IB Physics SL GOHS

2.6 Worksheet: Free Fall

$$v = v_o + at$$

$$\Delta x = \frac{1}{2}(v_o + v)t$$

$$\Delta x = v_o t + \frac{1}{2}at^2$$

$$v^2 = v_o^2 + 2a\Delta x$$

Quick Quiz

2.6) A tennis player on serve tosses a ball straight up. While the ball is in free fall, does its acceleration (a) increase, (b) decrease, (c) increase and then decrease, (d) decrease and then increase, or (e) remain constant?

2.7) As the tennis ball of Quick Quiz 2.6 travels through the air, its speed (a) increases, (b) decreases, (c) decreases and then increases, (d) increases and then decreases, or (e) remains the same.

2.8) A skydiver jumps out of a hovering helicopter. A few seconds later, another skydiver jumps out, so they both fall along the same vertical line relative to the helicopter. Both sky divers fall with the same acceleration. Does the vertical distance between them (a) increase, (b) decrease, or (c) stay the same? Does the difference in their velocities (d) increase, (e) decrease, or (f) stay the same? (Assume that *g* is constant.)

Concept Questions

16. A ball is thrown straight upward and moves in free fall. Choose a coordinate system with its origin at the release point of the ball and the positive direction upward. (a) What is the sign of the velocity of the ball just before the ball reaches its maximum height, just after it reaches its maximum height, and at its maximum height. (b) What is the sign of the acceleration of the ball just before the ball reaches its maximum height, just after it reaches its maximum height, and at its maximum height. (c) If the ball takes time *t*1 to reach its maximum height, how long will it take to return to ground level? (d) If the ball is thrown upward with a velocity of _*v*0, what will be the ball's velocity upon returning to ground level?

MORE ON THE BACK!!!!!!

17. A pebble is dropped into a water well, and the splash is heard 16 s later, as illustrated in the cartoon strip shown in Figure Q2.17. Estimate the distance from the rim of the well to the water's surface.

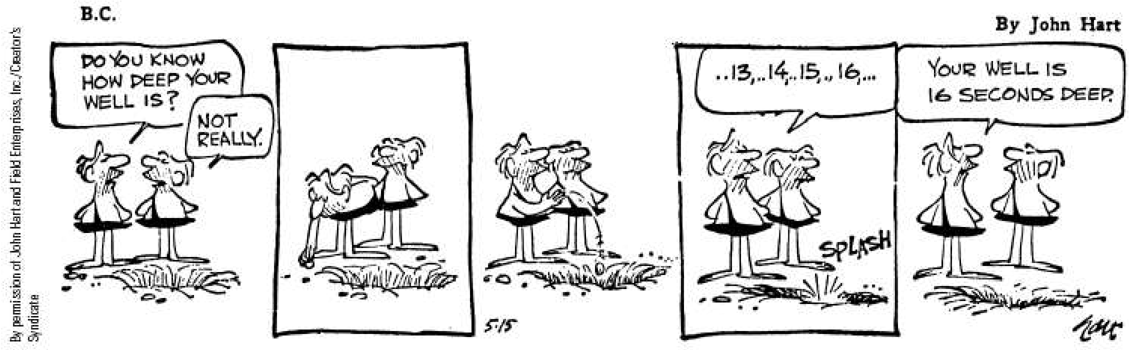

Figure Q2.17

<u>Problems</u>

43. A ball is thrown vertically upward with a speed of 25.0 m/s. (a) How high does it rise? (b) How long does it take to reach its highest point? (c) How long does the ball take to hit the ground after it reaches its highest point? (d) What is its velocity when it returns to the level from which it started?

44. It is possible to shoot an arrow at a speed as high as 100 m/s. (a) If friction is neglected, how high would an arrow launched at this speed rise if shot straight up? (b) How long would the arrow be in the air?

ANSWERS

Quick Quizzes

6. (e). The acceleration of the ball remains constant while it is in the air. The magnitude of its acceleration is the free-fall acceleration, $g = 9.80\ \text{m/s}^2$.

7. (c). As it travels upward, its speed decreases by 9.80 m/s during each second of its motion. When it reaches the peak of its motion, its speed becomes zero. As the ball moves downward, its speed increases by 9.80 m/s each second.

8. (a) and (f). The first jumper will always be moving with a higher velocity than the second. Thus, in a given time interval, the first jumper covers more distance than the second. Thus, the separation distance between them *increases*. At any given instant of time, the velocities of the jumpers are definitely different, because one had a head start. In a time interval after this instant, however, each jumper increases his or her velocity by the same amount, because they have the same acceleration. Thus, the difference in velocities *stays the same*.

Concept Questions

16. **(a)** positive, negative, zero

(b) The ball has the free-fall acceleration ($-9.80\ \text{m/s}^2$) at each point.

(c) $2t_1$

(d) $-v_0$

17. 78 m

Problems

2.43 (a) From $v^2 = v_0^2 + 2a(\Delta y)$ with $v = 0$, we have

$$(\Delta y)_{\text{max}} = \frac{v^2 - v_0^2}{2a} = \frac{0 - (25.0\ \text{m/s})^2}{2(-9.80\ \text{m/s}^2)} =$$ EMBED Equation.DSMT4 $\boxed{31.9\ \text{m}}$

(b) The time to reach the highest point is

$$t_{up} = \frac{v - v_0}{a} = \frac{0 - 25.0\ \text{m/s}}{-9.80\ \text{m/s}^2} =$$ EMBED Equation.DSMT4 $\boxed{2.55\ \text{s}}$

(c) The time required for the ball to fall 31.9 m, starting from rest, is found from

$\Delta y = (0)t + \frac{1}{2}at^2$ as $t = \sqrt{\frac{2(\Delta y)}{a}} = \sqrt{\frac{2(-31.9\ \text{m})}{-9.80\ \text{m/s}^2}} = \boxed{2.55\ \text{s}}$

(d) The velocity of the ball when it returns to the original level (2.55 s after it starts to fall from rest) is

$v = v_0 + at = 0 + (-9.80\ \text{m/s}^2)(2.55\ \text{s}) =$ EMBED Equation.DSMT4

$\boxed{-25.0\ \text{m/s}}$

2.44 (a) For the upward flight of the arrow, $v_0 = +100\ \text{m/s}$, $a = -g = -9.80\ \text{m/s}^2$, and the final velocity is $v = 0$. Thus, $v^2 = v_0^2 + 2a(\Delta y)$ yields

$$(\Delta y)_{\text{max}} = \frac{v^2 - v_0^2}{2a} = \frac{0 - (100\ \text{m/s})^2}{2(-9.80\ \text{m/s}^2)} =$$ EMBED Equation.DSMT4 $\boxed{510\ \text{m}}$

(b) The time for the upward flight is

$$t_{up} = \frac{(\Delta y)_{\text{max}}}{(v_{\text{av}})_{up}} = \frac{2(\Delta y)_{\text{max}}}{v_{\text{o}} + v} = \frac{2(510\ \text{m})}{100\ \text{m/s} + 0} = 10.2\ \text{s}$$

For the downward flight, $\Delta y = -(\Delta y)_{\text{max}} = -510\ \text{m},\ v_0 = 0,\ \text{and}\ a = -9.8\ \text{m s}^2$. Thus,

$\Delta y = v_0 t + \frac{1}{2}at^2$ gives $t_{down} = \sqrt{\frac{2(\Delta y)}{a}} = \sqrt{\frac{2(-510\ \text{m})}{-9.80\ \text{m/s}^2}} = 10.2\ \text{s}$ and the total time of the flight is $t_{total} = t_{down} + t_{down} = 10.2\ \text{s} + 10.2\ \text{s} = \boxed{20.4\ \text{s}}$