v_{0x} = 11.4$ m/s . The y component of the velocity of the ball just before it strikes the water is, according to Equation 3.3b,

$$v_y = v_{0y} + a_y t = \left[0 + (-9.80\text{ m/s}^2)(1.78\text{ s})\right] = -17.4\text{ m/s}$$

The speed of the ball just before it strikes the water is, therefore,

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(11.4\text{ m/s})^2 + (-17.4\text{ m/s})^2} = \boxed{20.8\text{ m/s}}$$

16. ***REASONING AND SOLUTION*** Using $v_y = 0$ and

$$v_{oy} = v_o \sin\theta = (11 \text{ m/s}) \sin 65^\circ = 1.0 \times 10^1 \text{ m/s}$$

and $v_y^2 = v_{oy}^2 + 2a_y y$, we have

$$y = \frac{-v_{0y}^2}{2a_y} = \frac{-\left(1.0\times10^1 \text{ m/s}\right)^2}{2\left(-9.80 \text{ m/s}^2\right)} = \boxed{5.1 \text{ m}}$$

17. **SSM** **WWW** ***REASONING*** Once the diver is airborne, he moves in the x direction with constant velocity while his motion in the y direction is accelerated (at the acceleration due to gravity). Therefore, the magnitude of the x component of his velocity remains constant at 1.20 m/s for all times t. The magnitude of the y component of the diver's velocity after he has fallen through a vertical displacement y can be determined from Equation 3.6b: $v_y^2 = v_{0y}^2 + 2a_y y$. Since the diver runs off the platform horizontally, $v_{0y} = 0$. Once the x and y components of the velocity are known for a particular vertical displacement y, the speed of the diver can be obtained from $v = \sqrt{v_x^2 + v_y^2}$.

SOLUTION For convenience, we will take downward as the positive y direction. After the diver has fallen 10.0 m, the y component of his velocity is, from Equation 3.6b,

$$v_y = \sqrt{v_{0y}^2 + 2a_y y} = \sqrt{0^2 + 2(9.80\ \text{m/s}^2)(10.0\ \text{m})} = 14.0\ \text{m/s}$$

Therefore,

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(1.20\ \text{m/s})^2 + (14.0\ \text{m/s})^2} = \boxed{14.1\ \text{m/s}}$$

18. ***REASONING***

a. The maximum possible distance that the ball can travel occurs when it is launched at an angle of 45.0°. When the ball lands on the green, it is at the same elevation as the tee, so the vertical component (or y component) of the ball's displacement is zero. The time of flight is given by the y variables, which are listed in the table below. We designate "up" as the $+y$ direction.

y-Direction Data

y	a_y	v_y	v_{0y}	t
0 m	$-9.80\ \text{m/s}^2$		+(30.3 m/s) sin 45.0° = +21.4 m/s	?

Since three of the five kinematic variables are known, we can employ one of the equations of kinematics to find the time t that the ball is in the air.

b. The longest hole in one that the golfer can make is equal to the range R of the ball. This distance is given by the x variables and the time of flight, as determined in part (a). Once again, three variables are known, so an equation of kinematics can be used to find the range of the ball. The $+x$ direction is taken to be from the tee to the green.

x-Direction Data

x	a_x	v_x	v_{0x}	t
R = ?	$0\ \text{m/s}^2$		+(30.3 m/s) cos 45.0° = +21.4 m/s	from part a

SOLUTION

a. We will use Equation 3.5b to find the time, since this equation involves the three known variables in the y direction:

$$y = v_{0y}t + \tfrac{1}{2}a_y t^2 = \left(v_{0y} + \tfrac{1}{2}a_y t\right)t$$

$$0\ \text{m} = \left[+21.4\ \text{m/s} + \tfrac{1}{2}\left(-9.80\ \text{m/s}^2\right)t\right]t$$

Solving this quadratic equation yields two solutions, $t = 0$ s and $t = 4.37$ s. The first solution represents the situation when the golf ball just begins its flight, so we discard this one. Therefore, $t = \boxed{4.37\ \text{s}}$.

b. With the knowledge that $t = 4.37$ s and the values for a_x and v_{0x} (see the x-direction data table above), we can use Equation 3.5a to obtain the range R of the golf ball.

$$\underbrace{x}_{=R} = v_{0x}t + \tfrac{1}{2}a_x t^2 = \left(+21.4\ \text{m/s}\right)\left(4.37\ \text{s}\right) + \tfrac{1}{2}\left(0\ \text{m/s}^2\right)\left(4.37\ \text{s}\right)^2 = \boxed{93.5\ \text{m}}$$

19. ***REASONING AND SOLUTION*** The components of the initial velocity are

$$v_{0x} = v_0 \cos\theta = (22 \text{ m/s}) \cos 40.0° = 17 \text{ m/s}$$
$$v_{0y} = v_0 \sin\theta = (22 \text{ m/s}) \sin 40.0° = 14 \text{ m/s}$$

a. Solving Equation 3.6b for y gives

$$y = \frac{v_y^2 - v_{0y}^2}{2a_y}$$

When the football is at the maximum height $y = H$, and the football is momentarily at rest, so $v_y = 0$. Thus,

$$H = \frac{0 - v_{0y}^2}{2a_y} = \frac{0 - (14 \text{ m/s})^2}{2(-1.62 \text{ m/s}^2)} = \boxed{6.0 \times 10^1 \text{ m}}$$

b. When the ball strikes the ground, $y = 0$; therefore, the time of flight can be determined from Equation 3.5b with $y = 0$.

$$y = v_{0y}t + \tfrac{1}{2} a_y t^2$$

or

$$0 = [(14 \text{ m/s}) + \tfrac{1}{2}(-1.62 \text{ m/s}^2)\, t]\, t$$

$$t = 17 \text{ s}$$

The range is

$$x = R = v_{0x}t = (17 \text{ m/s})(17 \text{ s}) = \boxed{290 \text{ m}}$$

20. ***REASONING AND SOLUTION*** The maximum vertical displacement y attained by a projectile is given by Equation 3.6b ($v_y^2 = v_{0y}^2 + 2a_y y$) with $v_y = 0$:

$$y = -\frac{v_{0y}^2}{2a_y}$$

In order to use Equation 3.6b, we must first estimate his initial speed v_{0y}. When Jordan has reached his maximum vertical displacement, $v_y = 0$, and $t = 1.00$ s. Therefore, according to Equation 3.3b ($v_y = v_{0y} + a_y t$), with upward taken as positive, we find that

$$v_{0y} = -a_y t = -\ (-9.80\ \text{m/s}^2)\ (1.00\ \text{s}) = 9.80\ \text{m/s}$$

Therefore, Jordan's maximum jump height is

$$y = -\frac{(9.80\ \text{m/s})^2}{2(-9.80\ \text{m/s}^2)} = \boxed{4.90\ \text{m}}$$

This result far exceeds Jordan's maximum jump height, so the claim that he can remain in the air for two full seconds is false.

21. $\boxed{\text{SSM}}$ ***REASONING AND SOLUTION*** The water exhibits projectile motion. The x component of the motion has zero acceleration while the y component is subject to the acceleration due to gravity. In order to reach the highest possible fire, the displacement of the hose from the building is x, where, according to Equation 3.5a (with $a_x = 0$),

$$x = v_{0x}t = (v_0 \cos\theta)t$$

with t equal to the time required for the water the reach its maximum vertical displacement. The time t can be found by considering the vertical motion. From Equation 3.3b,

$$v_y = v_{0y} + a_y t$$

When the water has reached its maximum vertical displacement, $v_y = 0$. Taking up and to the right as the positive directions, we find that

$$t = \frac{-v_{0y}}{a_y} = \frac{-v_0 \sin\theta}{a_y}$$

and

$$x = (v_0 \cos\theta)\left(\frac{-v_0 \sin\theta}{a_y}\right)$$

Therefore, we have

$$x = -\frac{v_0^2 \cos\theta \ \sin\theta}{a_y} = -\frac{(25.0 \text{ m/s})^2 \cos 35.0° \ \sin 35.0°}{-9.80 \text{ m/s}^2} = \boxed{30.0 \text{ m}}$$

22. ***REASONING AND SOLUTION*** The time required for the car to fall to the ground is given by

$$t = \sqrt{\frac{-2y}{g}} = \sqrt{\frac{-2(-54\text{ m})}{9.80\text{ m/s}^2}} = 3.3\text{ s}$$

During this time, the car traveled a horizontal distance of 130 m. Using $a_x = 0\text{ m/s}^2$ gives

$$v_{0x} = x/t = (130\text{ m})/(3.3\text{ s}) = \boxed{39\text{ m/s}}$$

23. ***REASONING*** We begin by considering the flight time of the ball on the distant planet. Once the flight time is known, we can determine the maximum height and the range of the ball.

The range of a projectile is proportional to the time that the projectile is in the air. Therefore, the flight time on the distant plant 3.5 times larger than on earth. The flight time can be found from Equation 3.3b ($v_y = v_{0y} + a_y t$). When the ball lands, it is at the same level as the tee; therefore, from the symmetry of the motion $v_y = -v_{0y}$. Taking upward and to the right as the positive directions, we find that the flight time on earth would be

$$t = \frac{v_y - v_{0y}}{a_y} = \frac{-2v_{0y}}{a_y} = \frac{-2v_0 \sin\theta}{a_y} = \frac{-2(45\text{ m/s})\sin 29°}{-9.80\text{ m/s}^2} = 4.45\text{ s}$$

Therefore, the flight time on the distant planet is $3.5 \times (4.45\text{ s}) = 15.6$ s. From the symmetry of the problem, we know that this is twice the amount of time required for the ball to reach its maximum height, which, consequently, is 7.80 s.

SOLUTION

a. The height y of the ball at any instant is given by Equation 3.4b as the product of the average velocity component in the y direction $\frac{1}{2}\left(v_{0y} + v_y\right)$ and the time t: $y = \frac{1}{2}\left(v_{0y} + v_y\right)t$. Since the maximum height H is reached when the final velocity component in the y direction is zero ($v_y = 0$), we find that

$$H = \tfrac{1}{2}v_{0y}t = \tfrac{1}{2}v_0(\sin 29°)t = \tfrac{1}{2}(45\text{ m/s})(\sin 29°)(7.80\text{ s}) = \boxed{85\text{ m}}$$

b. The range of the ball on the distant planet is

$$x = v_{0x}t = v_0(\cos 29°)t = (45\text{ m/s})(\cos 29°)(15.6\text{ s}) = \boxed{610\text{ m}}$$

26. ***REASONING*** The vertical displacement y of the ball depends on the time that it is in the air before being caught. These variables depend on the y-direction data, as indicated in the table, where the $+y$ direction is "up."

y-Direction Data

y	a_y	v_y	v_{0y}	t
?	$-9.80\ \text{m/s}^2$		0 m/s	?

Since only two variables in the y direction are known, we cannot determine y at this point. Therefore, we examine the data in the x direction, where $+x$ is taken to be the direction from the pitcher to the catcher.

x-Direction Data

x	a_x	v_x	v_{0x}	t
+17.0 m	$0\ \text{m/s}^2$		+41.0 m/s	?

Since this table contains three known variables, the time t can be evaluated by using an equation of kinematics. Once the time is known, it can then be used with the y-direction data, along with the appropriate equation of kinematics, to find the vertical displacement y.

SOLUTION Using the x-direction data, Equation 3.5a can be employed to find the time t that the baseball is in the air:

$$x = v_{0x}t + \tfrac{1}{2}a_x t^2 = v_{0x}t \qquad \left(\text{since } a_x = 0\ \text{m/s}^2\right)$$

Solving for t gives

$$t = \frac{x}{v_{0x}} = \frac{+17.0\ \text{m}}{+41.0\ \text{m/s}} = 0.415\ \text{s}$$

The displacement in the y direction can now be evaluated by using the y-direction data table and the value of $t = 0.415$ s. Using Equation 3.5b, we have

$$y = v_{0y}t + \tfrac{1}{2}a_y t^2 = (0\ \text{m/s})(0.415\ \text{s}) + \tfrac{1}{2}\left(-9.80\ \text{m/s}^2\right)(0.415\ \text{s})^2 = -0.844\ \text{m}$$

The distance that the ball drops is given by the magnitude of this result, so Distance = $\boxed{0.844\ \text{m}}$.

27. ***REASONING AND SOLUTION*** The time of flight of the motorcycle is given by

$$t = \frac{2v_0 \sin\theta_0}{g} = \frac{2(33.5\text{ m/s})\sin 18.0°}{9.80\text{ m/s}^2} = 2.11\text{ s}$$

The horizontal distance traveled by the motorcycle is then

$$x = v_0 \cos\theta_0\, t = (33.5\text{ m/s})(\cos 18.0°)(2.11\text{ s}) = 67.2\text{ m}$$

The daredevil can jump over (67.2 m)/(2.74 m/bus) = 24.5 buses. In even numbers, this means $\boxed{\text{24 buses}}$.

30. ***REASONING*** The rocket will clear the top of the wall by an amount that is the height of the rocket as it passes over the wall minus the height of the wall. To find the height of the rocket as it passes over the wall, we separate the rocket's projectile motion into its horizontal and vertical parts and treat each one separately. From the horizontal part we will obtain the time of flight until the rocket reaches the location of the wall. Then, we will use this time along with the acceleration due to gravity in the equations of kinematics to determine the height of the rocket as it passes over the wall.

SOLUTION We begin by finding the horizontal and vertical components of the launch velocity

$$v_{0x} = v_0 \cos 60.0° = (75.0 \text{ m/s}) \cos 60.0°$$

$$v_{0y} = v_0 \sin 60.0° = (75.0 \text{ m/s}) \sin 60.0°$$

Using v_{0x}, we can obtain the time of flight, since the distance to the wall is known to be 27.0 m:

$$t = \frac{27.0 \text{ m}}{v_{0x}} = \frac{27.0 \text{ m}}{(75.0 \text{ m/s}) \cos 60.0°} = 0.720 \text{ s}$$

The height of the rocket as it clears the wall can be obtained from Equation 3.5b, in which we take upward to be the positive direction. The amount by which the rocket clears the wall can then be obtained:

$$y = v_{0y} t + \tfrac{1}{2} a_y t^2$$

$$y = (75.0 \text{ m/s})(\sin 60.0°)(0.720 \text{ s}) + \tfrac{1}{2}(-9.80 \text{ m/s}^2)(0.720 \text{ s})^2 = 44.2 \text{ m}$$

$$\text{clearance} = 44.2 \text{ m} - 11.0 \text{ m} = \boxed{33.2 \text{ m}}$$

31. ***REASONING AND SOLUTION*** The coordinates of the bullet when it hits the target are $y = -(1/2)gt^2$ and $x = v_0 t$. The first of these yields the time of flight

$$t = \sqrt{\frac{-2y}{g}} = \sqrt{\frac{-2(-0.025\text{ m})}{9.80\text{ m/s}^2}} = 0.071\text{ s}$$

The horizontal distance traveled is then

$$x = (670\text{ m/s})(0.071\text{ s}) = \boxed{48\text{ m}}$$

61. ***REASONING AND SOLUTION*** The vertical motion consists of the ball rising for a time t stopping and returning to the ground in another time t. For the upward portion

$$t = \frac{v_{0y} - v_y}{g} = \frac{v_{0y}}{g}$$

Note: $v_y = 0$ m/s since the ball stops at the top. Now

$$v_{oy} = v_o \sin \theta_o = (25.0 \text{ m/s}) \sin 60.0° = 21.7 \text{ m/s}$$

$$t = (21.7 \text{ m/s})/(9.80 \text{ m/s}^2) = 2.21 \text{ s}$$

The required "hang time" is $2t = \boxed{4.42 \text{ s}}$.