Sources: https://www.microchip.com/stellent/groups/SiteComm_sg/documents/DeviceDoc/en543041.pdf
https://www.mathworks.com/products/connections/product_detail/hebi-robotics-actuators.html

Actuators

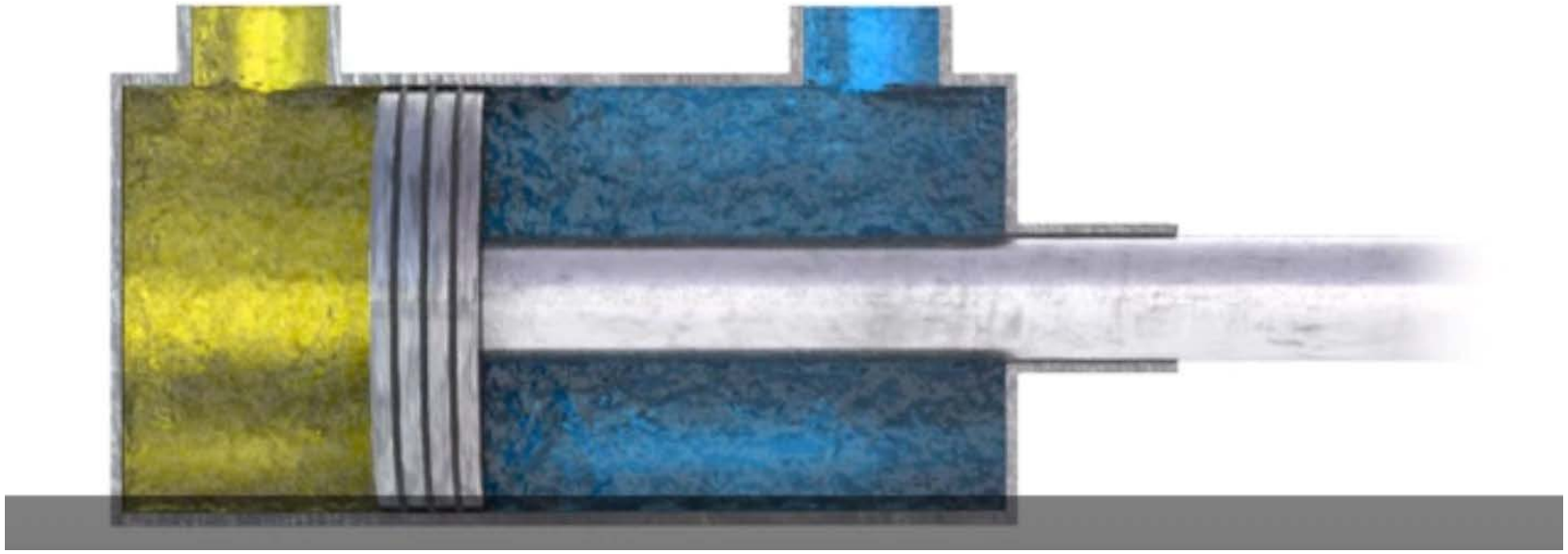
- What is it?
- How does it work?
- How do your characterize them?
- Gears
- Sizing them
- Driving them

ECE 3400 Intelligent Physical Systems

Actuators

A device that converts energy into mechanical motion

- Electric
- Mechanical
- Hydraulic
- Pneumatic



Actuators

A device that converts energy into mechanical motion

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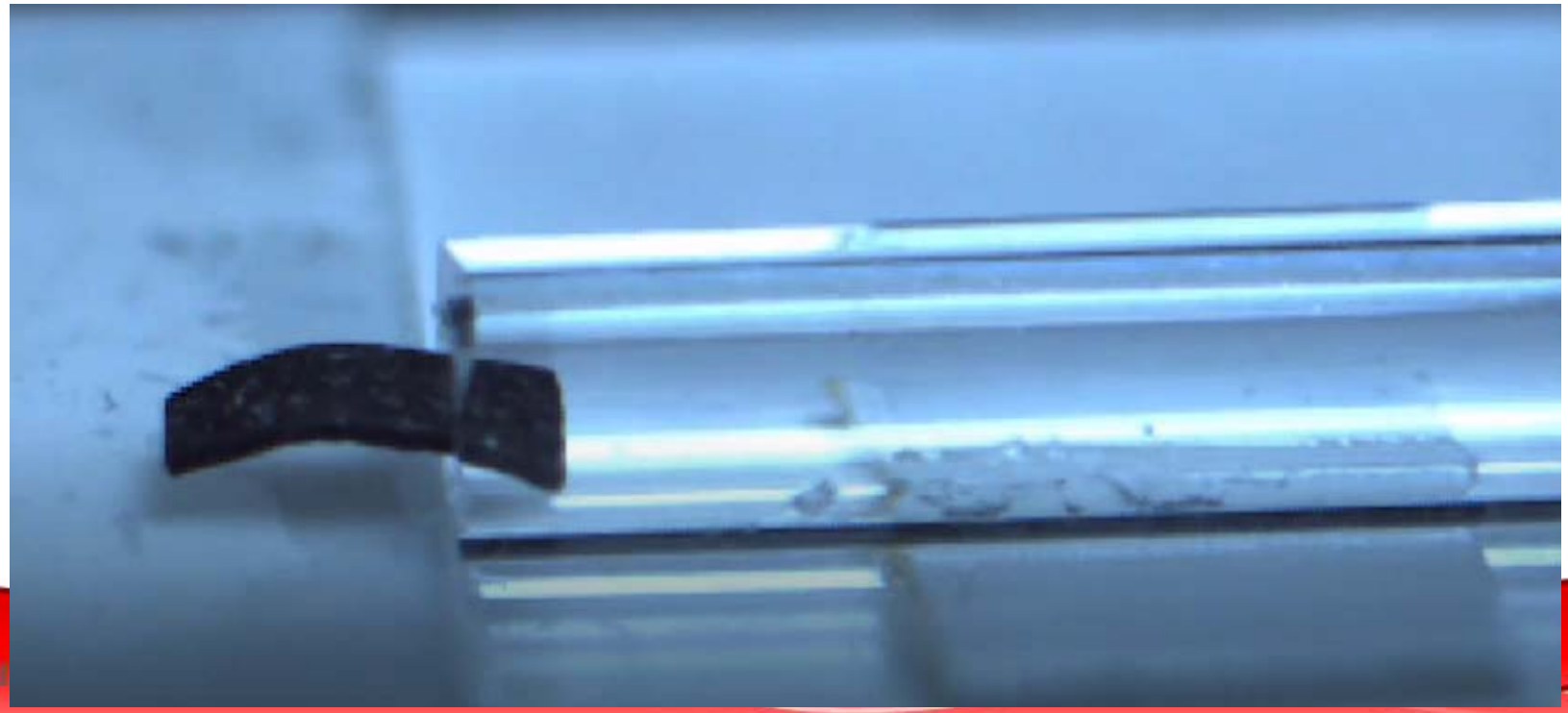
Actuators

A device that converts energy into mechanical motion

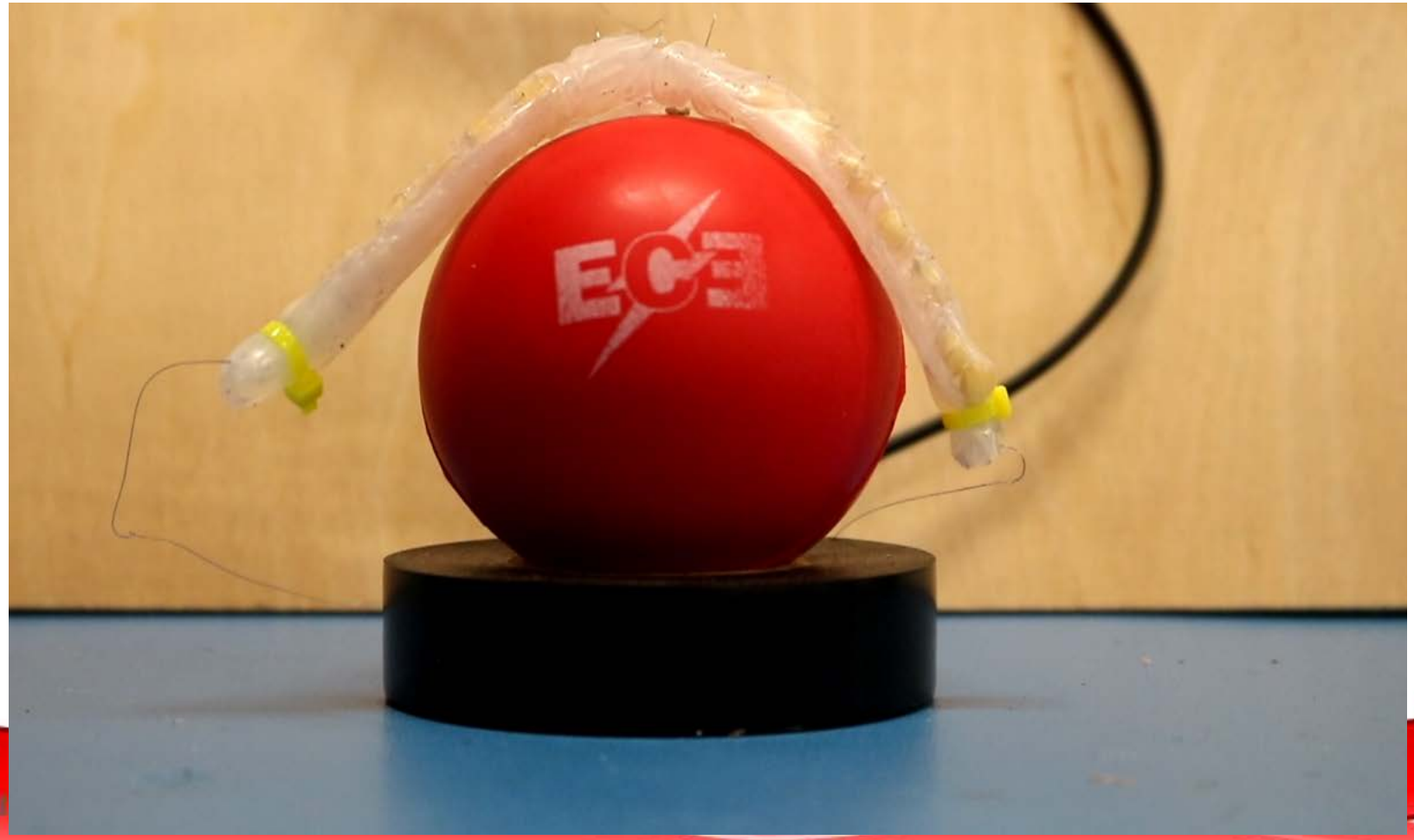
- Electric
- Mechanical
- Hydraulic
- Pneumatic
- Bio-hybrid
- Magnetic
- Light-driven
- Thermal



Actuators

A device that converts energy into mechanical motion

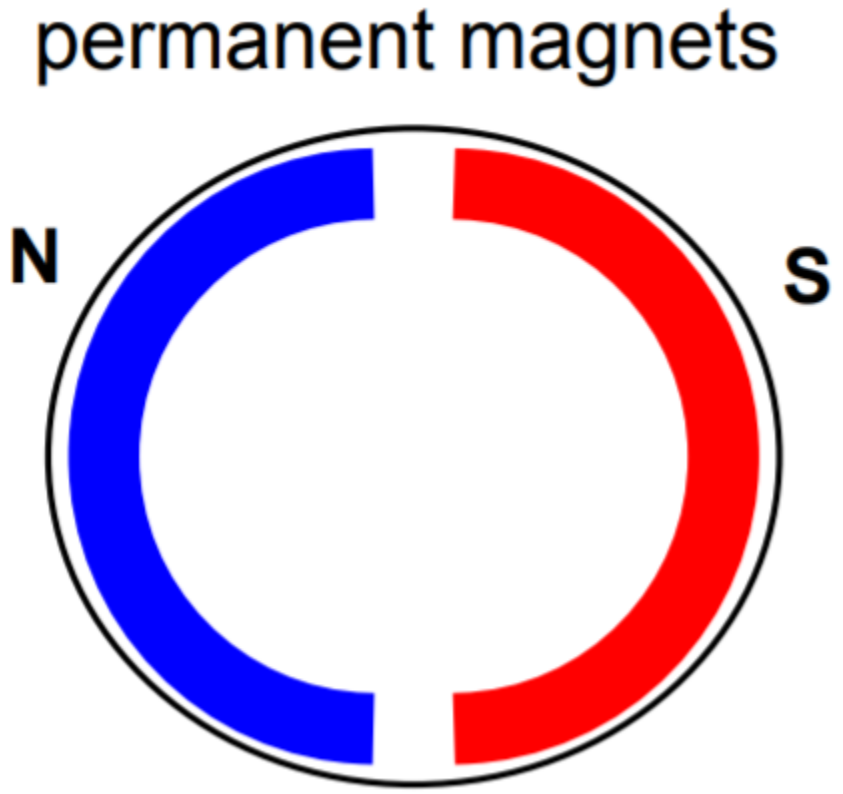
- Electric
- Mechanical
- Hydraulic
- Pneumatic
- Bio-hybrid
- Magnetic
- Light-driven
- Thermal
- …anything goes!



Actuators

Brushed DC motors

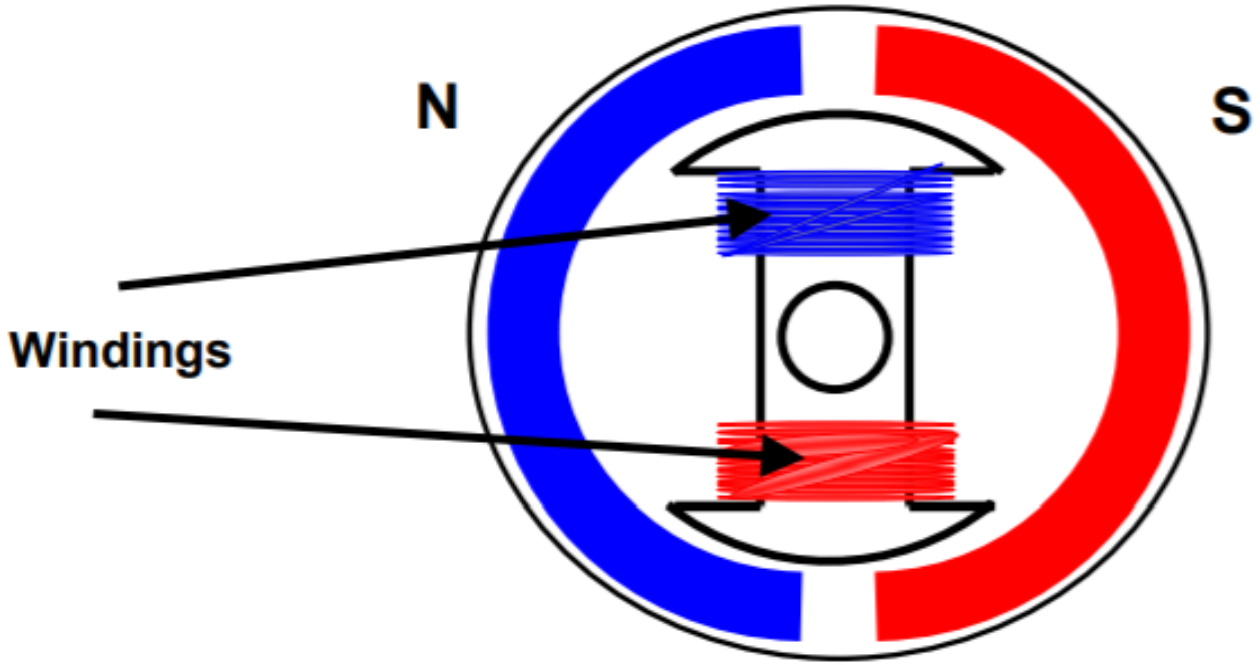
Brushed DC motor



PHYS 2213: Electromagnetism

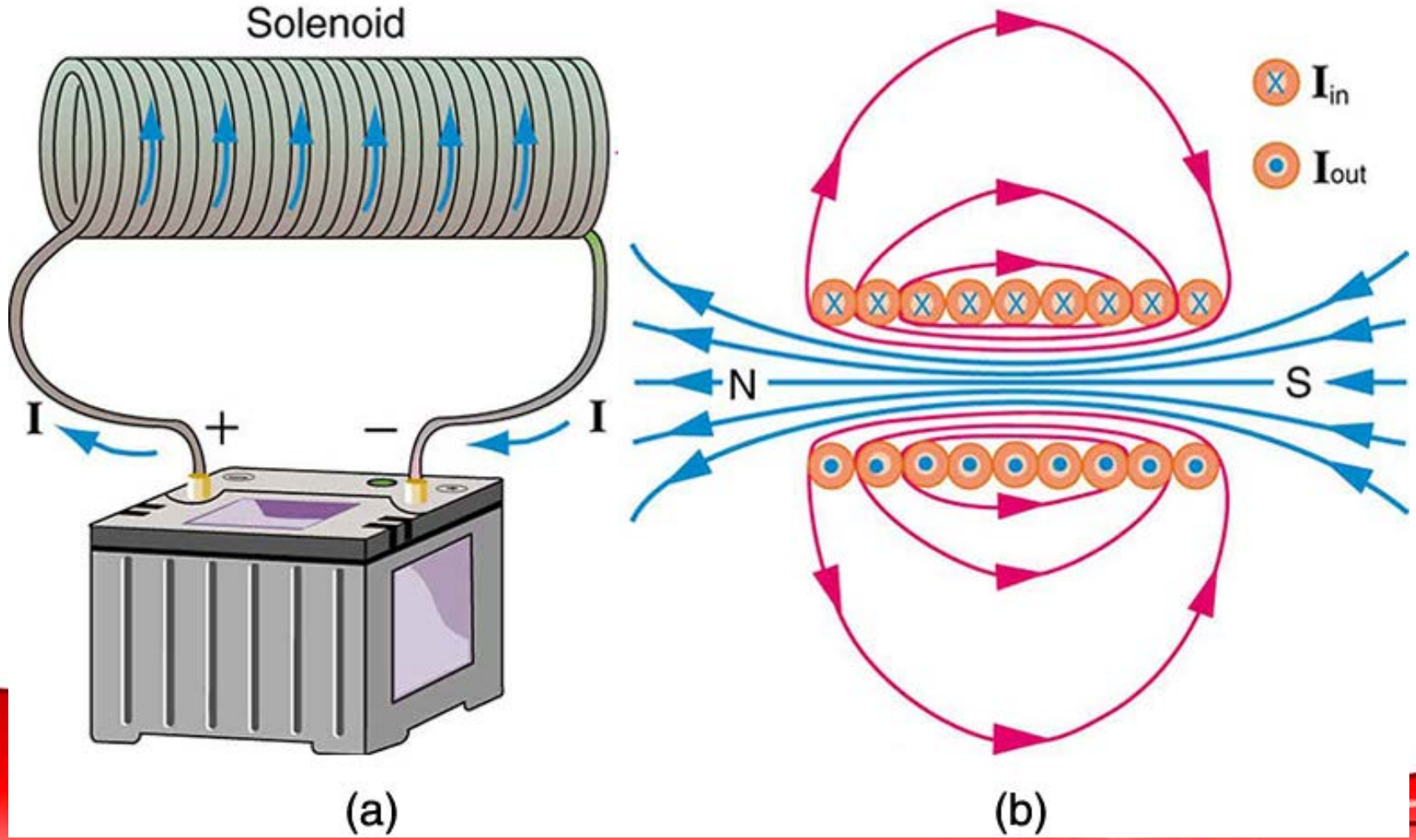
ECE 3030: Electromagnetic fields and waves

Brushed DC motor

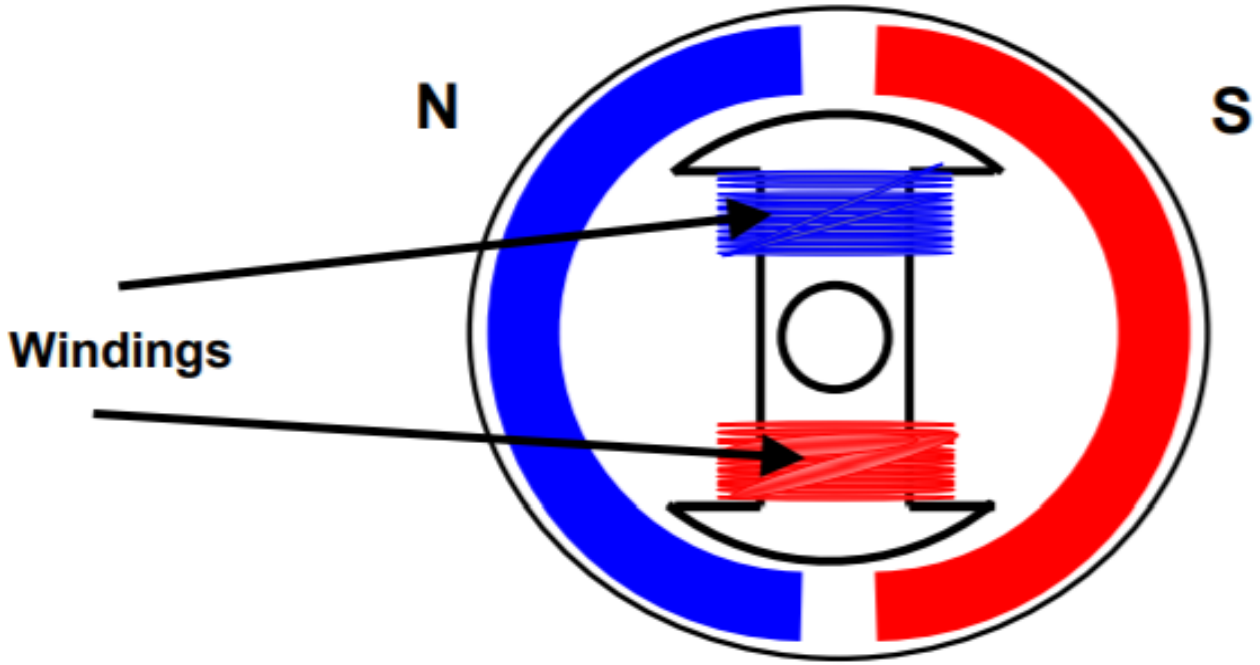


Brushed DC motor

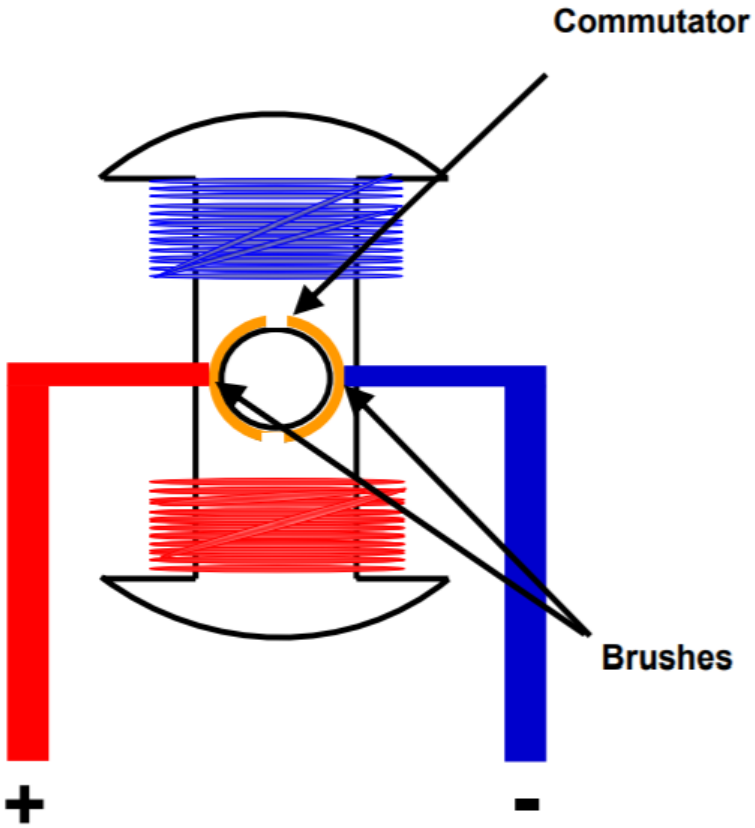
- Ampere's Right Hand Rule

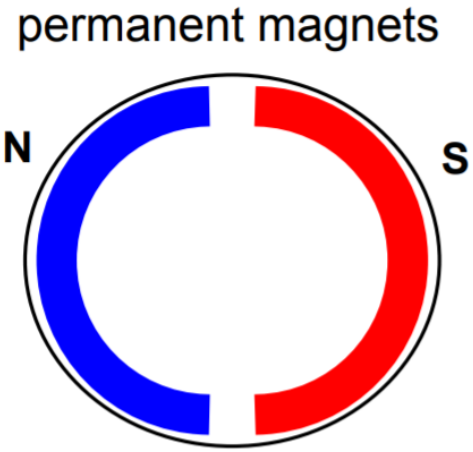


Brushed DC motor

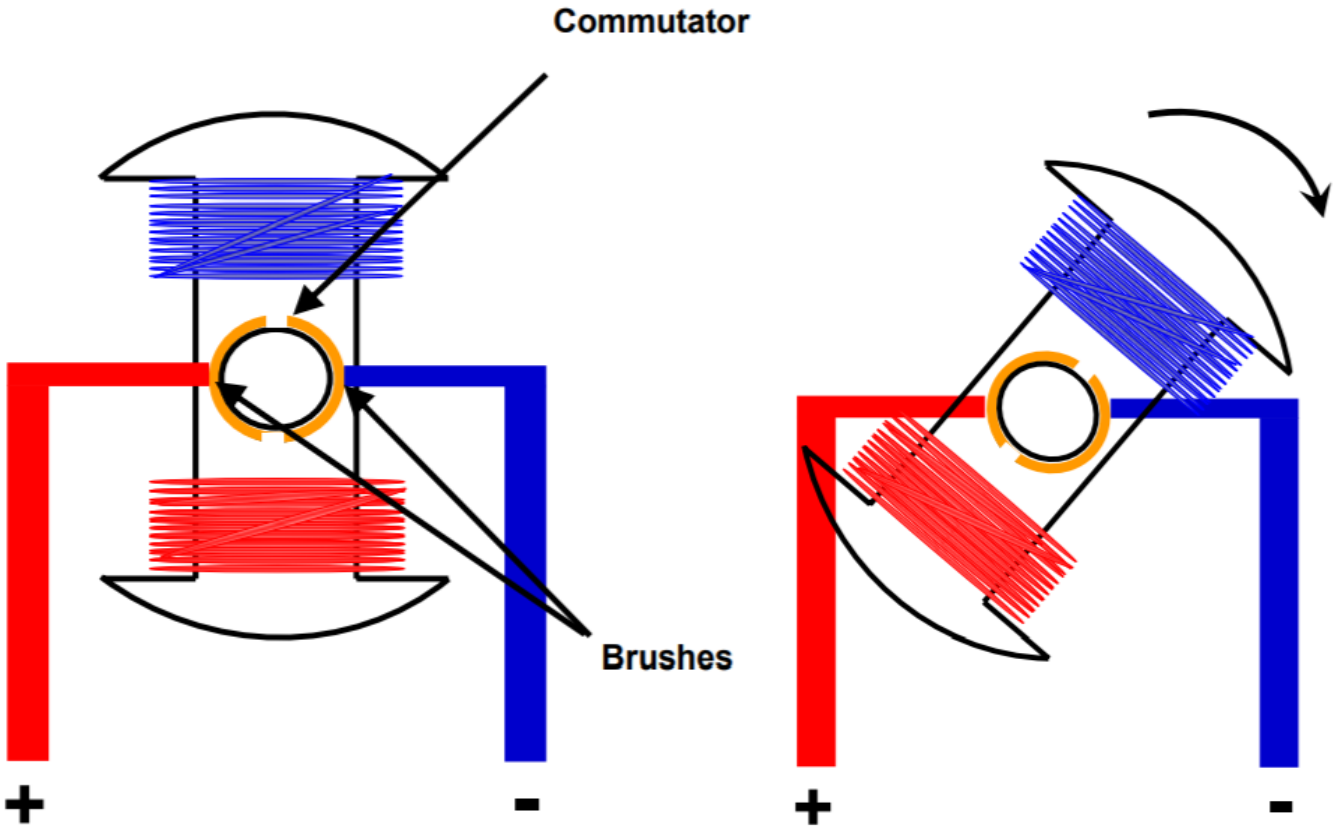


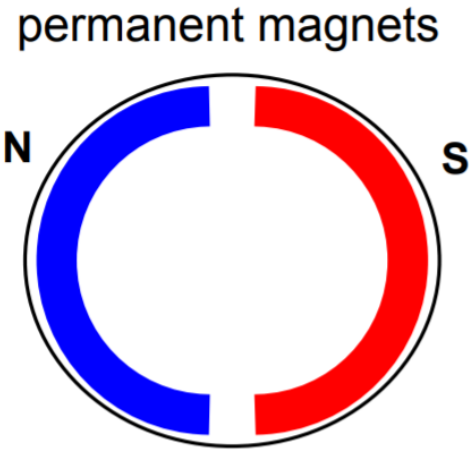
Brushed DC motor



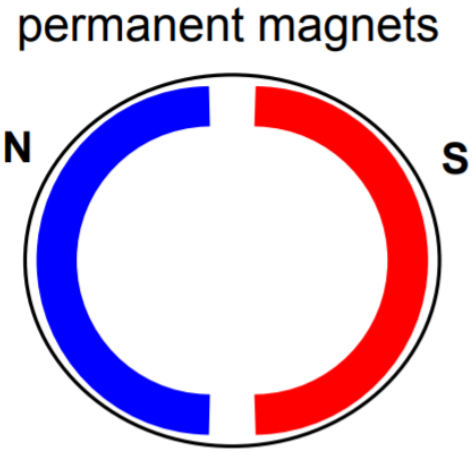


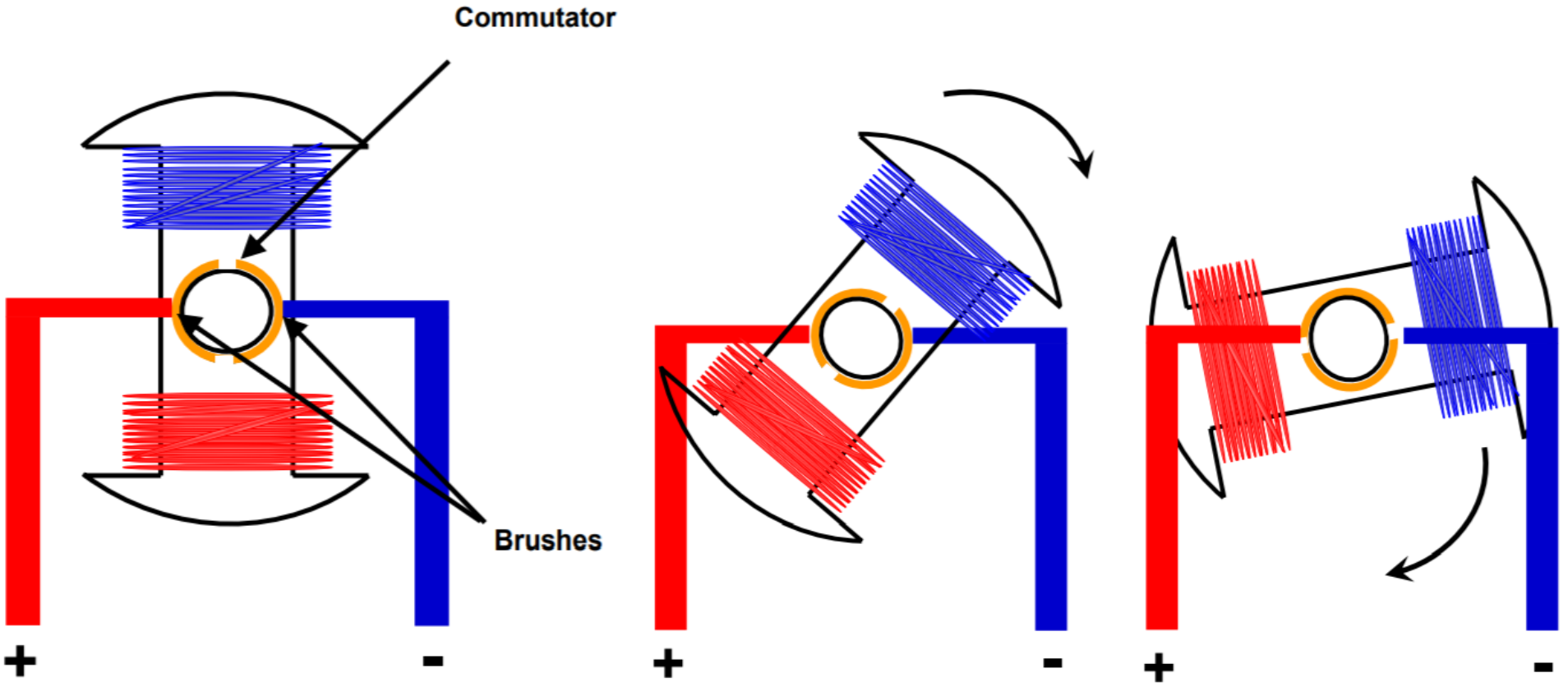
Brushed DC motor



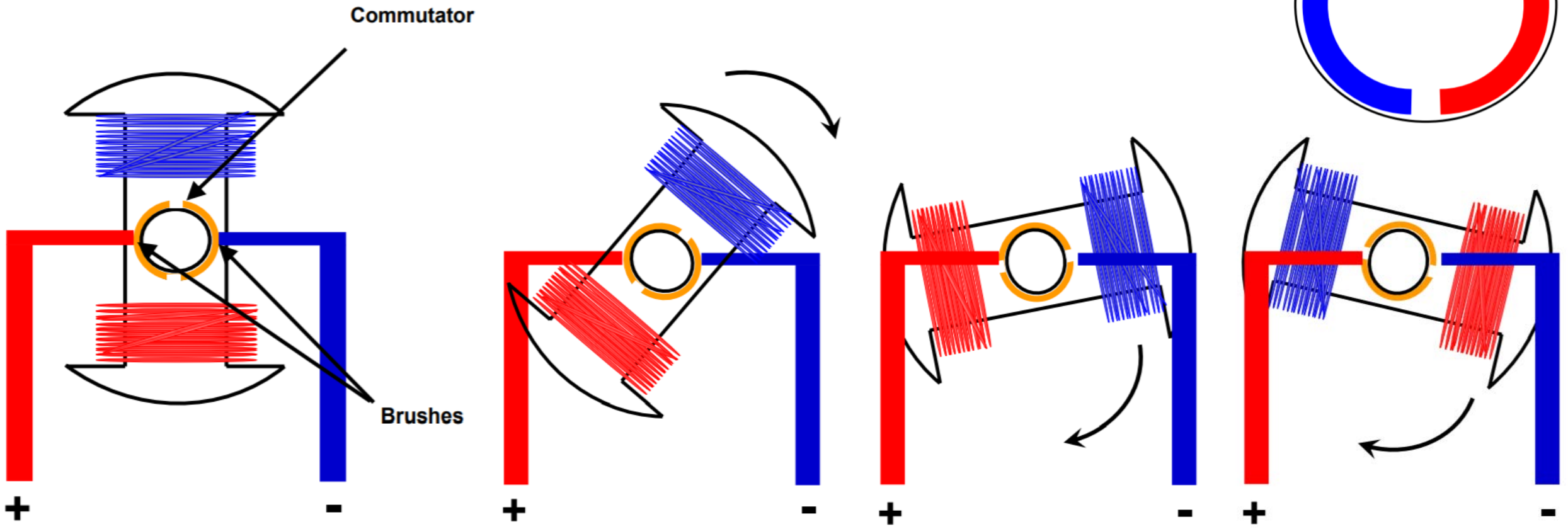


Brushed DC motor



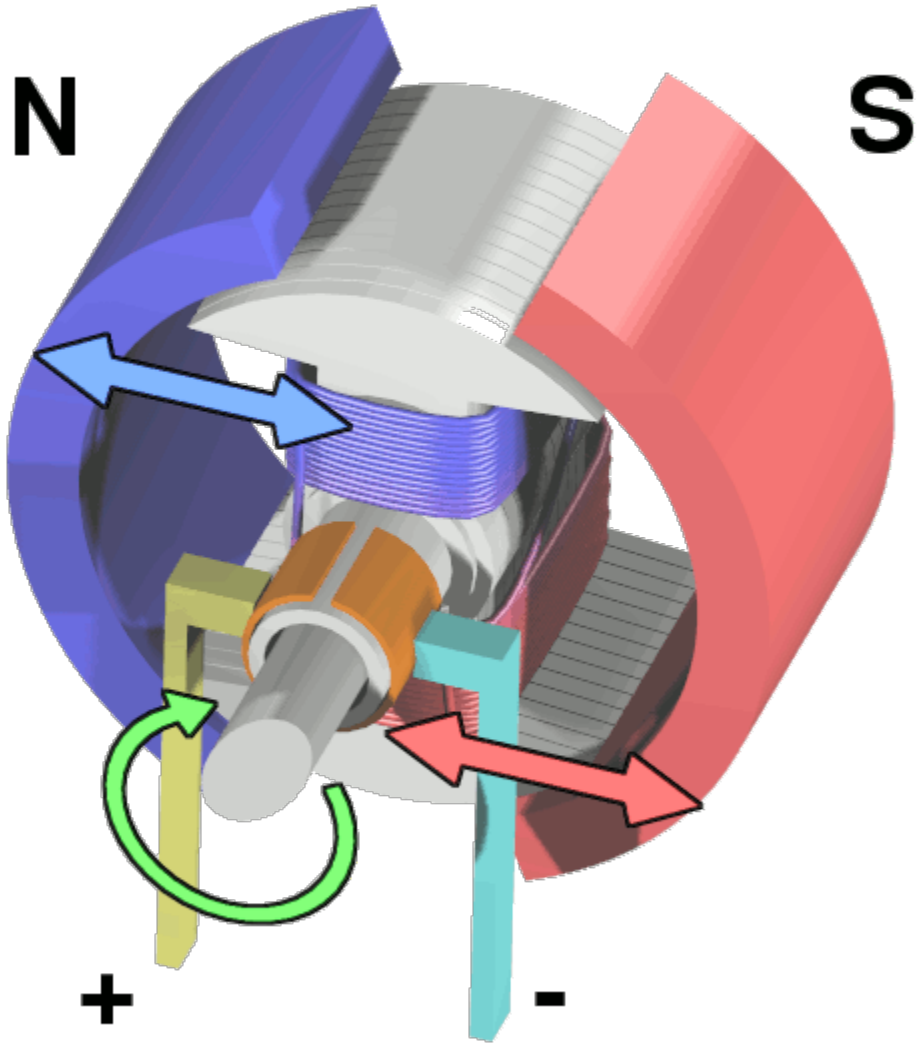


Brushed DC motor

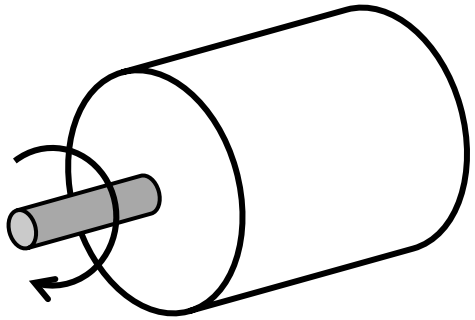


Brushed DC motor

- *Advantages*
  - Easy to control
  - Inexpensive
- *Disadvantages*
  - Brushes suffer from wear
  - Not very energy efficient

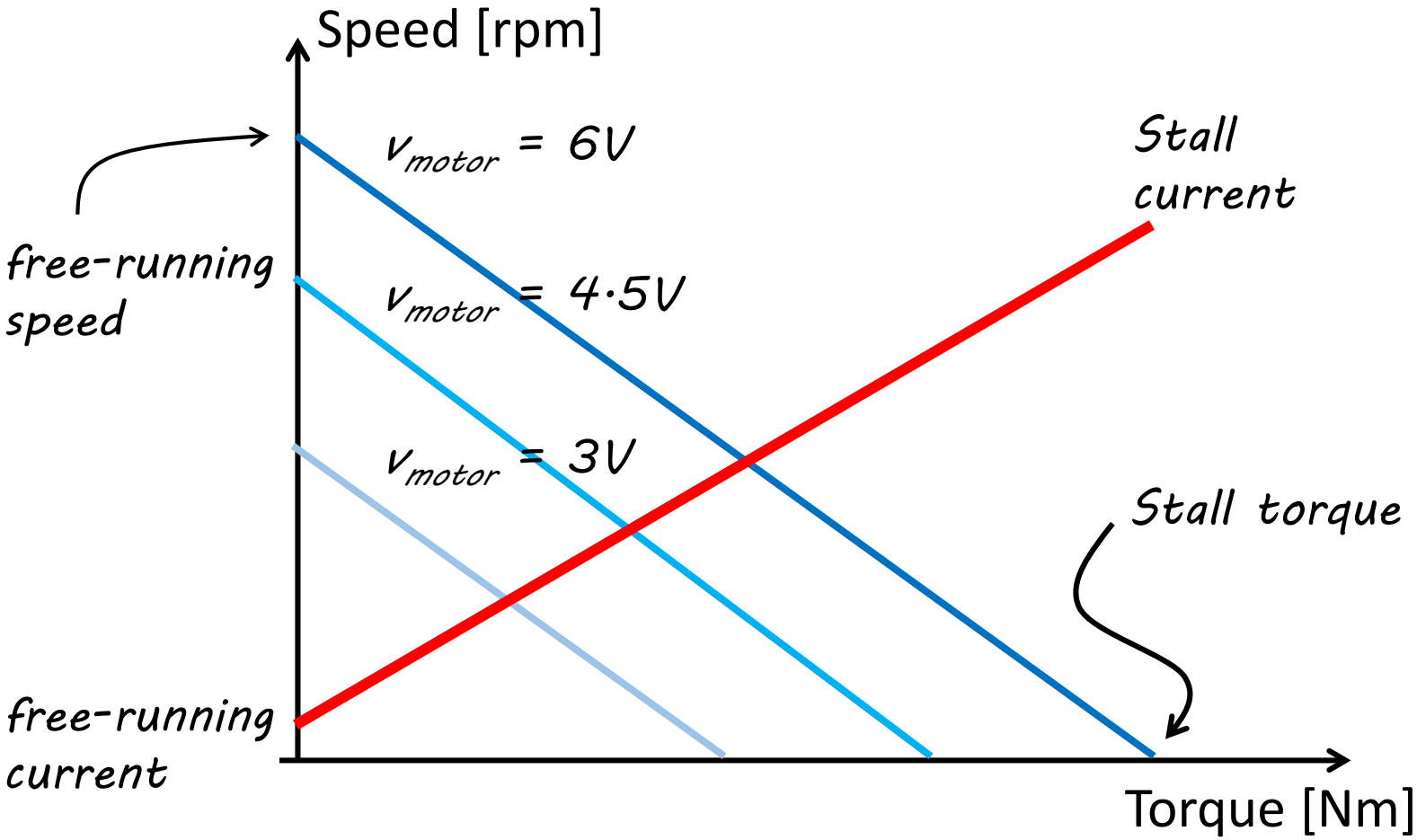


Brushed DC motor characterization

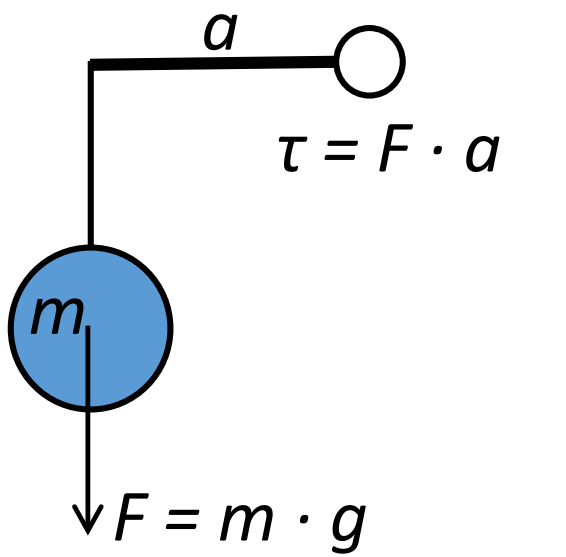


$P_{motor} = \tau_{motor} \cdot v_{motor}$

[kW] = [Nm] ·[rpm]



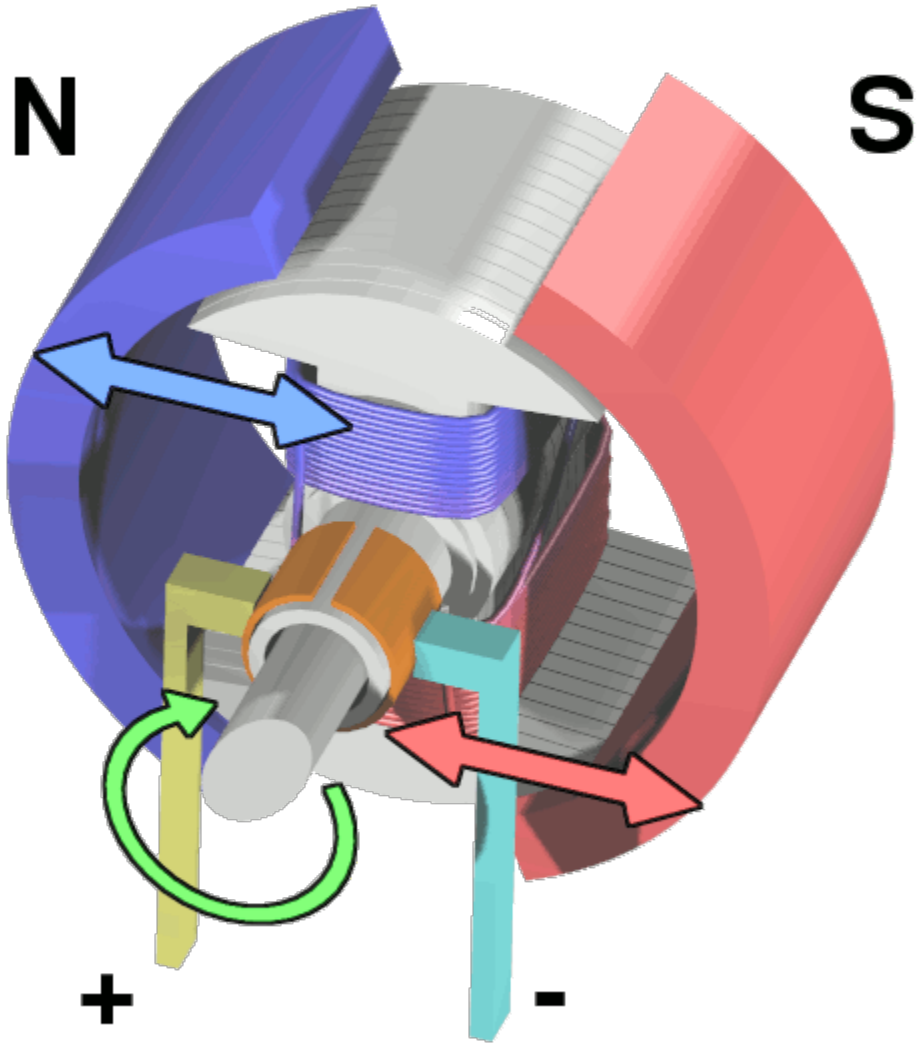
- What is torque?



- What happens if you turn down the voltage?

Brushed DC motor

- *Advantages*
  - Easy to control
  - Inexpensive
- *Disadvantages*
  - Brushes suffer from wear
  - Not very energy efficient
- Standard motors are fast and weak
- *What is done to decrease the speed?*
  - Gear trains!



Gear Trains

Spur gears: Transmit power between parallel shafts

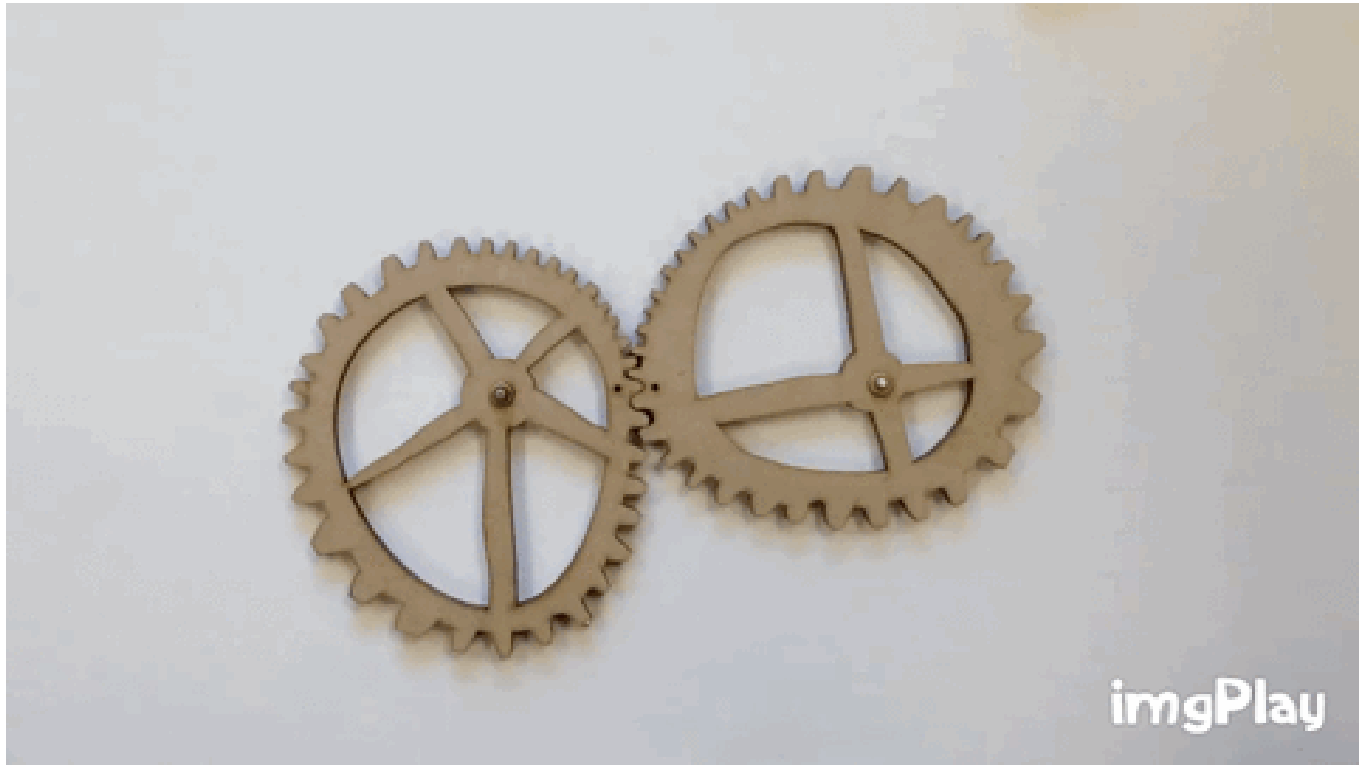
Helical gears: Transmit power between parallel and non-parallel shafts (less noise)

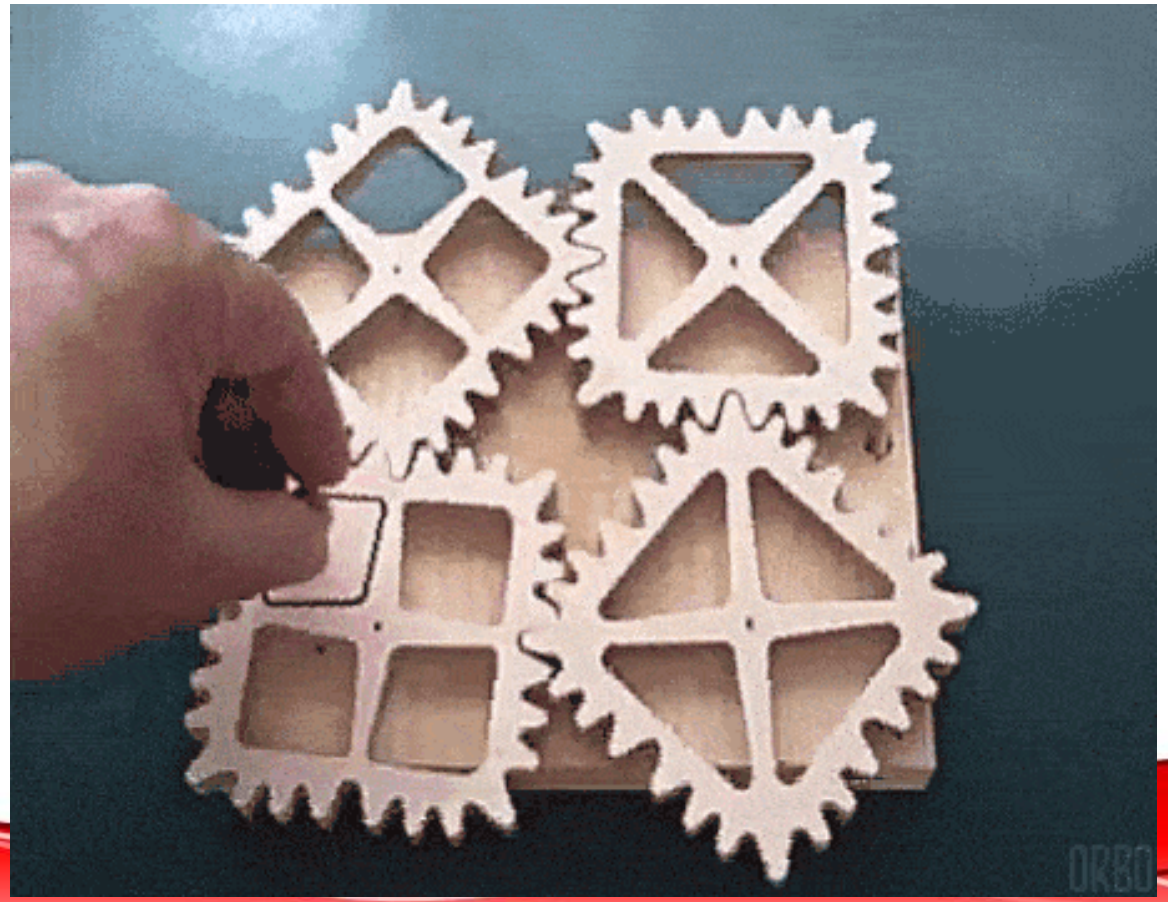
Worm gears: Used for very high gear ratios

Bevel gears: Transmit rotary motion between intersecting shafts

Linear gears: Rotary to linear motion

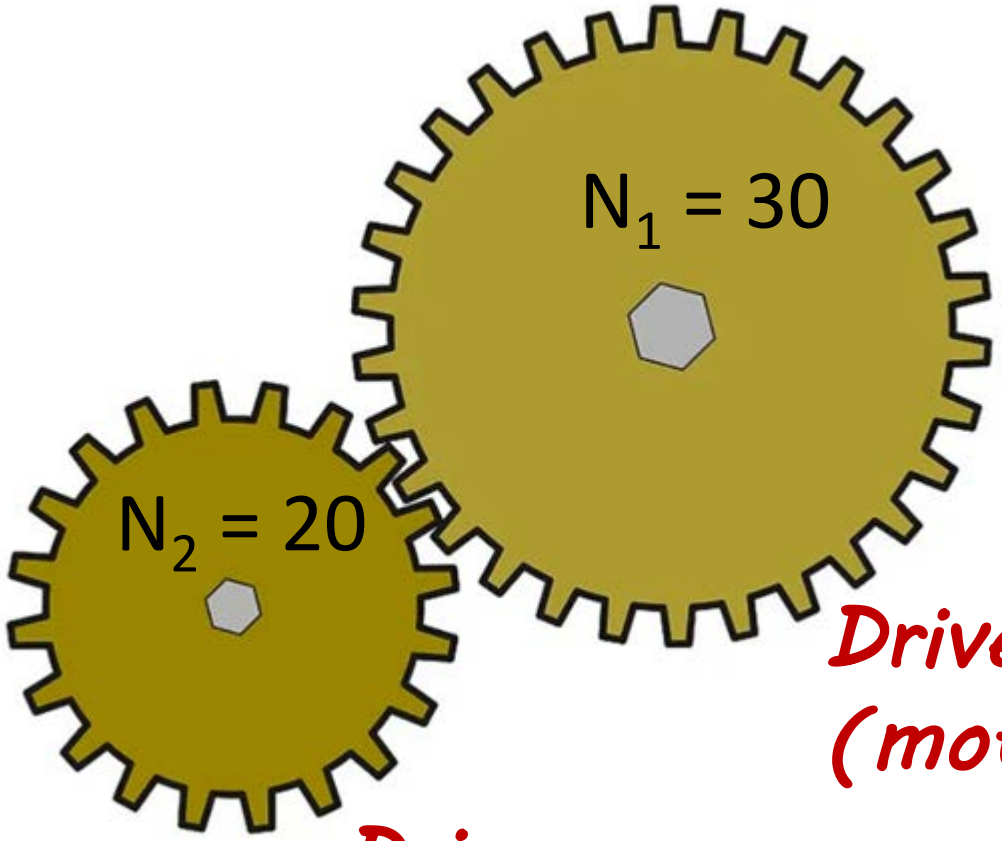
Gear Trains





Gear Trains

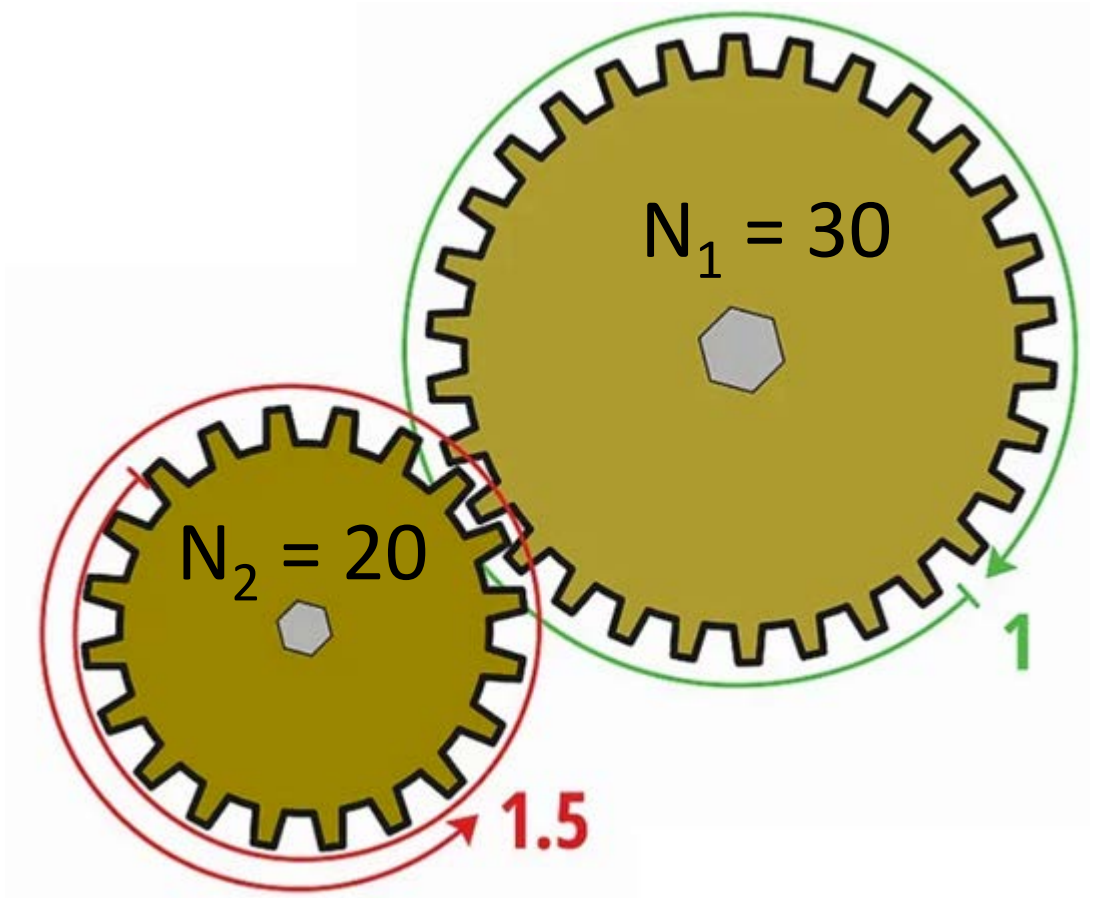
What is the gear ratio?



Drive gear (motor)

Driven gear

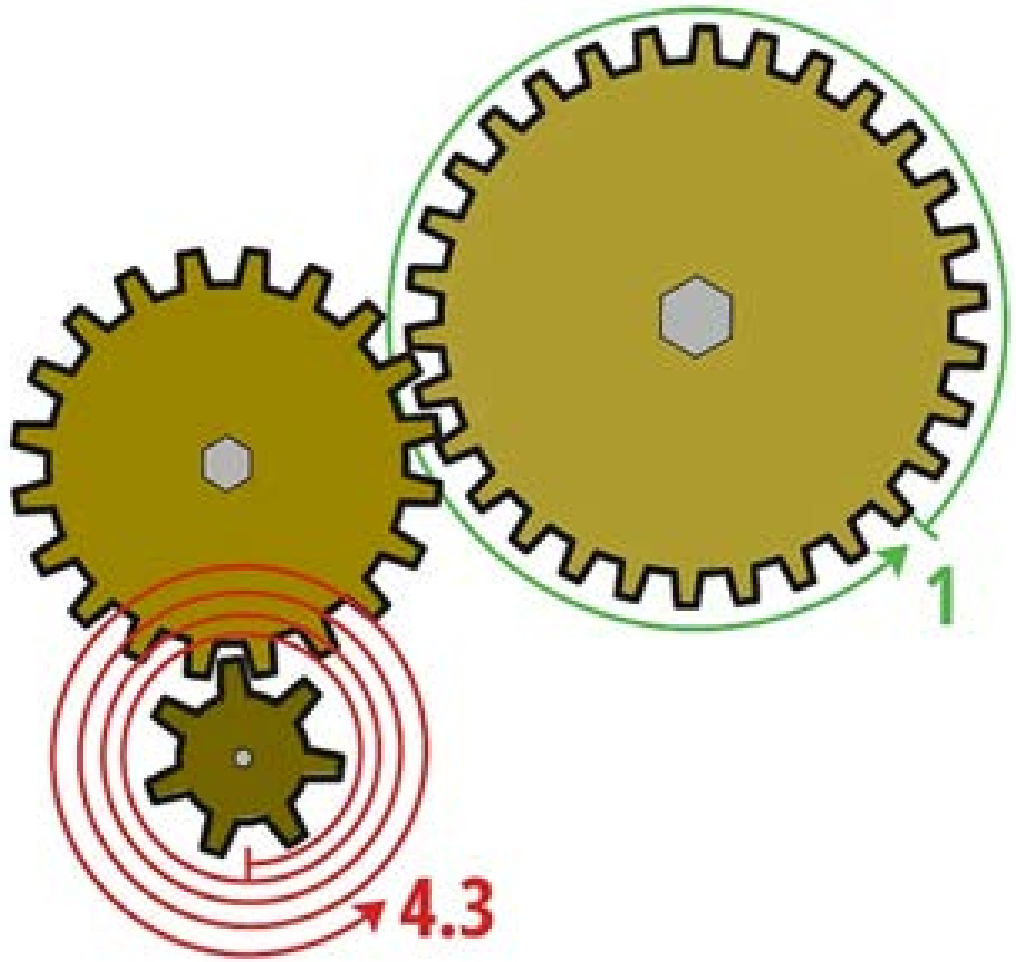
Gear Trains



What is the gear ratio?

$$v_2 = v_1 \cdot \frac{N_1}{N_2}$$

Gear Trains



What is the gear ratio?

$$v_3 = v_1 \cdot \frac{N_1}{N_2} \cdot \frac{N_2}{N_3}$$

$$v_3 = v_1 \cdot \frac{N_1}{N_3}$$

!!real gears have loss - rule of thumb: gears loose ~10% per contact point!!

Sizing your DC motor

Datasheet

- Speed: 0-50RPM
- 38 oz-in torque @ 6 V

Sizing your DC motor

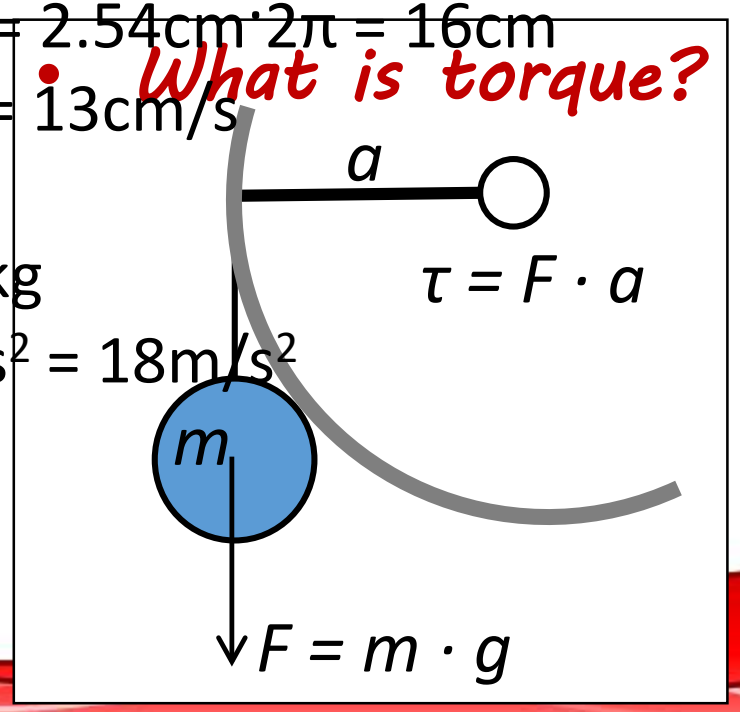
Datasheet

- Speed: 0-50RPM
- 38 oz-in torque @ 6 V

- τ_{stall} = 38 oz-in = 2.34 kg-cm
- Wheel diameter = 2” → r_{wheel} = 2.54cm
- ***The “force” that the motor can apply is:***
  - $m_{force} = \tau_{stall} / r_{wheel}$ = 2.34kg*cm / 2.54cm = 921 g
  - (if you used the wheel as a winch it could lift a weight of 921g before stalling)
- $v_{no\text{-}load}$ = 50RPM
- One round corresponds to the wheel circumference: $C_{wheel} = 2.54cm \cdot 2\pi = 16cm$
- Without a load: $v_{robot\text{-}top\_speed} = C_{wheel} \cdot v_{no\text{-}load}$ = 800cm/min = 13cm/s
- ***What about the acceleration?***
- Constant max torque 2.34kg-cm, and a robot weight of 0.5kg
  - $F = m_{force} \cdot g = m_{robot} \cdot a \rightarrow a = 0.921kg/0.500kg \cdot 9.82m/s^2 = 18m/s^2$
  - ***What does that mean?***

(It will take the robot ~70ms to reach top

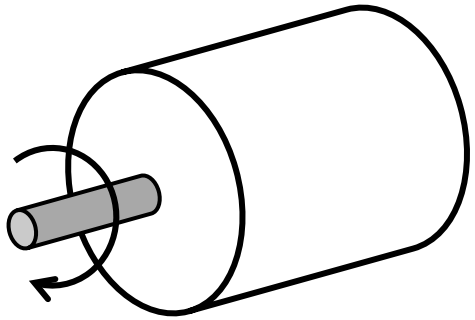
- ***What is torque?***



Sizing your DC motor

- Except that is not true….
- *What slows the robot down?*
  - NEVER size your motor for stall torque
    - (It's okay to overcome static friction, but don't do it continuously)
  - Friction in the bearings
  - Friction between wheel and ground
  - Aerodynamics (probably not)
  - Turning off axis
  - Imperfect wheel balance
  - …the motor has to overcome all of this.
- *So how could you estimate how much power is needed?*
  - Example: How much weight at the end of a pulley does it take to move your robot?

Sizing your DC motor



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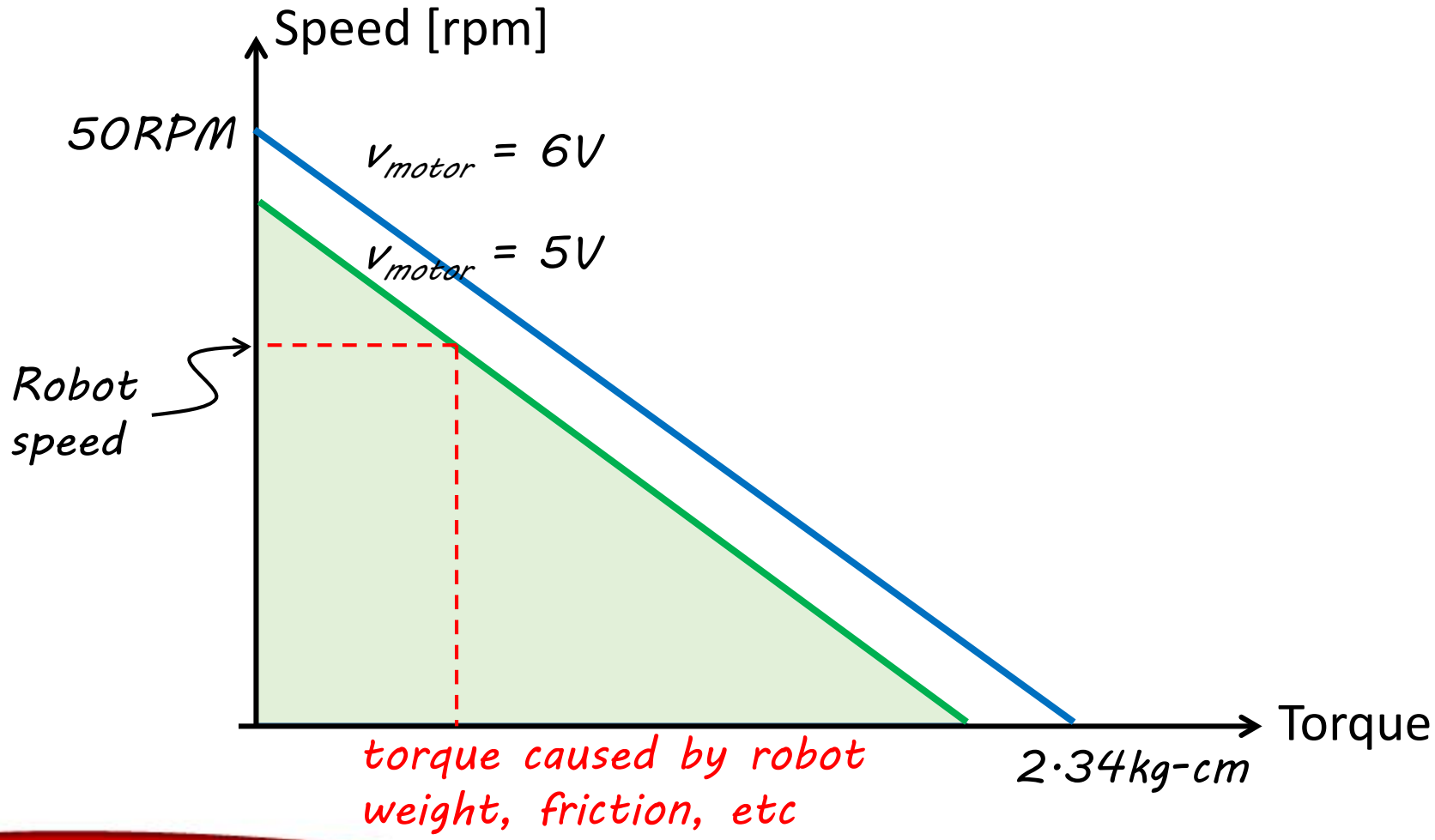
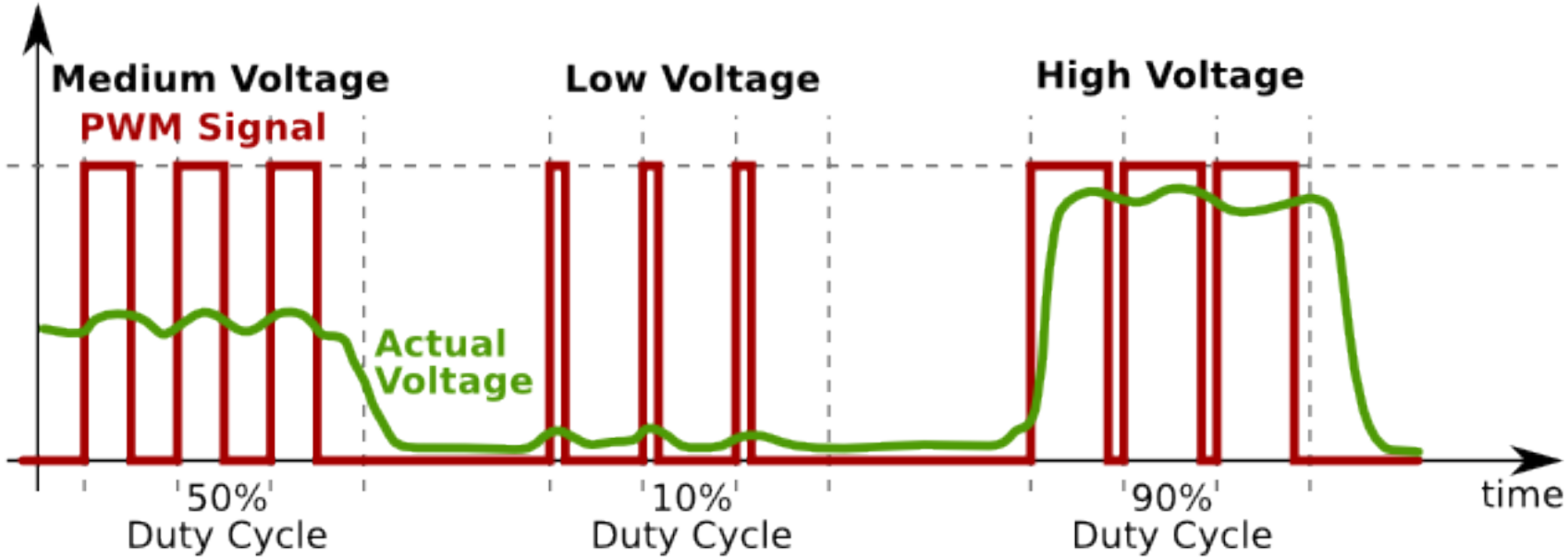


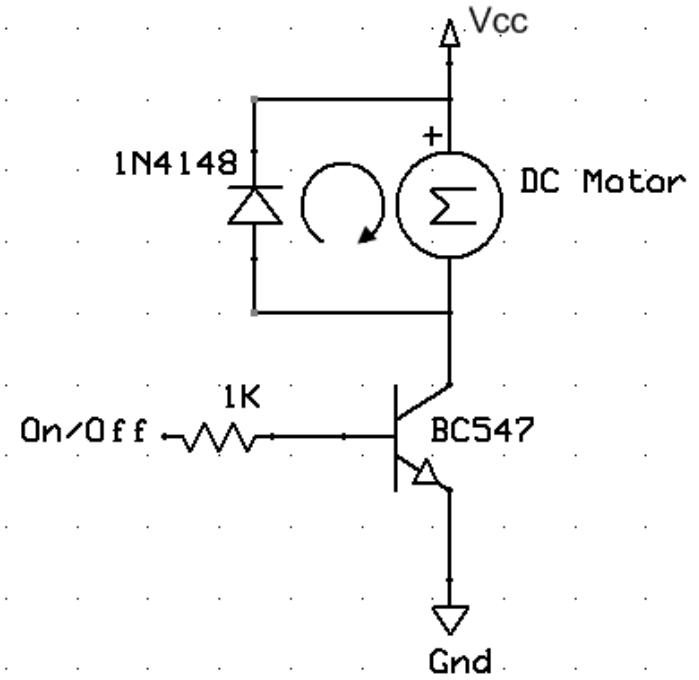
Driving a DC motor

Driving a DC motor

- Analog voltage

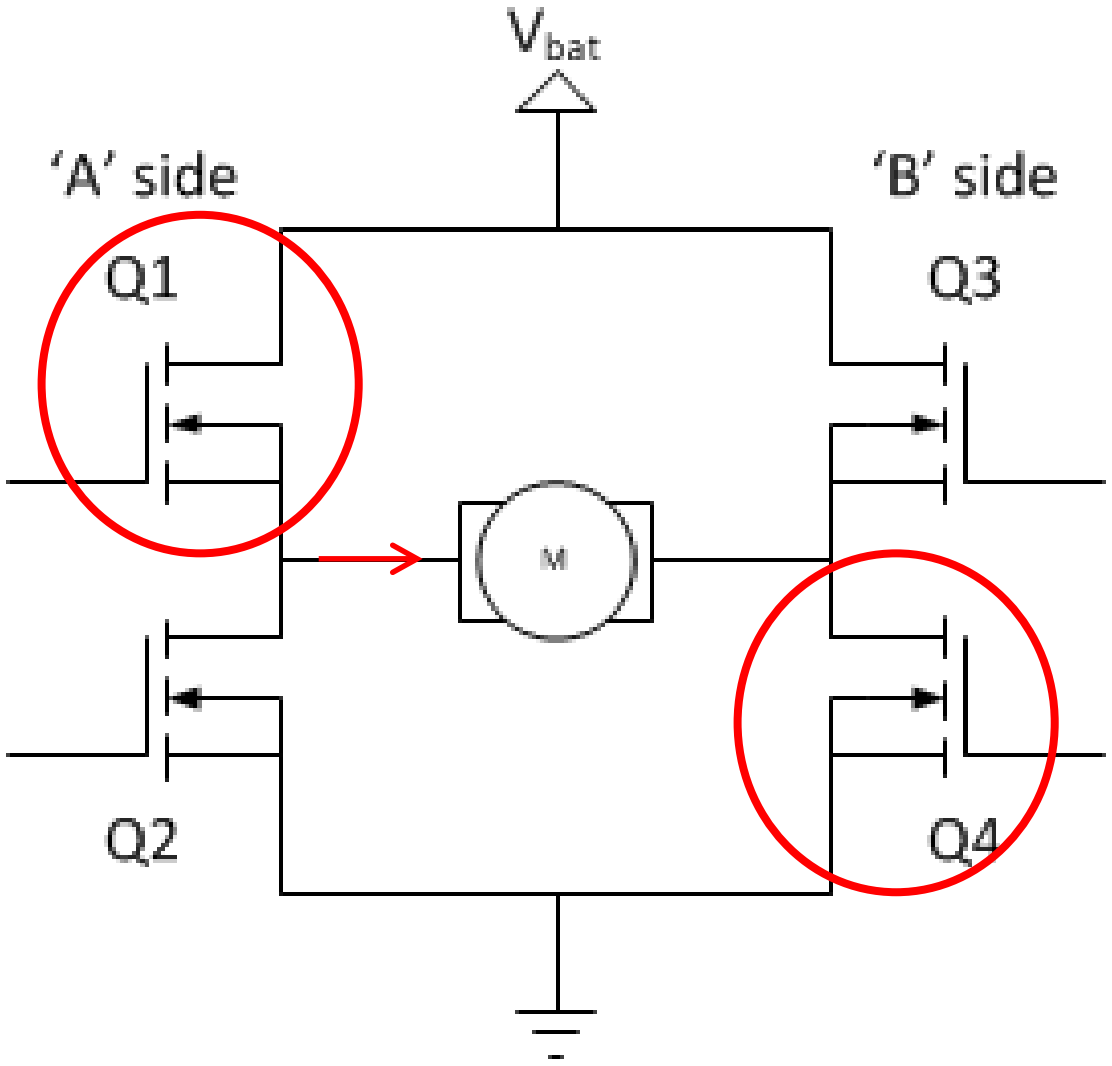


- *Why is this circuit not enough?*



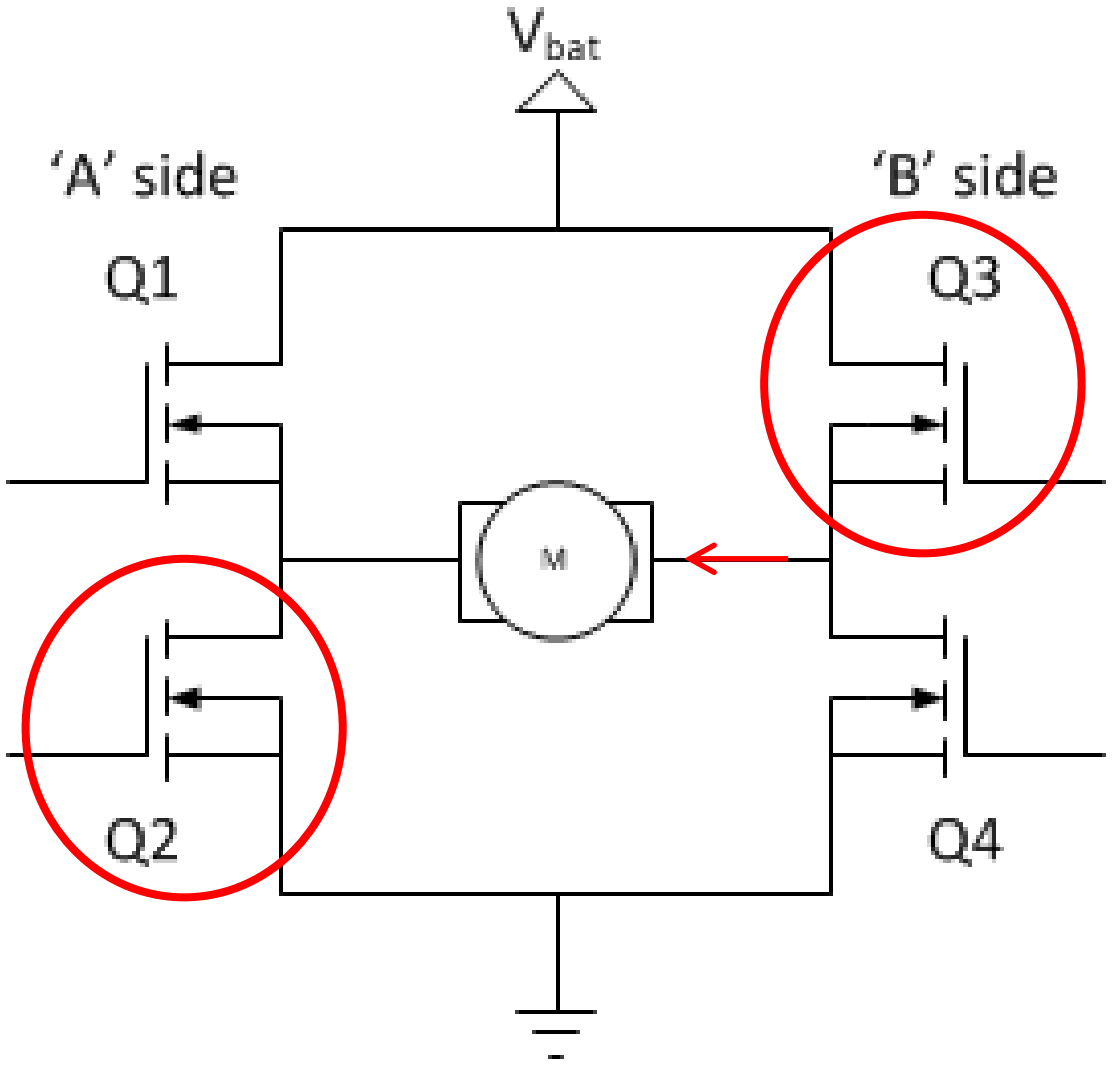
Driving a DC motor

- Analog voltage
- H-Bridge



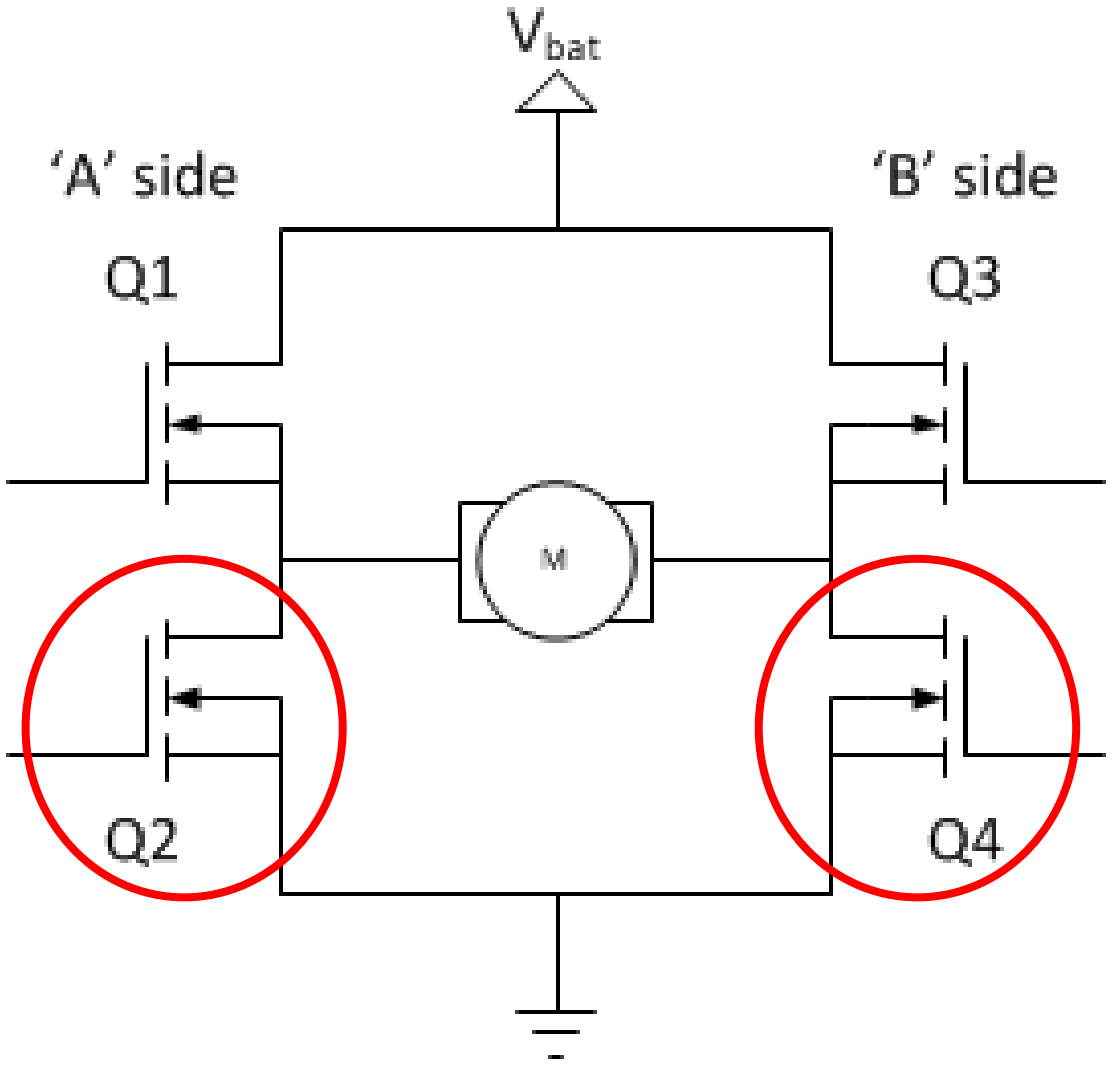
Driving a DC motor

- Analog voltage
- H-Bridge



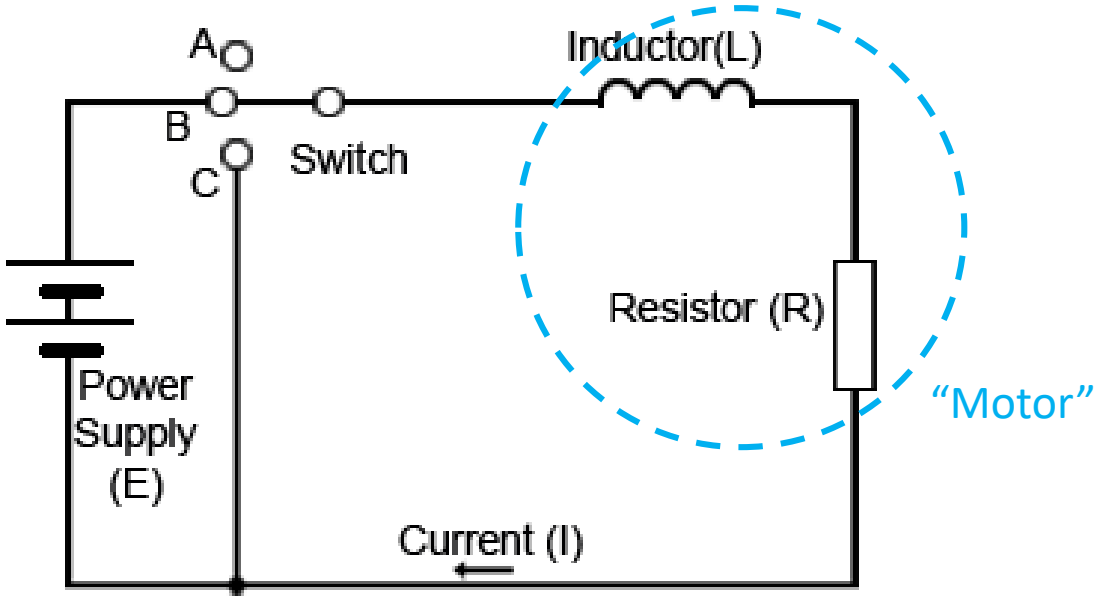
Driving a DC motor

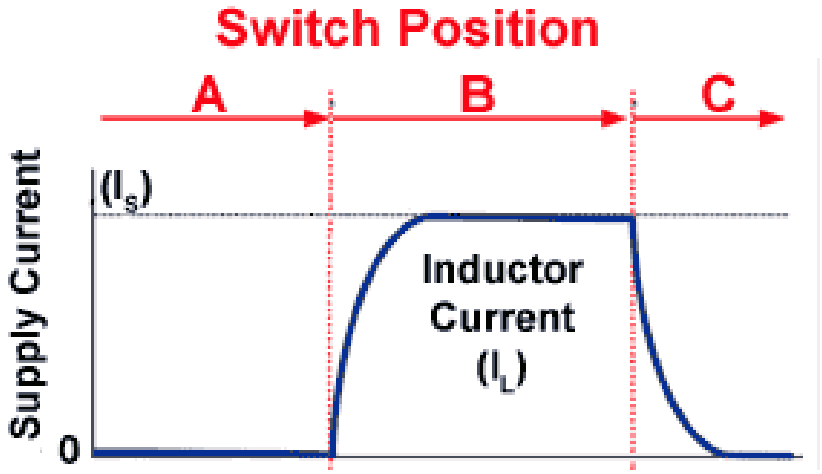
- Analog voltage
- H-Bridge

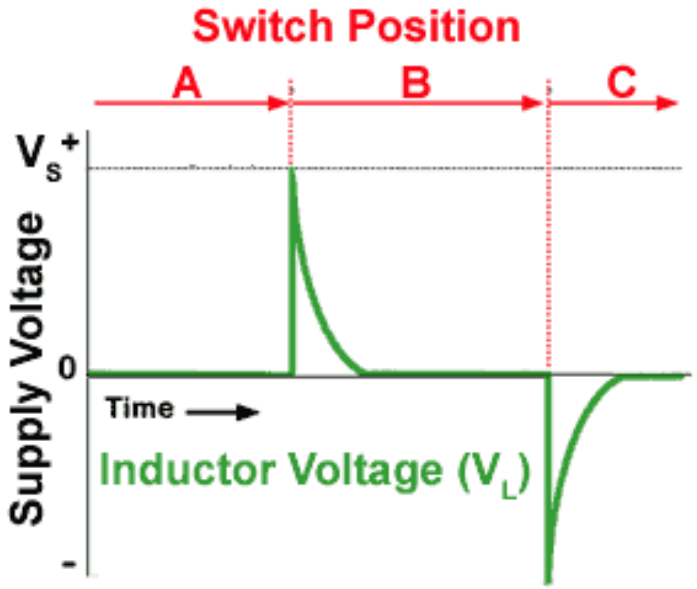


Driving a DC motor

- Analog voltage
- H-Bridge
- Electromotive Force (EMF)

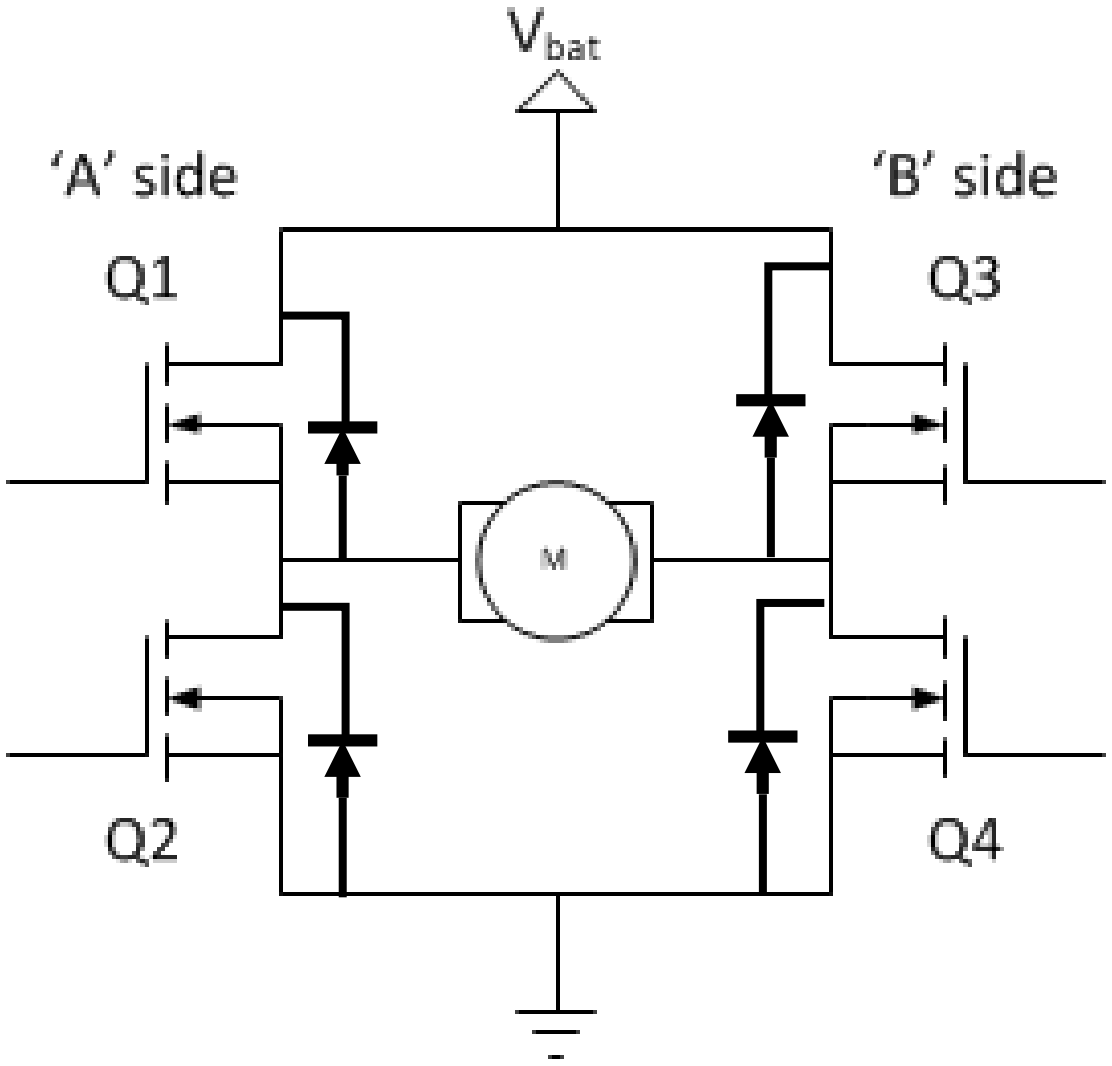






Driving a DC motor

- Analog voltage
- H-Bridge
- Electromotive Force (EMF)



Go Build Robots!