Simulation is going to be a tool that we use frequently in this class to solve problems. Why? Well, many physics problems are not solvable with just algebra. Now, you might have suspected this, and figured that, okay, maybe not with algebra, but maybe if I invoke some higher math such as calculus, I can start to do real physics problems. Well, that helps, but even with calculus and some of the most sophisticated math out there, you still can’t solve most of the interesting real-world problems that we have. You can solve models, you can solve simplifications, but to try and get everything, the problems are actually undoable.

For example, just to make an extreme example, think about the Earth, the Sun, and the moon. The force on these three objects can be described by a force law from the 17th century, that says the force of gravity between two masses, say the earth and the moon, is their masses and the distance between them squared. That’s it. For two objects, say, just the Earth and the moon, you can write an equation that describes their motion using this force law. However, you *cannot* write down an equation that describes the motion of the Sun, the Earth, and the moon; you need go to simulation. Moreover, the ideas of simulation that we’re going to be discussing here and throughout this class are being used more and more in essentially all fields of science to solve complex problems. In the Fall 2015 semester, one of the SIs for Physics 131 was using these same ideas to solve problems in his life science based senior honors thesis as an undergraduate. Hopefully, this impresses upon you the relevance of this technique to all fields of science and medicine in the modern day.

What’s the philosophy, the premise, behind the idea of simulation? Well, this is perhaps best done in the context of an example. Let’s say we have a runner, like the one below:

(insert picture of runner here)  
  
Well, if we want to model the motion of the runner, we would think about the average velocity and how that’s related to their position and the change in time. If we imagine a really small amount of time, then this runner’s velocity from, say the red instant to the green instant, does not change very much. We’re going to say that these two are super close together. If we make our time interval small enough, then the velocity essentially doesn’t change from red to green; it’s essentially constant. The runner could be running at, say, 5 m/s, at the red instant, and 5.0001 at the green instant, but the change is small enough where we could just say that the runner is running at the average between those two velocities, which is essentially 5 m/s anyways.

Now we’re going to do a little bit of algebra. Using , multiplying Δt to the other side gives us

,

or

Bringing over the initial position of the runner gives us the final position

.

We’re assuming that the speed is essentially constant, so we can use the runners initial speed for average speed, and so we can solve for , where they are at the end of this time interval. In other words, if we know where I am now, and my speed now, and I’m free to assume that my speed won’t change because I’m considering just a tiny time interval, then I can use that information to predict where I’m going to be in the future. This is the idea of simulation. I use what I know about the system at any given instant to predict how things are going to be in the next small time, little bit of time later.

The same philosophy holds true for acceleration. I could have repeated the entire series of steps with acceleration. Let’s start with the definition of acceleration, . If I’m thinking about a very small time interval then the average acceleration is going to be the acceleration; the acceleration is not going to change very much as long as this Δt is really, really small. Doing a little bit of algebra,

Again, if I know my speed at some instant, my acceleration at some instant, and my Δt is small enough, then I can use that information to predict what my Δv is going to be some small time later. We’ll be doing this throughout the course with a wide variety of concepts, from forces to temperature to entropy. In all cases, you’re using what you know now to predict what will happen a small time later.