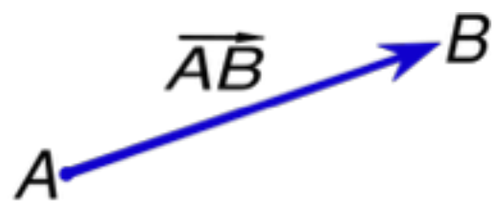
Vectors and Forces

oh my!

Vector Review:

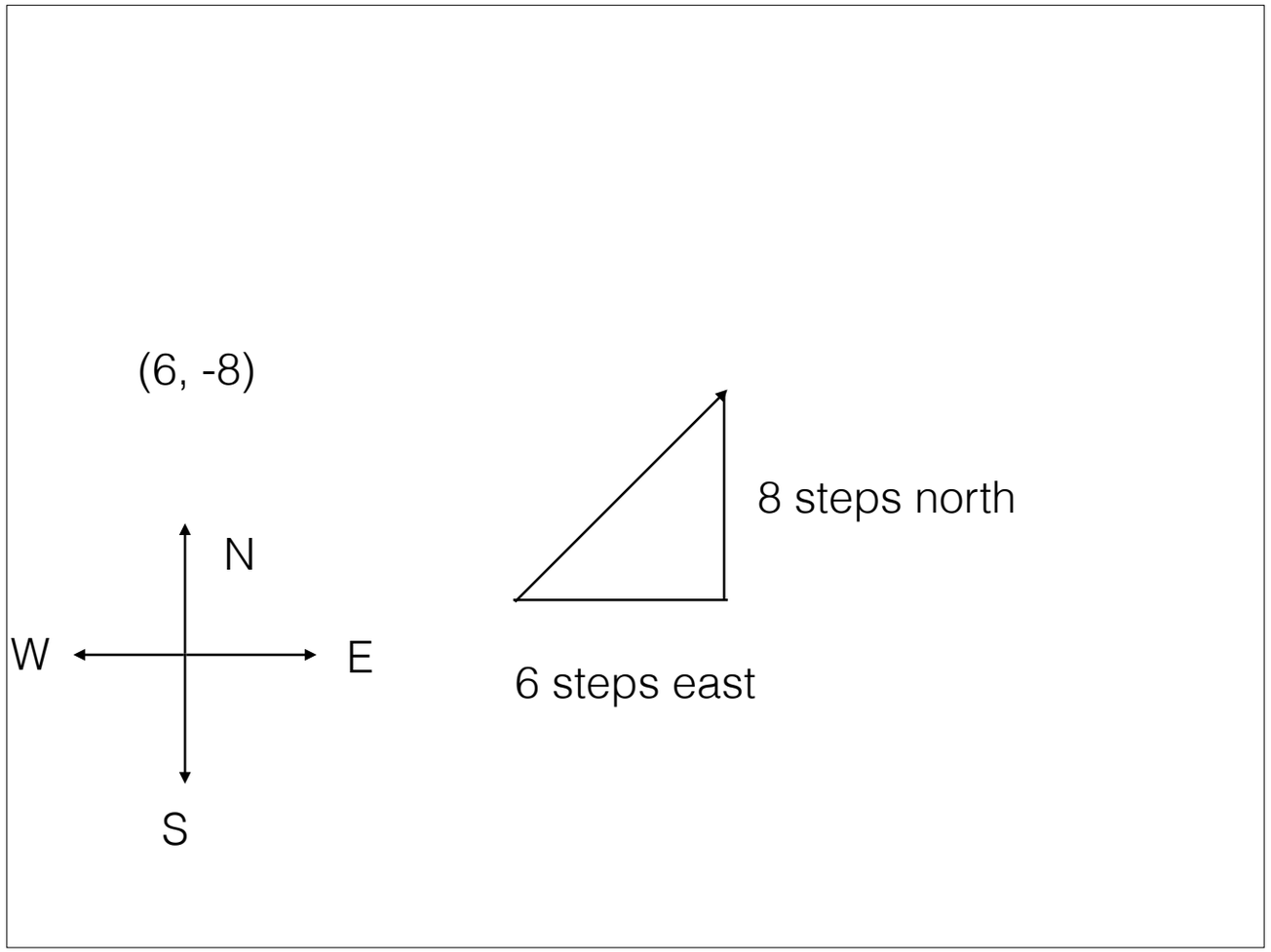
- Euclidean Vector
- entity with magnitude and direction



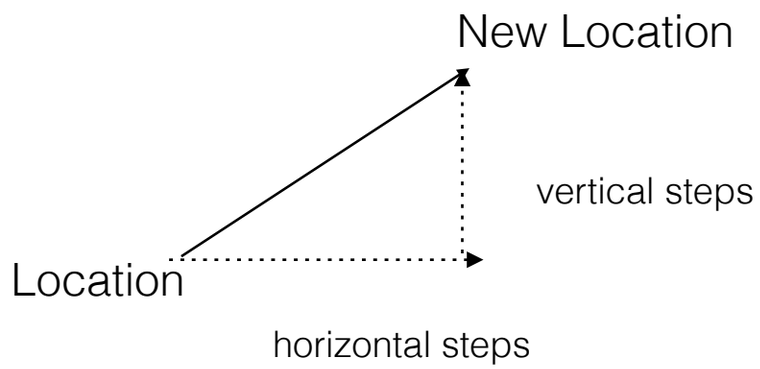
p5.Vector

sketch.js

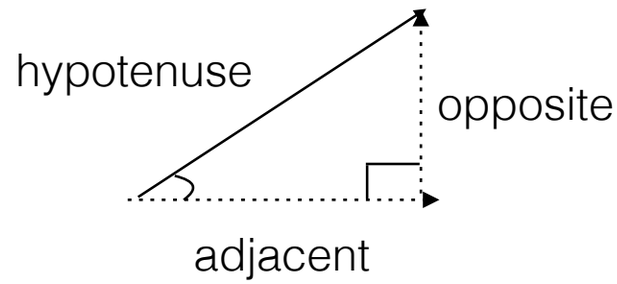
```
var p1, p2;
var w = 40;

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);

```



- think of it as the difference between two points



location is a singular point in space
but a way to describe a location is the path taken from the origin to reach that location
hence, a location can be the vector representing the difference between the location + origin

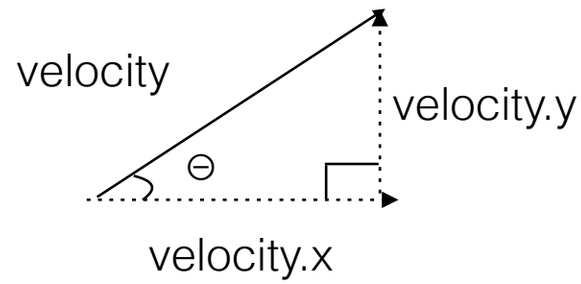


SOH CAH TOA

sine = opposite / hypotenuse

cosine = adjacent / hypotenuse

tangent = opposite / adjacent



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

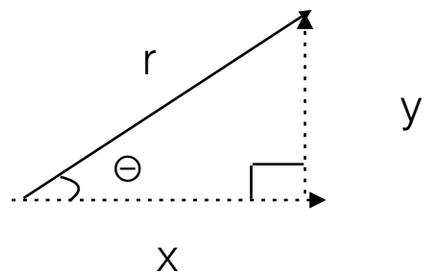
tangent = opposite / adjacent

atan2 for all directions

tangent is great for finding the angle

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

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



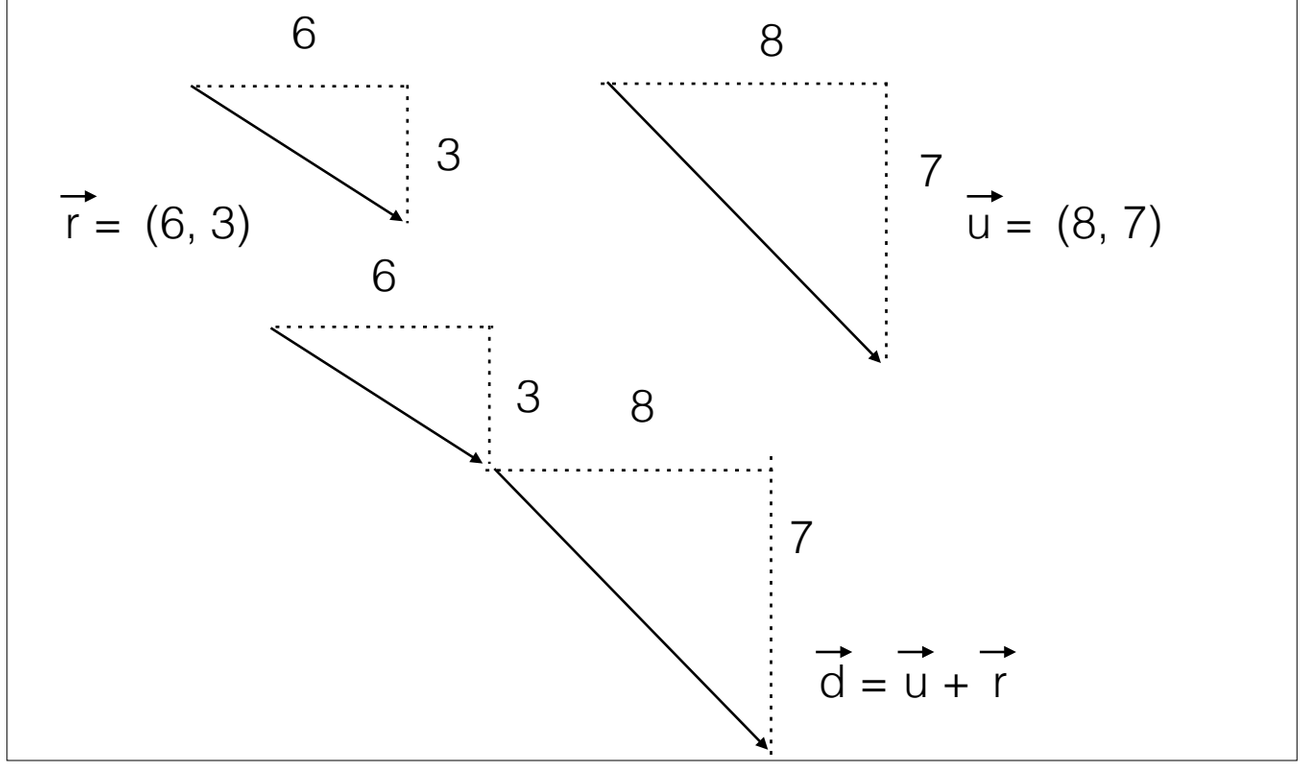
cartesian coordinate = the x,y component of a vector

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

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

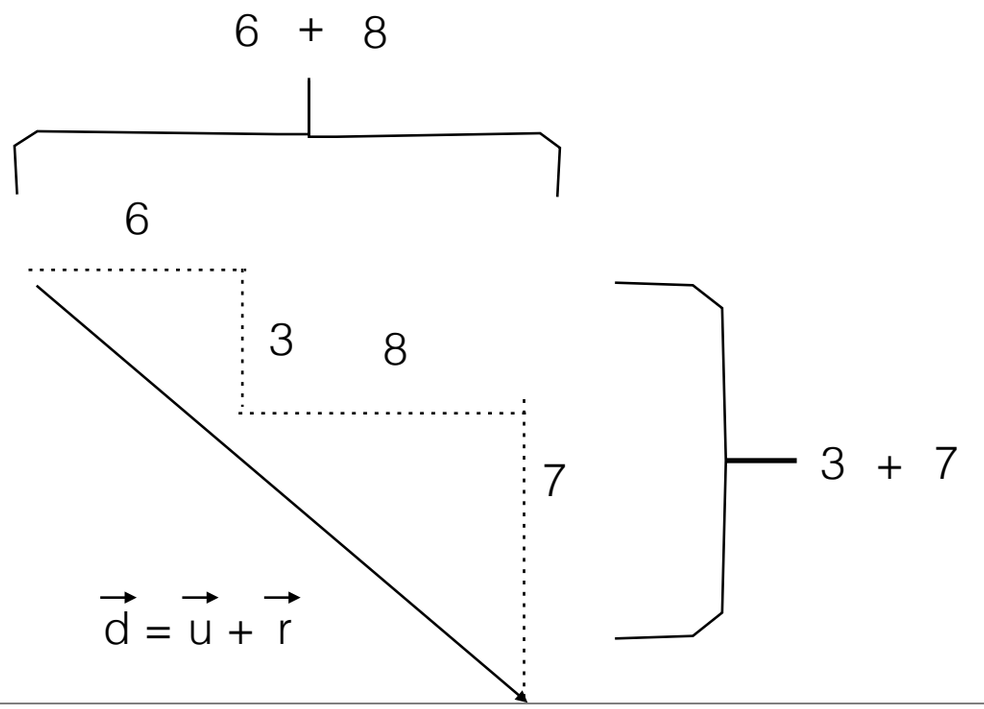
sine & cosine are great for converting back and forth between polar and cartesian coordinates

Mathematical Operations



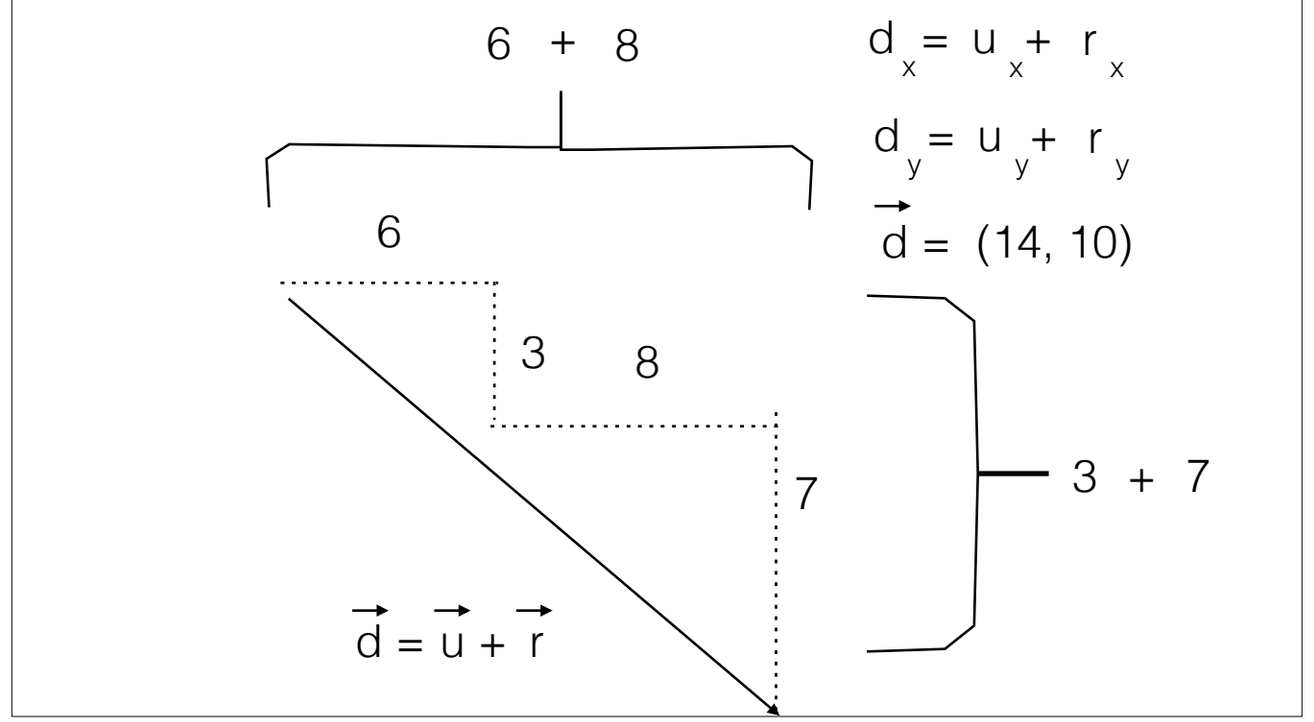
addition operator (+) is reserved for primitive values (int, float, etc)

Mathematical Operations



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

Mathematical Operations



addition operator (+) is reserved for primitive values (int, float, etc)

Mathematical Operations

```
4  var loc;
5
6  function setup() {
7    createCanvas(400, 400);
8    loc = createVector(6, 3);
9    velocity = createVector(8, 7);
10   loc.add(velocity);
11 }
12
```

Mathematical Operations

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

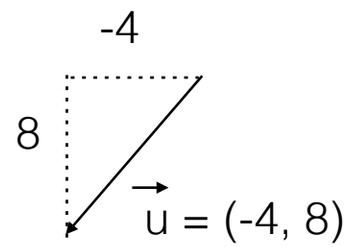
multiplication + division is scaling the vector, remember!

Mathematical Operations

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

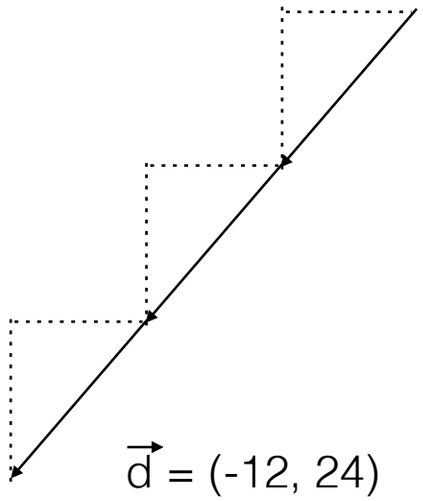
$d_x = u_x * k$

$d_y = u_y * k$



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

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



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

Static vs Non-Static Functions

```
float x = 4;
float y = 7;
x = x + y;
```

value of x changes

```
float x = 0;
float y = 5;
float z  = x + y;
```

value of x does not change

Seems obvious, but not so obvious when working with vectors

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
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 all us to perform generic math operations on vector objects,
without having to adjust the value of one of the input vectors

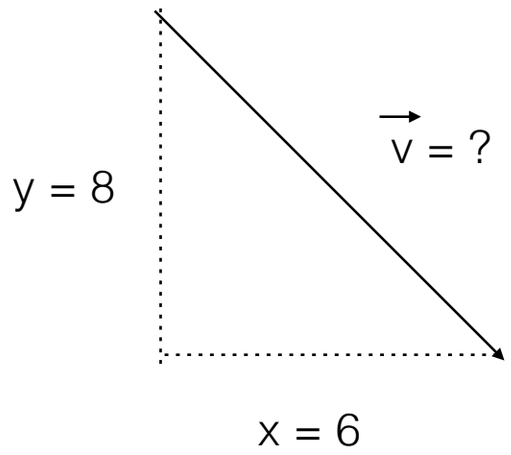
use when you want a new vector returned, or you don’t want to effect the current vector. make a copy

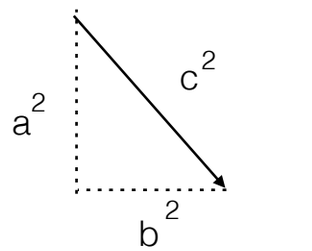
Static vs Non-Static Functions

```
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





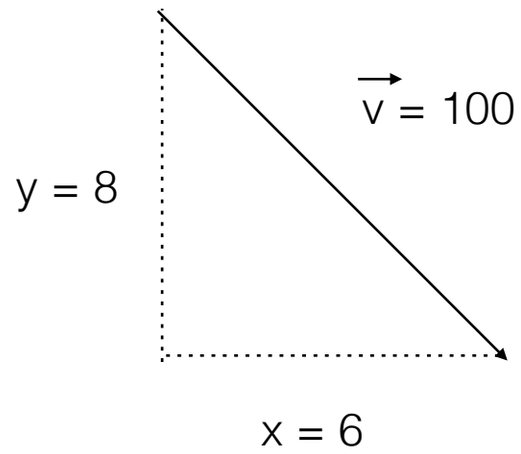
$$c = \sqrt{a^2 + b^2}$$

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

length of a vector

Normalizing a Vector

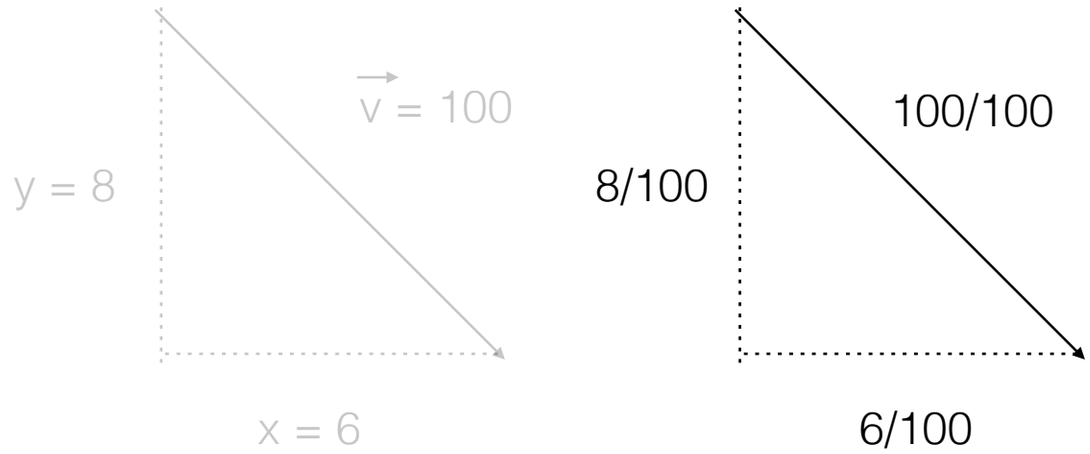
- Divide each component by it's magnitude



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

Forces

Force = Mass x Acceleration

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

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

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

see code

Steering