flipping physics

Flipping Physics Lecture Notes:
Introduction to Acceleration with Prius Brake Slamming Example Problem

Acceleration: $\boxed{a = \frac{\Delta v}{\Delta t}}$ & $a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$ & $a \Rightarrow \frac{m/\cancel{s}}{\cancel{s}/1} = \frac{m}{s} \times \frac{1}{s} = \frac{m}{s^2}$ (flip the guy and multiply!)

Acceleration, just like Displacement and Velocity, has both Magnitude and Direction.

Example Problem: Mr.p is driving his Prius at 36 km/hr East when a basketball appears bouncing across the street in front of him. His gut reaction is to slam on the brakes. This brings the vehicle to a stop in 1.75 seconds. What was the acceleration of the vehicle?

Knowns: $v_i = 36\frac{km}{hr} East \times \frac{1hr}{3600s} \times \frac{1000m}{1km} = 10\frac{m}{s} East; v_f = 0; \Delta t = 1.75s; a = ?$

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{0-10}{1.75} = -5.7143 \approx \boxed{-5.7\frac{m}{s^2} East}$$

FYI: $v_i = 36\frac{km}{hr} \times \frac{1000m}{1km}\frac{1mi}{1609m} = 22.3741 \approx 22\frac{mi}{hr}$

(Yes, 23.3741 was a typo in the video, sorry.)

Flipping Physics Lecture Notes:
A Basic Acceleration Example Problem and Understanding Acceleration Direction

Example Problem: Mr.p is riding his bike at -14.3 km/hr when he begins pedaling the bike to cause a constant acceleration. If, after 6.4 seconds, the bike is moving at -23.7 km/hr, what was the acceleration of the bike?

Knowns: $v_i = -14.3\frac{km}{hr} \times \frac{1hr}{3600s} \times \frac{1000m}{1km} = -3.97\overline{2}\frac{m}{s}$; $v_f = -23.7\frac{km}{hr} \times \frac{1hr}{3600s} \times \frac{1000m}{1km} = -6.58\overline{3}\frac{m}{s}$;

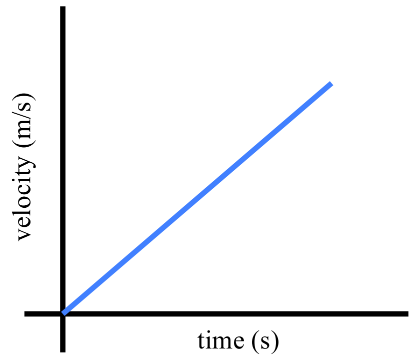
$\Delta t = 6.4s$; $a = ?$

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{-6.58\overline{3} - \left(-3.97\overline{2}\right)}{6.4} = -0.407986\overline{1} \approx \boxed{-0.41\frac{m}{s^2}}$$

Common Question: If the bike is “speeding up” how can the acceleration be negative?

If an object is “speeding up” that means the magnitude of the velocity is increasing. That means that the acceleration and the velocity will be in the same direction. In other words, if the velocity is negative and the object is speeding up, then the acceleration will also be negative. People are usually used to having positive velocities and therefore a negative acceleration would be opposite the velocity and the object would be slowing down.

Flipping Physics Lecture Notes:
Walking Position, Velocity and Acceleration as a Function of Time Graphs



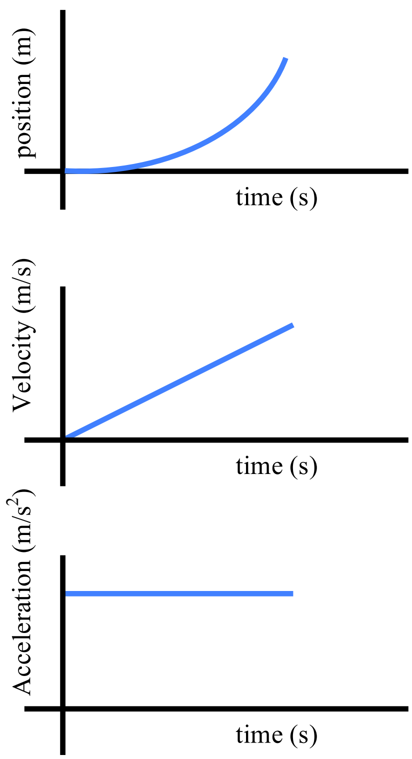
$$slope = m = \frac{rise}{run} = \frac{\Delta y}{\Delta x} = \frac{\Delta velocity}{\Delta time} = acceleration$$

The slope of a velocity versus time graph is acceleration.

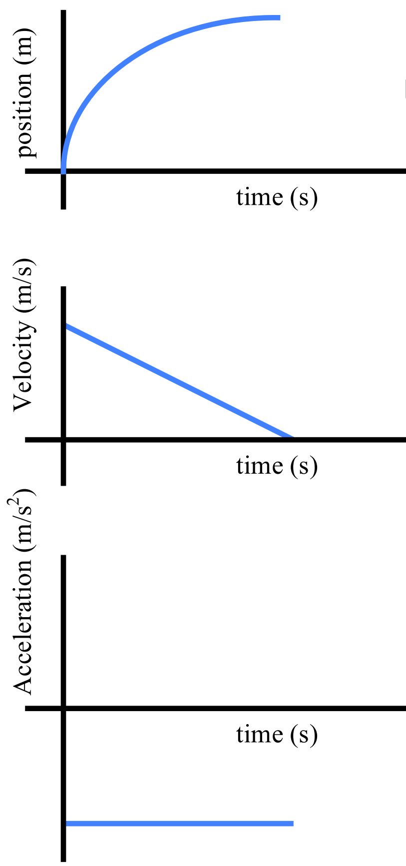
(review: The slope of a position versus time graph is velocity.)

A tangent line is a straight line that touches a curve at a point but does not cross the curve.

Example #1

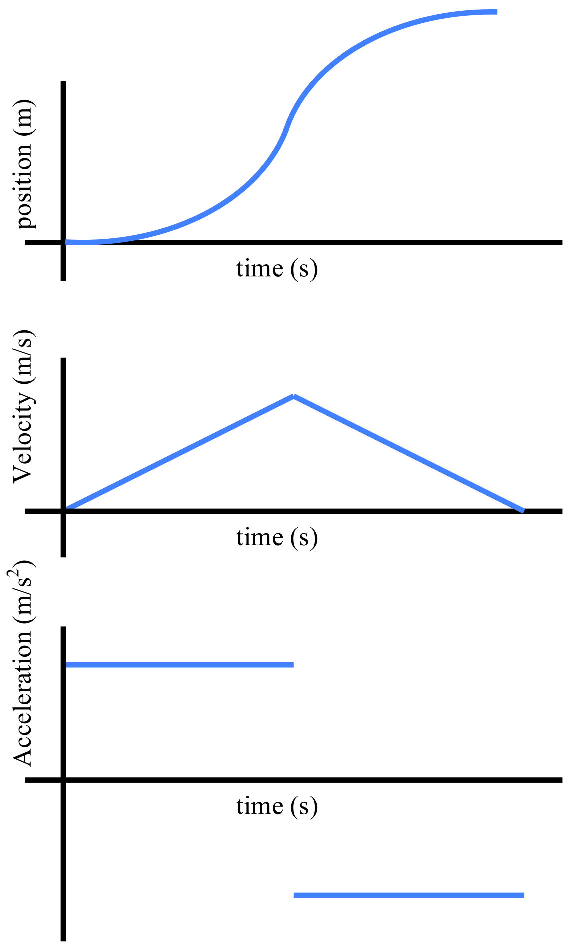


Example #2



Example #4

Example #3



Flipping Physics Lecture Notes:
Introduction to Uniformly Accelerated Motion
with Examples of Objects in UAM

Uniformly Accelerated Motion (UAM) is motion of an object where the acceleration is constant. In other words, the acceleration remains uniform; the acceleration is equal to a number and that number does not change as a function of time.

Examples of objects in UAM:

- A ball rolling down an incline.
- A person falling from a plane.
- A bicycle on which you have applied the brakes.
- A ball dropped from the top of a ladder.
- A toy baby bottle released from the bottom of a bathtub.

(Technically, because of friction and a non-constant gravitational field, etc., they are not quite Uniformly Accelerated Motion, however, at this point we will treat them as if they are, because it is close enough, *for now.)*

These are the equations that describe an object in Uniformly Accelerated Motion:

$$\boxed{\begin{aligned} &v_f = v_i + a\Delta t \\ &\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2 \\ &{v_f}^2 = {v_i}^2 + 2a\Delta x \\ &\Delta x = \frac{1}{2}\left(v_i + v_f\right)\Delta t \end{aligned}}$$

There are 5 variables in the UAM equations:

$$v_i = velocity\,initial$$
$$v_f = velocity\ final$$
$$a = acceleration$$
$$\Delta x = displacement$$
$$\Delta t = change\,in\,time$$

My Suggestion. When you use the UAM equations, you should use base SI dimensions; meters and seconds.

Here is how it works:
There are FIVE variables in the UAM equations.
There are FOUR UAM equations.
If you know THREE of the variables,
you can determine the other TWO variables.
This leaves you with ONE happy physics student.
(note: not one answer. There can be more than one answer.)

A helpful definition:
peanut gallery (noun): a group of people who criticize someone, often by focusing on insignificant details.

Flipping Physics Lecture Notes:
Introductory Uniformly Accelerated Motion Problem – A Braking Bicycle

Example Problem: Mr.p is riding his bike at 22.9 km/hr when he applies the brakes causing the bike to slow down with a constant acceleration. After 1.01 seconds he has traveled 4.00 meters. (a) What was his acceleration and (b) what was his final speed?

Knowns: $v_i = 22.9\frac{km}{hr} \times \frac{1hr}{3600\sec} \times \frac{1000m}{1km} = 6.36\overline{1}\frac{m}{s}; \Delta x = 4.00m; \Delta t = 1.01s; v_f = ?; a = ?$

Part (a) $\Delta x = v_i \Delta t + \frac{1}{2}a\Delta t^2 \Rightarrow \Delta x - v_i \Delta t = \frac{1}{2}a\Delta t^2 \Rightarrow a = \frac{\Delta x - v_i \Delta t}{0.5\Delta t^2}$

$$a = \frac{4-\left(6.36\overline{1}\right)\left(1.01\right)}{\left(0.5\right)\left(1.01\right)^2} = -4.75389 \approx \boxed{-4.75\frac{m}{s^2}}$$

Part (b) $v_f^{\,2} = v_i^{\,2} + 2a\Delta x \Rightarrow v_f = \sqrt{v_i^{\,2} + 2a\Delta x} = \sqrt{\left(6.36\overline{1}\right)^2 + \left(2\right)\left(-4.75389\right)\left(4.00\right)} = 1.55968 \approx \boxed{1.56\frac{m}{s}}$

Note: I could also have used $v_f = v_i + a\Delta t = 6.36\overline{1} + \left(-4.75389\right)\left(1.01\right) = 1.55968 \approx 1.56\frac{m}{s}$

Or even $\Delta x = \frac{1}{2}\left(v_f + v_i\right)\Delta t \Rightarrow \frac{2\Delta x}{\Delta t} = v_f + v_i \Rightarrow \frac{2\Delta x}{\Delta t} - v_i = v_f$

$\Rightarrow v_f = \frac{(2)(4)}{1.01} - 6.36\overline{1} = 1.55968 \approx 1.56\frac{m}{s}$ & gotten the same answer, again.

The reason there are 3 equations we could use is because after we have solved part (a) we now know four of the UAM variables and not just 3.

Hopefully Helpful Definitions:
Perspicacious (adjective): having or showing an ability to notice and understand things that are difficult or not obvious.
ilk (noun): a type of people or things similar to those already referred to.
Pedantic (adjective): of or like a pedant.
Pedant (noun): a person who is excessively concerned with minor details and rules or with displaying academic learning.

Flipping Physics Lecture Notes:
Toy Car UAM Problem with Two Difference Accelerations

Example Problem: A toy car starts from rest and experiences an acceleration of 1.56 m/s^2 for 1.6 seconds and then brakes for 1.1 seconds and experiences an acceleration of -2.07 m/s^2. (a) How fast is the car going at the end of the braking period and (b) how far has it moved?

Knowns: $v_{1i}=0;\ \Delta t_1=1.6s;\ a_1=1.56\frac{m}{s^2};\ \Delta t_2=1.1s;\ a_2=-2.07\frac{m}{s^2};\ v_{2f}=?;\ \Delta x_t=?$

Part 1: $v_{1f}=v_{1i}+a_1\Delta t_1=0+(1.56)(1.6)=2.496\frac{m}{s}=v_{2i}$

Note: v_{1f} = v_{2i} because they are at the same moment in time. The end of part 1 is the beginning of part 2.

Part 2: $v_{2f}=v_{2i}+a_2\Delta t_2=2.496+(-2.07)(1.1)=0.219\frac{m}{s}\approx\boxed{0.22\frac{m}{s}}$ [answer for part (a)]

In order to solve part (b), you need to realize that the total displacement is equal to the displacement for part 1 plus the displacement for part 2. (technically, the magnitudes of the displacements because we don't have direction.) So now we need to find each displacement individually and then add them together.

Part 1: $\Delta x_1=\frac{1}{2}\left(v_{1f}+v_{1i}\right)\Delta t_1=\frac{1}{2}(2.496+0)(1.6)=1.9968m$

Part 2: $\Delta x_2=v_{2i}\Delta t_2+\frac{1}{2}a_2\left(\Delta t_2\right)^2=(2.496)(1.1)+\frac{1}{2}(-2.07)(1.1)^2=1.49325m$

Total: $\Delta x_t=\Delta x_1+\Delta x_2=1.9968+1.49325=3.49005\approx\boxed{3.5m}$ [answer for part (b)]

The following is an incorrect solution to part (b) …

$$\Delta x_t=\frac{1}{2}\left(v_{2f}+v_{1i}\right)\Delta t_t=\frac{1}{2}\left(v_{2f}+v_{1i}\right)\left(\Delta t_1+\Delta t_2\right)=\frac{1}{2}(0.219+0)(1.6+1.1)=0.29565\approx0.30m$$

Because the acceleration is not constant for the whole problem; it is only constant for each part individually, not as a whole.

Flipping Physics Lecture Notes:
Understanding Uniformly Accelerated Motion

We usually look at the dimensions for acceleration as: $a = \frac{\Delta v}{\Delta t} \Rightarrow \frac{m}{s^2}$

Today we are going to look at the dimensions for acceleration as: $a = \frac{\Delta v}{\Delta t} \Rightarrow \frac{m/s}{s}\ or\ \frac{m}{s}\ every\ second$

Example #1: A ball is released from rest and has an acceleration of 2 meters per second every second. (a) What is the velocity of the ball at t = 1, 2, 3, 4 and 5 seconds? (b) If the initial position of the ball is zero, what is the position of the ball at t = 1, 2, 3, 4 and 5 seconds?

Part (a): If the initial velocity of the ball is zero and the acceleration is $2\frac{m}{s}$ every second, then the velocity will increase by $2\frac{m}{s}$ every second. At t = 0 s, v = $0\frac{m}{s}$; at t = 1 s, v = $2\frac{m}{s}$; at t = 2 s, v = $4\frac{m}{s}$; at t = 3 s, v = $6\frac{m}{s}$; at t = 4 s, v = $8\frac{m}{s}$ & at t = 5 s v = $10\frac{m}{s}$.

Part (b): $\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2 = (0)\Delta t + \frac{1}{2}(2)\Delta t^2$

$\Rightarrow \Delta x = \Delta t^2 \Rightarrow \Delta x_1 = 1^2 = 1m$; $\Delta x_2 = 2^2 = 4m$

$\Delta x_3 = 3^2 = 9m$; $\Delta x_4 = 4^2 = 16m$; $\Delta x_5 = 5^2 = 15m$

t (s)	x (m)	v (m/s)	a (m/s each s)
0	0	0	2
1	1	2	2
2	4	4	2
3	9	6	2
4	16	8	2
5	25	10	2

Example #2: A ball is given an initial velocity of -10 m/s and has an acceleration of 2 meters per second every second. (a) What is the velocity of the ball at t = 1, 2, 3, 4 and 5 seconds? (b) If the initial position of the ball is 25 meters, what is the position of the ball at t = 1, 2, 3, 4 and 5 seconds?

Part (a): If the initial velocity of the ball is $-10\frac{m}{s}$ and the acceleration is $2\frac{m}{s}$ every second, then the velocity will increase by $2\frac{m}{s}$ every second. At t = 0 s, v = $-10\frac{m}{s}$; at t = 1 s, v = $-8\frac{m}{s}$; at t = 2 s, v = $-6\frac{m}{s}$; at t = 3 s, v = $-4\frac{m}{s}$; at t = 4 s, v = $-2\frac{m}{s}$ & at t = 5 s v = $0\frac{m}{s}$.

t (s)	x (m)	v (m/s)	a (m/s each s)
0	25	-10	2
1	16	-8	2
2	9	-6	2
3	4	-4	2
4	1	-2	2
5	0	0	2

Part (b): $\Delta x = x_f - x_i = v_i \Delta t + \frac{1}{2} a \Delta t^2$

$\Rightarrow x_f - (25) = (-10)\Delta t + \frac{1}{2}(2)\Delta t^2$

$\Rightarrow x_f = 25 + (-10)\Delta t + \Delta t^2 \Rightarrow x_{1f} = 25 + (-10)(1) + 1^2 = 16m$; $x_{2f} = 25 + (-10)(2) + 2^2 = 9m$

$x_{3f} = 25 + (-10)(3) + 3^2 = 4m$; $x_{4f} = 25 + (-10)(4) + 4^2 = 1m$; $x_{5f} = 25 + (-10)(5) + 5^2 = 0m$

Flipping Physics Lecture Notes:
Understanding Instantaneous and Average Velocity using a Graph

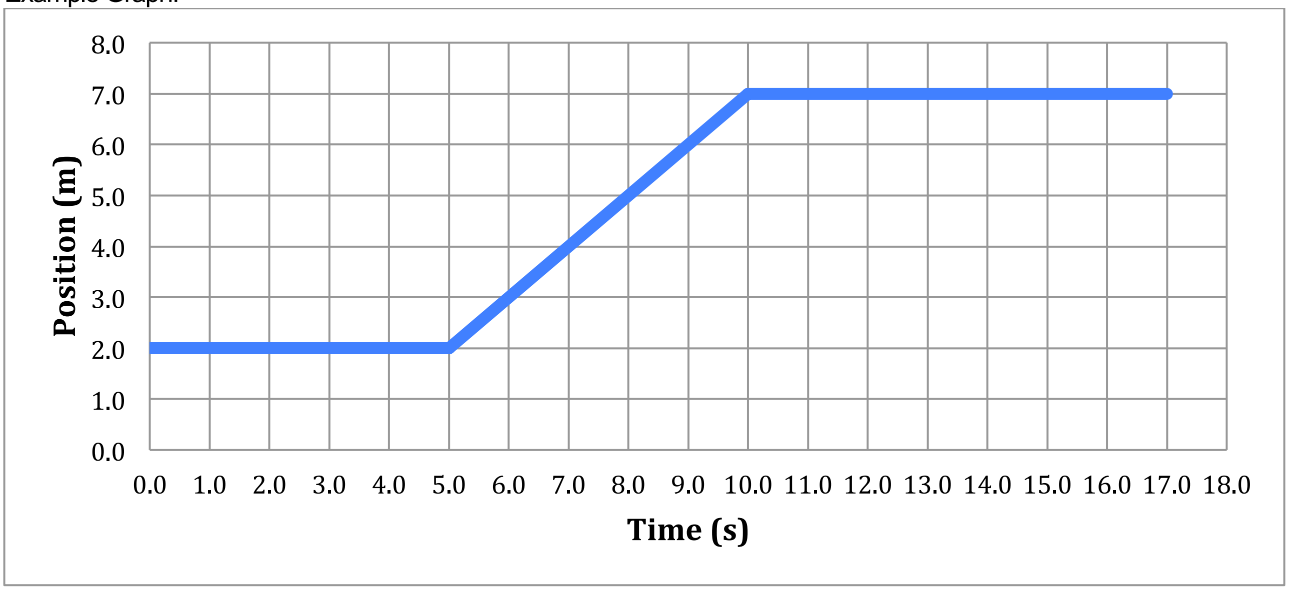
Instantaneous Velocity: The velocity at a specific point in time.

- The UAM variables Velocity Final and Velocity initial are instantaneous velocities because they are at specific points in time.

Average Velocity: The velocity over a time period.

- $v=\frac{\Delta x}{\Delta t}$ is an average velocity because Δt is the time period over which the velocity occurs.

Example Graph:



$$v=\frac{\Delta x}{\Delta t}\Rightarrow v_{(0-5\,\text{sec})}=\frac{\Delta x}{\Delta t}=\frac{x_f-x_i}{t_f-t_i}=\frac{x_5-x_0}{t_5-t_0}=\frac{2-2}{5-0}=\frac{0}{5}=\boxed{0}$$

$V_{(0-5\,\text{sec})}$ => An *average* velocity because it is a time period from 0 to 5 seconds.

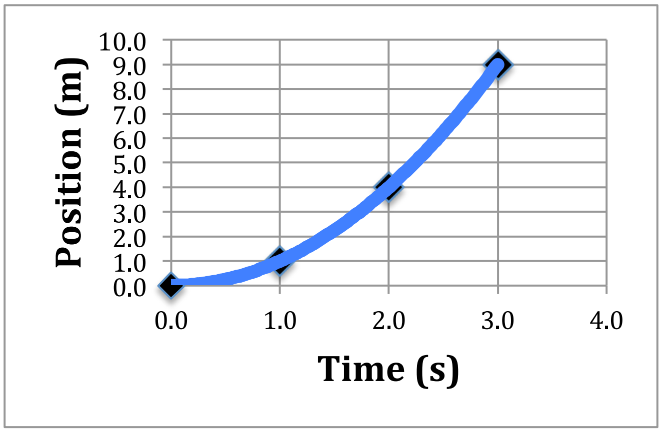
$$v_{(5-10\,\text{sec})}=\frac{\Delta x}{\Delta t}=\frac{x_{10}-x_5}{t_{10}-t_5}=\frac{7-2}{10-5}=\frac{5}{5}=\boxed{1.0\frac{m}{s}}$$ (again, an average velocity)

Velocity at 6 seconds, at 7 seconds, at 9.85342 seconds are all equal to 1.0 m/s. All are at a specific point in time and therefore *instantaneous* velocities. Note: It's the slope of the line, which we have shown to be velocity.

$$v_{(0-17\,\text{sec})}=\frac{\Delta x}{\Delta t}=\frac{x_{17}-x_0}{t_{17}-t_0}=\frac{7-2}{17-0}=\frac{5}{17}=0.29412\approx\boxed{0.29\frac{m}{s}}$$

Flipping Physics Lecture Notes:
Graphical UAM Example Problem

Example Problem: Assuming an initial position of zero, complete the empty graphs. (assume 2 sig figs)
(please note: in the problem, only the velocity versus time graph was given, the other two were blank)

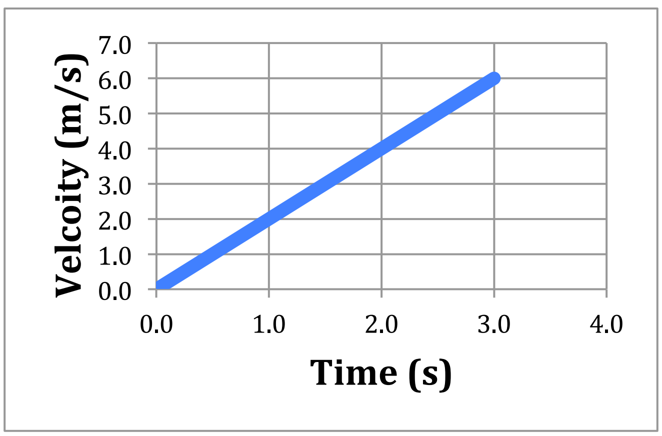


We know the acceleration is constant (and this is a graph of Uniformly Accelerated Motion) because the slope of the velocity vs. time graph is constant and the slope of a velocity vs. time graph is acceleration.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} \Rightarrow a\Delta t = v_f - v_i \Rightarrow v_f = v_i + a\Delta t$$

Therefore the equation definition of acceleration: $a = \frac{\Delta v}{\Delta t}$

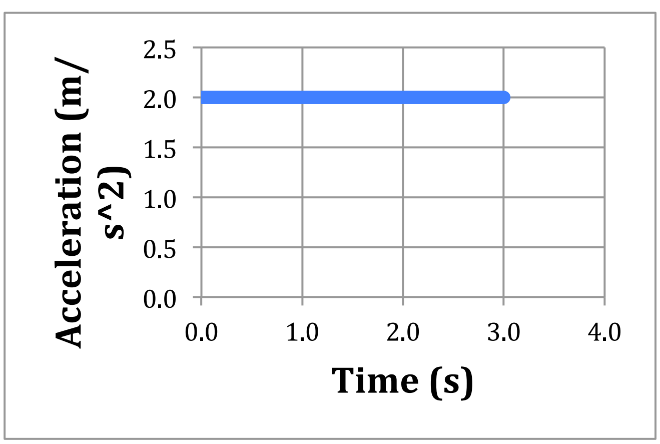
And the UAM equation: $v_f = v_i + a\Delta t$



Are equivalent and we can use either to find acceleration.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i} = \frac{6-0}{3-0} = 2.0\frac{m}{s^2}$$

Therefore on the acceleration vs. time graph we draw a horizontal line with a slope of zero at a value of 2.0 m/s^2.



The position as a function of time graph is slightly more complicated. We know:
- The initial position is zero, because it was stated in the problem.
- The slope of the line should increase as time increases because the velocity increases. In other words, it is an upward sloping curve.
- The slope of the position vs. time graph starts at zero because the initial velocity is zero.
- We can use a UAM equation because the acceleration is constant.

Now we need to pick some times and start determining displacements.

$$\Delta x = \frac{1}{2}\left(v_f - v_i\right)\Delta t = \frac{1}{2}\left(v_f - v_i\right)\left(t_f - t_i\right)$$

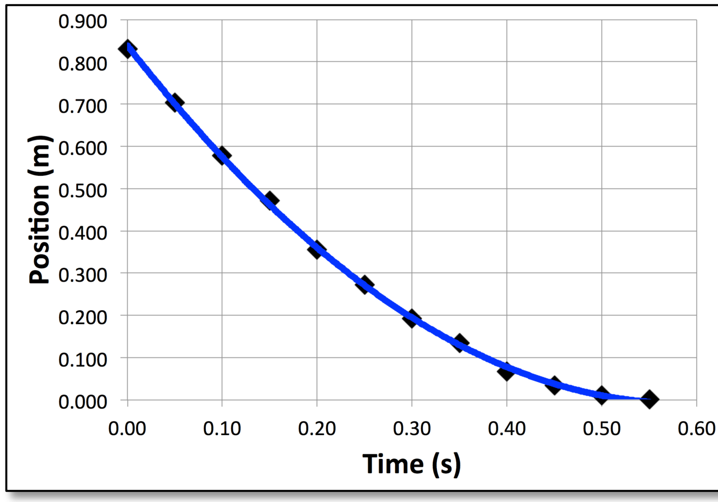
$$\Delta x_{0-1} = \frac{1}{2}\left(v_1 - v_0\right)\left(t_1 - t_0\right) = \frac{1}{2}(2-0)(1-0) = 1.0m$$

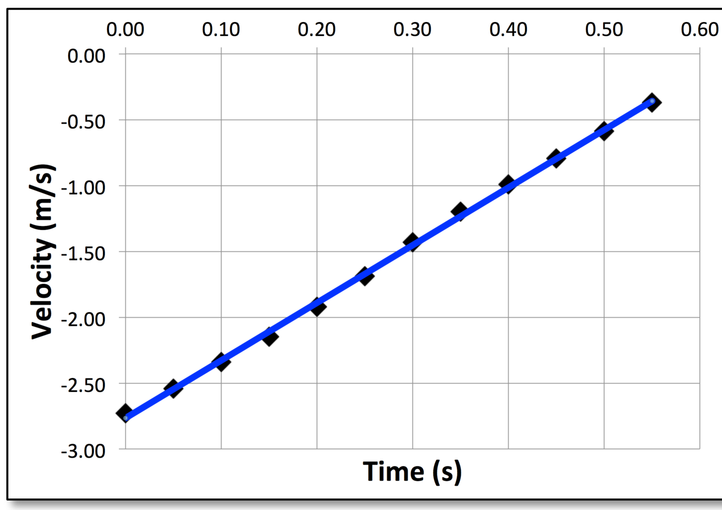
$$\Delta x_{0-2} = \frac{1}{2}\left(v_2 - v_0\right)\left(t_2 - t_0\right) = \frac{1}{2}(4-0)(2-0) = 4.0m$$

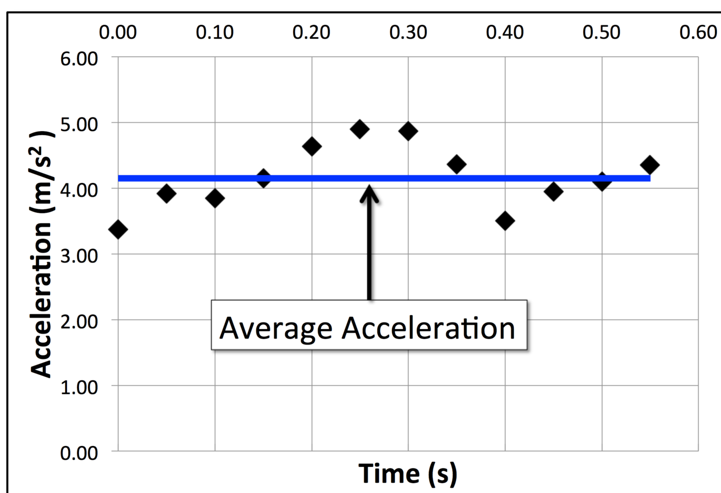
$$\Delta x_{0-3} = \frac{1}{2}\left(v_3 - v_0\right)\left(t_3 - t_0\right) = \frac{1}{2}(6-0)(3-0) = 9.0m$$

After you determine your displacement, plot the points and then add the upward sloping curve to connect the points.

In the video a street hockey puck is given an initial velocity to the left and the position, velocity and acceleration as a function of time are experimentally determined. The black squares are the experimentally observed data. In the position and velocity as a function of time graphs, the blue curve/line is a best-fit curve/line that best approximates and interpolates the data.







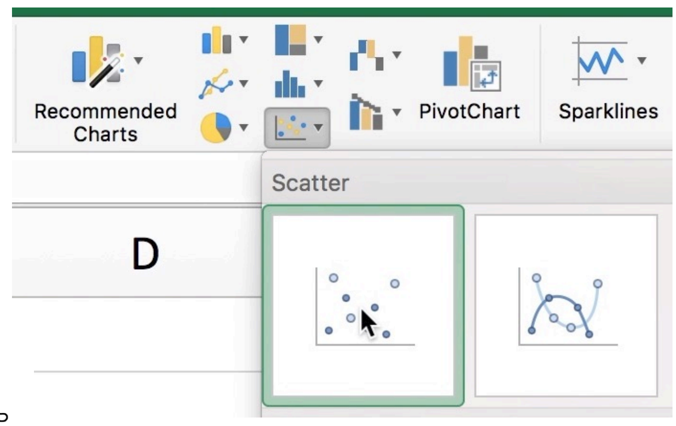
Tables:

- Use the Correct number of decimal places.
- Each column must have label & units.
- Use the = to harness the power.
- Don't forget parenthesis when harnessing the power.
- Square is done with ^2
- If you want to put π into an equation use pi()
- *You **must** turn in a data table with every graph.*
    - Your data table is the background information for your graph.

	A	B	C
1	Δt (s)	Displacement (cm)	v_{avg} (cm/s)
2	0.415	10.0	24.1
3	0.602	20.0	33.2
4	0.734	30.0	40.9
5	0.858	40.0	46.6
6	0.978	50.0	51.1
7	1.068	60.0	56.2
8	1.171	70.0	59.8
9	1.248	80.0	64.1
10	1.308	90.0	68.8
11	1.379	100.0	72.5
12	1.446	110.0	76.1

Charts: (aka Graphs)

- Use Marked Scatter (only dots, no lines)
- Y vs. X
- Y as a function of X
- Label axis (with units)
- You don't need a legend
- Make changes to graph with "Add Chart Element".



Trendline Line / Curve: (aka Best Fit Line / Curve)

- Is in "Add Chart Element" Menu
- Chose "Linear" or "Polynomial" of order 2
- Check 2 options:
    - Set intercept = 0
    - Display equation on chart.
- Move the Equation so it can be read