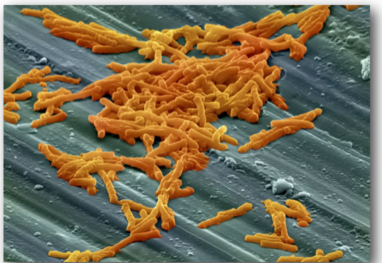
PHYS-183 : Day #1

- In this class, our goal will be to explore the underlying principles of the physical world, with a focus on applications to biological systems.

- All biological systems perform the same tasks: they move, they interact, and they exchange energy between each other and their surroundings.



Clostridium difficile

- The essential relations for understanding this behavior are:

Motion ↔ **Forces** ↔ **Energy**

- Understanding the laws of motion is the fundamental building block from which all other physical principles arise, and it will be our focus in this and the next chapter.

<u>Basic Types of Motion:</u>

- There are two basic types of motion:

  - Motion with constant velocities.

  - Motion with changes in velocity, also called **acceleration**.

- Consider what it is like to sit in a car moving at a constant velocity, say 60 km/hr:

- If you close your eyes, can you tell that you are moving?

- No!, there is no way to tell that you are moving at a constant velocity.

ALL PHYSICS IS THE SAME AT ZERO VELOCITY AND AT CONSTANT VELOCITY

- Zero velocity is just a special case of constant velocity.

was this picture taken while the car was moving at 60 km/hr or 0 km/hr?

- What do you feel when your car starts from a green light or suddenly stops?

    - You can tell that the car is moving when the velocity of the car changes.

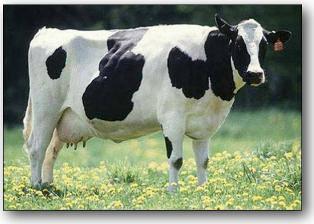
    - Changes in velocities are called **accelerations**.

- You know when you are accelerating, but cannot tell if you are moving at a constant velocity.
    - Why is this?

- This is a consequence of Newton's Laws; the physical rules that tell **any** object how to move.

Center-of-Mass Motion:

- We are interested in studying the motion of many different kinds of objects.

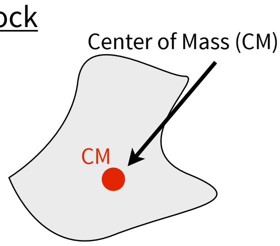

- Each of these objects is made up of many, many, small pieces.

- Keeping track of the motion for each of these pieces is extremely difficult.

- We must simplify each object that we are interested in.

- In this class, we will only study objects that can be described as being one-piece having what is called a **center of mass**.

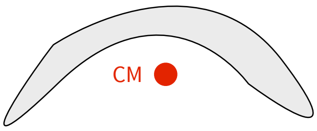
ex: Rock



- Center of mass (CM) is a single point on any object that can be used to completely describe the motion of the entire object.

- Location of CM depends on the shape of the object

- Here, we are interested in objects that do not change shape (no bending, squishing,....)



CM can be outside of object!

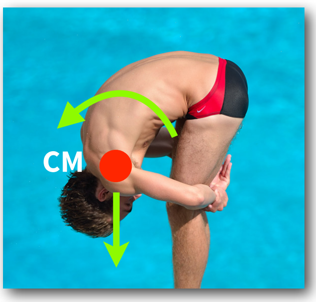
- If CM moves right 1m, then every piece of the object moves by the same amount

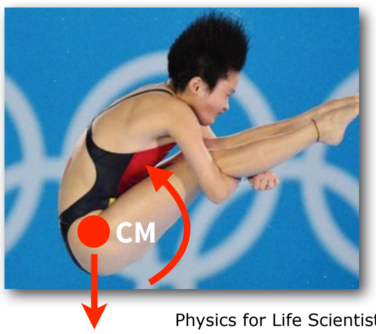
- If an object rotates, then every piece of the object rotates around the CM.

ex: Humans

- The motion of people can also be described by a CM.

- For men, the CM is near the shoulders, for women it is at the hips.



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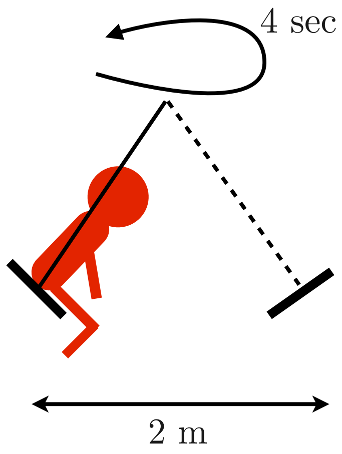
Motion in One-Dimension (1D):

- To begin, we will study motion in one-dimension.
  - This motion can be described by a single parameter “x” called the position, as well as time “t”.
  - The position is a **dependent variable** that dependents on the time “t”

Ex : Child on Swing



- In order to measure motion, we must collect data

-Example: record the position of the swing at several times.

Two important quantities for position:

Distance: The total length traveled over a certain amount of time.

t_i : **I**nitial **t**ime t_f : **F**inal **t**ime

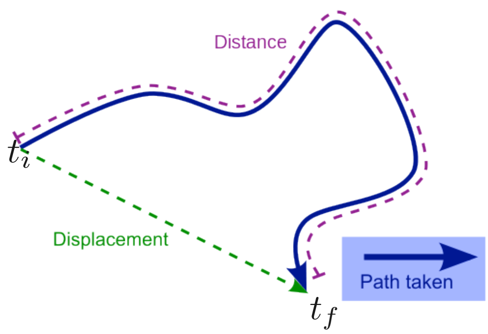
$$d(2\ \text{sec}) = 2\ \text{m}$$

-Distances are always positive and add together:

$$d(4\ \text{sec}) = 2\ \text{m} + 2\ \text{m} = 4\ \text{m}$$

Displacement: The shortest distance between points at initial and final times.

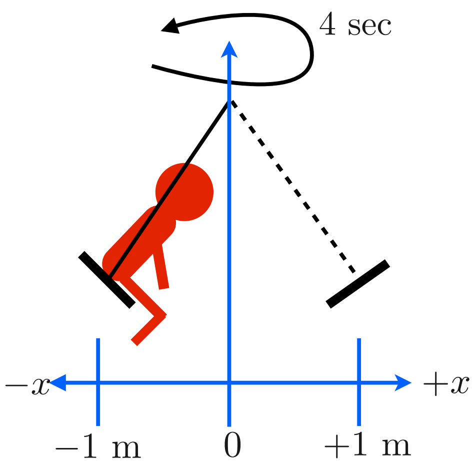
$$\Delta x = x(t_f) - x(t_i)$$



- Displacements can be positive or negative.

➡ Displacements have a direction

- Displacement can be zero, even when distance is not



Data at two-points:

Time	Position	Distance	Displacement
0	-1m	0m	0m
4	-1m	0m	0m

- Data is much easier to understand if we plot it on a graph

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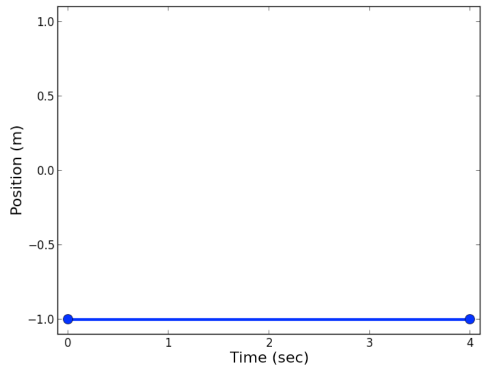
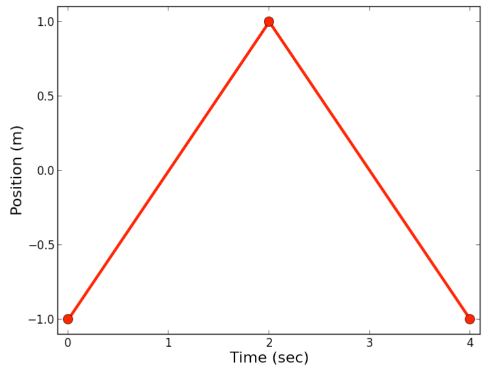


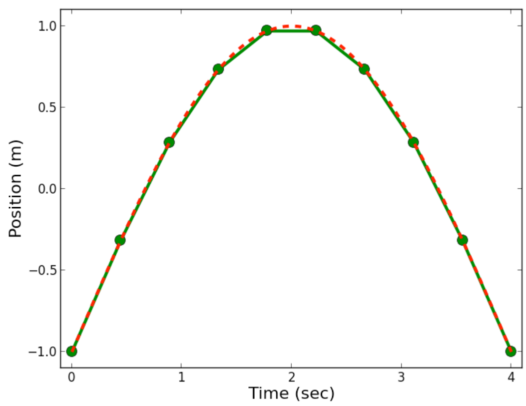
Data at three Points:

Time	Position	Distance	Displacement
0	-1m	0m	0m
2	+1m	2m	+2m
4	-1m	4m	0m



Data at 10 Points:

Time	Position	Distance	Displacement
0	-1m	0m	0m
0.44	-0.32m	0.68m	+0.68m
0.89	+0.29m	1.29m	+1.29m
1.33	+0.73m	1.73m	+1.73m
1.78	0.97m	1.97m	+1.97m
2.22	0.97m	1.97m	+1.97m
2.67	0.73m	2.21m	+1.73m
3.11	0.29m	2.65m	+1.29m
3.56	-0.32m	3.26m	+0.68m
4	-1m	3.94m	0m



- The faster you take data, the more accurate you model the actual object.

- The graph becomes smooth and continuous

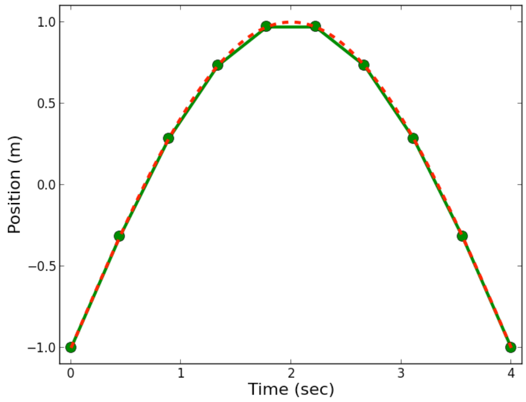
- The position at every point in time is called the **instantaneous position**

- More data allows for mathematical models that can <u>predict</u> the motion of the object

Speed and Velocities:

- In addition to position, we want to know how long it takes for an object to get from $x(t_i)$ to $x(t_f)$

<u>Average Speed</u>: Total <u>distance</u> traveled from $x(t_i)$ to $x(t_f)$ divided by the elapsed time



Average speed of swing between 0 and 2 sec:

$$s = \frac{0.97\ \mathrm{m} - (-1\ \mathrm{m})}{2\ \mathrm{sec}} = \frac{1.97\ \mathrm{m}}{2\ \mathrm{sec}} = 0.98\ \mathrm{m/sec}$$

- Speed has units of meters/sec.

- Always, always make sure you **include the units**!

<u>Average Velocity</u>: Displacement divided by elapsed time

$$\bar{v} = \frac{\Delta x}{\Delta t} \quad \Delta t = t_f - t_i$$

(Velocities have a direction)

Average velocity of swing between 3 and 4 sec:

$$\bar{v} = \frac{-1\ \mathrm{m} - 0.29\ \mathrm{m}}{4\ \mathrm{sec} - 3\ \mathrm{sec}} = -1.29\ \mathrm{m/sec}$$

(Average speed would be positive here)

- Average velocity tells us how an object moves over a finite amount of time.

- What if I want the velocity of an object at a single point in time?

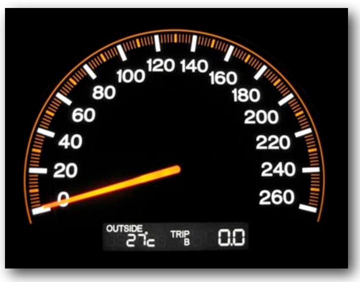
- I need the **<u>instantaneous velocity:</u>**

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

Mathematically: $\dfrac{x(t_i + \Delta t) - x(t_i)}{\Delta t}$ $\quad \Delta t \to 0$

Physically: Collect data so fast that average motion is almost identical to actual motion.

- How do we actually use/calculate the instantaneous velocity?



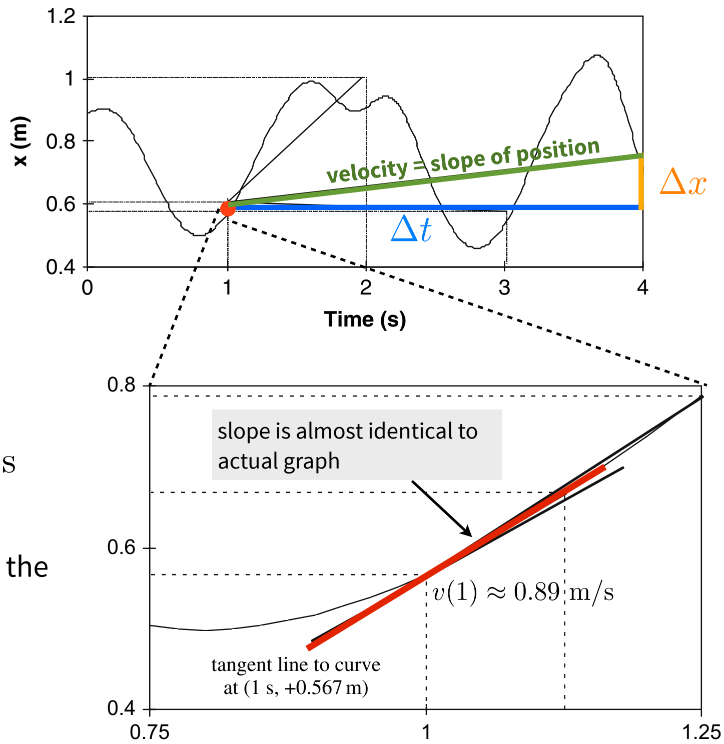
Car speedometer

Ex: What is the instantaneous velocity of the car at t=1 sec?

We want $v(1\ \mathrm{s})$ so we need two points

$$v(1) = \frac{x(1+\Delta t) - x(1)}{\Delta t}$$

pick this to be very small



Ex: let $\Delta t = 3$: elapsed time not small so average velocity

$$\bar{v} = \frac{0.7\ \mathrm{m} - 0.57\ \mathrm{m}}{4\ \mathrm{s} - 1\ \mathrm{s}} = 0.044\ \mathrm{m/s}$$

- Velocity is the **slope of the line** connecting the two positions.

- Must pick second point near t=1

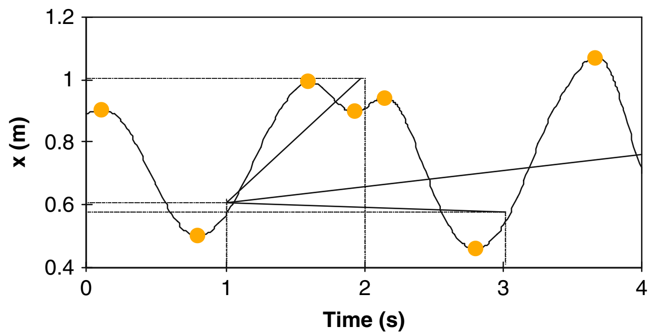
Instantaneous velocity is the slope (tangent line) of the position/time graph at the point of interest.

- We can get the graph of velocity vs. time by evaluating the slope of the position vs. time

Step #1: Find times at which the velocity (slope) is zero.

Hint: Use your hand

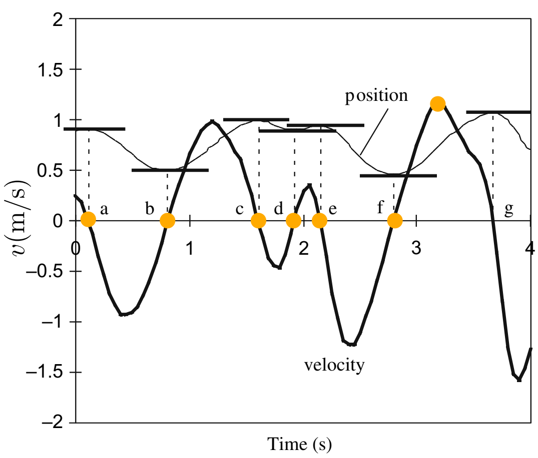
- Velocity is zero, not position!



Step #2: Start at initial time at calculate slope in between zero points.

- You should become an expert at this.

Important Point: Constant velocity means that the instantaneous velocity at every point in the elapsed time is the same.



- Both constant velocity and changes in velocity are important to understanding the laws of motion

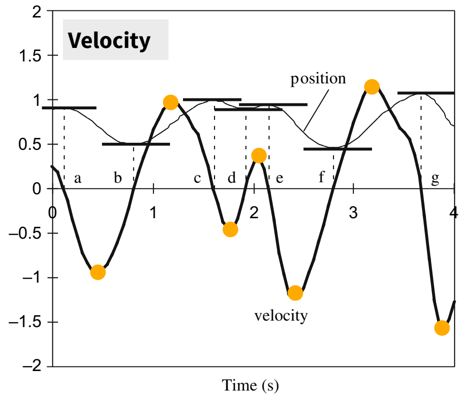
Average Acceleration:

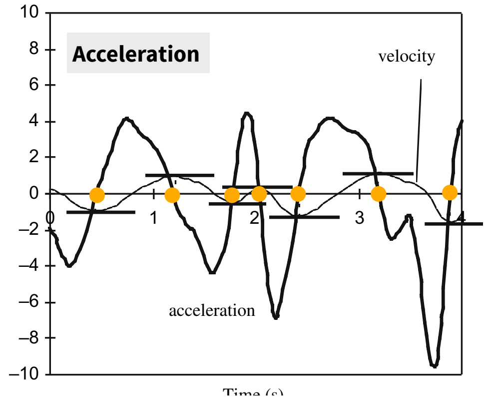
$$\bar{a} = \frac{\Delta v}{\Delta t}$$

Instantaneous Acceleration:

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

- Acceleration is the slope of the velocity vs. time graph.

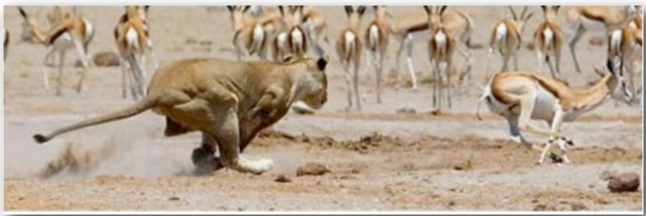




- What about the slope of acceleration, and the slope of the slope of the acceleration?

- Acceleration is the fundamental quantity in the motion of physical systems

Ex: Life and Death in Acceleration:



Lion stalking a Thomson's Gazelle

- For many animals, how fast you can accelerate determines life and death

- Natural selection has designed both predator and prey to take advantage of physics.

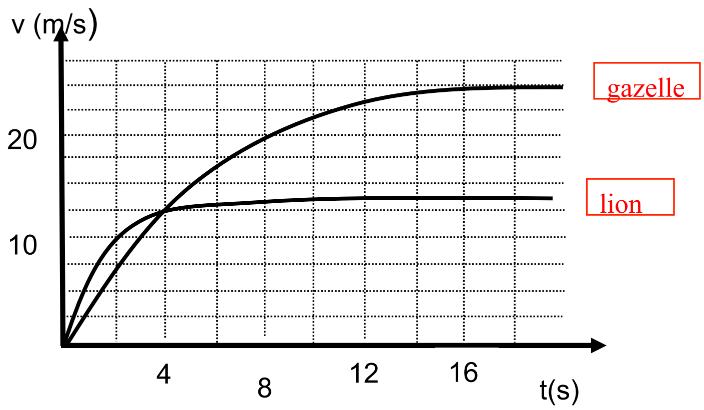
- Lions have a faster acceleration than Gazelle's

- Gazelle's have a higher maximum velocity

- Lions have only 4 seconds to catch the Gazelle before its velocity becomes to fast and it escapes.

- Lions must get very close before they start to run.

- Gazelles must begin running as early as possible to live.




Best Animal Moments