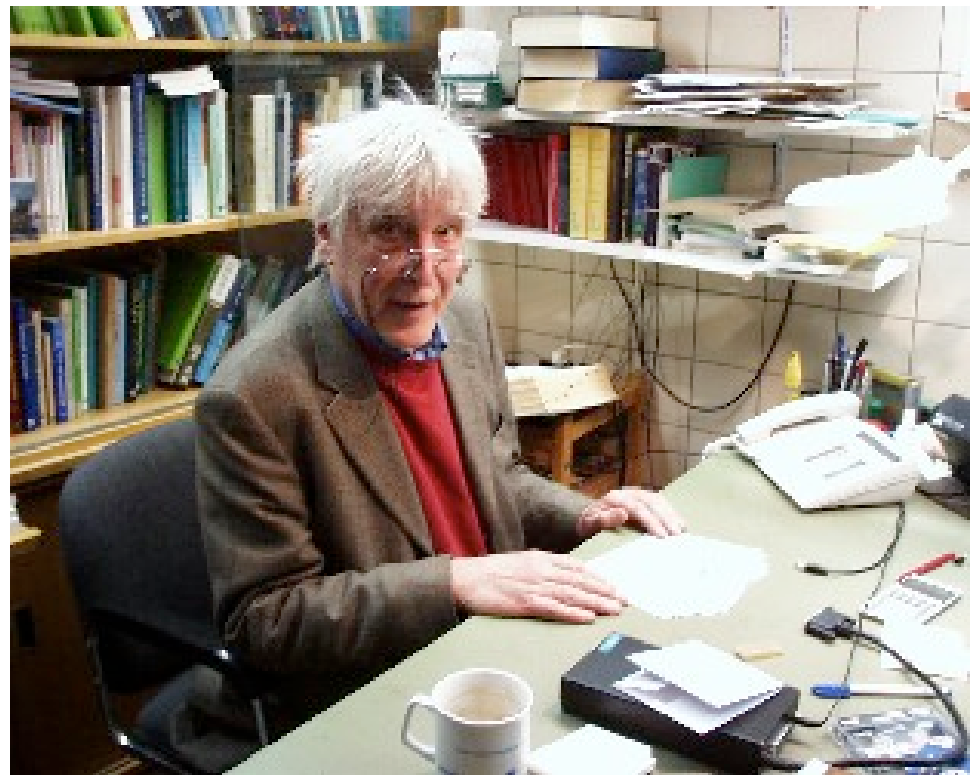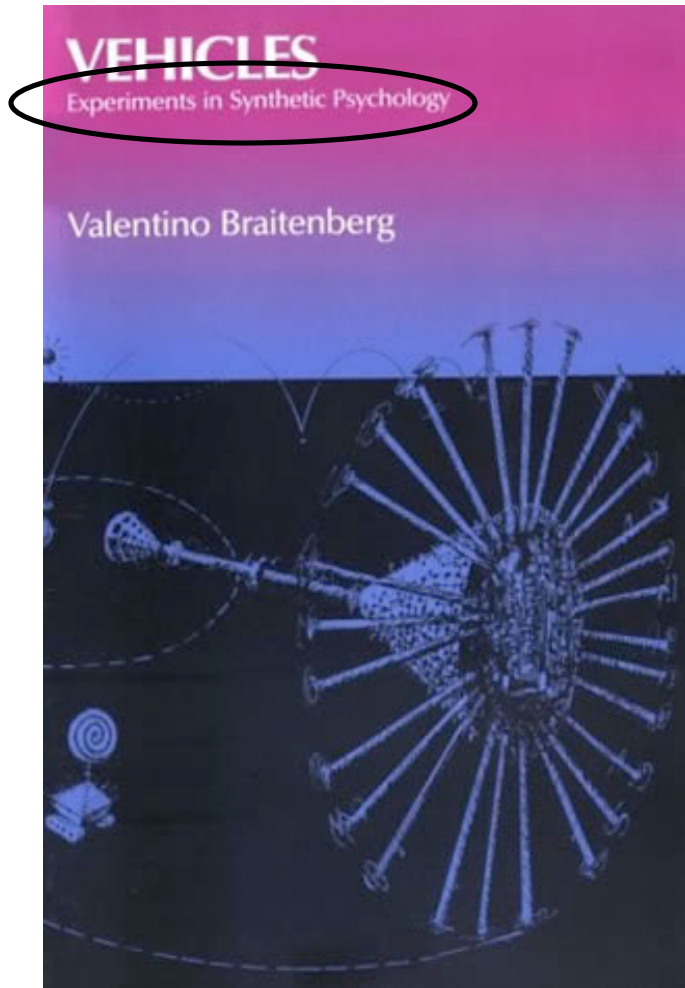# Motors and Motor Control

- Braitenberg's Vehicles
- Circuits 101
  - Some things the CMPEs know and the CMSCs are afraid to ask
- Physics 101
  - Some things we all knew at one time but forgot
- Motors 101
  - Pre-reqs Circuits 101 and Physics 101
  - Motors 101 Lab
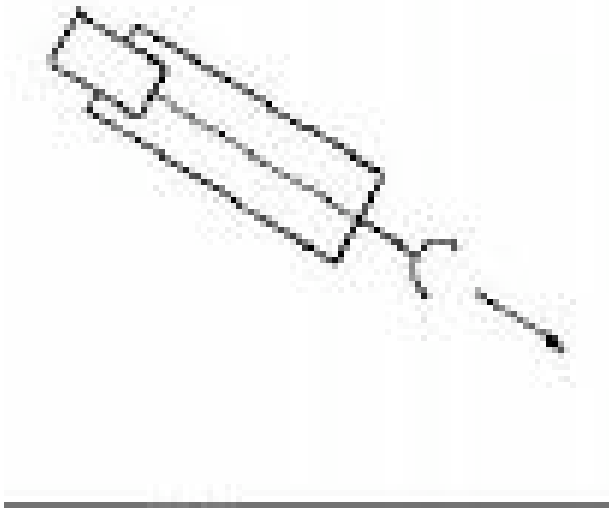- Motors 201
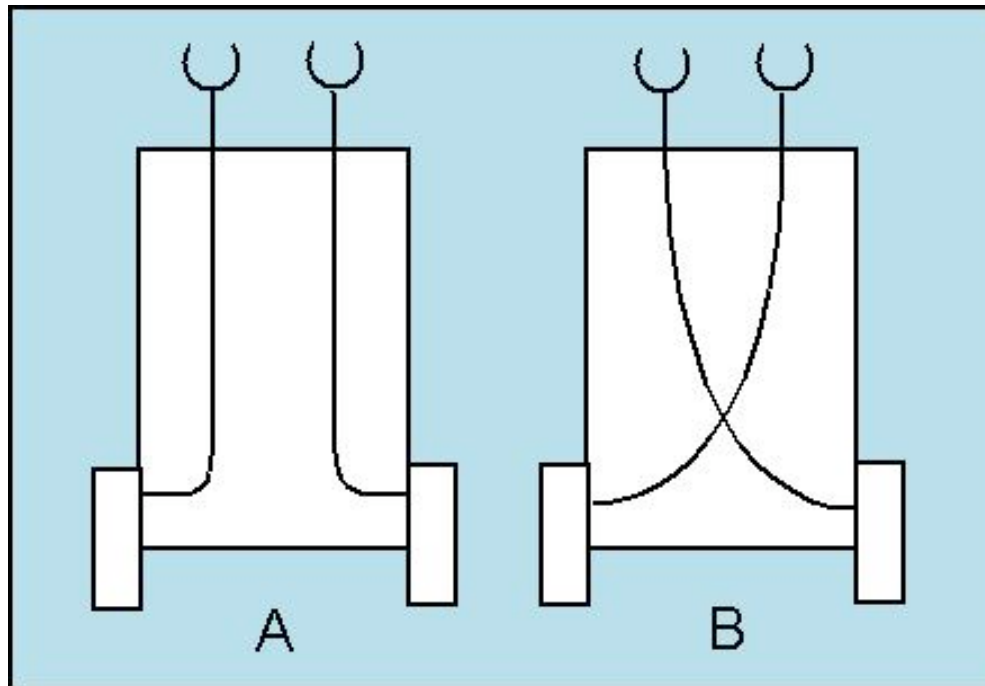 - Servos and servo control

Braitenberg's Vehicles

Alive!

- One sensor
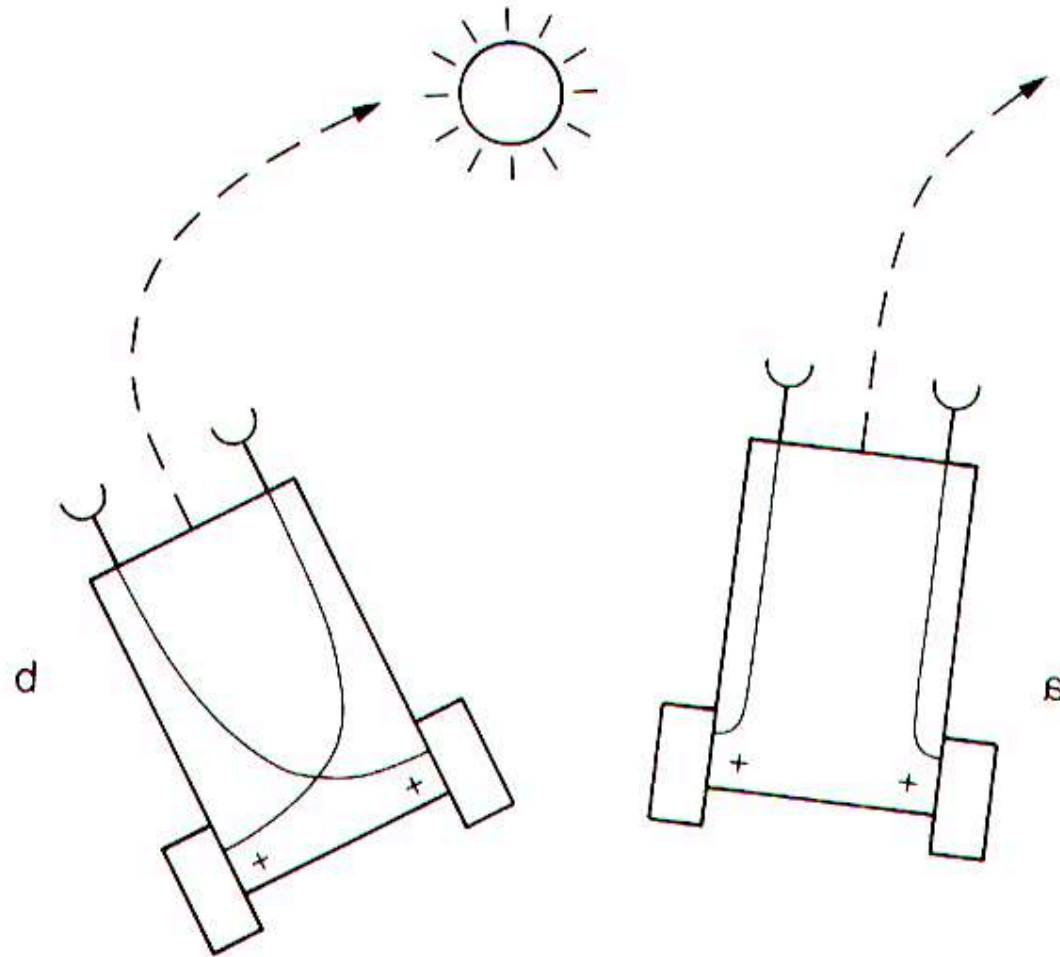- One drive wheel
- Excitatory connection
- Behavior?

Variants

- More wheels
- More sensors
- Crossed connections

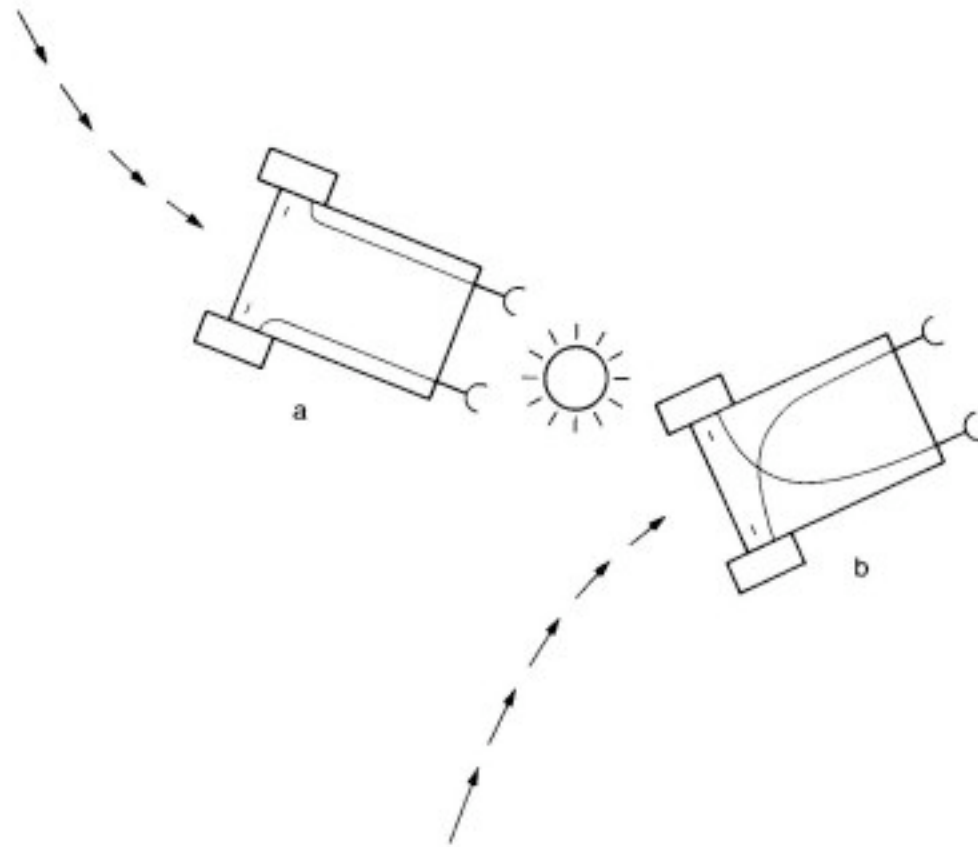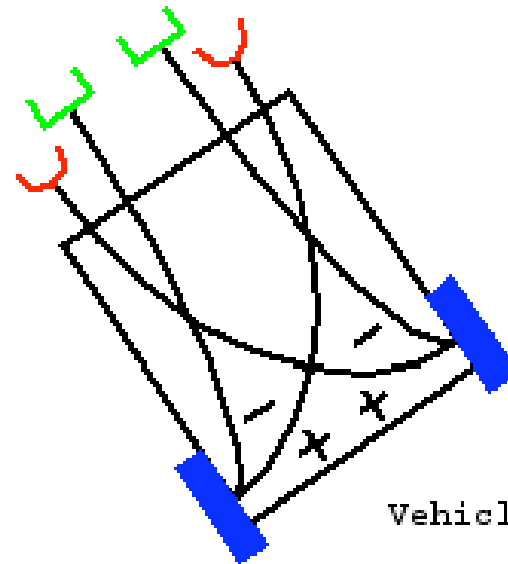# Fear and Aggression - Excitatory Links
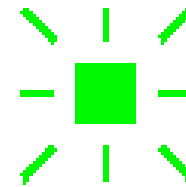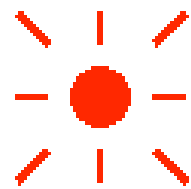
Love - Inhibitory Links

More Complexity: What does this one do?

Vehicle 3

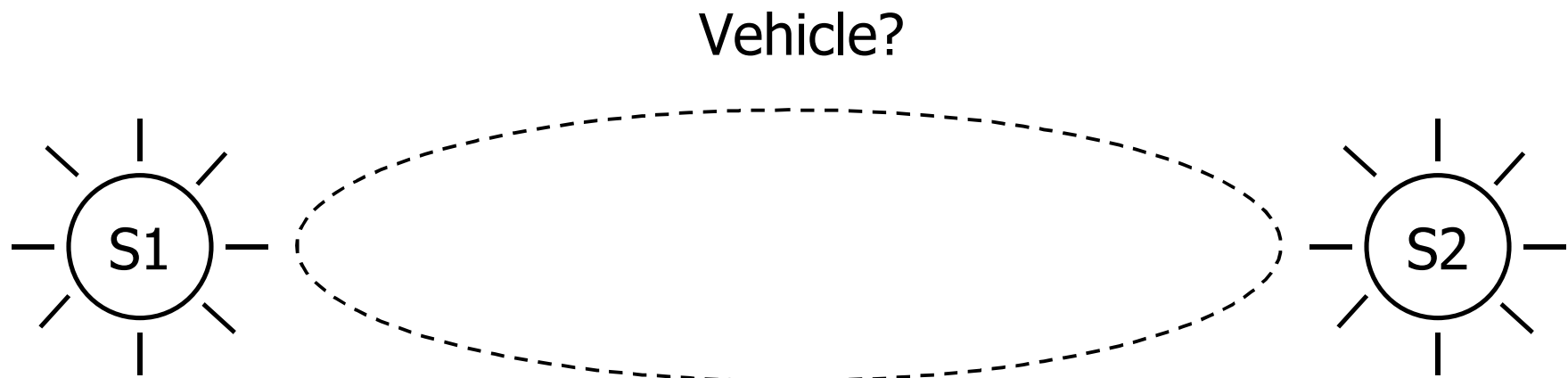# Special Tastes

Velocity
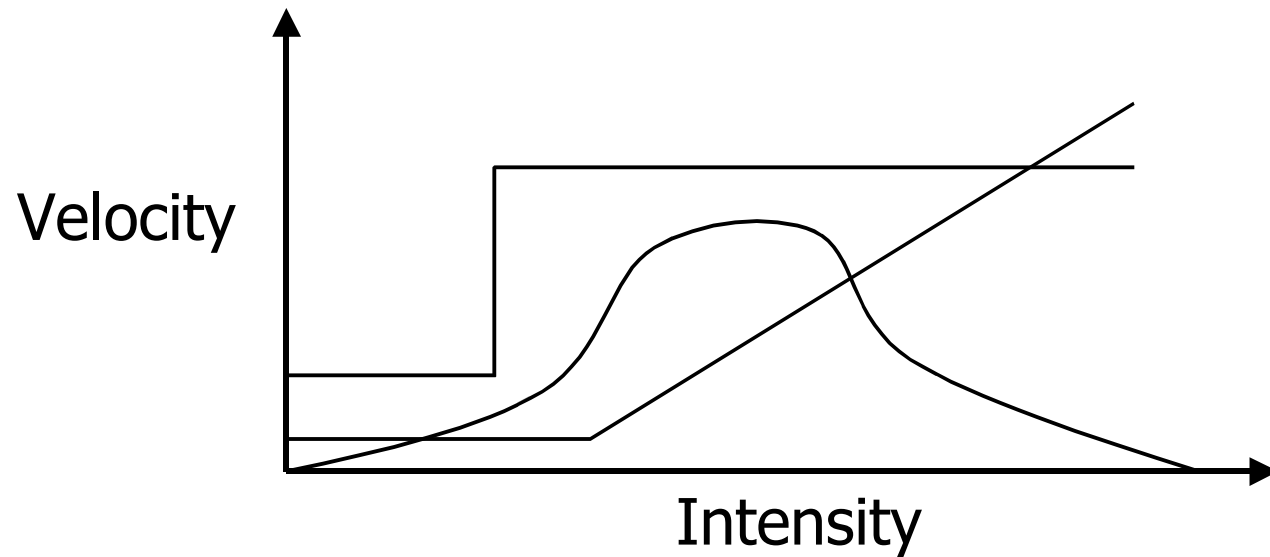
Intensity

- Non-linear relationship between intensity and velocity
- Behaviors?

Exercise

Vehicle?

S1   S2
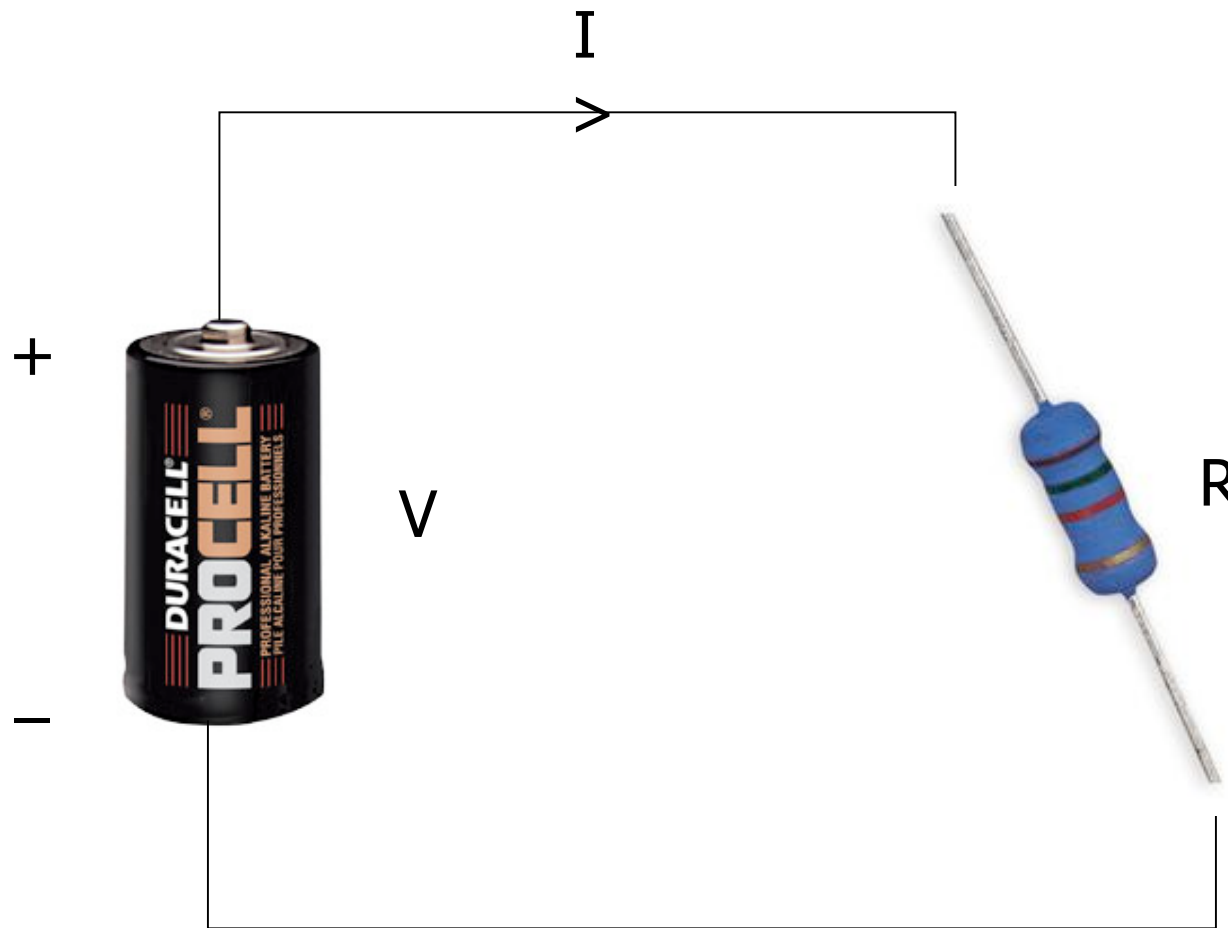
- Design a vehicle that behaves as shown above
- How many sensors and wheels?
- Connections and activation profile?

Circuits 101

I

V

+

−

R

- V = I R
- I = V / R
- R = V / I

Circuits 101

I

>

+

−

V

R = ∞
I = ?

- V = I R
- I = V / R
- R = V / I

Circuits 101

I

- V = I R
- I = V / R
- R = V / I

+

V
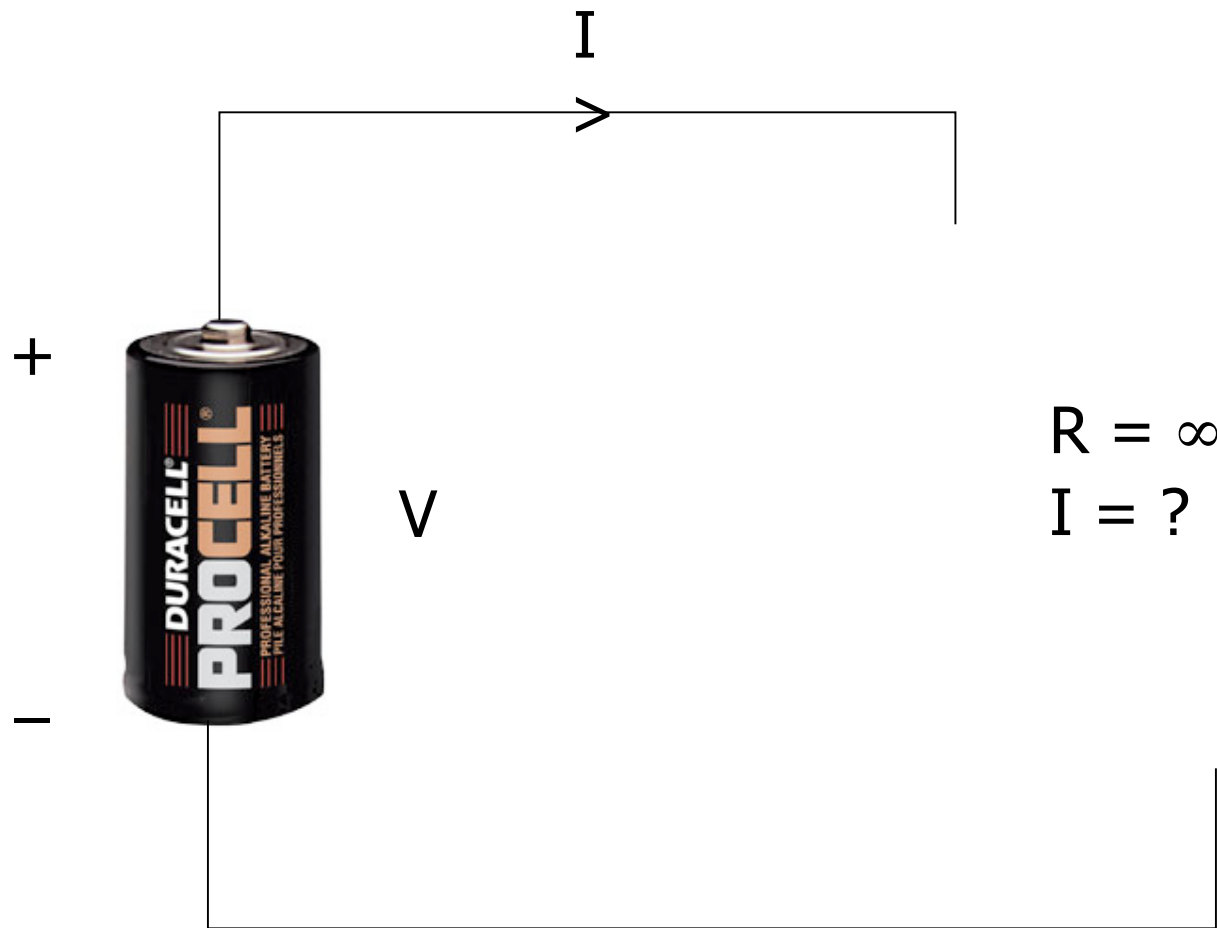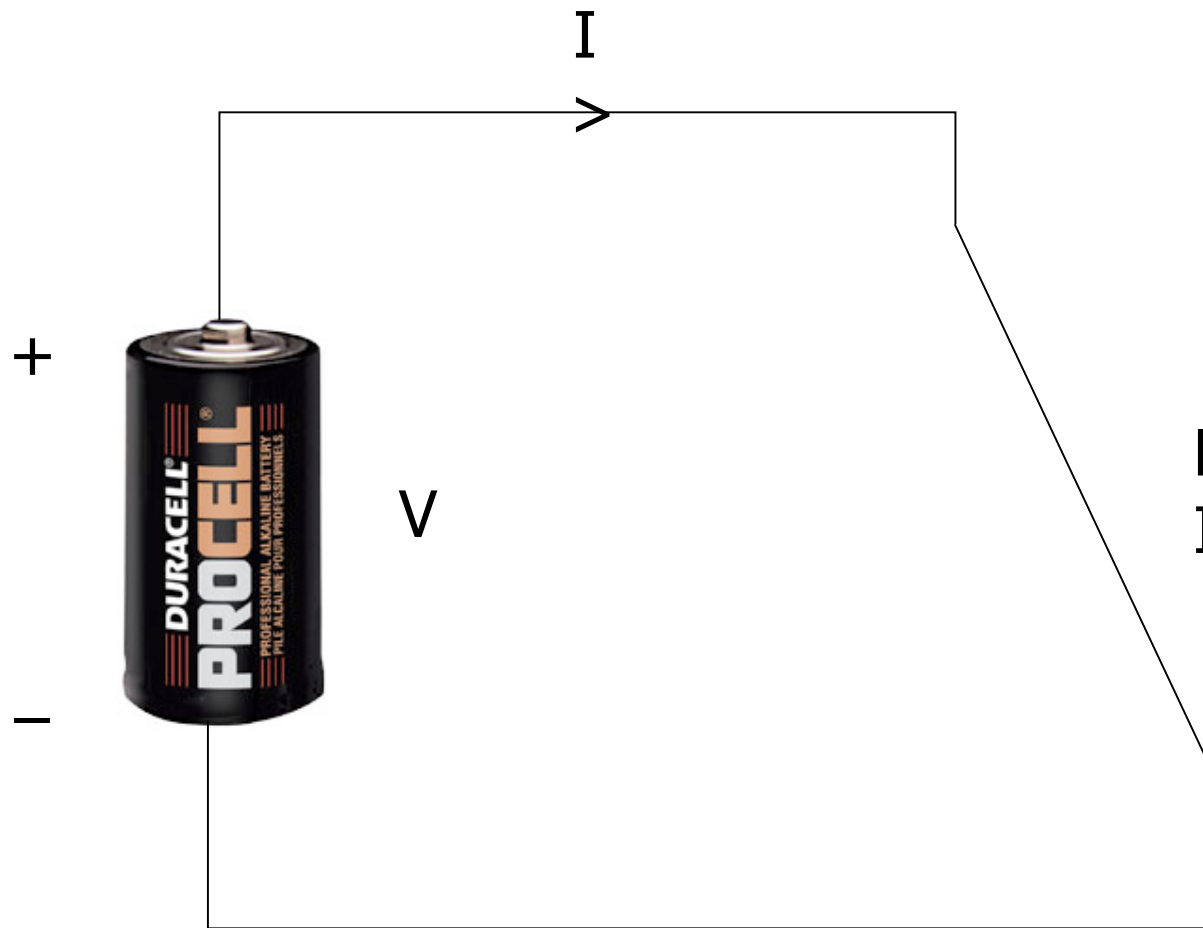
R = 0
I = ?

−

Microcontrollers

???
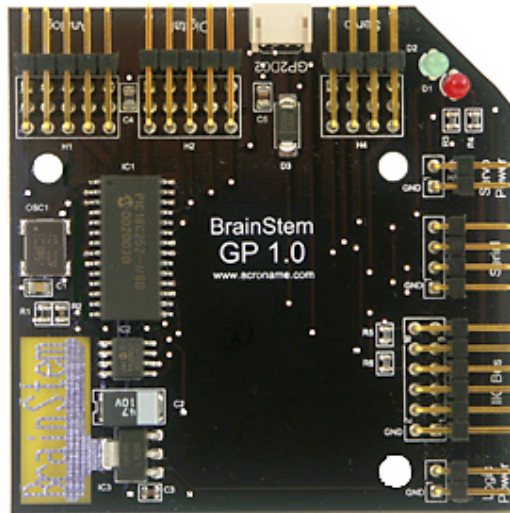
Microcontrollers
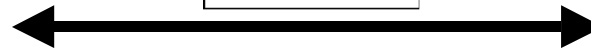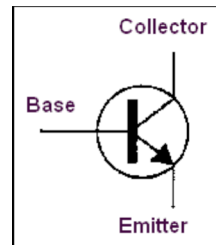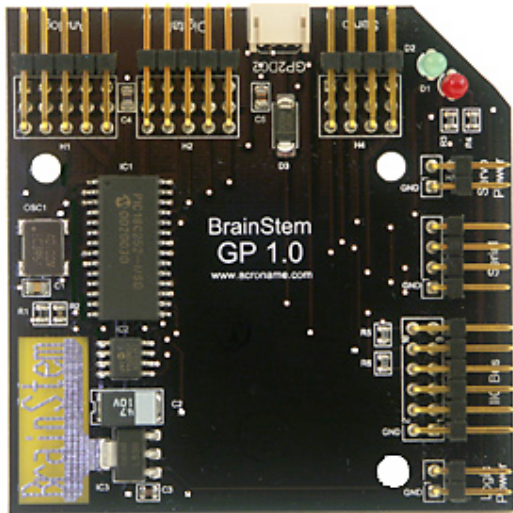
Transistors
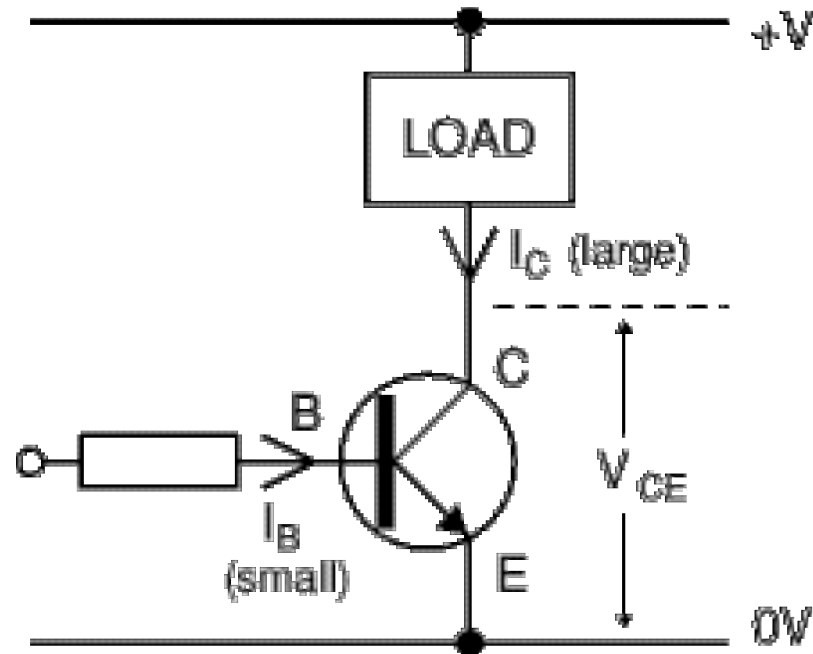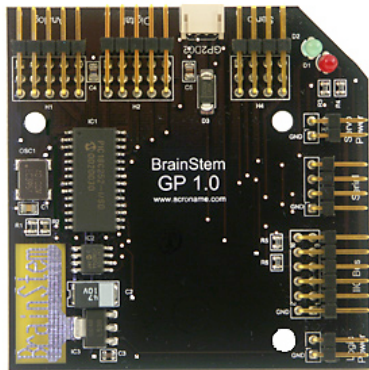
- Often used as switches
- Small BE current controls much larger CE current

Physics 101 - Magnets
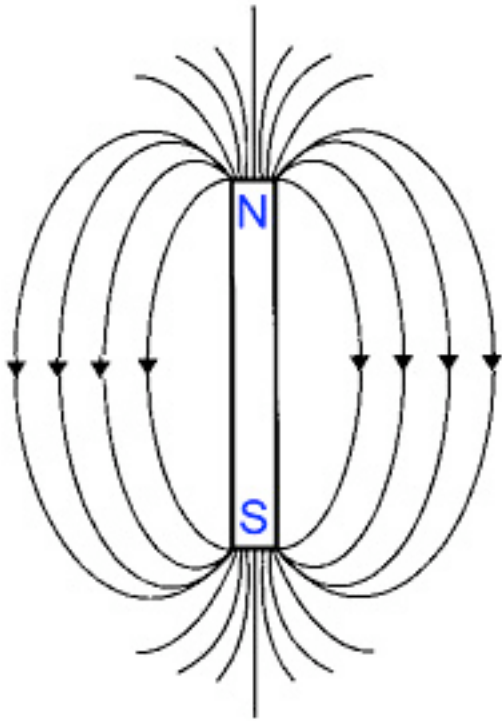
- Two poles - North and South
  - Like poles repel
  - Opposite poles attract
- Magnetic field
  - Flux lines
  - Directed from North to South

Physics 101 - Lorentz Force
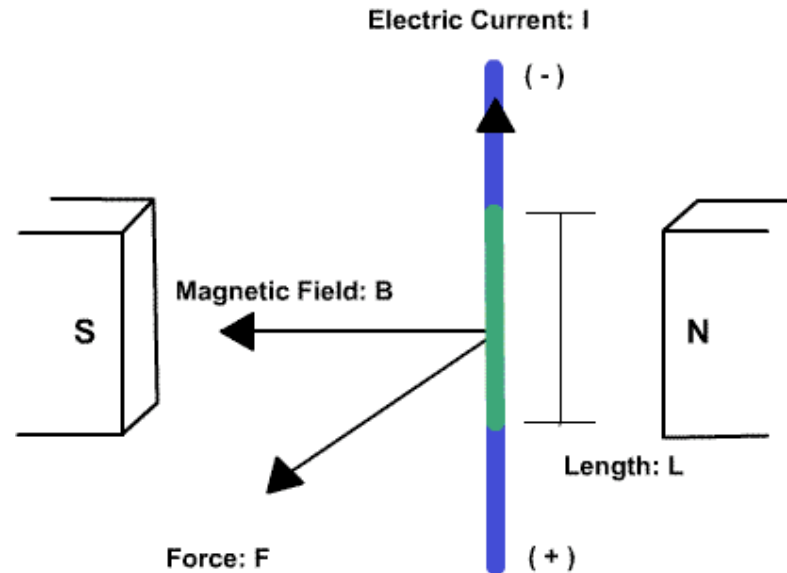
- Force acts on wire carrying current in magnetic field
- Direction of force from right-hand rule
  - Curl fingers from direction of current flow (+ to -) in direction of flux flow (N to S)
  - Check thumb, it points in direction of force on wire

Motors 101 - DC Motors

(a)

current

(b)

N   B→ F   F   S
        torque
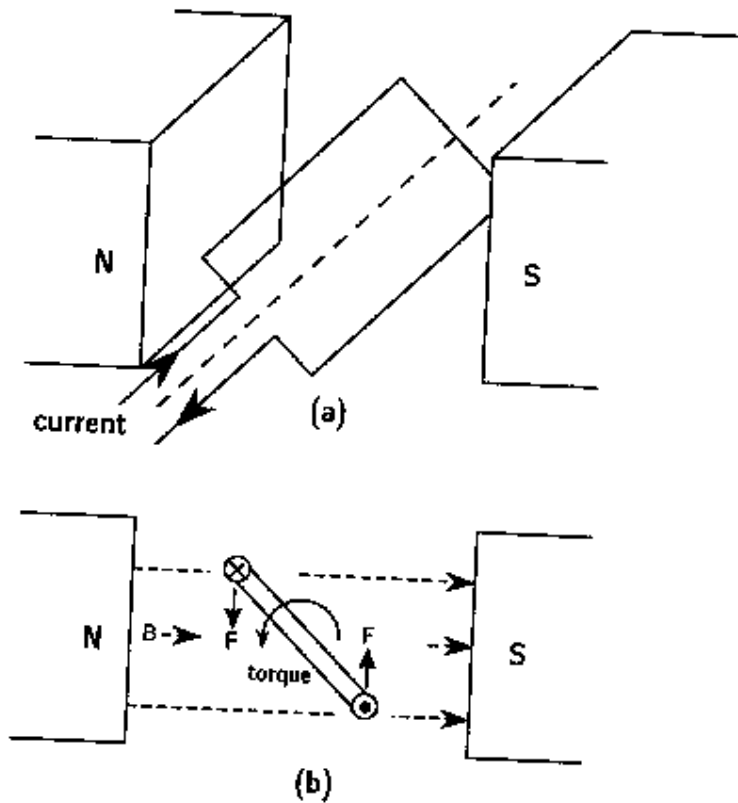
- What forces are acting on wire?
- How do forces change when wire rotates?

Motors 101 - Commutation
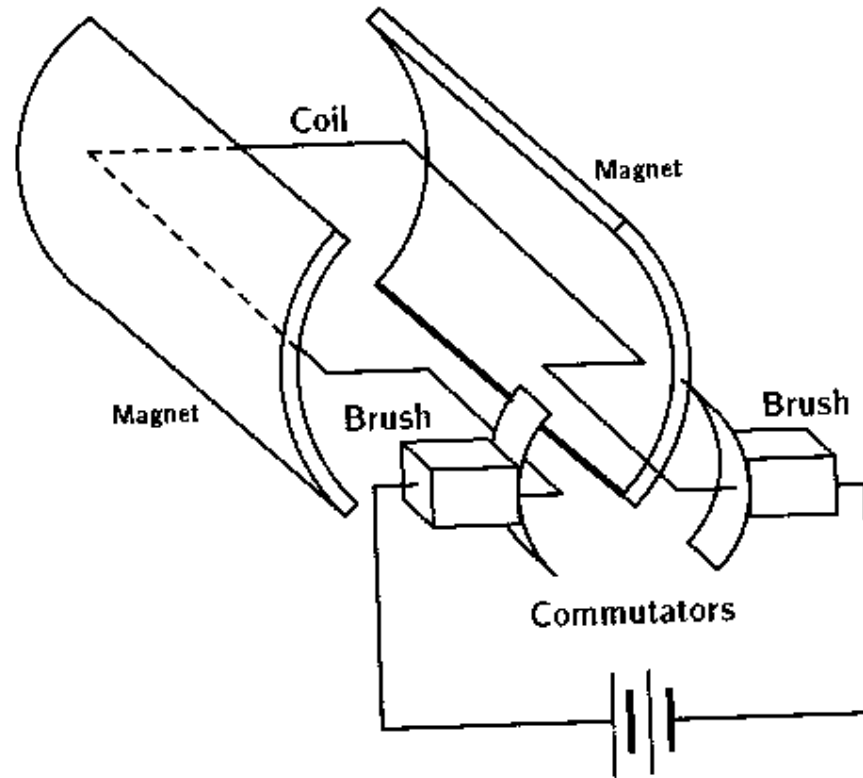
Motors 101 Lab

- Build your own motor!!!
- Form groups of 3
- Read handout and build motor
- Let me know when it's working
- Experiments
    - Flip magnet
    - Flip coil
- Questions
    - How/why does motor work?
    - Which side of the magnet is north?
    - What if you sand both sides of coil?

Motors 101

Copyright 1998 by Marshall Brain

Motors 201 - Speed Control
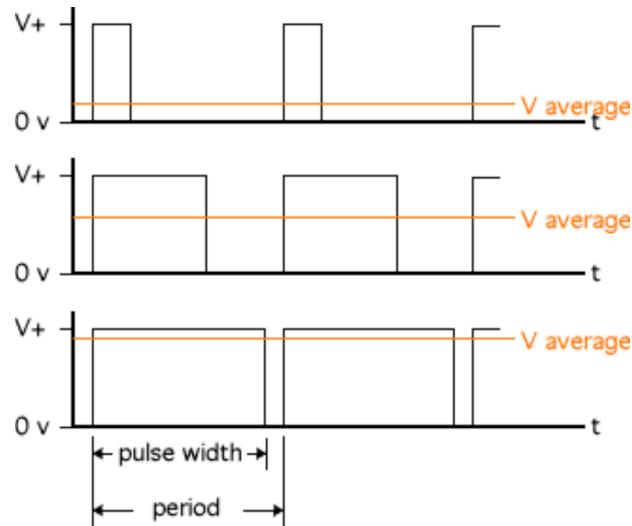
Why not reduce voltage with a variable resistor?

- Turn power on and off quickly
  - Period
  - Pulse width
  - Pulse width / Period = Duty cycle
- Longer pulses lead to faster rotation
  - Try it with your lab motors

Motors 201 - Direction Control
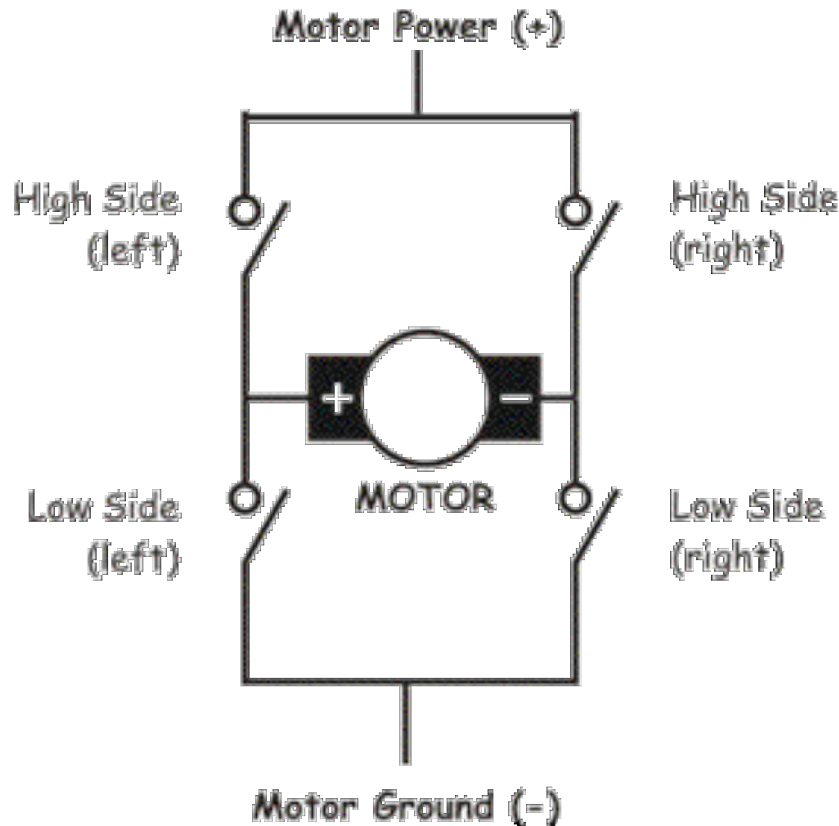
- H-bridge
- Four switches
- Easily change polarity on motor
- Reverse direction
- Used in conjunction with PWM

Motors 201 - Direction Control

- H-bridge
- Four switches
- Easily change polarity on motor
- Reverse direction
- Used in conjunction with PWM

Motors 201 - Torque

©SANYO Sales & Supply Co

- Torque
  - Rotational force
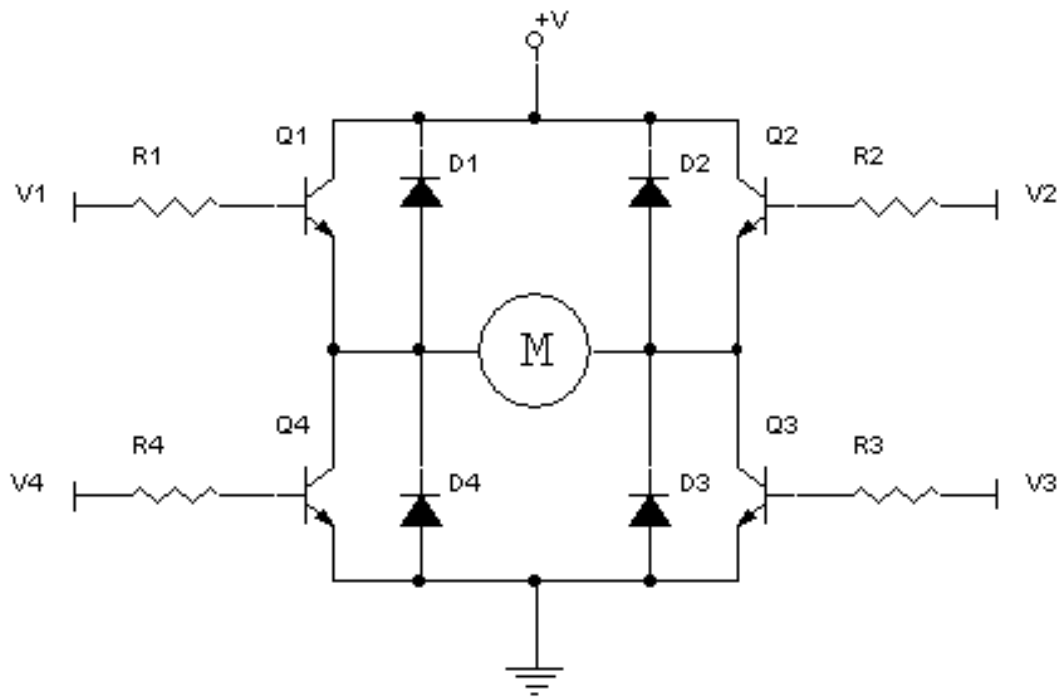 - Linear force times distance
  - Units: oz-in
  - Force required to lift 1oz using 1in radius pulley
- DC Motors
  - High angular velocity
  - Low torque
  - Use gears to flip that relationship so robot can move larger masses more slowly
- DC gearhead motors

Motors 201 - Motor Specs

SPECS:
Speed: 0.23 sec/60 degrees at 4.8V
        0.19 sec/60 degrees at 6.0V
Torque: 44 oz-in (3.2 kg-cm) at 4.8V
        57 oz-in (4.1 kg-cm) at 6.0V
Length: 1.6" (41mm)
Width: 0.8" (20mm)
Height: 1.4" (36mm)
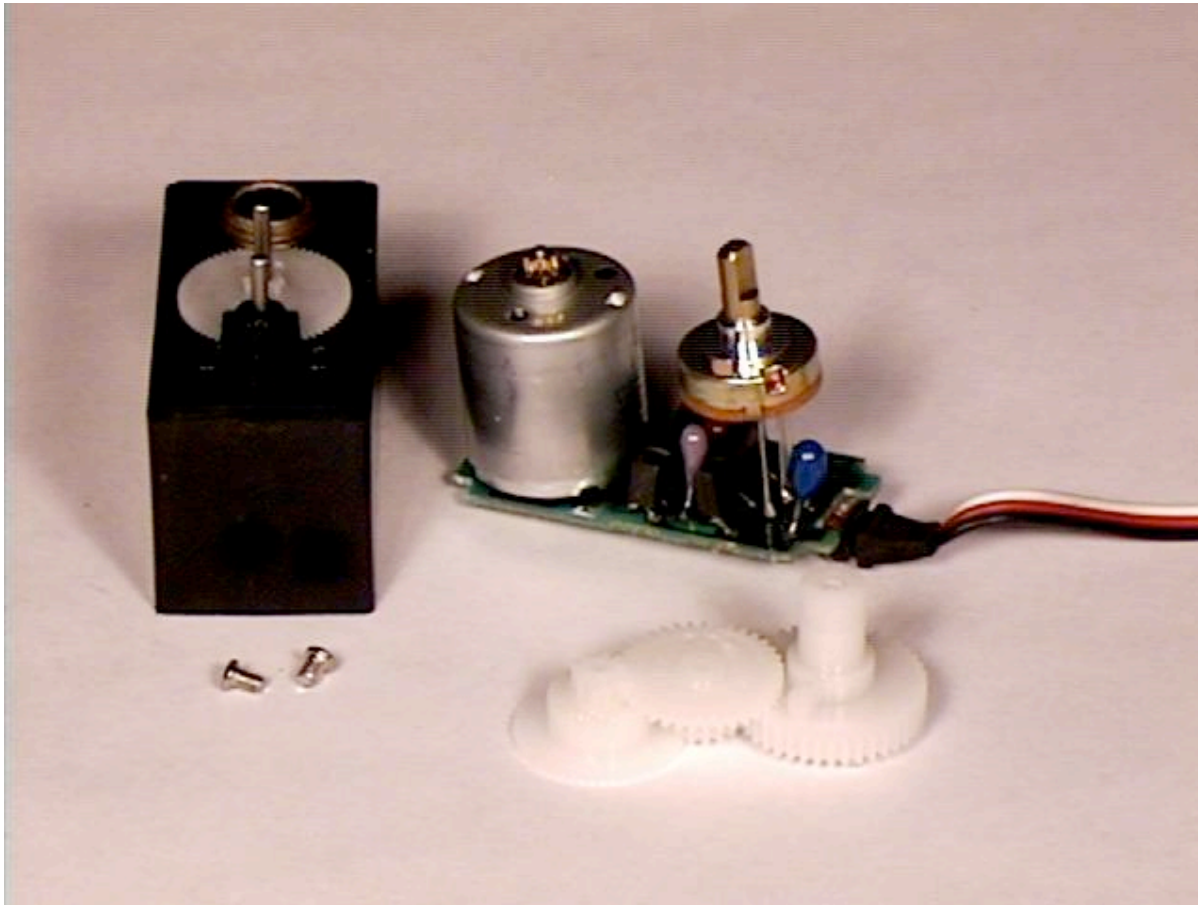Weight: 1.3 ounce (37.2 grams)

Motors 201 - Servos

- DC motor + gears + control circuitry
- Constrained motion - typically 180 degrees
- Set desired rotational position
- Active control to maintain that position
- Applications
    - Robotics - arms, legs
    - RC Airplanes
    - Many others
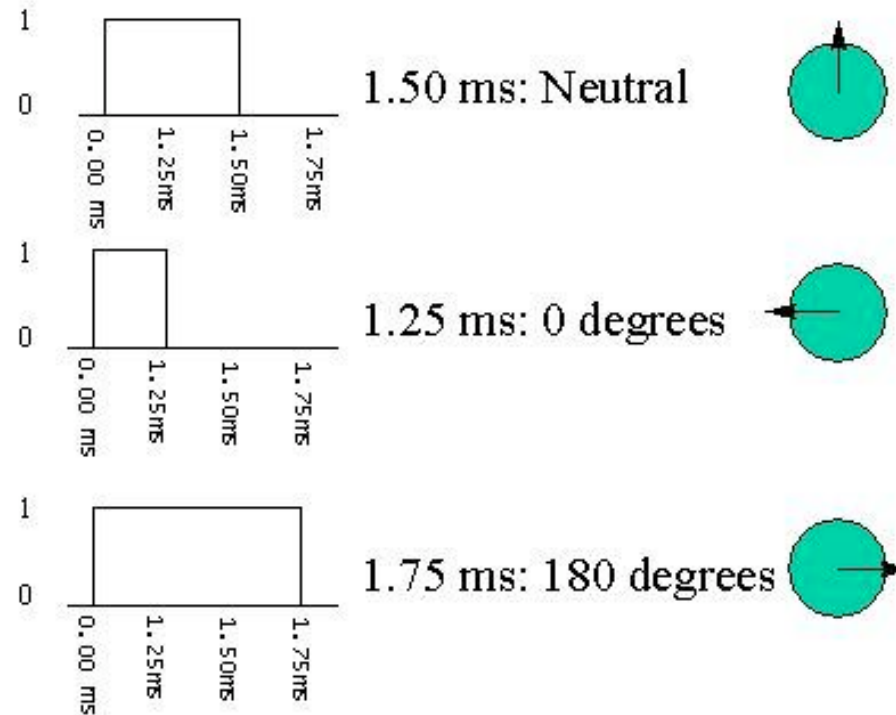
Motors 201 - Servos

- DC motor
- Gears (torque)
- Circuit
- Potentiometer
- Control cable
- Hard stop

Motors 201 - Servo Position Control

- Pulse width modulation (for a different purpose)
- 20ms period, duty cycle indicates position