



CS-417 INTRODUCTION TO ROBOTICS AND INTELLIGENT SYSTEMS

Actuators

Slides by P. Giguere

What is an actuator?

- Device for moving or controlling a system.
- “Robot Muscles”



Hydraulic Actuators

- Pros:
 - Powerful
 - Fast
 - Stiff
- Cons
 - Messy
 - Maintenance
 - External Pump



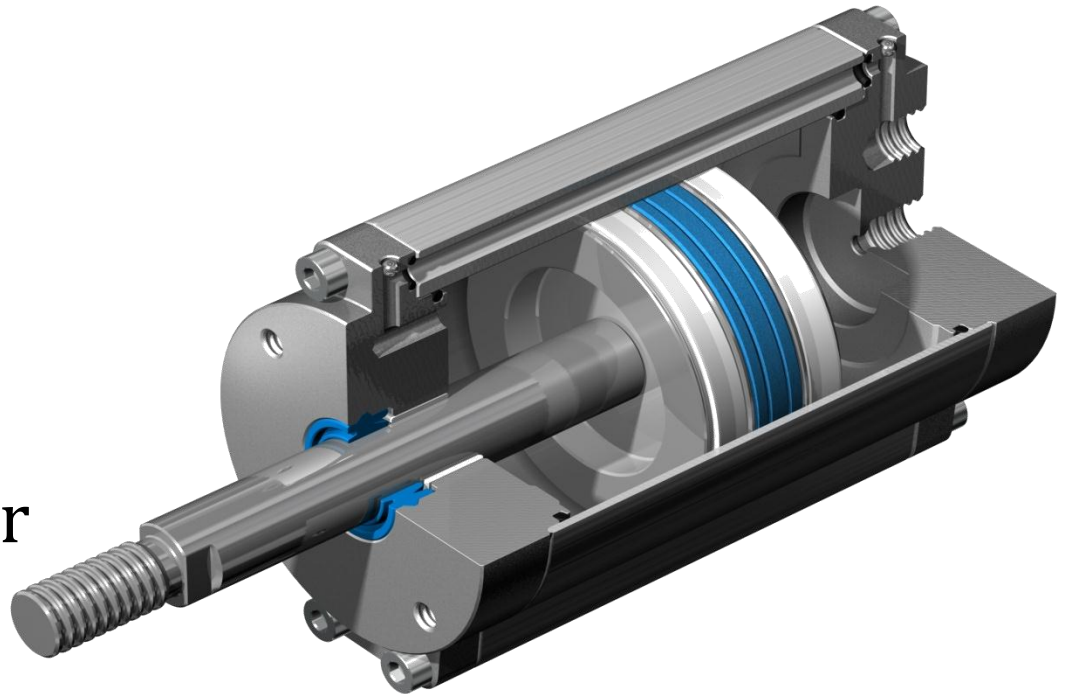
Hydraulic Actuator Application

- BigDog from Boston Dynamics



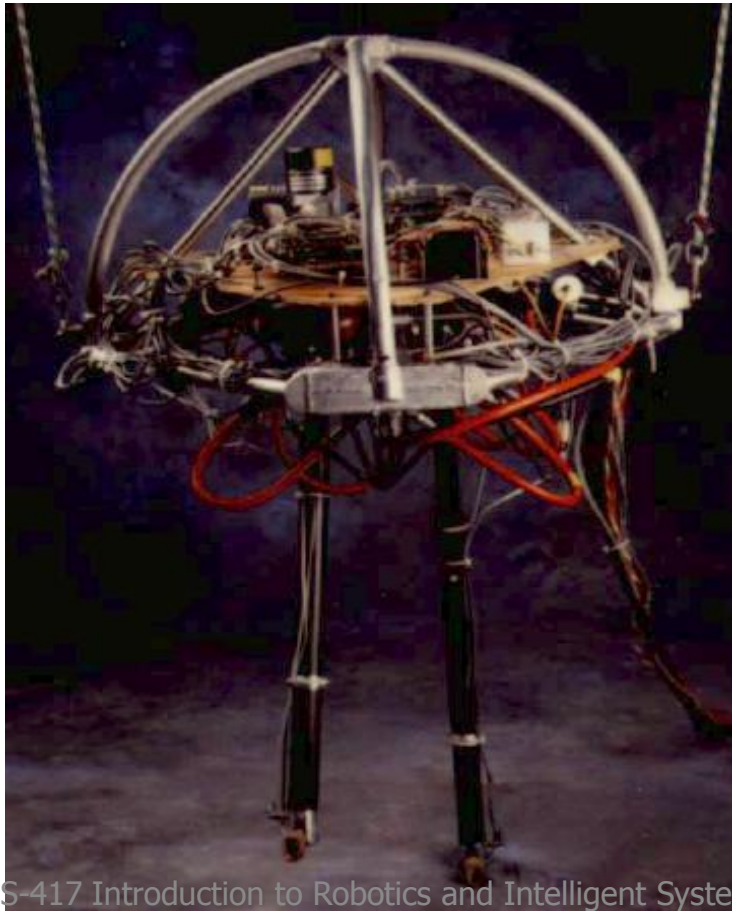
Pneumatic Actuators

- Pros:
 - Powerful
 - Cheap
- Cons
 - Soft/Compliant
 - External Compressor

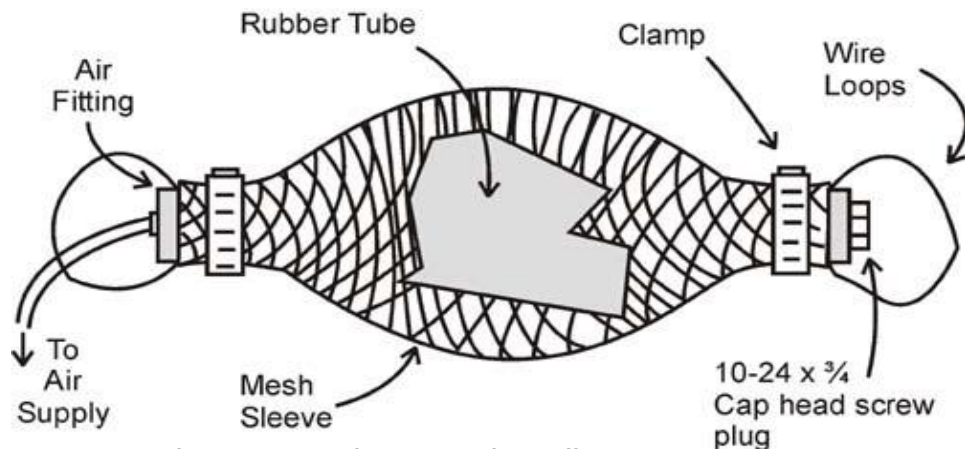
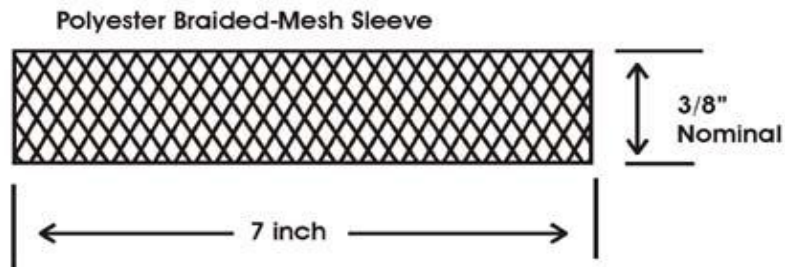
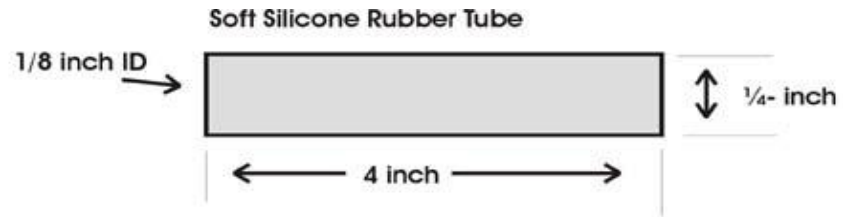


Pneumatic Actuators

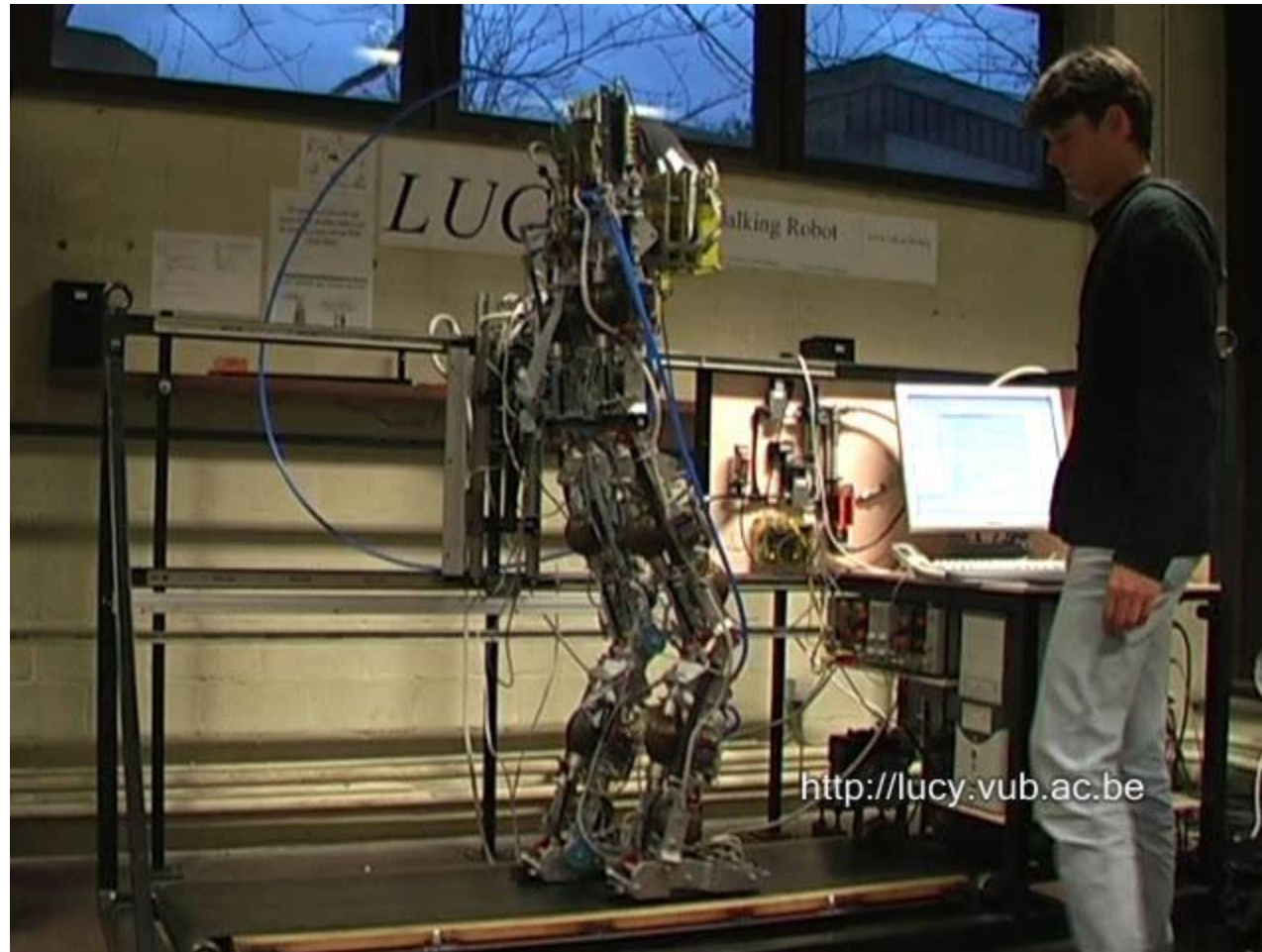
- 3D Biped ('89-'95) from MIT Leg Lab



Air Muscle



Air Muscle Application

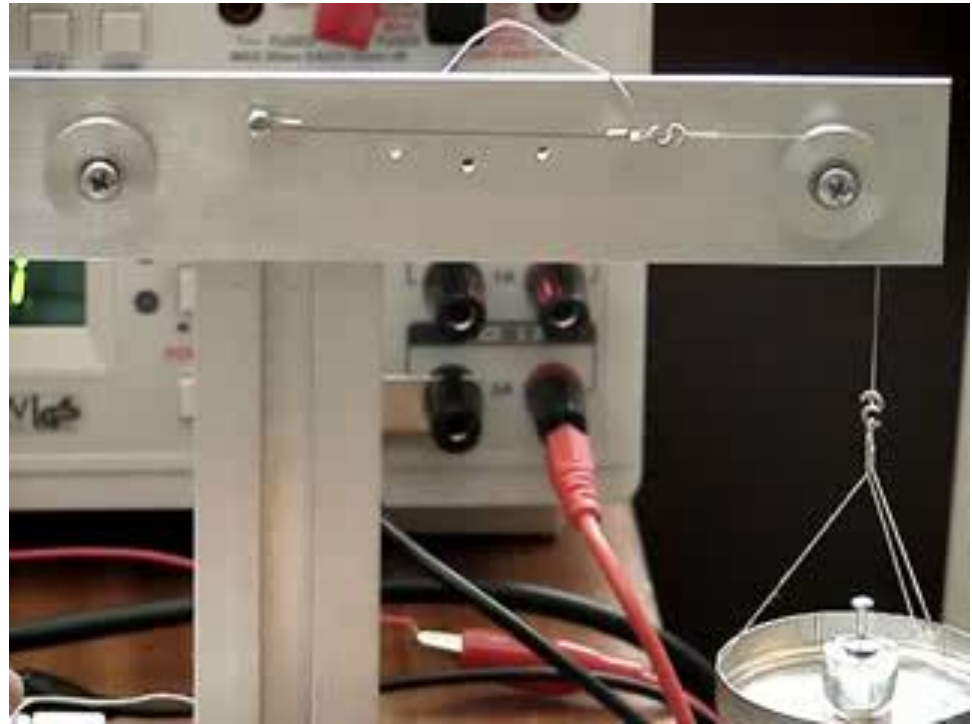


Air Muscle Application

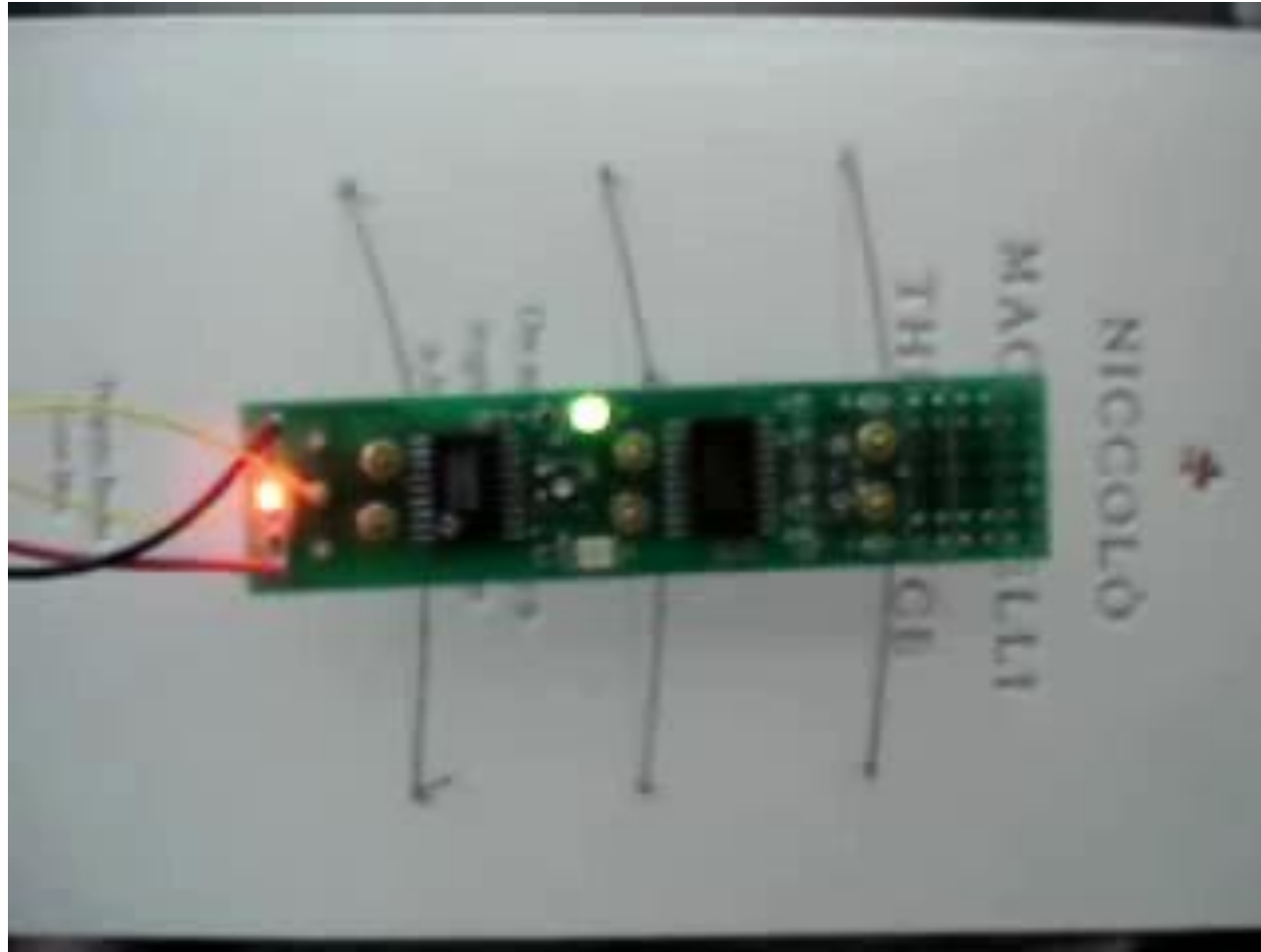


Shape Memory Alloy Actuators

- Works by warming and cooling Nitinol wires.
- Pros:
 - Light
 - Powerful
- Cons:
 - Slow (cooling)



Stiquito



Jonathan Mills, Indiana University



Electric Actuators

- Pros
 - Better position precision
 - Well understood
 - No separate power source
 - Cheap
- Cons
 - Heavy
 - Weaker/slower than hydraulics
 - Cooling issue

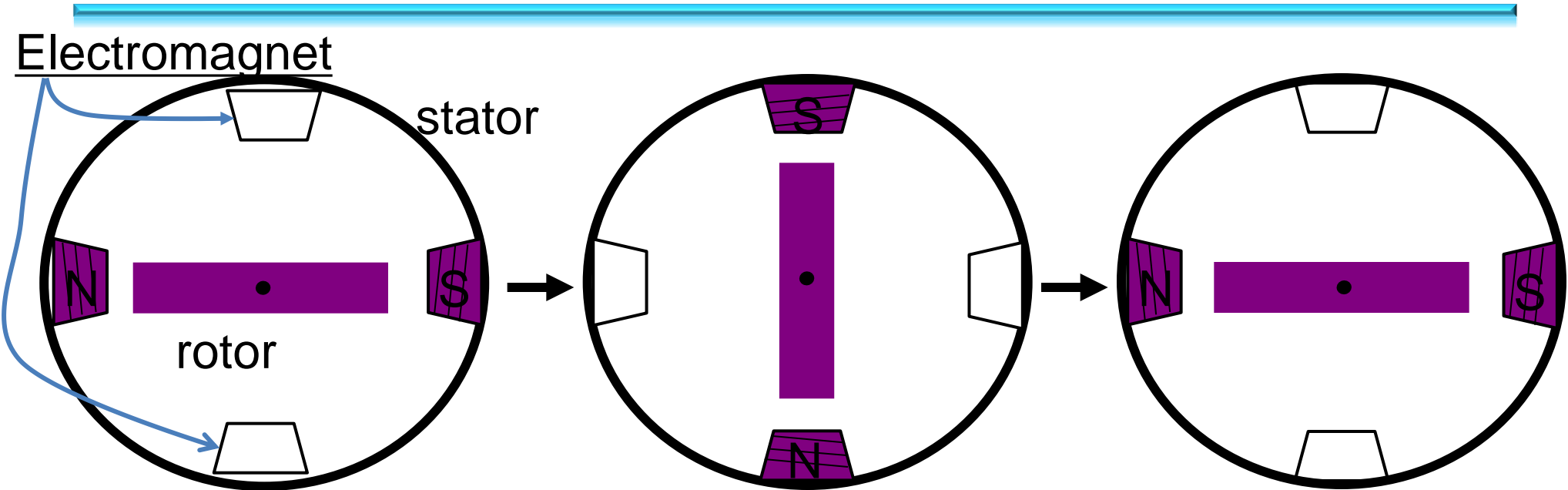


Electric Actuators

- Stepper motors
- DC motors
 - Servos
 - Continuous
 - Position
- Others (not discussed)
 - Linear actuators
 - AC motors



Stepper Motor Basics



Stator: made out of coils of wire called “winding”

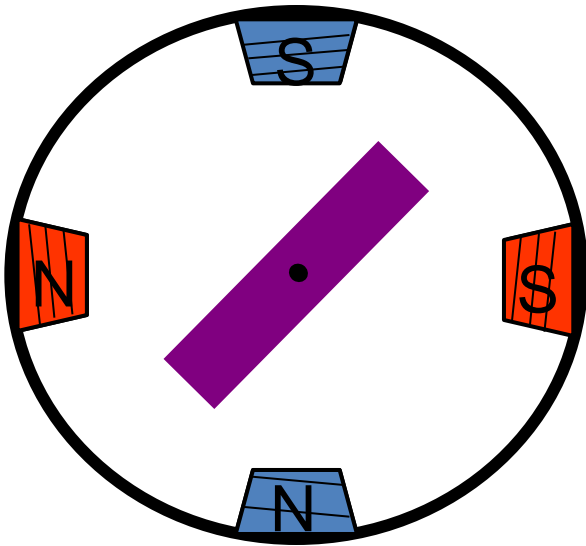
Rotor: magnet rotates on bearings inside the stator

- Direct control of rotor position (no sensing needed)
- May oscillate around a desired orientation (resonance at low speeds)
- Low resolution

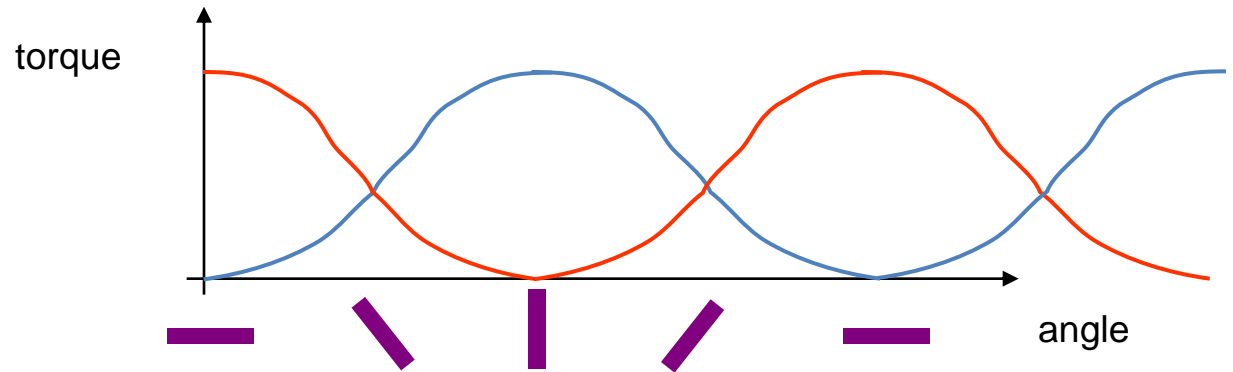
printers
computer drives



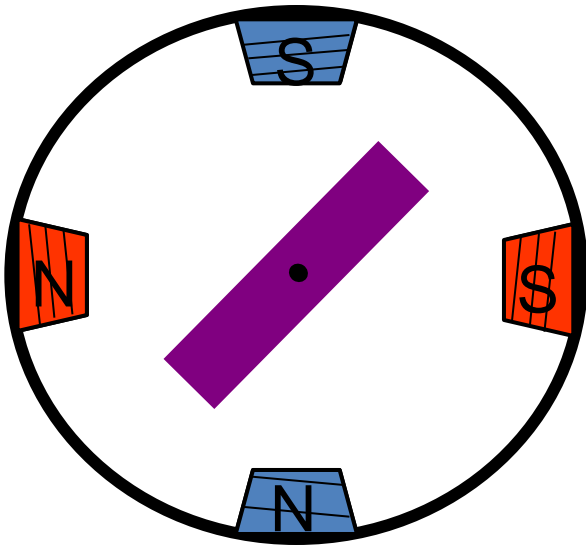
Increased Resolution



Half stepping

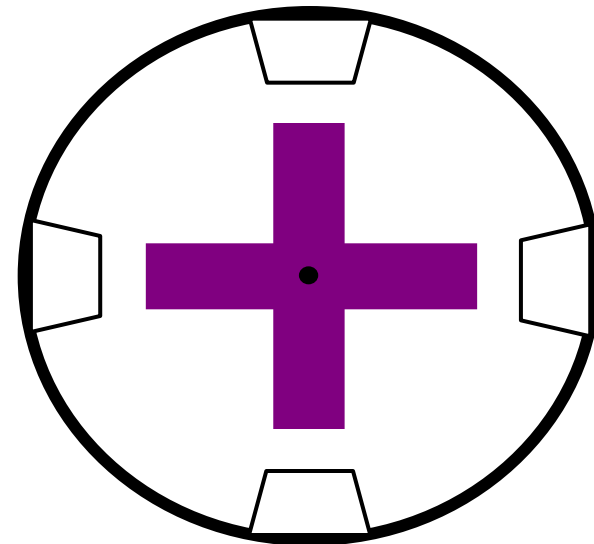


Increased Resolution

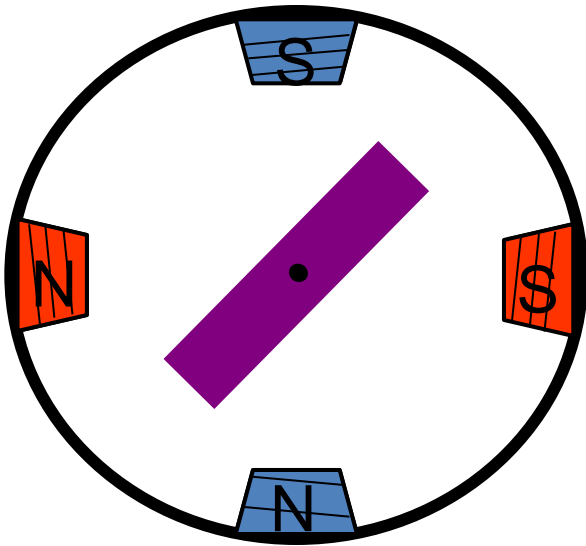


Half stepping

More teeth on rotor or stator

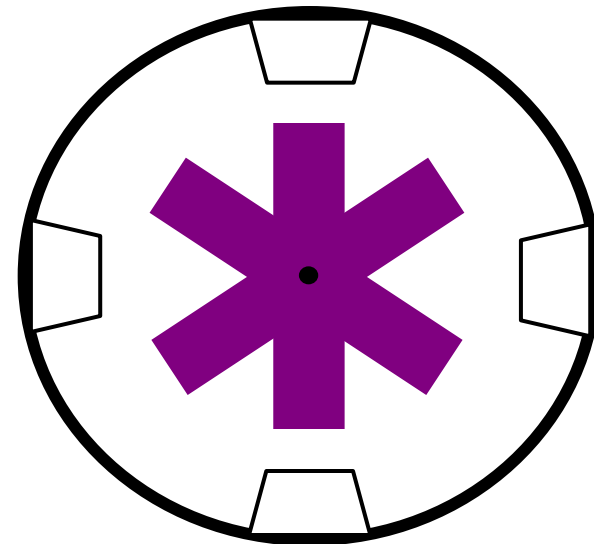


Increased Resolution

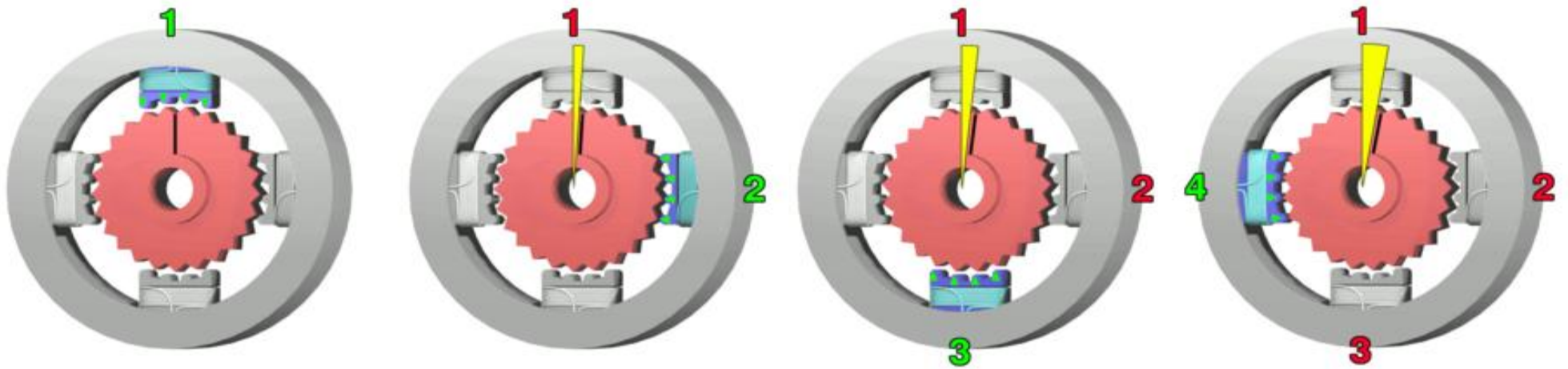


Half stepping

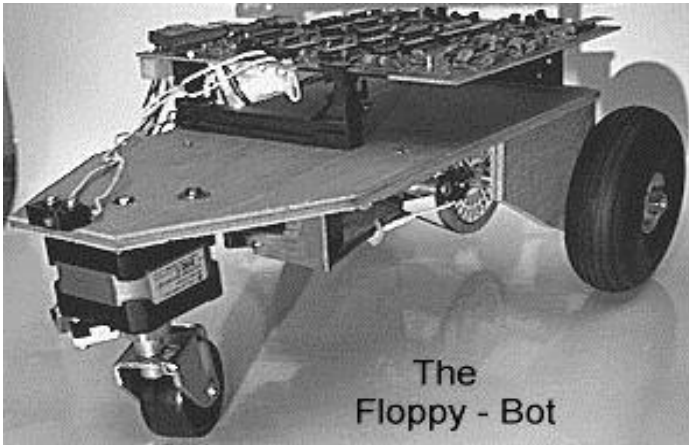
More teeth on rotor or stator



More Teeth on Rotor



Stepper Motors

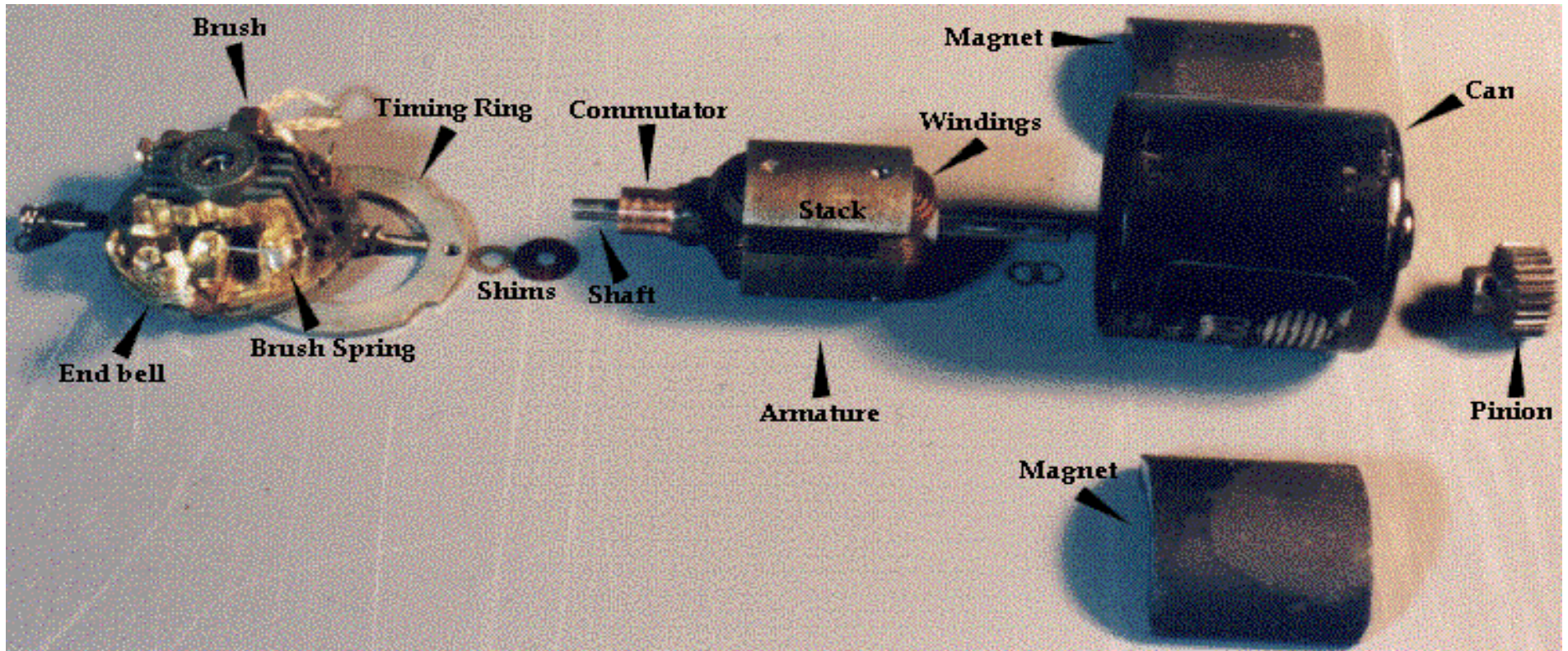


- Pros:
 - Direct position control
 - Precise positioning
 - Easy to control

- Cons:
 - Oscillations
 - Low torque at high speeds

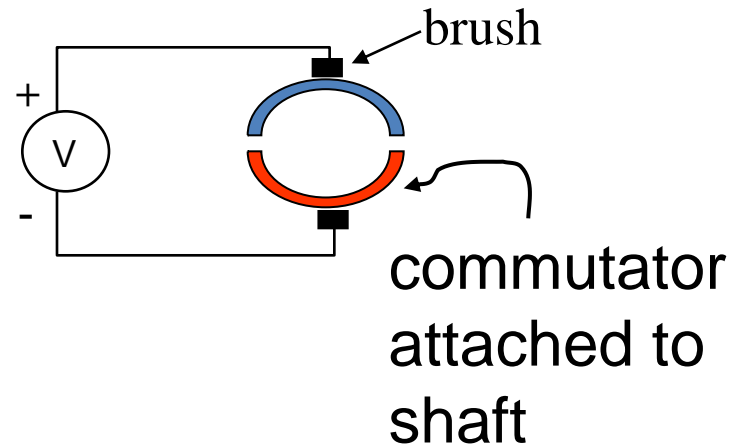
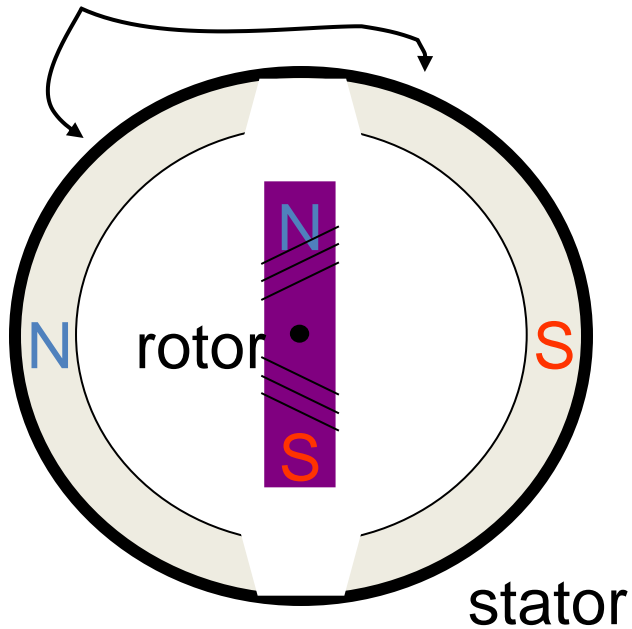


DC motors -- exposed !



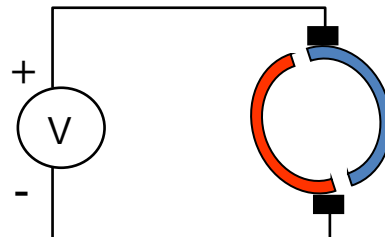
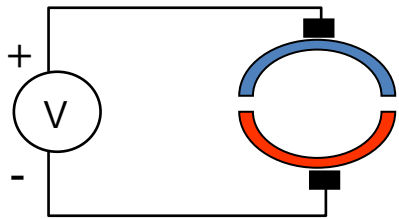
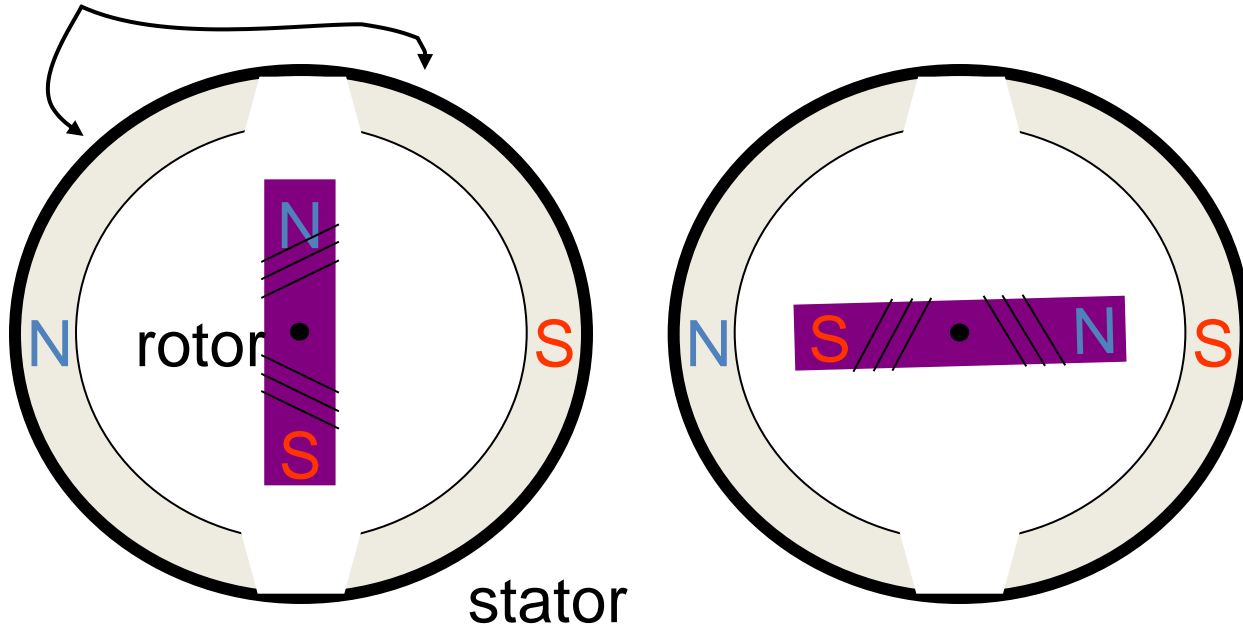
DC motor basics

permanent magnets



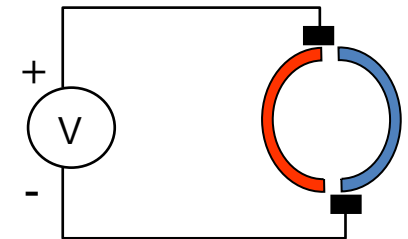
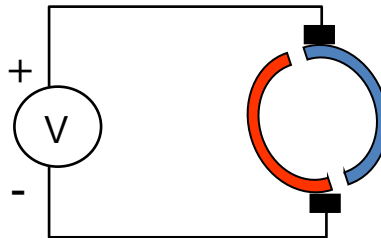
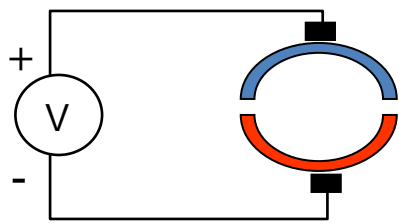
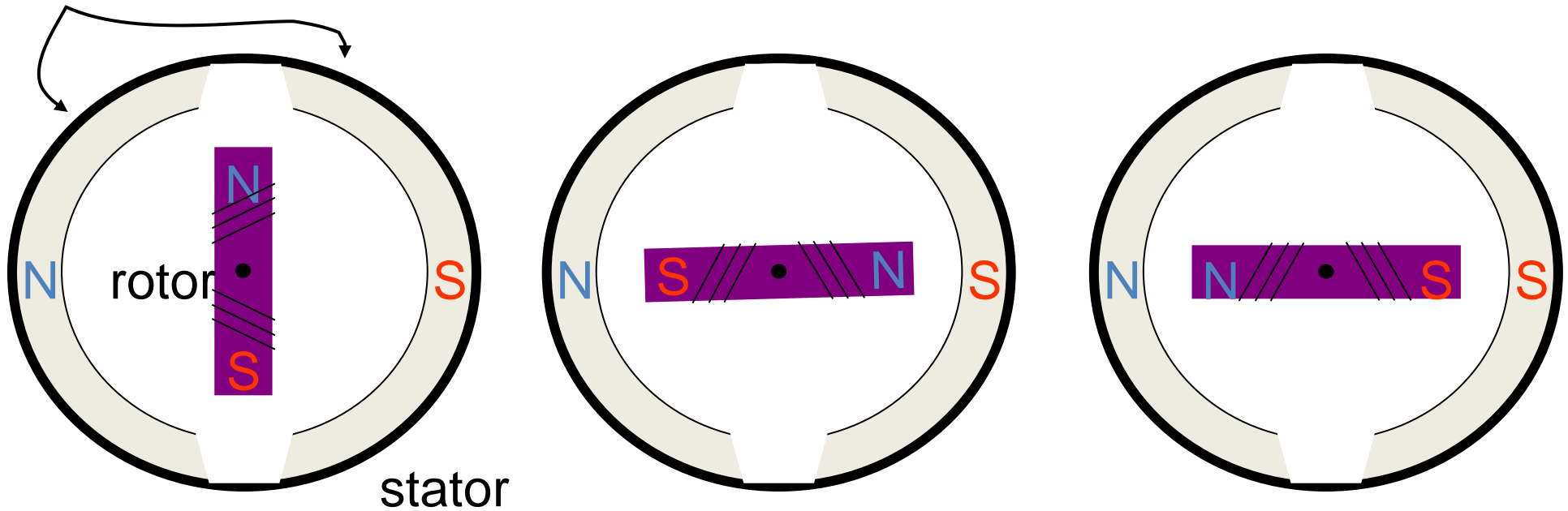
DC motor basics

permanent magnets

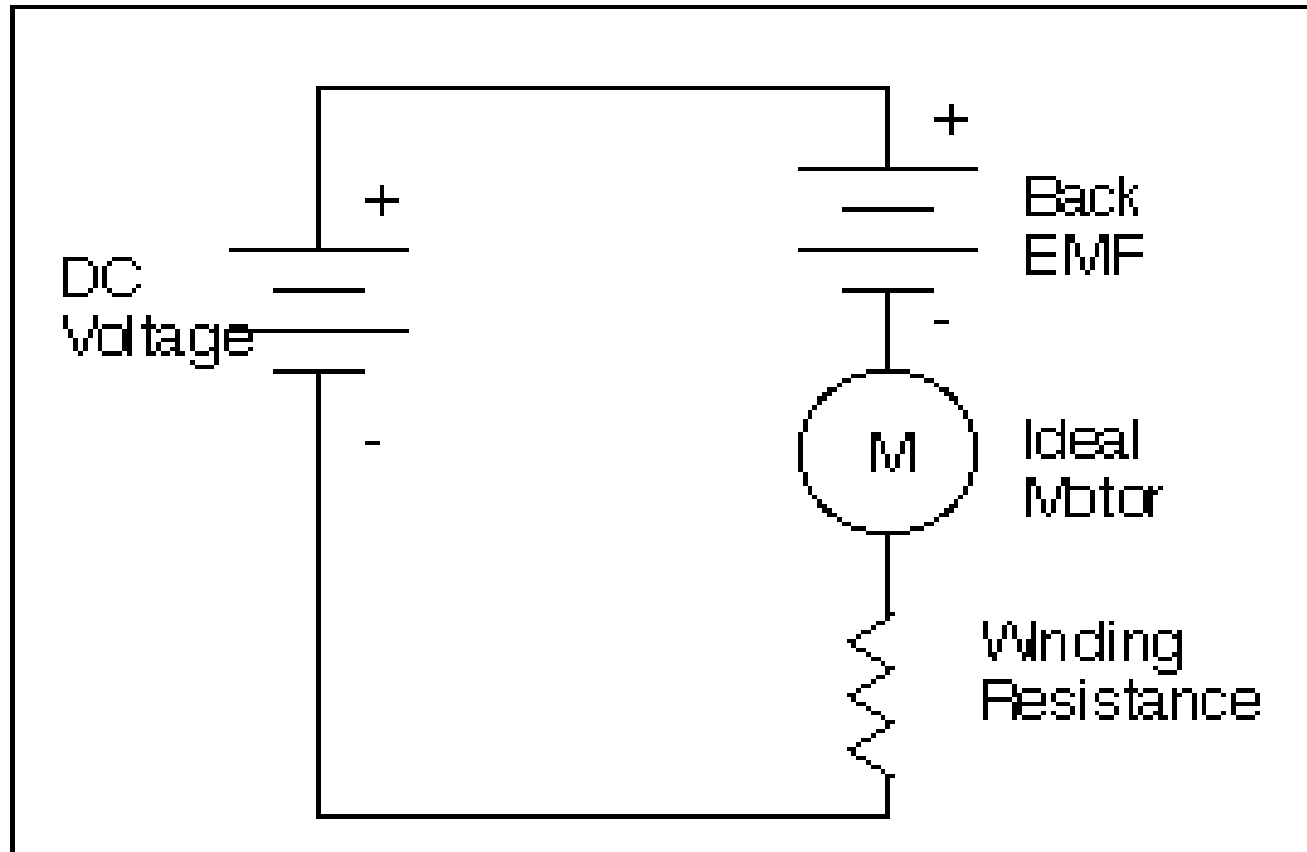


DC motor basics

permanent magnets



DC motor back-EMF

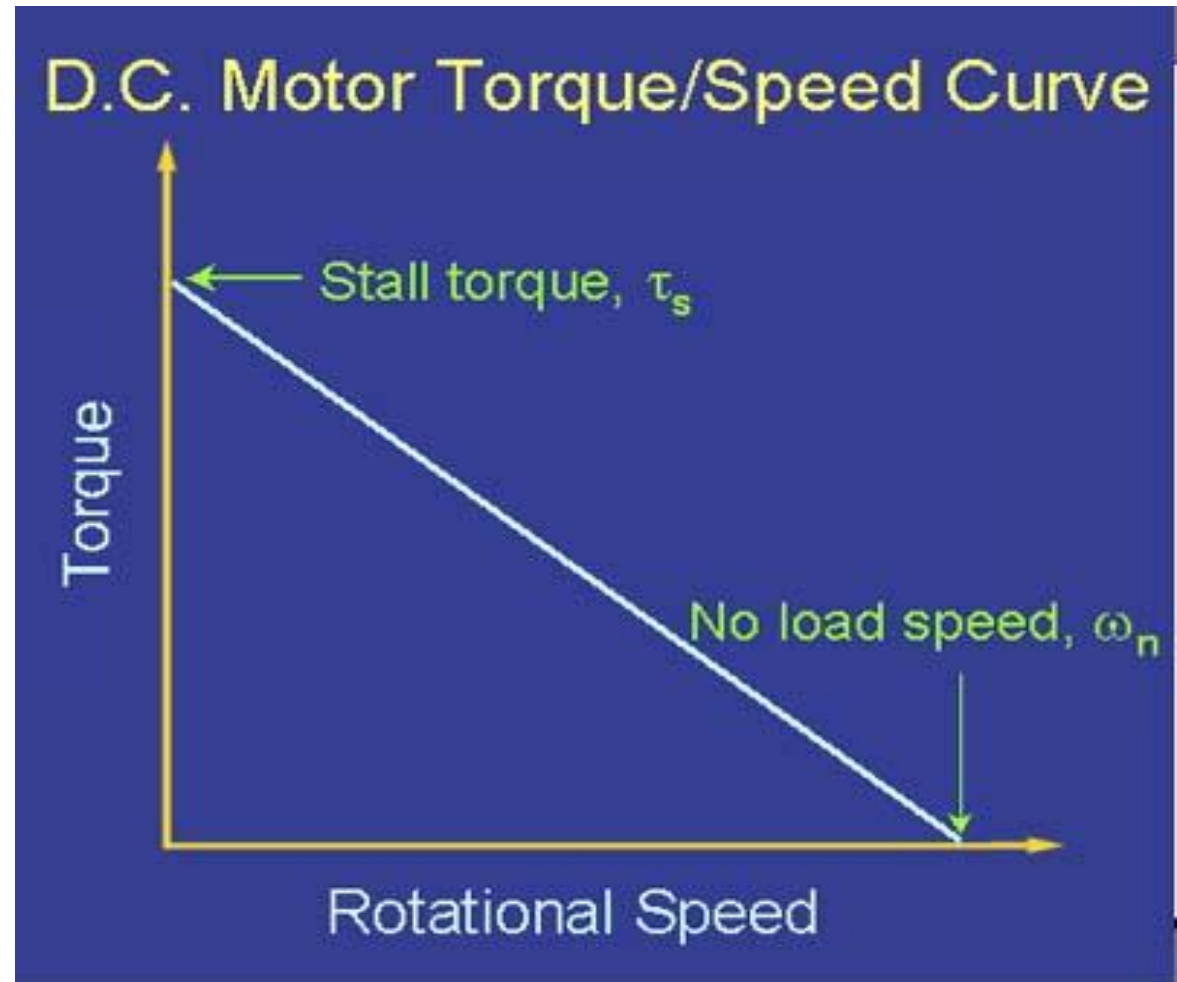


DC motor torque τ

τ = torque

I = current

$$\tau \propto I$$



Commercial Electric Hobby “Servos”

- Same as ones found on your robot.
- Dirt cheap (~10\$)
- Comes in two flavors:
 - “standard”
 - Position
 - Continuous
 - Rotation rate



Internals of “Hobby” Servo



Commercial Electric Hobby “Servos”

- Use PWM for commands:

