1.4 Kinematics:

- The study of motion as an explicit function of time: position, velocity, acceleration
- Not concerned with what causes the motion

You're driving along the road. What is your speed? Maybe your speedometer reads 30 miles per hour. What does this mean? This is a rate... your position is changing at a rate of 30 miles every hour. So, in two hours you would travel 60 miles and in 10 minutes (a sixth of an hour) your position would change by 5 miles (a sixth of 30 miles). In this class, we'll use meters and seconds, so you'd express velocity as a rate of change of position in meters per second (m/s). What is a meter per second? Can you walk at one meter per second? Please do that now. The fastest humans can run at a rate of 10 meters per second. At this rate, how long would it take someone to run the length of a soccer field, about 100 meters? Close your eyes and imagine seeing that happen. Does this seem reasonable?

Getting used to new terms: What we see is that $v=\Delta x/\Delta t$, or $v=dx/dt$, where
v is velocity,
x is position,
t is time, and
the terms "Δ" and "d" represent the difference in. Yes, velocity is the rate of change of position over time.
Change in position, Δx, is also referred to as "displacement", so velocity is also "time rate of displacement change."

Exercise 1:
Please guess off the top of your head, how many miles per hour is 1 m/s. Then, please use your knowledge that a mile is about 1.6 km, and there are 3600 s in an hour. Please use this to estimate the speed of 1 m/s in miles per hour. Please show your work and cancel units.

Graphing: Because $v=dx/dt$, if you graph your position as a function of time, the rate of change of your position is the *slope* of that line.

Exercise 2:
Sometimes I teach a rocket course to children. The kids make rockets out of paper that we launch with high air pressure from a bicycle pump. We take videos with our cell phones to calculate the rocket take-off velocity knowing that normal videos record at 30 frames per second. Please see below three consecutive frames from a rocket taking off. Please use these frames to estimate the speed of the rocket. I say, "estimate" because I don't show you a meter stick. However, I trust that you can find things in the picture that provide an adequate scale for you to get a measurement within 10% uncertainty.

- Make a graph showing the vertical displacement (height) of the rocket for the first three thirtieths of a second.
- What is the take-off speed in m/s?
- What is the take-off speed in mi/hr?

Does your calculated answer surprise you? Does it seem reasonable?

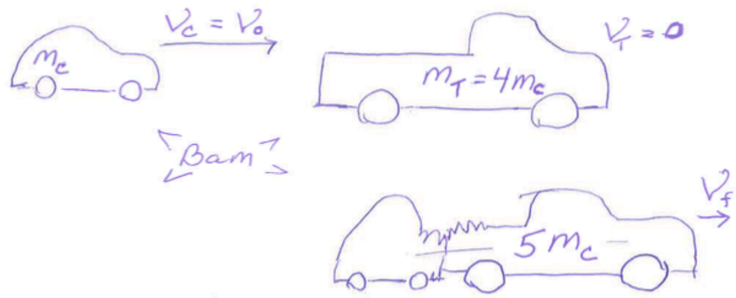
Figure 1, Three consecutive frames of a rocket launch at 30 frames per second. Red circle identifies rocket position.

Exercise 3

In the example of the car hitting the truck shown in section 1.1 (figure 2), let's say that the car is moving at some initial velocity, v_o = 20 m/s, and the truck is initially at rest and has 4 times the mass of the car. Assume the vehicles have a completely inelastic collision, meaning that they stick together when they collide.

1. What is the final velocity of the car-truck wreckage?
2. If the car is 1000 kg (and the truck is 4000 kg) What is the change in momentum of the car? …and change in momentum of the truck?
3. What is the change in velocity of the car? …the change in velocity of the truck?
4. Was momentum conserved in the collision? Was velocity conserved in the collision?

<u>Solution</u> (*!! On a test, the reasoning immediately below is the most important part of the answer*)
"I decide to use a momentum lens because there are (almost) no outside forces on the system of two cars. If there are no outside forces on the system then the momentum doesn't change. I will make sure that the total momentum before the collision is equal to the total final momentum."



Before = After

$$p_c + p_T^{\to 0} = p_c + p_T$$

$$m_c v_c = (m_c + m_T) v_f = 5 m_c v_f$$

1) Before the event, all the momentum is in the car. After the collision, the momentum is all in the car-truck wreckage, which has 5 times the mass of the car alone.
   So, $m_f = \underline{5}m_c$. However,
   Momentum, $p = mv$, doesn't change. If the momentum doesn't change, but the moving mass is now 5 times as great, then the speed must be 1/5 as great, or 4 m/s.
2) The car slows from 20 m/s to 4 m/s or it slows down 16 m/s. with a mass of 1000 kg, this change of momentum is:
   $\Delta p = m\Delta v = 16{,}000 \frac{\text{kg m}}{\text{s}}$ in the negative direction. We can be sure that the change in momentum of the truck is the same in the positive direction, but let's calculate it to be sure. The truck speeds up from rest to 4 m/s and has a mass of 4,000 kg, resulting in:
   $\Delta p = m\Delta v = 16{,}000 \frac{\text{kg m}}{\text{s}}$ in the positive direction.
3) and 4) we can see from above that we conserve momentum, not velocity. The momentum lost by one equals the momentum gained by the other. Because the truck has 4 times the mass of the car, then Δv of the car will be 4 times Δv of the truck.