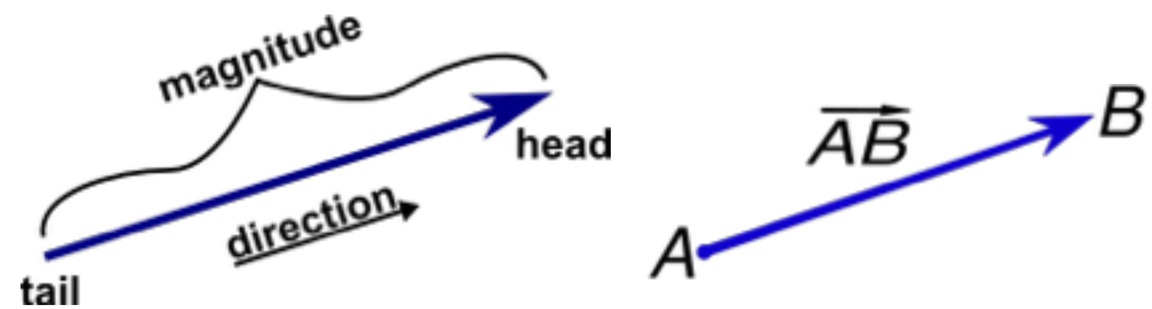
Vectors and Forces

oh my!

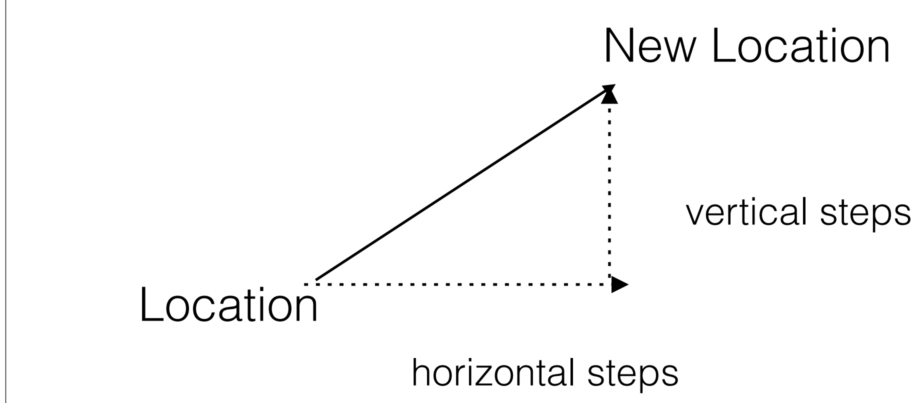
Look at NOC_1_1
- ball traveling around
- properties represented in variables
- variables for location, speed, acceleration, target location, wind, friction —-> x + y for each!!! God forbid we are working in 3D and need a variable also for the z axis for each

Vector Review:

- Euclidean Vector
- entity with magnitude and direction

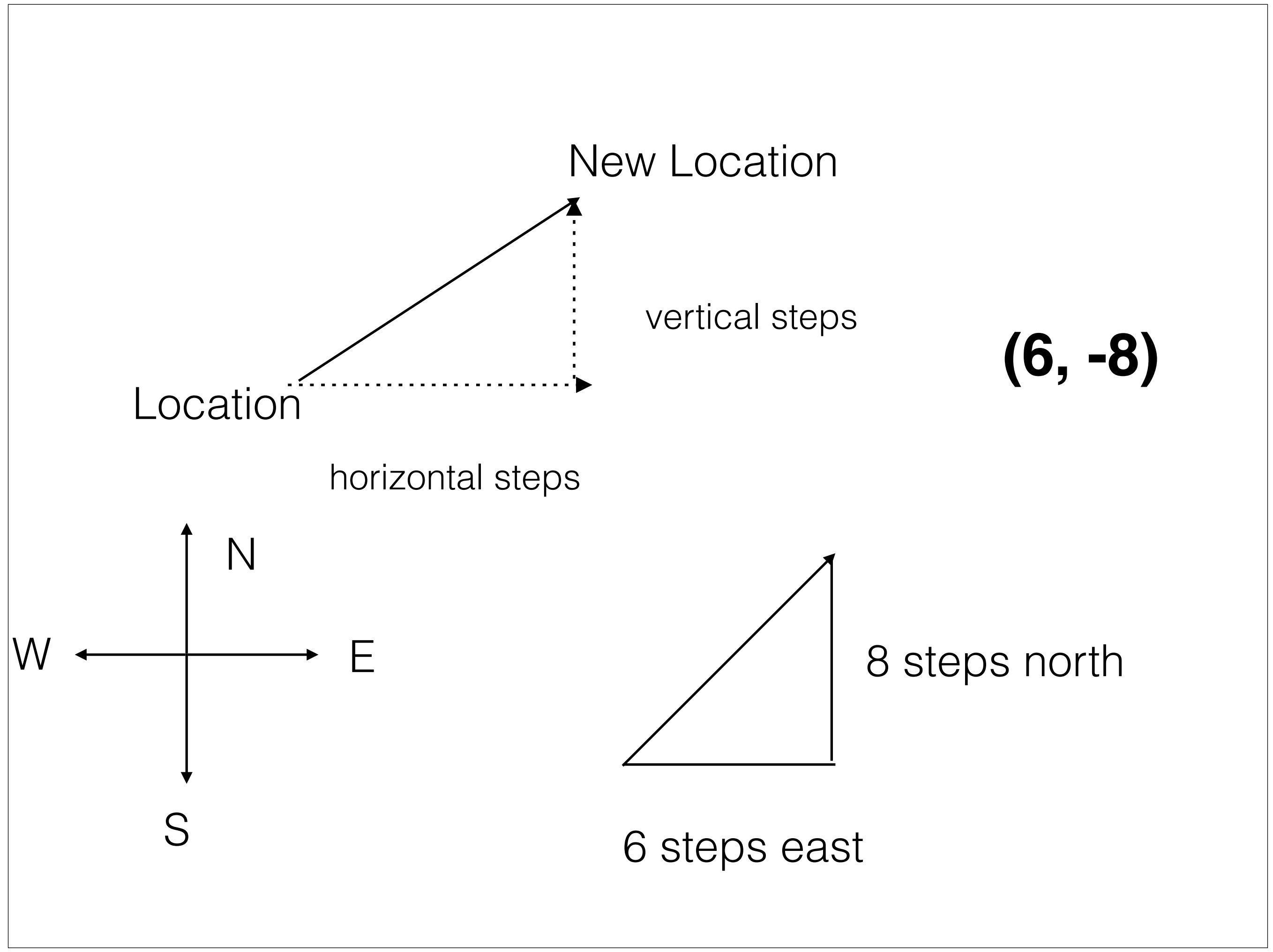


entity with magnitude and direction



location is a singular point in space

- think of it as the difference between two points



the path taken from the origin to reach that location
As a result: a location can be the vector representing the difference between the location + origin
Vector = convienent way to store 2 values

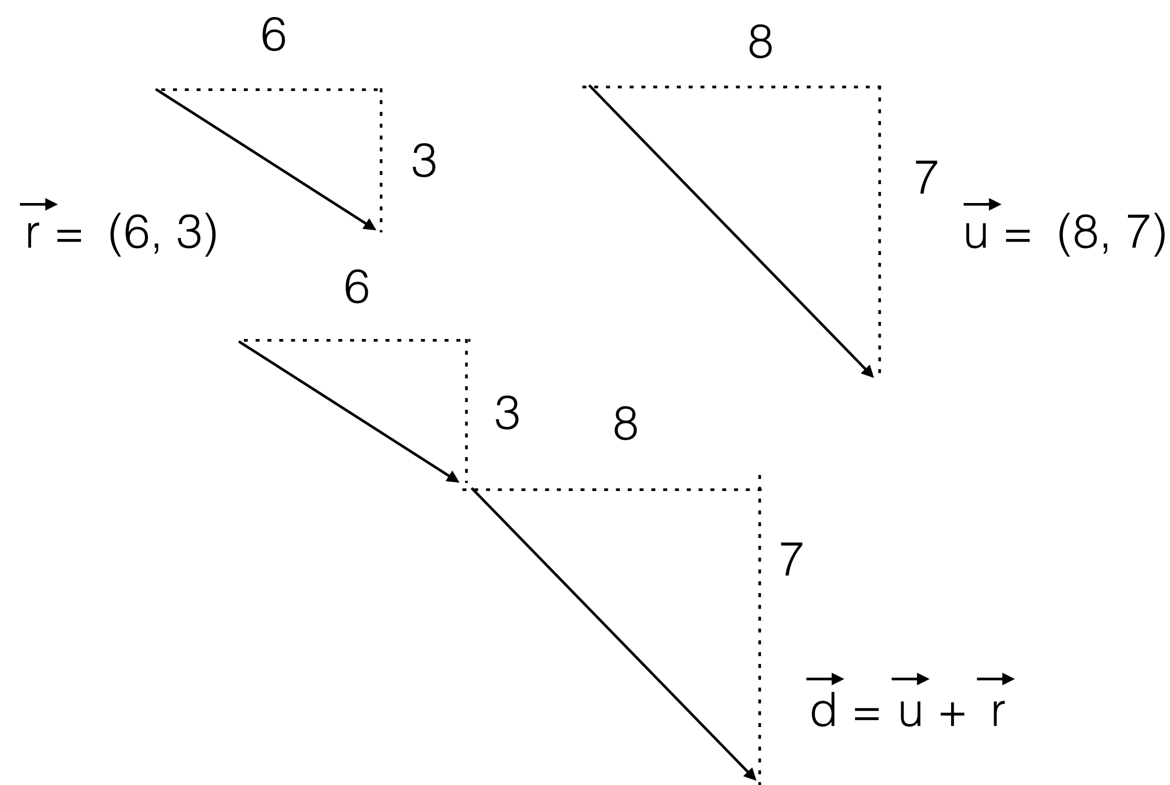
p5.Vector

sketch.js

```
var p1, p2;
var w = 40;

function setup() {
  createCanvas(400, 400);
  p1 = createVector(42, 104);
  p2 = createVector(110, 260);
}

function draw() {
  fill(87, 219, 232);
  noStroke();
  ellipse(p1.x, p1.y, w, w);

  fill(255, 121, 97);
  ellipse(p2.x, p2.y, w, w);

```

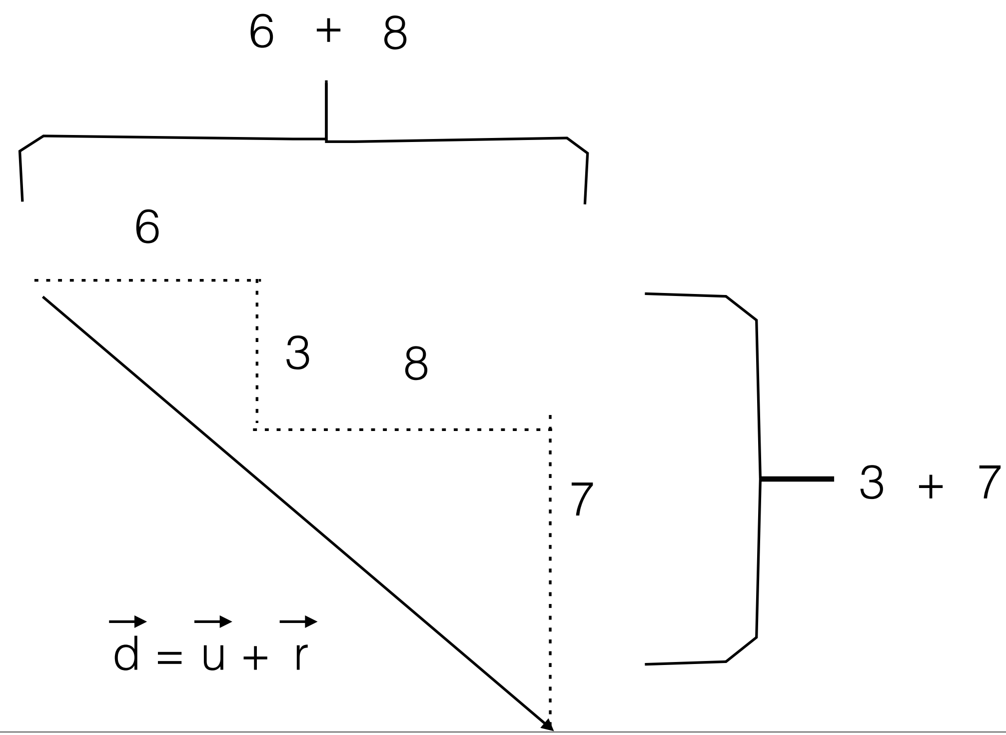
When we want to use a vector for placing graphics, we still need to independently reference it’s to components to apply them to the x + y of the graphics independently

Mathematical Operations



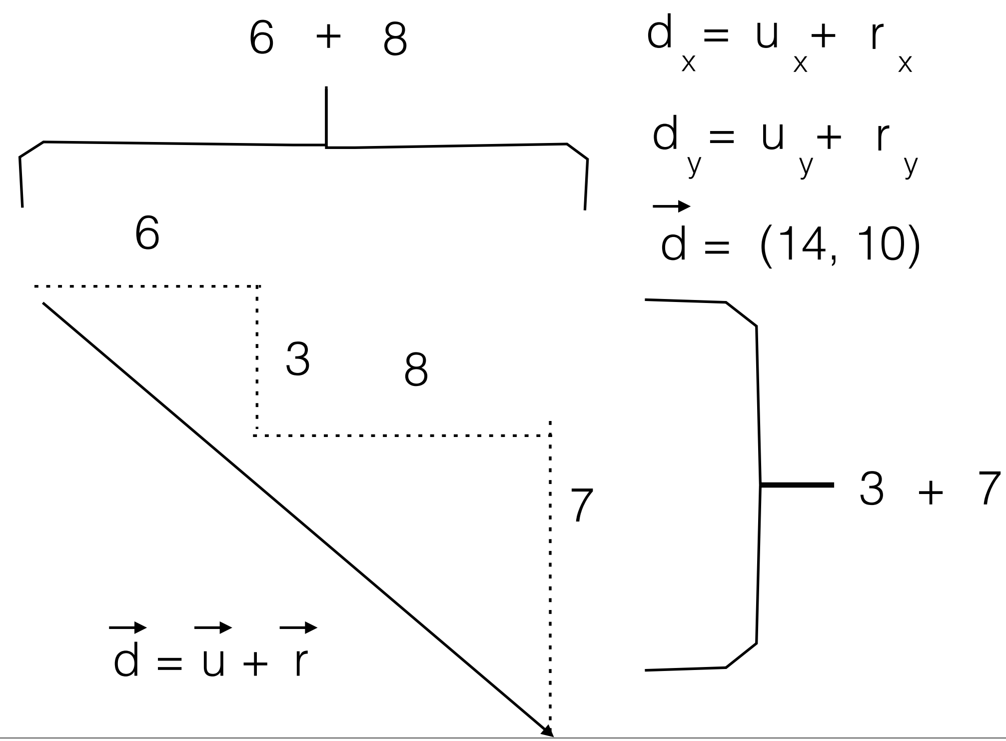
you have two vectors + you want to add them together…

Mathematical Operations



to add vectors, put them end to end
addition operator (+) is reserved for primitive values (int, float, etc)

Mathematical Operations



addition operator (+) is reserved for scalar values (int, float, etc — single value numbers)

Mathematical Operations

```
var loc;

function setup() {
  createCanvas(400, 400);
  loc = createVector(6, 3);
  velocity = createVector(8, 7);
  loc.add(velocity);
}
```

So, instead of +, we use the add method from the vector’s class
doing so allows us to add two vectors together
We can use this to create motion of objects
and to allow forces to effect our objects motion

Mathematical Operations

- add()
- sub()
- mult()
- div()
- mag()
- normalize()
- limit()
- dot()

These all come from making an object from the P5.vector class
methods of the class

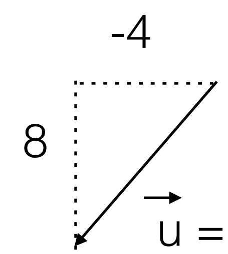
they do different types of mathematical operations on a vector.
some pass vectors in, some pass scalar values
Take for instance
multiplication + division

Mathematical Operations

$\vec{d} = \vec{u} * k$

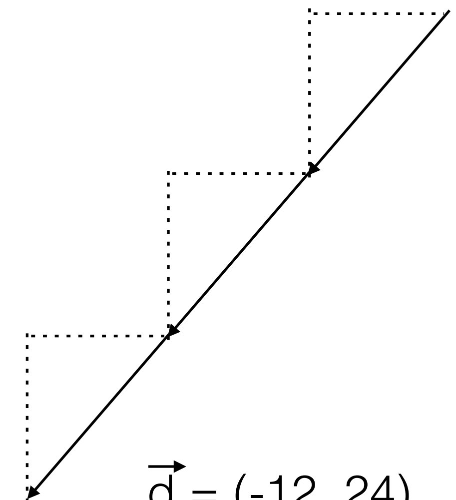
$d_x = u_x * k$

$d_y = u_y * k$



$\vec{u} = (-4, 8)$

$\vec{d} = \vec{u} * 3$



$\vec{d} = (-12, 24)$

Check out code

Static vs Non-Static Functions

float x = 4;	float x = 0;
float y = 7;	float y = 5;
x = x + y;	float z = x + y;
value of x changes	value of x does not change

Seems obvious, but not so obvious when working with vectors
Are we manipulating a vector?
Or do we want to create a new vector?

Static vs Non-Static Functions

```
var v = createVector(0, 0);

var g = createVector(4, 5);

var w = v.add(u);
```

Static vs Non-Static Functions

```
var v = createVector(0, 0);

var g = createVector(4, 5);
```

~~var w = v.add(u);~~

```
var add = function(v){

      this.x = this.x + v.x;

      this.y = this.y + v.y

}
```

add method doesn't return a new vector; manipulates a given vector
not only that, but it changes the value of the vector which it was called

Static vs Non-Static Functions

Functions that we call from the class name itself (rather than a specific object instance) are known as *static functions*

v.add(u); **Not static: called from an object instance**
p5.Vector.add(v, u); **Static: called from the class name**

var w = p5.Vector.add(v, u);

in order to get a new vector, we must use the static add function.
static functions allow us to perform generic math operations on vector objects,
without having to adjust the value of one of the input vectors

use when you want a new vector returned, or you don't want to effect the current vector. make a copy

Static vs Non-Static Functions

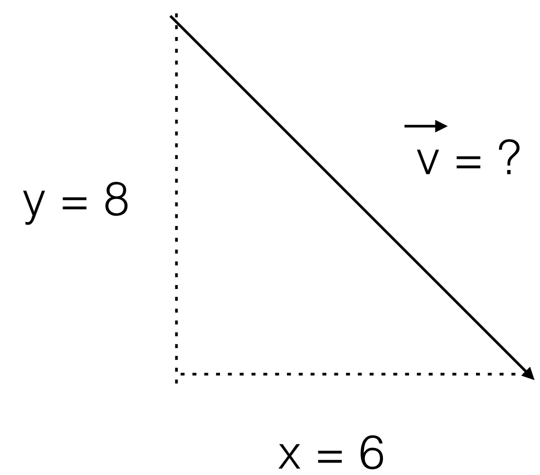
```
var v = createVector(0, 0);

var g = createVector(4, 5);
```

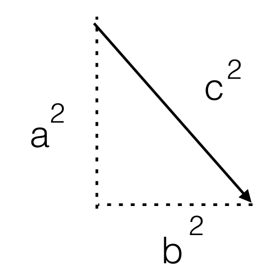
~~var w = v.add(u);~~

```
var w = p5.Vector.add(v, u);
```

p5.Vector returns a new vector

Vector Magnitude





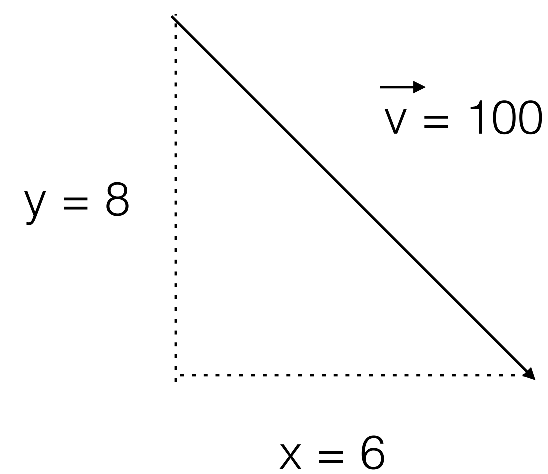
$$c = \sqrt{a^2 + b^2}$$

$$c = \sqrt{a_x * b_x + a_y * b_y}$$

length of a vector

Normalizing a Vector

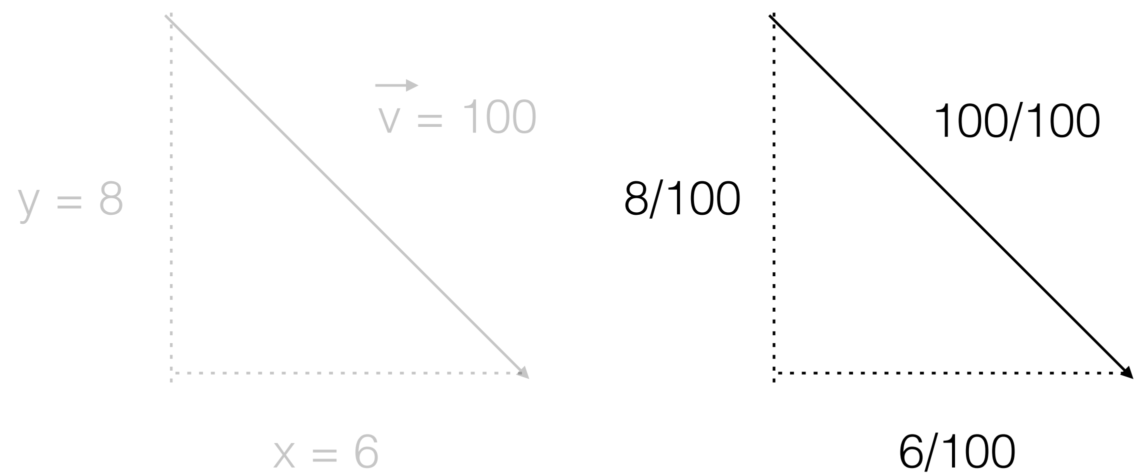
- Divide each component by it's magnitude



Unit vector

Normalizing a Vector

- Divide each component by it's magnitude



Unit vector

Motion 101

1. Add velocity to location
2. draw object at location

Motion 101

1. Add velocity to location
2. draw object at location

```
var Mover = function() {

  this.position = createVector(random(width), random(height));
  this.velocity = createVector(random(-2, 2), random(-2, 2));

  this.update = function() {
    this.position.add(this.velocity);
  };

  this.display = function() {
    stroke(0);
    strokeWeight(2);
    fill(127);
    ellipse(this.position.x, this.position.y, 48, 48);
  };
```

Motion 101: acceleration

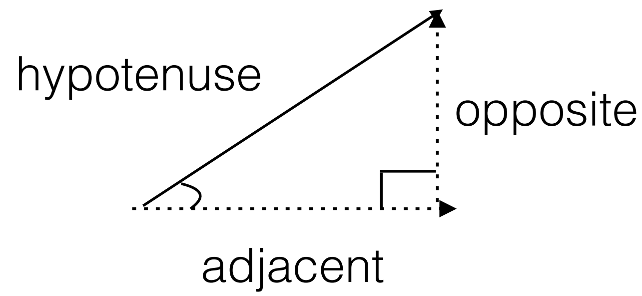
- rate of change of velocity

rate of change of velocity

Motion 101: acceleration

```
function Mover() {
  this.position = createVector(width/2,height/2);
  this.velocity = createVector();
  this.acceleration = createVector(-0.001, 0.01);
  this.topspeed = 10;

  this.update = function() {
    this.velocity.add(this.acceleration);
    this.velocity.limit(this.topspeed);
    this.position.add(this.velocity);
  }

  this.display = function() {
    stroke(0);
    strokeWeight(2);
    fill(127);
    ellipse(this.position.x, this.position.y, 48, 48);
  }
```

.limit() keeps velocity within a reasonable range



SOH CAH TOA

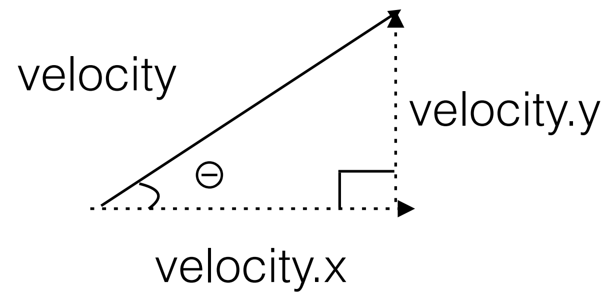
sine = opposite / hypotenuse

cosine = adjacent / hypotenuse

tangent = opposite / adjacent

Provided the triangle as a 90degree angle, we can use Trig to find out other information about the triangle:

- if we know 2 sides, we can figure out the angle
- if we know the angle and one side, we can figure out the other sides
-



tangent(angle) = velocity.y / velocity.x

angle = arctan(velocity.y / velocity.x)

angle = atan(velocity.y / velocity.x)

angle = atan2(velocity.y / velocity.x)

SOH CAH TOA

sine = opposite / hypotenuse

cosine = adjacent / hypotenuse

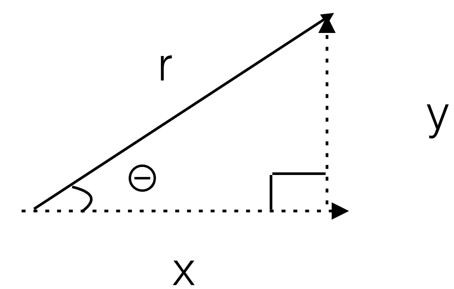
tangent = opposite / adjacent

atan2 for all directions

tangent is great for finding the angle

$$\cos(\ominus) = x / r \longrightarrow x = r * \cos(\ominus)$$

$$\sin(\ominus) = y / r \longrightarrow y = r * \sin(\ominus)$$



cartesian coordinate = the x,y component of a vector

polar coordinate = the magnitude (length) and direction (angle)

$\vec{v} = (x, y)$ $\qquad$ $\vec{v} = (r, \ominus)$

sine & cosine are great for converting back and forth between polar and cartesian coordinates

Forces

Force = Mass x Acceleration

$\vec{F} = M \times \vec{A}$

$\vec{A} = \vec{F} / M$

Acceleration is directly proportional to force

and inversely proportional to mass

Mass = amount of matter in an object
Weight = the force of gravity on an object
density is the amount of mass per unit of volume

Steering