

11. **REASONING AND SOLUTION** Other than being horizontal, the motion of an experimental vehicle that slows down, comes to a momentary halt, reverses direction and then speeds up with a constant acceleration of 9.80 m/s^2 , is identical to that of a ball that is thrown straight upward near the surface of the earth, comes to a halt, and falls back down. In both cases, the acceleration is constant in magnitude and direction and the objects begin their motion with the acceleration and velocity vectors pointing in opposite directions.

12. **REASONING AND SOLUTION** The first ball has an initial speed of zero, since it is dropped from rest. It picks up speed on the way down, striking the ground at a speed v_f . The second ball has a motion that is the reverse of that of the first ball. The second ball starts out with a speed v_f and loses speed on the way up. By symmetry, the second ball will come to a halt at the top of the building. Thus, in approaching the crossing point, the second ball travels faster than the first ball. Correspondingly, the second ball must travel farther on its way to the crossing point than the first ball does. Thus, the crossing point must be located in the upper half of the building.

37. **SSM** *REASONING AND SOLUTION* The speed of the penny as it hits the ground can be determined from Equation 2.9: $v^2 = v_0^2 + 2ay$. Since the penny is dropped from rest, $v_0 = 0$ m/s. Solving for v , with downward taken as the positive direction, we have

$$v = \sqrt{2(9.80 \text{ m/s}^2)(427 \text{ m})} = \boxed{91.5 \text{ m/s}}$$

40. **REASONING AND SOLUTION** In a time t the card will undergo a vertical displacement y given by

$$y = \frac{1}{2} at^2$$

where $a = -9.80 \text{ m/s}^2$. When $t = 60.0 \text{ ms} = 6.0 \times 10^{-2} \text{ s}$, the displacement of the card is 0.018 m , and the distance is the magnitude of this value or $d_1 = 0.018 \text{ m}$.

Similarly, when $t = 120 \text{ ms}$, $d_2 = 0.071 \text{ m}$, and when $t = 180 \text{ ms}$, $d_3 = 0.16 \text{ m}$.

45. **SSM** *REASONING AND SOLUTION* Equation 2.8 can be used to determine the displacement that the ball covers as it falls halfway to the ground. Since the ball falls from rest, its initial velocity is zero. Taking down to be the negative direction, we have

$$y = v_0 t + \frac{1}{2} a t^2 = \frac{1}{2} a t^2 = \frac{1}{2} (-9.80 \text{ m/s}^2)(1.2 \text{ s}) = -7.1 \text{ m}$$

In falling all the way to the ground, the ball has a displacement of $y = -14.2 \text{ m}$. Solving Equation 2.8 with this displacement then yields the time

$$t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(-14.2 \text{ m})}{-9.80 \text{ m/s}^2}} = \boxed{1.7 \text{ s}}$$

48. **REASONING AND SOLUTION** The time required for the first arrow to reach its maximum height can be determined from Equation 2.4 ($v = v_0 + at$). Taking upward as the positive direction, we have

$$t = \frac{v - v_0}{a} = \frac{0 \text{ m/s} - 25.0 \text{ m/s}}{-9.80 \text{ m/s}^2} = 2.55 \text{ s}$$

Since both arrows reach their maximum height at the same time, the second arrow reaches its maximum height

$$2.55 \text{ s} - 1.20 \text{ s} = 1.35 \text{ s}$$

after being fired. The initial speed of the second arrow can then be found from Equation 2.4:

$$v_0 = v - at = 0 \text{ m/s} - (-9.80 \text{ m/s}^2)(1.35 \text{ s}) = \boxed{13.2 \text{ m/s}}$$

51. **SSM** *REASONING AND SOLUTION* The stone will reach the water (and hence the log) after falling for a time t , where t can be determined from Equation 2.8: $y = v_0 t + \frac{1}{2} a t^2$. Since the stone is dropped from rest, $v_0 = 0$ m/s. Assuming that downward is positive and solving for t , we have

$$t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(75 \text{ m})}{9.80 \text{ m/s}^2}} = 3.9 \text{ s}$$

During that time, the displacement of the log can be found from Equation 2.8. Since the log moves with constant velocity, $a = 0 \text{ m/s}^2$, and v_0 is equal to the velocity of the log.

$$x = v_0 t = (5.0 \text{ m/s})(3.9 \text{ s}) = 2.0 \times 10^1 \text{ m}$$

Therefore, the horizontal distance between the log and the bridge when the stone is released is $\boxed{2.0 \times 10^1 \text{ m}}$.

76. **REASONING** We choose due north as the positive direction. Our solution is based on the fact that when the police car catches up, both cars will have the same displacement, relative to the point where the speeder passed the police car. The displacement of the speeder can be obtained from the definition of average velocity given in Equation 2.2, since the speeder is moving at a constant velocity. During the 0.800-s reaction time of the policeman, the police car is also moving at a constant velocity. Once the police car begins to accelerate, its displacement can be expressed as in Equation 2.8 ($x = v_0 t + \frac{1}{2} a t^2$), because the initial velocity v_0 and the acceleration a are known and it is the time t that we seek. We will set the displacements of the speeder and the police car equal and solve the resulting equation for the time t .

SOLUTION Let t equal the time during the accelerated motion of the police car. Relative to the point where he passed the police car, the speeder then travels a time of $t + 0.800$ s before the police car catches up. During this time, according to the definition of average velocity given in Equation 2.2, his displacement is

$$x_{\text{Speeder}} = v_{\text{Speeder}} (t + 0.800 \text{ s}) = (42.0 \text{ m/s})(t + 0.800 \text{ s})$$

The displacement of the police car consists of two contributions, the part due to the constant-velocity motion during the reaction time and the part due to the accelerated motion. Using Equation 2.2 for the contribution from the constant-velocity motion and Equation 2.9 for the contribution from the accelerated motion, we obtain

$$\begin{aligned} x_{\text{Police car}} &= \underbrace{v_{0, \text{ Police car}} (0.800 \text{ s})}_{\substack{\text{Constant velocity motion,} \\ \text{Equation 2.2}}} + \underbrace{v_{0, \text{ Police car}} t + \frac{1}{2} a t^2}_{\substack{\text{Accelerated motion,} \\ \text{Equation 2.8}}} \\ &= (18.0 \text{ m/s})(0.800 \text{ s}) + (18.0 \text{ m/s})t + \frac{1}{2}(5.00 \text{ m/s}^2)t^2 \end{aligned}$$

Setting the two displacements equal we obtain

$$\underbrace{(42.0 \text{ m/s})(t + 0.800 \text{ s})}_{\text{Displacement of speeder}} = \underbrace{(18.0 \text{ m/s})(0.800 \text{ s}) + (18.0 \text{ m/s})t + \frac{1}{2}(5.00 \text{ m/s}^2)t^2}_{\text{Displacement of police car}}$$

Rearranging and combining terms gives this result in the standard form of a quadratic equation:

$$(2.50 \text{ m/s}^2)t^2 - (24.0 \text{ m/s})t - 19.2 \text{ m} = 0$$

Solving for t shows that

$$t = \frac{-(-24.0 \text{ m/s}) \pm \sqrt{(-24.0 \text{ m/s})^2 - 4(2.50 \text{ m/s}^2)(-19.2 \text{ m})}}{2(2.50 \text{ m/s}^2)} = 10.3 \text{ s}$$

We have ignored the negative root, because it leads to a negative value for the time, which is unphysical. The total time for the police car to catch up, including the reaction time, is

$$0.800 \text{ s} + 10.3 \text{ s} = \boxed{11.1 \text{ s}}$$