Physics Lecture #6: Falling Objects

A falling object accelerates as it falls. A bowling ball dropped on your foot will hurt more if it is dropped from a greater height since it has more time to increase its speed.

Whether you are dropping a bowling ball or a pebble, all falling objects near the surface of the earth accelerate at a rate downward at a rate of 9.81 m/s^2. Sometimes we use -9.81 m/s^2; the negative sign indicates that the object is accelerating downward. For some problems it helps to use the negative sign in the calculation, and for others we don't need to use a negative sign.

If an object is speeding up and doesn't change direction, we can use all positive numbers. We also use positive numbers if we use $\Delta y = \frac{1}{2} at^2$ or any form of $v^2 = 2a\Delta y$. These two formulas are used when an object starts from rest or slows to a stop.

Generally, we use a negative sign if the object slows down and/or changes direction. Under these conditions, we use a negative sign on the acceleration unit. If the object is moving down, we use a negative sign for the velocity and for the displacement.

From rest, a rock is dropped and falls for 3.0 seconds before hitting the ground. What is its velocity right before it hits the ground?

Answer

Since the rock is falling, the acceleration is implicitly given to us as 9.81 m/s^2. Since it is at rest, the initial velocity is zero.

$v_f = v_i + at$

$v_f = 0 + (9.81)(3.0)$ **Notice that since the object speeds up and keeps the same direction, we use +9.81 in the calculation.**

$v_f = 29.43$ **or 29 m/s downward**

If the problem asks for velocity, we need to give a direction. To indicate the object is moving downward, we could write -29 m/s.

A flower pot slips off a window sill and falls 42.0 m. Find the velocity of the flower pot when it hits the ground, and the time it takes to hit the ground.

Answer

Since the initial velocity is zero, we can use $v_f^2 = 2a\Delta y$ and use all positive numbers. Notice that I'm using Δy since the object is moving vertically. If it was moving horizontally, I'd use Δx.

$v_f^2 = 2a\Delta y$

$v_f^2 = 2(9.81)(42)$

$v_f^2 = 824.04$

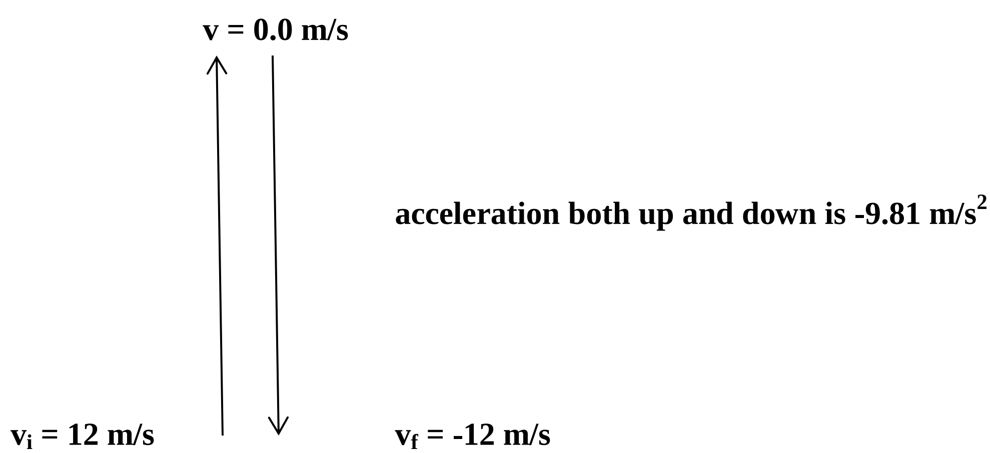
v_f = 28.706 or 28.7 m/s downward.

$v_f = v_i + at$

$28.7 = 0 + (9.81)t$

t = 2.925 or 2.93 seconds

What happens to the velocity of an object if it is thrown straight up? Suppose you throw a baseball straight up with an upward initial upward velocity of 12 m/s. As it moves up, gravity slows its rate of ascent by -9.81 m/s^2. It eventually slows down to a velocity of 0.0 m/s. At this point, it has stopped moving up and has reached its peak. Immediately afterward, the ball begins to descend and increases its downward speed at a rate of -9.81 m/s^2. If you catch the ball at the same height at which you threw it, the ball hits your hand with a final velocity of -12 m/s.



The time it takes for the baseball to go up is equal to the time it takes for it to fall back to its original position. Or, time going up = time going down.

A baseball is tossed into the air with an initial upward velocity of 12 m/s. It is then caught at the same height from which it was thrown. How long did it take to reach its peak? How much higher did it go? What was the total time it spent in the air?

Answer

Going up, its initial velocity is 12 m/s. When it reaches its peak, its velocity is 0.0 m/s. We can treat the velocity at the peak as a final velocity.

$v_f = v_i + at$

$0.0 = 12 + (-9.81)t$ **Notice that since the object slows down, we use -9.81, not + 9.81.**

$-12 = -9.81t$

$t = \frac{-12}{-9.81}$

t = 1.223 or 1.2 seconds.

Since the object comes to a stop, we can use $v_i^2 = 2a\Delta y$ to find the maximum change in height. For the abbreviated formulas, we can use a positive value for acceleration.

$v_i^2 = 2a\Delta y$

$12^2 = 2(9.81)\Delta y$

$144 = 19.62\Delta y$

$\Delta y = \frac{144}{19.62} = 7.339$ **or 7.3 m**

Since the time it spends going up equals the time it spends going down, the total time in the air would be

Total time = time going up x 2 = 1.2 x 2 = 2.4 seconds.

We could have also found the total time this way:

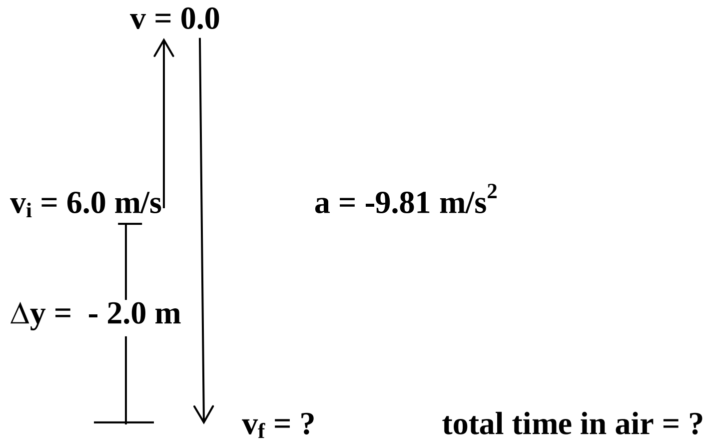
$v_f = v_i + at$

$-12 = +12 + (-9.81)t$

$-24 = -9.81t$

t = 2.44 or 2.4 seconds

A coin is tossed into the air and moves up with an initial velocity of 6.0 m/s. If the coin started at a height of 2.0 m above the floor, how long will it be in the air before it hits the floor?



We'll solve for v_f, then use this value to solve for total time (t). Our object slows down and changes direction, so we need to put the correct sign (+ or -) in front of the velocities, distance, and acceleration.

$v_f^2 = v_i^2 + 2a\Delta y$

$v_f^2 = 6.0^2 + 2(-9.81)(-2.0)$

$v_f^2 = 36 + 39.24$

$v_v^2 = 75.24$

v_f = 8.674 m/s downward, or -8.7 m/s

$v_f = v_i + at$

$-8.7 = 6.0 + (-9.81)t$

$-14.7 = -9.81t$

$t = \frac{-14.7}{-9.81}$ **= 1.498 or 1.5 seconds in the air**

We could have also solved the problem with $\Delta y = v_i t + ½ at^2$ and used the quadratic equation to solve for t.

$\Delta y = v_i t + ½ at^2$

$-2.0 = 6.0t + ½ (-9.81)t^2$

$-2.0 = 6.0t – 4.9t^2$

$4.9t^2 – 6t – 2 = 0$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{-(-6) \pm \sqrt{(-6)^2 - 4(4.9)(-2)}}{2(4.9)}$$

$$t = \frac{6 \pm \sqrt{36 + 39.2}}{9.8}$$

$$t = \frac{6 \pm 8.67}{9.8}$$

$t = \frac{6 + 8.67}{9.8} =$ 1.496 or 1.5 seconds