Flipping Physics Lecture Notes:
Common Free-Fall Pitfalls

There are several common misconceptions or mistakes students make when it comes to free-fall problems. These are all problems where the object is flying through the vacuum that you can breathe and isn't touching anything else and therefore:

$$g_{Earth} = 9.81\frac{m}{s^2} \text{ and } a_y = -g = -9.81\frac{m}{s^2} = 9.81\frac{m}{s^2}\,Down$$

1st, if the object is going up, students often assume that the acceleration must be positive because the velocity is positive. This is not true, the object's velocity is decreasing, and therefore the acceleration is opposite the direction of the velocity and is therefore down and negative.

Sometimes students tell me that the initial velocity for an object being thrown upward is zero. That doesn't work. If the initial velocity in the y-direction is not positive, the object will not go up. In fact, the initial velocity in the y-direction must be positive for the object to move upward.

Also, students will often think that the object will accelerate faster if you throw it down rather than drop it. It will be moving faster, yes, however, because it is an object in free-fall, it will not *accelerate* faster than $9.81 m/s^2$ down.

Next one isn't a mistake students make, it is just a reminder that the velocity at the top, in the y-direction, is zero. The velocity is positive on the way up and negative on the way down, so it must pass through zero at the top. Therefore, the object stops at the top and has a velocity, in the y-direction, of zero. Which leads us to the last one.

Lastly, students sometimes think that, because the object's velocity at the top is zero, then it's acceleration must also be zero. This is not true. The equation for acceleration is: $a = \frac{\Delta v}{\Delta t}$ therefore, if the acceleration at the top were zero, then Δv would equal zero. (We are assuming time doesn't stop and therefore $\Delta t \neq 0$, which seems pretty reasonable). If $\Delta v = 0$ then the velocity would not change and would continue to be zero and the object would stop at the top and float in midair. I think we can all agree that, in this universe, that does not happen. So it is illogical that the acceleration at the top would be zero. So, again, it is an object in free-fall and therefore:

$$g_{Earth} = 9.81\frac{m}{s^2} \text{ and } a_y = -g = -9.81\frac{m}{s^2} = 9.81\frac{m}{s^2}\,Down$$

1) Object going up. $a_y = -9.81\ m/s^2$ (acceleration still negative).
2) Object thrown upward, $v_{iy} > 0$.
3) Object thrown downward. $a_y = -9.81\ m/s^2$ (Yes, it is moving faster. No it doesn't *accelerate* more).
4) v_{top} in y-direction = 0
5) $a_{top} = -9.81\ m/s^2$ (again, in the y-direction and even though $v_{top} = 0$).