1.6 acceleration: The study of motion without concern for the forces that cause the motion. We study the explicit study of position, velocity, acceleration.

You're driving along the road, let's say with a velocity of 30 miles per hour. But your velocity was not always 30 mph, nor will it remain 30 mph forever. Acceleration is the rate of change of your velocity, or $a=\Delta v/\Delta t$, or $a=dv/dt$. What is the acceleration of your car? How long did it take to get to the speed of 30 mph. We often measure the acceleration of cars as the time to 60 mph. For instance Tesla boasts that it's prototype accelerates to 60 mph in about 3 seconds. Wow, that's about 30 m/s in 3 seconds, or the speed increases 10 m/s every second: it's acceleration from rest is about 10 m/s^2, about the same as gravitational acceleration! That means if you're in a Tesla accelerating from rest, your acceleration forward is the same as your acceleration downward would be if you were dropped from a cliff in that same Tesla.

How about smaller accelerations? What is 1 m/s^2. Your maximum running velocity is likely between 5 m/s and 10 m/s, so let's say 8 m/s. If you then accelerated at 1 m/s^2, you would require 8 seconds to reach your maximum running speed. So, our legs provide forces that can accelerate us much more than 1 m/s^2.

<u>Exercise 1</u>: Let's go back to that rocket from the San Luis Obispo MakerSpace.

- Do you think that the rocket has a large acceleration when it takes off?
- After the rocket takes off is it still accelerating? Are there forces acting on it besides gravity?
- After take-off, should it's acceleration be more than gravitational acceleration, less, or the same?

In the video frame before the left most frame, the rocket was still at rest on top of the piece of plastic pipe. Please estimate the acceleration of the rocket as it takes off. Estimate doesn't mean "guess", it means "calculate it with the understanding that there are some uncertainties in your measurements and simplifications in your calculations." After you have estimated the rocket's acceleration at take-off, consider what would happen to you if you had that acceleration. You can look up how much acceleration a human can sustain.

Estimate the speed between video frame 1 and video frame 2 more carefully than you did in chapter 1.4, by measuring the distance more accurately between rocket positions. Is the velocity constant? Is the rocket speeding up? Slowing down? How much time transpired between the speeds you calculated? Please estimate what the acceleration of the rocket after taking off and compare it to gravitational acceleration. What do you find?

Figure 1 Three consecutive frames of a rocket launch at 30 frames per second. Red circle identifies rocket position.

Graphing: Because *a=dv/dt*, if you graph your velocity as a function of time, the rate of change of your velocity is the *slope* of the line. Please make a rough graph of the rocket's velocity as a function of time from t = 0 seconds when it is still at rest on the launch pad, to t = 0.1 s after three video frames.

Because *a=dv/dt*, and *v=dx/dt*, acceleration is therefore the second derivative of position or $a=d^2x/dt^2$, or the *curvature of the graph.*

Exercise 2: Let's say you throw a ball up into the air at an initial velocity of 20 m/s…. about 44 miles an hour. And we wonder if it's easy for a person to throw a ball that fast. We can look up fast pitches and see that people can throw balls at 100 m/h, or about 45 m/s, so this should be no problem. So, consider throwing a ball at 20 m/s upwards and let's make the ball small and massive (like a golf ball) so we can neglect air friction and consider only gravitational acceleration.

- How fast will the ball be moving 1 second after it leaves my hand?

- How long before gravity stops the ball at the top of its trajectory?
- How long will the ball be in the air total time?

Please make a velocity – time graph for the entire time the ball is in the air.

Please make a position – time graph for the entire time the ball is in the air. Does this graph have curvature to it? Is it curving downward or upward? What is the direction of acceleration?