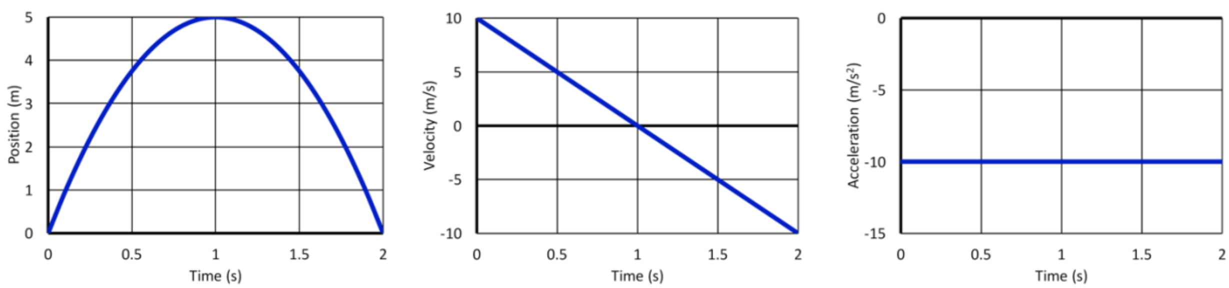
Flipping Physics - *Lecture Notes*
Stumbling Blocks for Unit 1: Kinematics - AP® Physics 1

- An object with a negative acceleration can be increasing its speed.
    - I avoid using the word "deceleration" for this reason.
    - An object which is moving in a negative direction which has a negative acceleration will have a negative velocity which is becoming more negative. This means the magnitude of its instantaneous velocity is increasing and therefore its instantaneous speed is increasing.
        - I have a video where I demonstrate this.
- The terms instantaneous and average are often misunderstood.
    - Instantaneous means at a specific time.
    - Average means over a time period.
    - An object with an average velocity of zero can have a nonzero instantaneous velocity for most of its motion.



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    - The object's average acceleration from 0 to 2 seconds is constant at negative 10 m/s^2.
        - The object's instantaneous acceleration is also -10 m/s^2 for every time from 0 to 2 seconds.
    - The object's average velocity from 0 to 2 seconds is zero.

$$v_{(0\rightarrow 2s)}=\frac{\Delta x}{\Delta t}=\frac{x_2-x_0}{t_2-t_0}=\frac{(0m)-(0m)}{2s-0s}=\frac{0m}{2s}=0$$

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    - The object's instantaneous velocity is positive for every instant between 0 and 1 second, zero at 1 second, and negative for every instant between 1 and 2 seconds.
    - Its instantaneous speed is decreasing from 0 to 1 second.
        - Its instantaneous speed is increasing from 1 to 2 seconds.
    - Be careful to notice where the horizontal axis on each graph is located!
    - Slope of position vs. time is velocity.
        - Slope/velocity at 0 seconds is 10 m/s
        - Slope/velocity at 0.5 seconds is 5 m/s.

$$v_{0.5s}=\frac{\Delta x}{\Delta t}=\frac{x_2-x_1}{t_2-t_1}=\frac{(5m)-(1.2m)}{0.75s-0s}=5.0\overline{6}\approx 5.1\frac{m}{s}$$

- Slope/velocity at 1 second is 0 m/s.
- Slope/velocity at 1.5 seconds is -5 m/s.
- Slope/velocity at 2 seconds is -10 m/s.
  - Each of these are *instantaneous* velocities.
- Slope/velocity from 0 to 2 seconds is 0 m/s.
  - This is the *average* velocity from 0 to 2 seconds.

- Slope of velocity vs. time is acceleration.
  - Slope is constant at -10 m/s^2.
  - Yes, this could be an object in free-fall with an $a_y \approx 10$ m/s^2.
  - I did an entire video about common free-fall misconceptions, so I am not going to repeat those here.
- Area "under" acceleration vs. time curve is change in velocity.

$$\text{Area}_{(0\to 2s)} = \Delta v = (\text{width})(\text{height}) = (2s)\left(-10\frac{m}{s^2}\right) = -20\frac{m}{s}$$

  - Remember area below the horizontal axis is negative, as you can see here.
- Area "under" velocity vs. time curve is change in position or displacement.

$$\text{Area}_{(0\to 2s)} = \Delta x = A_1 + A_2 = \frac{1}{2}b_1h_1 + \frac{1}{2}b_2h_2$$

$$\Rightarrow \text{Area}_{(0\to 2s)} = \frac{1}{2}(1s)\left(10\frac{m}{s}\right) + \frac{1}{2}(1s)\left(-10\frac{m}{s}\right) = (5m) + (-5m) = 0$$

- A curved line on a position vs. time graph means the velocity of the object is changing. That means the object is accelerating.
- A horizontal line on an acceleration vs. time graph means the acceleration of the object is constant.
- A horizontal line on a velocity vs. time graph means the velocity of the object is constant.
- A horizontal line on a position vs. time graph means the position of the object is constant. That means the object is not moving.
- A straight, nonhorizontal line on a position vs. time graph means the velocity of the object is constant and nonzero.
- A straight, nonhorizontal line on a velocity vs. time graph means the acceleration of the object is constant and nonzero.

Unfortunately, positive and negative directions are often confusing:

- Up, North, and to the right are conventionally positive.
- Down, South, and to the left are conventionally negative.
  - I suggest you almost always use this convention.
  - If you ever do not use this convention, make it *very clear* in your solution which directions are positive and which directions are negative.
- A typical issue with forgetting that down is negative.
  - Example: What is the velocity of a ball after it is dropped from rest and it has fallen 5.0 meters? (use g = 10 m/s^2)

$$\text{Knowns: } v_{iy} = 0;\ a_y = -10\frac{m}{s^2};\ \Delta y = 5.0m;\ v_{fy} = ?$$

$$v_{fy}^2 = v_{iy}^2 + 2a_y\Delta y = 0^2 + (2)(-10)(5) = -100 \Rightarrow v_{fy} = \sqrt{-100}$$

If you forget the negative on the displacement, you get the square root of a negative number which only yields imaginary numbers. Don't do that.

$$\text{Knowns: } v_{iy} = 0;\ a_y = -10\frac{m}{s^2};\ \Delta y = -5.0m;\ v_{fy} = ?$$

$$v_{fy}^2 = v_{iy}^2 + 2a_y\Delta y = 0^2 + (2)(-10)(-5) = 100 \Rightarrow v_{fy} = \sqrt{100} = 10\frac{m}{s}$$

Please remember to be smarter than your calculator. Whenever you take the square root of a number, you determine if the answer is positive or negative. We know it is negative this time because the ball is moving downward, and down is negative.

$$\Rightarrow v_{fy} = \sqrt{100} = \pm 10\frac{m}{s} = -10\frac{m}{s}$$

And please recognize this is simply the second half of the graphs we did earlier!

Lastly, realize you can only use the Uniformly Accelerated Motion or Kinematics equations when the acceleration of the object is constant. If the acceleration of the object is not constant, you must find another way to solve the problem!!