P2211K

8/31/2010

Prob. 2.17. A student standing on the ground throws a ball straight up. The ball leaves the student's hand with a speed of 12.0 *m/s* when the hand is 2.10 *m* above the ground.

a. How long is the ball in the air before it hits the ground? (The student moves her hand out of the way.) (*t = 2.61s)*

b. How high does it go? (*h = 7.35 m above release point or 9.45 m above the ground.)*

Prob. 2.70. As a science project, you drop a watermelon off the top of the Empire State Building, 320 m above the sidewalk. It so happens that Superman flies by at the instant you release the watermelon. Superman is headed straight down with a constant speed of 36.0 m/s.

- How fast is the watermelon going when it passes Superman? .(*72 m/s*)

Prob. 2.77. A rocket is launched straight up with constant acceleration. Four (4.00) seconds after liftoff, a bolt falls off the side of the rocket. The bolt hits the ground 6.40 s later.

- What was the rocket's acceleration? *($a = 5.97\ m/s^2$)*

Example: A flower pot is observed to fall past a 4.0m tall window in 0.50 s.

- How high above the top of the window did it begin? ($h = 1.6\ m$)

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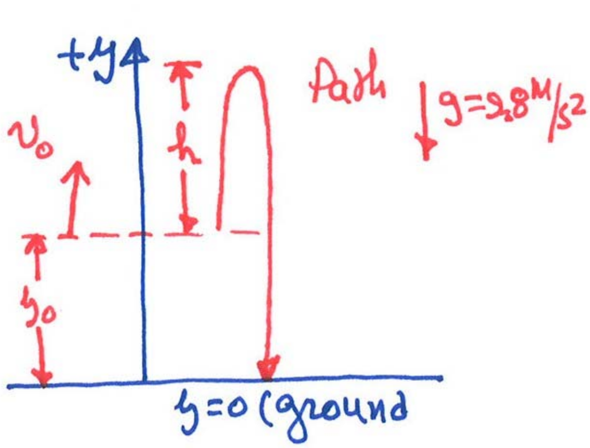

Solutions:

a. The relation $y = y_0 + v_0t + ½at^2$ connects the position @ t to the initial position (y_0), the initial speed (v_0), and the acceleration. In this case, the acceleration is due to gravity (*g = 9.8 m/s², down*).

The goal is to find the time T when $y = 0$; thus

$0 = 2.1m + (12\ m/s)T + ½(-9.8\ m/s^2)T^2$. This relation is quadratic in T of the form

$0 = c + bT + aT^2$, and T is given by the relation

$$T = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-12 \pm \sqrt{144 + 2(9.8)(2.1)}}{-9.8}\ s$$

The two solutions are $T = -0.164\ s$ and $\boldsymbol{T = +2.61\ s}$. Obviously, T can’t be negative because that indicates it reached $y = 0$ before starting!

b. The relation $v_f^2 = v_0^2 + 2ah$ connects the initial speed, the acceleration (due to gravity), and the height. At h, $v_f = 0$ (this is the “turning point”). Thus,

$$0 = (12\ m/s)^2 + 2(-9.8\ m/s^2)h, \text{ and}$$

$$\boldsymbol{h = \frac{144\ m^2/s^2}{19.6\ m/s^2} = 7.35\ m}$$

This is the height above the release point, so it is ***(7.35 + 2.1) m = 9.45 m*** above the ground.

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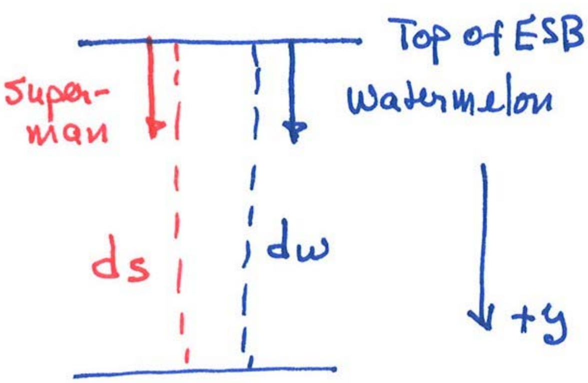
• How fast is the watermelon going when it passes Superman? (*72 m/s*)



SOLUTION:

Basic analysis: *the watermelon passes Superman when the two are the same distance from the top at the same time.*

For Superman: $D_s = v_s T$

The watermelon starts with speed = 0 and accelerates because of gravity, so: $D_w = ½gT^2$.

Thus, the watermelon passes Superman at T such that $D_s = D_w$, and that is given by $v_s T = ½gT^2$, or $T = \frac{36\ m/s}{4.9\ m/s^s} = 7.35\ s.$

In addition, the watermelon's speed at T is $v_w = gT$; therefore

$$\boldsymbol{v_w = 9.8\left(\frac{36}{4.9}\right) m/s = 72\ m/s.}$$

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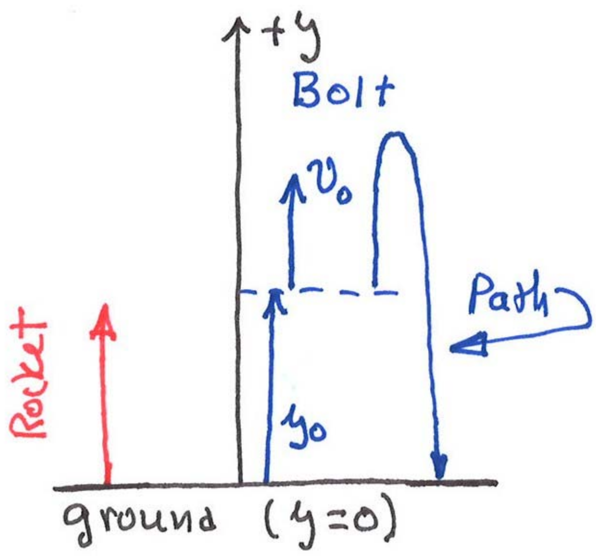
• What was the rocket's acceleration? *($a = 5.97\ m/s^2$)*



SOLUTION:

Basic Analysis: The rocket and bolt accelerate together from rest at $y = 0$ at the rate a. This occurs for the first 4.0 s, when the bolt comes loose. At that time, both the bolt and the rocket have the speed $v_4 = a(4s)$, and are at the height $y_4 = ½a(4s)^2$.

After coming off, the bolt behaves simply as an object projected from height y_4 with speed v_4 (upwards) under the influence of gravity. Thus, the bolt's y position after coming loose, and before hitting the ground, is

$$y_B = y_4 + v_4 t + ½at^2.$$

At $t = 6.4s$ (after coming loose), the bolt reaches the ground ($y_B = 0$). Putting all these together gives the relation:

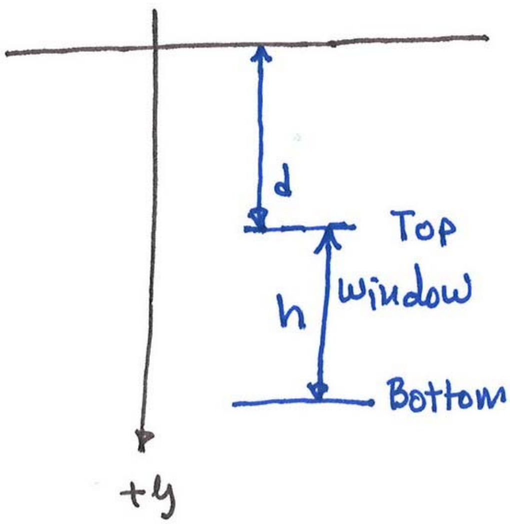
$$0 = ½a(4\ s)^2 + [a(4\ s)](6.4\ s) + ½(-9.8\ m/s^2)(6.4\ s)^2.$$

Only the rocket's acceleration (a) is unknown in this relation; thus,

$$\boldsymbol{a = \frac{(4.9)(6.4)^2}{[8 + (4)(6.4)]}\ m/s^2 = 5.97\ m/s^2}$$

Example: A flower pot is observed to fall past a 4.0m tall window in 0.50 s.

• How high above the top of the window did it begin? (*h = 1.6 m)*



SOLUTION:

Basic Analysis: The object falls from rest ($v_0 = 0$) from the distance *d* above the top of the window and is accelerated downwards under the influence of gravity. For this portion of the trip, the speed at the top of the window is given by the relation:

$$(eq. 1) \quad v_{top}^2 = v_0^2 + 2gd$$

The pot passes by the *4 m* tall (*h*) window in *0.5 s*. During this time, it gains speed because of gravity and has the speed at the bottom given by:

$$(eq. 2) \quad v_{bottom} = v_{top} + gt$$

Also, the speed at the bottom of the window is related to the speed at the top by:

$$(eq. 3) \quad v_{bottom}^2 = v_{top}^2 + 2gh$$

Using *eq. 2* and the numbers, we get

$$v_{bottom} = v_{top} + (9.8)(0.5)\, m/s = v_{top} + 4.9 m/s$$

Substituting this into *eq. 3* along with *h = 4*, we get

$$v_{bottom}^2 = [v_{top} + 4.9\, m/s]^2$$
$$= v_{top}^2 + 2v_{top}(4.9\ m/s) + (4.9\, m/s)^2 = v_{top}^2 + 2(9.8\, m/s^2)(4\, m)$$

Cleaning this algebraically, and solving for v_{top} gives

$$v_{top} = \frac{[(2)(9.8)(4) - (4.9)^2]}{(2)(4.9)} m/s = 5.55\, m/s$$

Finally, from *eq. 1*,

$$\boldsymbol{v_{top}^2 = v_0^2 + 2gd \rightarrow d = \frac{v_{top}^2 - v_0^2}{2g} = \frac{(5.55)^2 - 0}{2(9.8)}\, m = 1.57\, m}$$