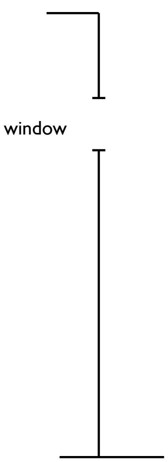
How High is the Building?

You are sitting in a room on an unknown floor of a high-rise looking out a 1.5 meters tall window. Someone drops a ball from the roof top. It takes the ball .2 seconds to pass from the top to the bottom of your window. The ball falls to the ground, bounces elastically (i.e., no energy lost) and reappears at your window 12 seconds later. How high is the building.

START BY DRAWING A SKETCH OF THE SITUATION!



Strategy

1. Draw a sketch and coordinate axis, then put as much information as you can in on the sketch.

2.) This problem is obscure enough and complex enough to be a real headache to start. When something like that happens, the best thing to do is to go to the part of the problem you know the most about. In this case, that would be the section of freefall associated with the window. You know how far the object falls as it passes the window (1.5 m) and how long it takes to go that distance (.2 seconds). With that information, you use

$$\Delta y_w = v_2\Delta t_w + \frac{1}{2}a_y\left(\Delta t_w\right)^2$$

to figure out how fast it is moving just as it gets to the window top.

3.) To determine how fast it's moving at the window's bottom, use

$$v_1 = v_2 + a_y\Delta t_w$$

4.) With the time to bottom of window (half of 12 seconds) and the window-bot velocities, you can get the distance from ground to window bottom using

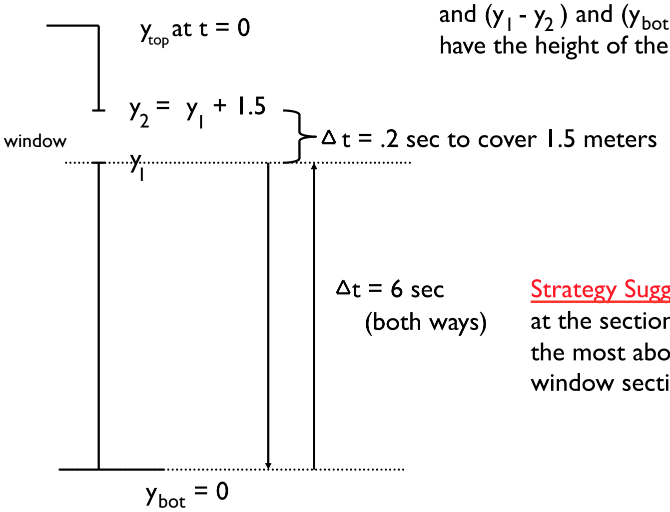
$$\Delta y_b = v_1\Delta t_b + \left(1/2\right)a_y\left(\Delta t_b\right)^2$$

5.) And with the window top velocity and the fact that the freefall started from rest (i.e., v=0), you can get the distance from the window top to the top of the building using

$$v_2^{\,2} = v_{top}^{\,2} + 2a\Delta y_t$$

6.) Once you have all the distances, add them up for the total height.

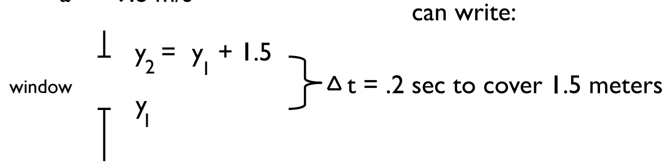
$a = -9.8\ m/s^2$



If you can add the pieces $(y_2 - y_{top})$ and $(y_1 - y_2)$ and $(y_{bot} - y_1)$, you'll have the height of the building.

Strategy Suggestion: Look at the section you know the most about (i.e. the window section) first.

$a = -9.8\ m/s^2$



In the middle (window) section, you can write:

To get the velocity v_2 at the top of the window, we can write:

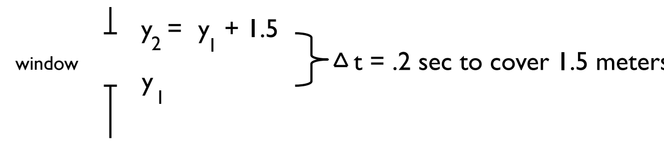
$$\Delta y = v_2 \Delta t + \left(\tfrac{1}{2}\right) a (\Delta t)^2$$

$$\Rightarrow \quad (-1.5\text{m}) = v_2(.2\,\text{sec}) + .5(-9.8\text{m/s})(.2\,\text{sec})^2$$

$$\Rightarrow \quad v_2 = -6.52\text{m/s}$$

What about the velocity v_1 at the bottom of the window?

$a = -9.8\ m/s^2$



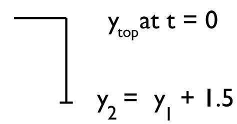
In the middle (window) section, you can write:

To get the velocity v_1 at the bottom of the window:

$$v_1 = v_2 + a\Delta t_{window}$$
$$= (-6.52\text{m/s}) + (-9.8\text{m/s})(.2\,\text{sec})$$
$$= -8.48\text{m/s}$$

To get the velocity v_2 at the top of the window, we can look at the upper section.

$a = -9.8\ m/s^2$



In the upper section, you can write:

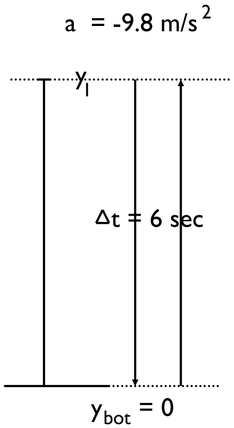
$$v_2^{\,2} = v_{top}^{\,2} + 2a\Delta y$$

$$\Rightarrow \quad \Delta y = \frac{v_2^{\,2} - v_{top}^{\,2}}{2a}$$

$$\Rightarrow \quad \Delta y = \frac{(6.52\text{m/s})^2 - (0)^2}{2(-9.8\text{m/s}^2)}$$

$$\Rightarrow \quad \Delta y = 2.17\text{m}$$

And finally, the lower section:



In the bottom section with an "initial" velocity of v_1, you can write:

$$\Delta y = v_2 \Delta t + \left(\tfrac{1}{2}\right) a \left(\Delta t\right)^2$$

$$\Rightarrow \quad \Delta y = (-8.48\,m/s)(6\,sec) + .5(-9.8\,m/s)(6\,sec)^2$$

$$\Rightarrow \quad = 227\ m$$