We have introduced kinematics equations in the previous two classes:

\[
\begin{align*}
x &= x_0 + v_0 t + \frac{1}{2}at^2 \\
v &= v_0 + at \\
v^2 &= v_0^2 + 2a\Delta x, \quad \text{where } \Delta x = (x - x_0)
\end{align*}
\]  

Remember that the last one is directly derived using the first two. It is very useful, and we consider it as a part of our toolbox, but it is not an independent equation. (We’ll call it the “third equation.”)

The first two equations describe the motion fully, and we call them the equations of motion.

In this class we started going through some examples, in order to see how to use these equations, what they mean, etc. This is the only way to understand something (well), by doing it, using it. At this point it is imperative to start solving a lot of problems, in case you haven’t started yet.

Labs First we talked at length about labs, that start this week. Please download that manual (from our “Syllabus” page on the web site), and please always look through the upcoming experiment. It makes the whole difference, coming to the lab with having seen (even only a bit) about it. As for the report that you produce in the lab, this is something you are learning about this term, too. Be a little patient, in a few weeks you will probably have a crystal clear idea of how exactly that should be written. There will be a sample report posted.

Problem 1. Our first ‘problem’ (example). A car is driving at 60 mi/hr, and starts braking at the rate of 5 m/s\(^2\). What is the “stopping distance” for this car? (The distance in which it stops.) The important point intended to convey here is about the system one normally employs when solving problems. It is common practice, a general approach. These stages/steps overlap.

- Study your problem, and draw a sketch. (This does help.)
- Decide and set (draw) a coordinate system. This is most important to do! At this point you will likely be thinking about the problem a lot, since a decision about the coordinate system affects the forthcoming work (and solutions).
- Now write the (general) kinematics equations, shown above, for this problem, in this coordinate system. This is when the equations come alive – adjusted for the problem at hand.
- You are ready now to think in detail how to approach and solve the problem. It may well be that by this stage you already have figured it all out – since you have been analyzing the problem while sketching it and setting up the coordinate system.

Please note: the above breakdown is not a literal recipe, that will always apply. There is no such thing. But it is what you do in general, practically always, and it is a good system.

Units The first mention of units – this is very important to get used to. Everything has units, and we have to keep track of those. (Some quantities are unit-less . . . but then that again is a specification of units for them!) We converted mi/hr (miles-per-hour, mph) \(\rightarrow\) m/s (meter-per-second). This will come handy to know, in this class.

Free fall We barely started with this – introduced it, for the next class.
**Problem 1**

Driving 60 mph, braking w/ 5 mi/s².

Stopping distance?

\[ v_0 = 60 \text{ mph}, \quad a = -5 \frac{\text{mi}}{\text{s}^2}, \quad \Delta x = ? \]

\[ x = x_0 + v_0 t + \frac{1}{2}at^2 \]
\[ v = v_0 + at \]
\[ v^2 = v_0^2 + 2a \Delta x \]
\[ x = \left(60 \frac{\text{mi}}{\text{hr}}\right)t + \frac{1}{2}(-5 \frac{\text{mi}}{\text{s}^2})t^2 \]

(etc...)

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**Set your COORDINATE SYSTEM!**

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Eq's in THIS problem, THIS frame (coordinate system)

1. sketch
2. COORDINATE SYSTEM in this frame
3. equations
\[ v_0 \quad \text{stops} \quad N_f = 0 \]

\[ x_0, v_0 \quad x_f \quad \text{"final"} \]

\[ N_f^2 = N_0^2 + 2a \Delta x \quad (\Delta x = x_f - x_0) \]

\[ \text{stops:} \quad N_f^2 = 0 \]

\[ \Rightarrow 0 = N_0^2 + 2a \Delta x \]

\[ \Delta x = -\frac{N_0^2}{2a} \quad \text{(is \Delta x exactly the stopping distance?)} \]

\[ 0 = N_0^2 + 2a (x_f - x_0) \quad \text{\( \rightarrow \) zero here!} \]

\[ \Delta x = x_f - x_0 = x_f \quad (x_0 = 0) \]

The "final" position in this set up (coord. syst.) \( x_f \) is the stopping distance!

TRY: use \( \frac{v}{t} \approx 0.5 \text{ m/s} \) --- compare with exact estimate is...
\[ \frac{1 \text{ mi}}{5 \text{ s}} = \frac{1609 \text{ m}}{3600 \text{ s}} = 0.447 \frac{\text{m}}{\text{s}} \]

\[ \frac{1 \text{ mi}}{\text{hr}} = 2.237 \frac{\text{mi}}{\text{hr}} \approx 2.24 \frac{\text{mi}}{\text{hr}} \]

**Free fall**

\[ g = 9.8 \frac{\text{m}}{\text{s}^2} \]

\[ x_0 = 0, \quad v_0 = 0 \]

\[ x = \frac{1}{2} at^2 \]

\[ t = \sqrt{\frac{2x}{a}} \quad \Rightarrow \quad t_f = \sqrt{\frac{2(10 \text{ m})}{9.8 \frac{\text{m}}{\text{s}^2}}} \]