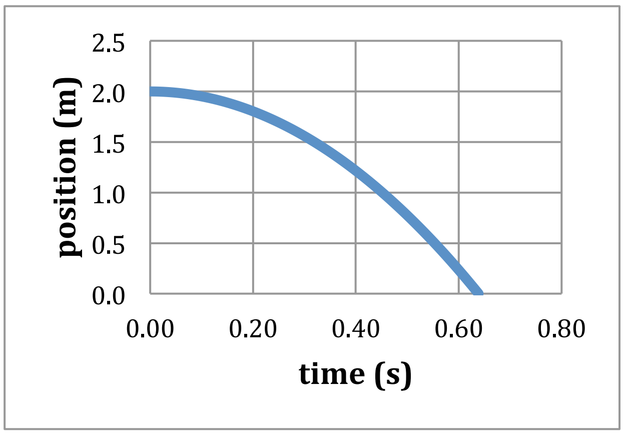
Flipping Physics Lecture Notes:
Throwing a Ball up to 2.0 Meters & Proving the Velocity at the Top is Zero
An Introductory Free-Fall Acceleration Problem

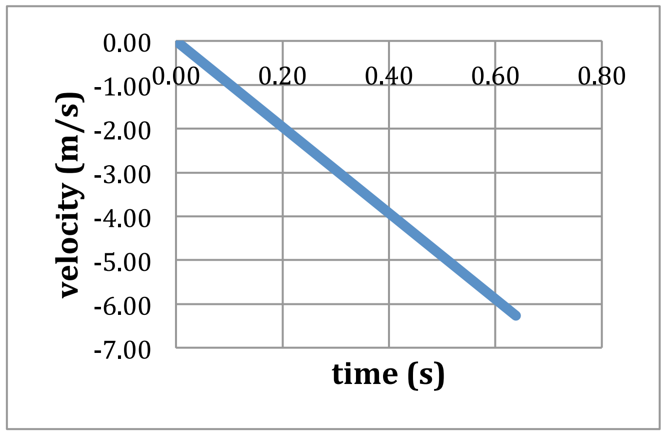
We have already done this example problem and drawn the graphs of position, velocity and acceleration as a function of time.

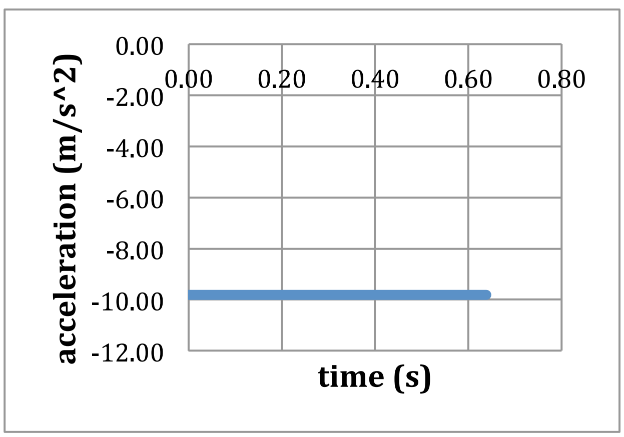
Previous Example Problem: Mr.p drops a medicine ball from a height of 2.0 m above the ground. (a) What is the velocity of the ball right before it strikes the ground? (b) How long did the ball fall?

Knowns: $\Delta y = -2.0$ m, $a_y = -9.81$ m/s^2, $v_{iy} = 0$;
Determined variables: $v_{fy} = -6.26418 \approx -6.3$ m/s, $\Delta t = 0.638551 \approx 0.64$ seconds

Previous graphs:





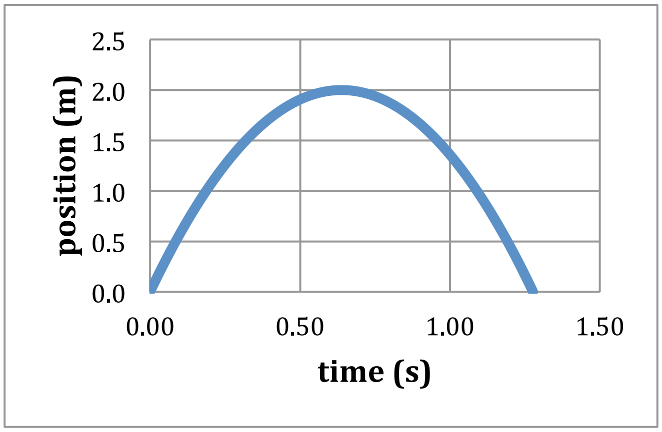


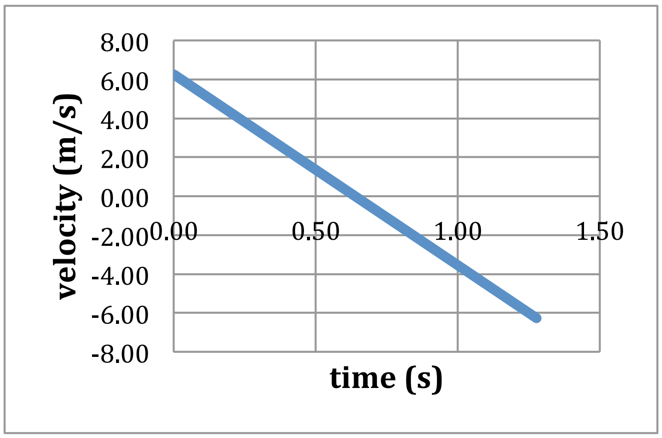
Note: Our solution to this problem is based on having solved the previous problem and is meant to make comparisons between the two. This is why we can start with the graphs to solve this problem.

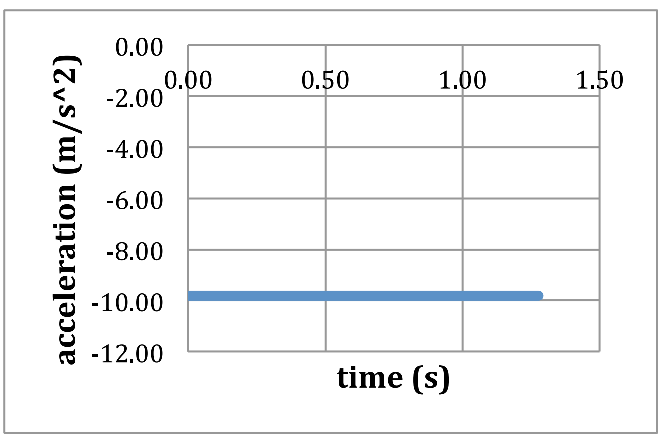
(this point starts all the new stuff for this problem)

Now we have the problem: Mr.p throws a medicine ball upward and catches it again at the same height that he threw it. If the maximum height the ball achieves above where he threw it is 2.0 meters, how long was the ball not in mr.p's hands?

Acceleration vs. Time Graph:
Just like last time, the easiest graph to start with is the acceleration graph because the value is constant at -9.81 m/s^2 because the medicine ball is in free-fall. Therefore the acceleration vs. time graph has a horizontal line at -9.81 m/s^2.







Velocity vs. Time Graph:
We know that the velocity vs. time graph has a slope of -9.81 m/s^2, however, we need to know where it starts and ends. I won't prove it right now, however, I know it will start at 6.26418 m/s and end at -6.26418 m/s. We'll know why in a moment.

Position vs. Time Graph:
With regards to position as a function of time, we don't know the initial height, so we can just pick an arbitrary initial point of zero meters. And we know it ends at the same height or zero meters. We also know it has a maximum height of 2.0 meters, so in the middle it will have a maximum value of 2.0 meters.

We know the initial slope of the position vs. time graph needs to be about 6.3 m/s and the final slope needs to be -6.3 m/s. (the slope of the position vs. time graph is velocity) This means that the slope will constantly decrease from 6.3 m/s to -6.3 m/s. So the position vs. time graph is concave down and symmetrical.

But what does this mean that the velocity is zero right in the middle of the graph? It means that *the velocity is zero at the very top of the balls path*. The velocity is positive on the way up and negative on the way down, so at the very top it must be zero. You can also see it in the position as a function of time graph, the slope of the line at the very top is zero, and therefore the velocity at the top is zero.

Notice that the 2nd half of these graphs are *exactly* the same as the graphs we drew in the previous lecture. Therefore we can conclude that the 2nd half took 0.638551 seconds and due to symmetry, the first half will also take 0.638551 seconds. Therefore the total time is:

$$\Delta t_{total} = \Delta t_{up} + \Delta t_{down} = 0.638551 + 0.638551$$

$$\Rightarrow \Delta t_{total} = (2)(0.638551) = 1.277102 \approx \boxed{1.3\,\text{sec}}$$

Where does the initial velocity of +6.26418 m/s come from? Well we know, for the whole event:

$$\Delta t_t = 1.277102\,\text{sec};\ v_{fy} = -6.26418\frac{m}{s};\ a_y = -9.81\frac{m}{s^2};\ \Delta y_t = 0;\ \ v_{iy} = ?$$

$$v_{fy}{}^2 = v_{iy}{}^2 + 2a_y\Delta y_t \Rightarrow v_{fy}{}^2 = v_{iy}{}^2 + (2)(-9.81)(0) \Rightarrow v_{iy} = \sqrt{v_{fy}{}^2} \Rightarrow v_{iy} = \pm v_{fy} = -(-6.26418) \approx \boxed{+6.3\frac{m}{s}}$$

We know we must use the positive answer, because the ball is moving upward.

Note: The times will *not* be the same going up and down if the Δy ≠ 0.