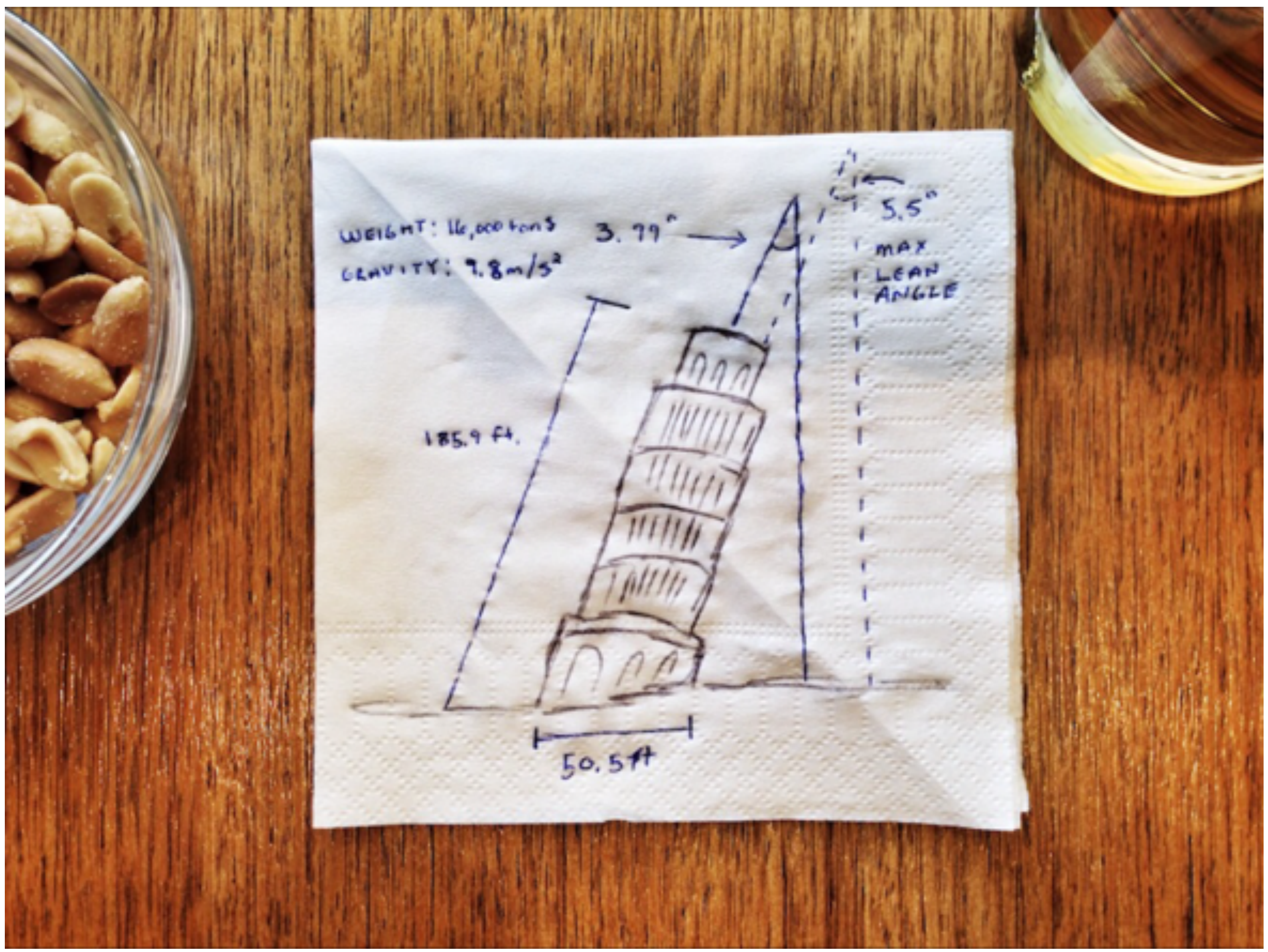
Three Napkin Design



Who Am I?

Catherine Coleman

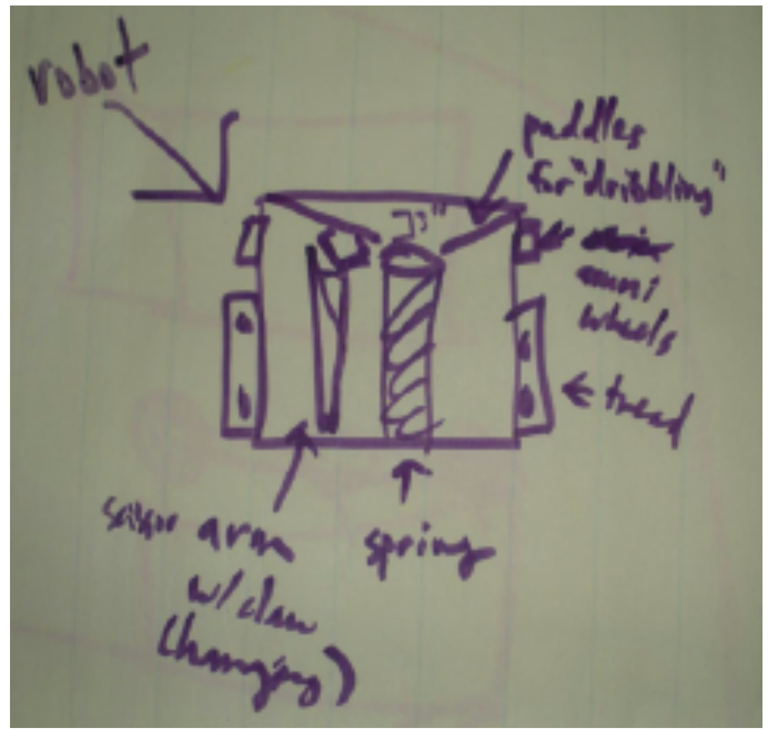
- Advanced Manufacturing Engineer at Apple
- Masters in Robotics from WPI
- Participated in FLL, FTC, and FRC
- Mentored FLL, FTC, and FRC

Napkins Design

- Strategy
- Low Resolution Design
- Final Well Engineered

Always let strategy drive your robot design!

Low Resolution Design



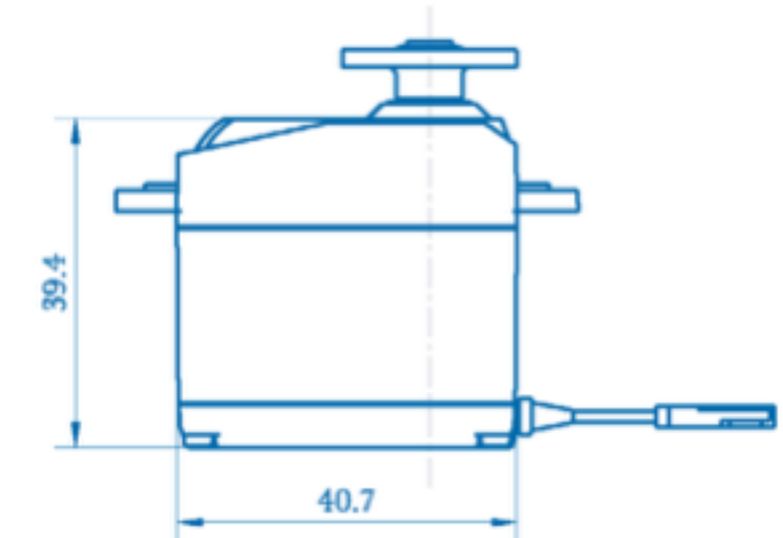
"The way to build a complex system that works is to build it from very simple systems that work."

-Kevin Kelly
Cofounder of Wired Magazine

Motors and Servos

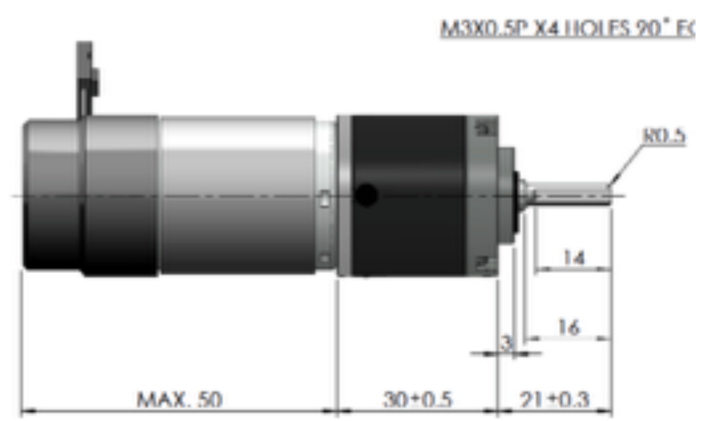
HD HEX Motor

NeveRest Motor

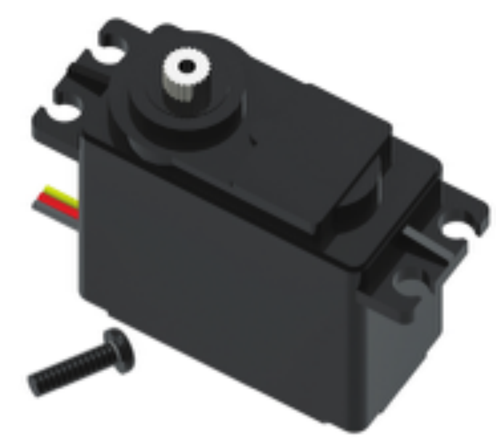


Matrix Servo

Tetrix Max DC Motor



Matrix Motor



Tetris Continuous Servo

What is the difference?

Motors

- Only has **two wires**, one for power and one for ground
- Controlled by an **external controller** sending it a PWM (pulse width modulated) signal to control the speed/ torque of the motor.

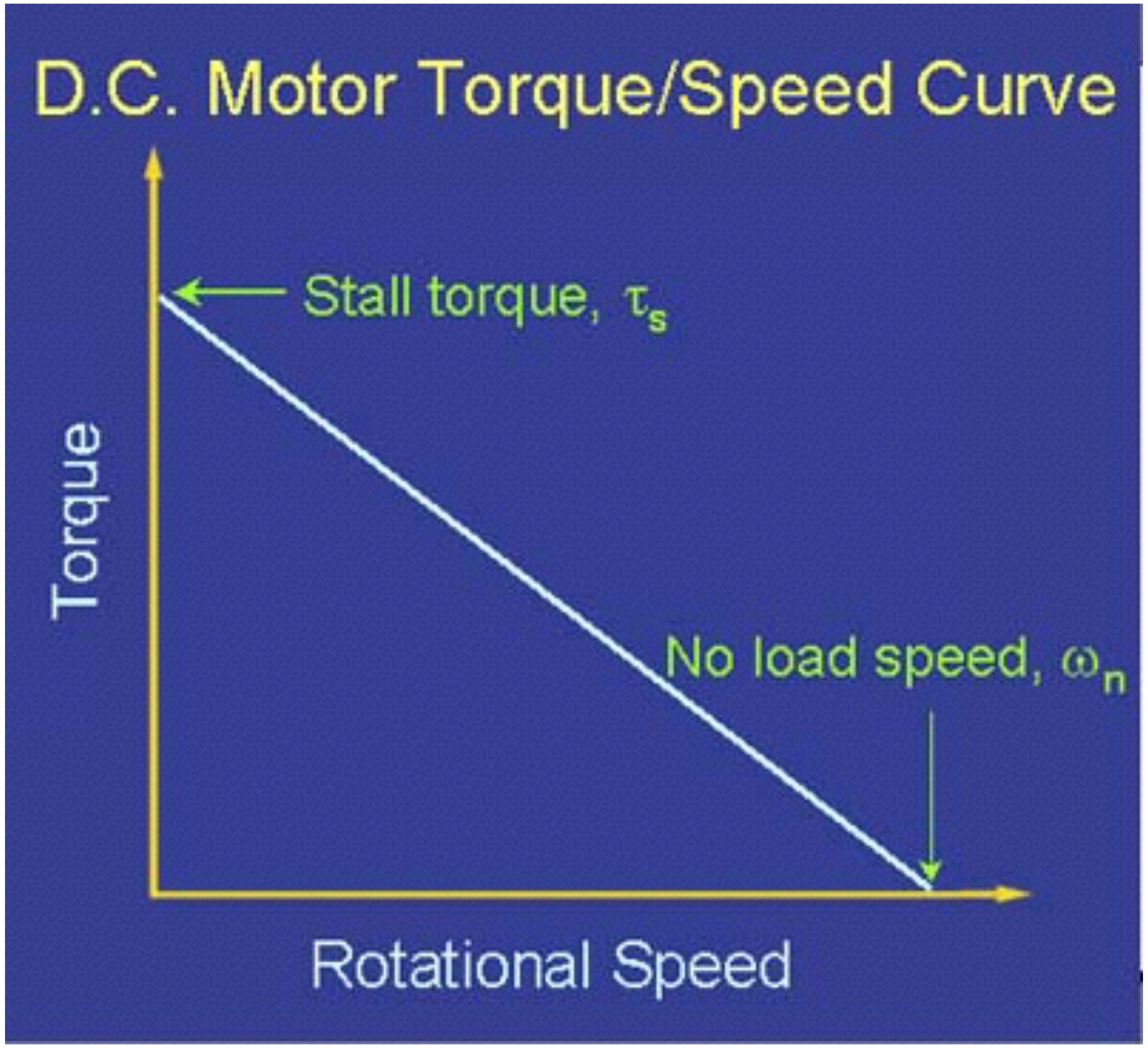
Servos

- Has **three wires**, power, ground and **signal**
- **Self contained package** of DC motor, gear reduction module, potentiometer, and controller.
- Control signal sets a desired position, and the internal controller supplies power to the motor until the desired position is reached based on the potentiometer sensor

Motors

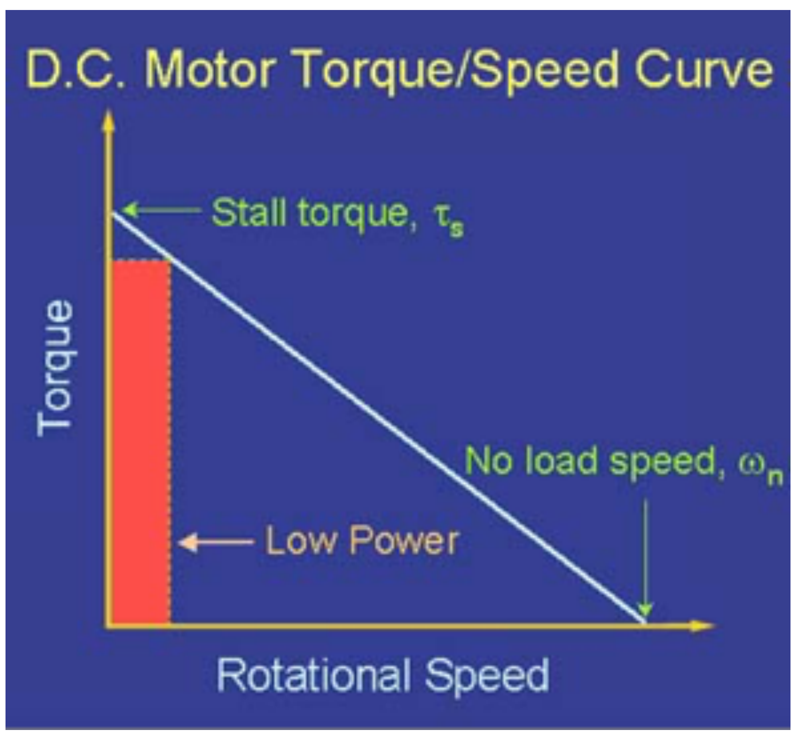
3) $\tau_{motor} = \tau_s - \omega\tau_s/\omega_n$

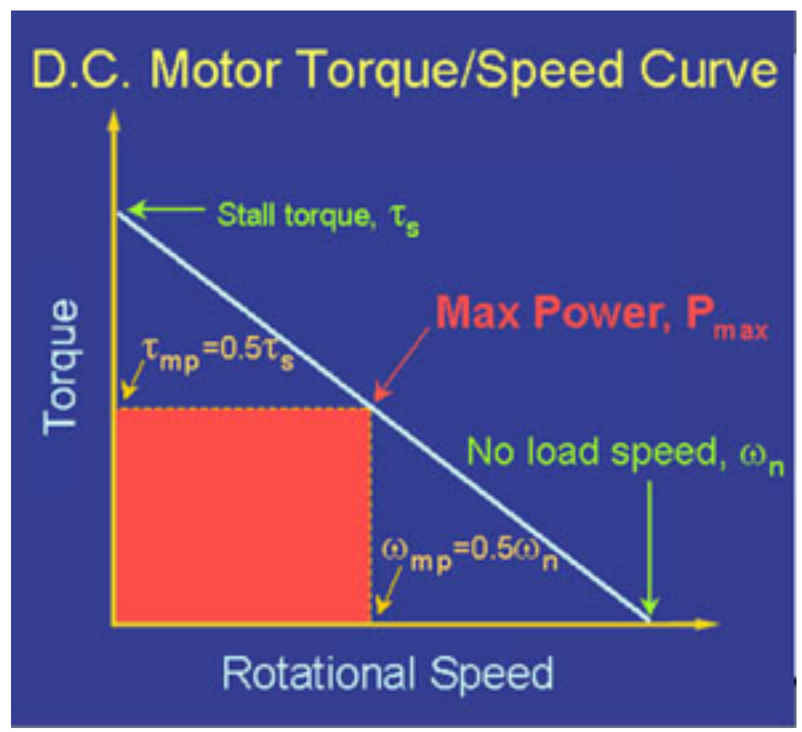
4) $\omega_{motor} = (\tau_s - \tau)\omega_n/\tau_s$

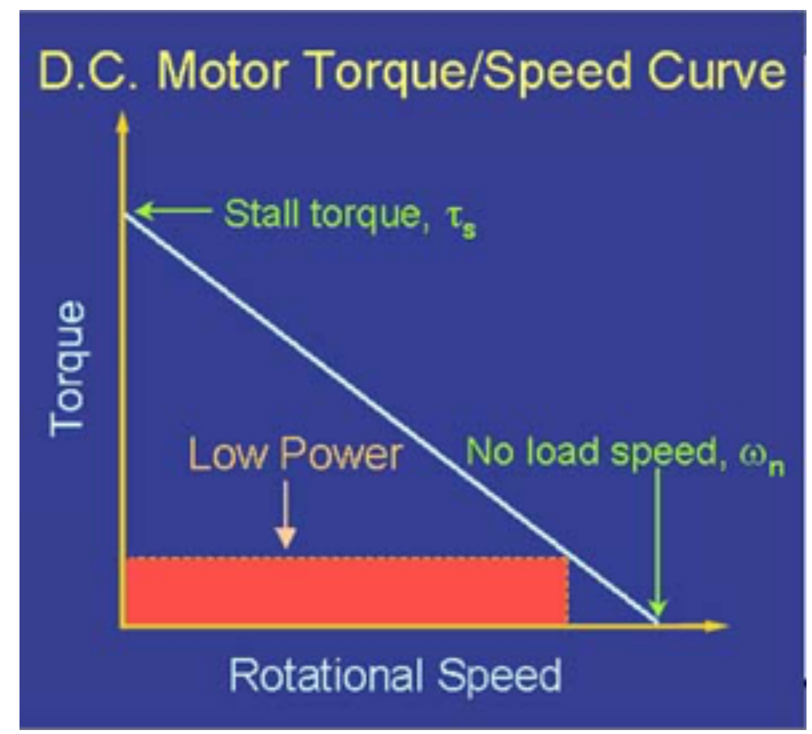


Motors

2) Power: $P_{rot} = \tau \cdot \omega$







Motors

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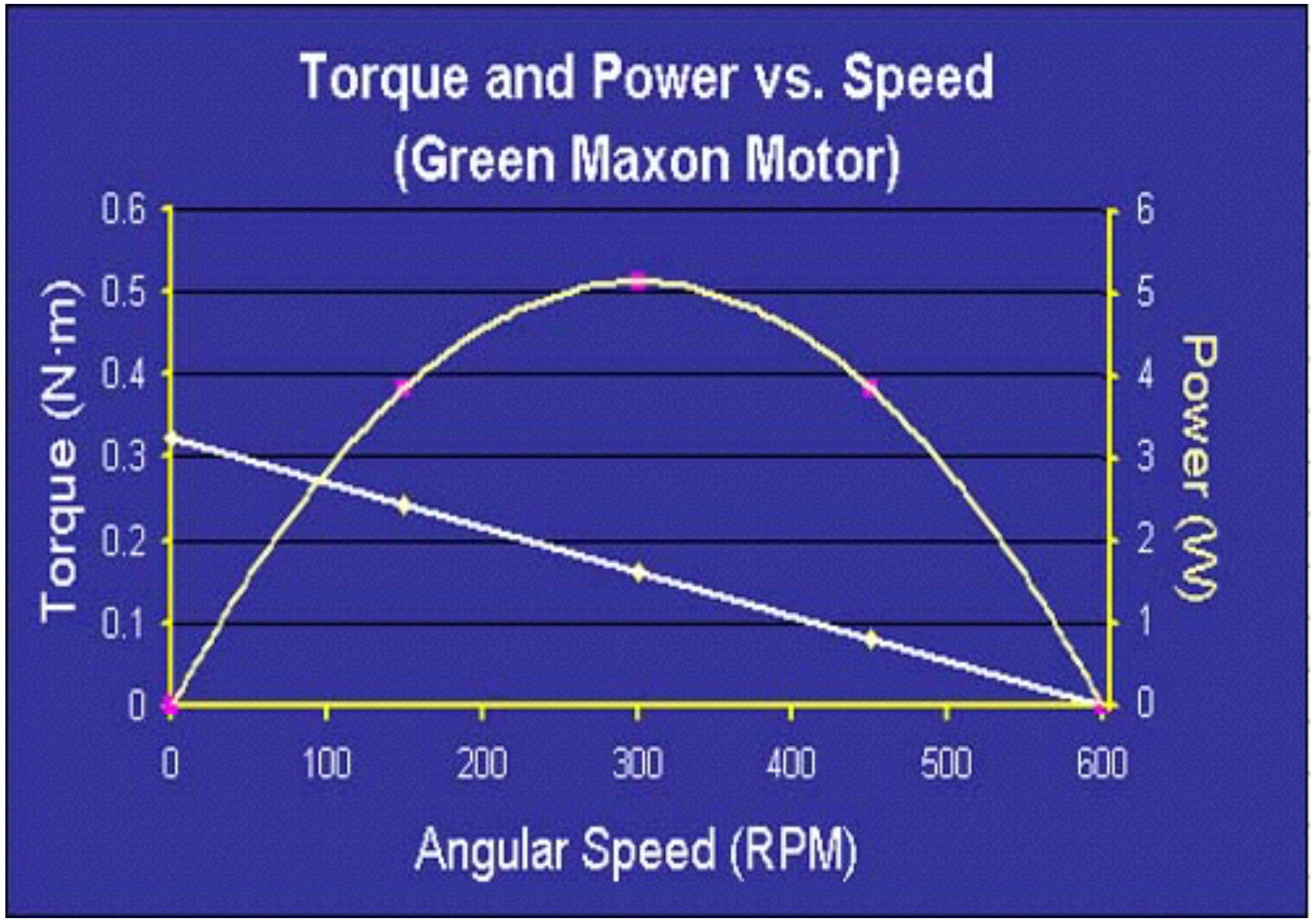
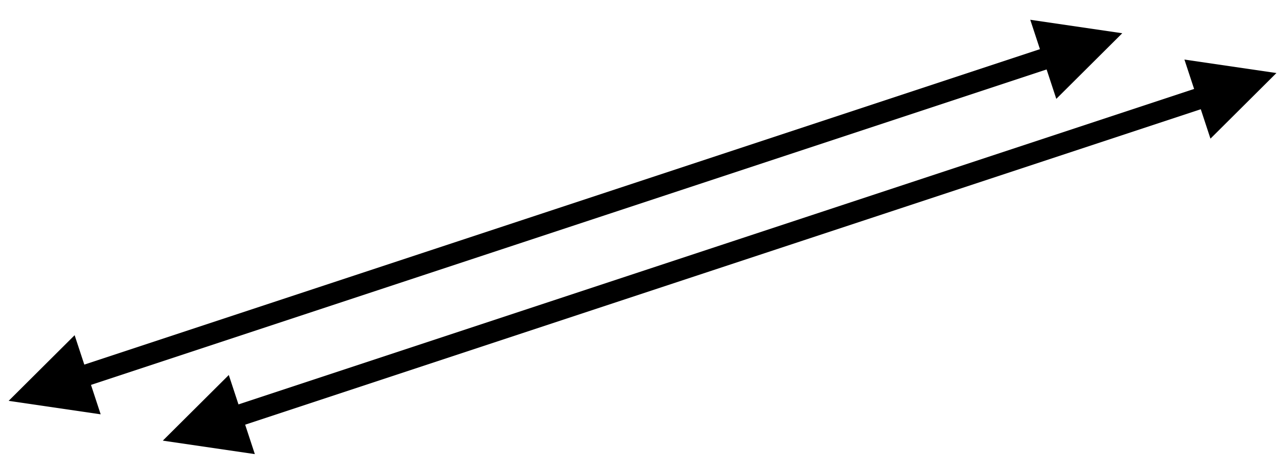
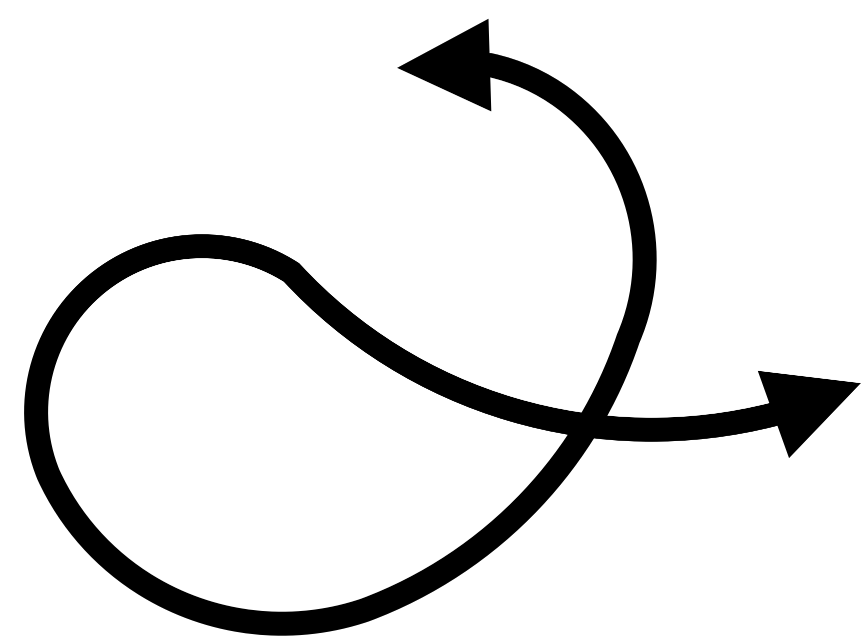


Types of Motion

- Rotational
- Linear
- Complex





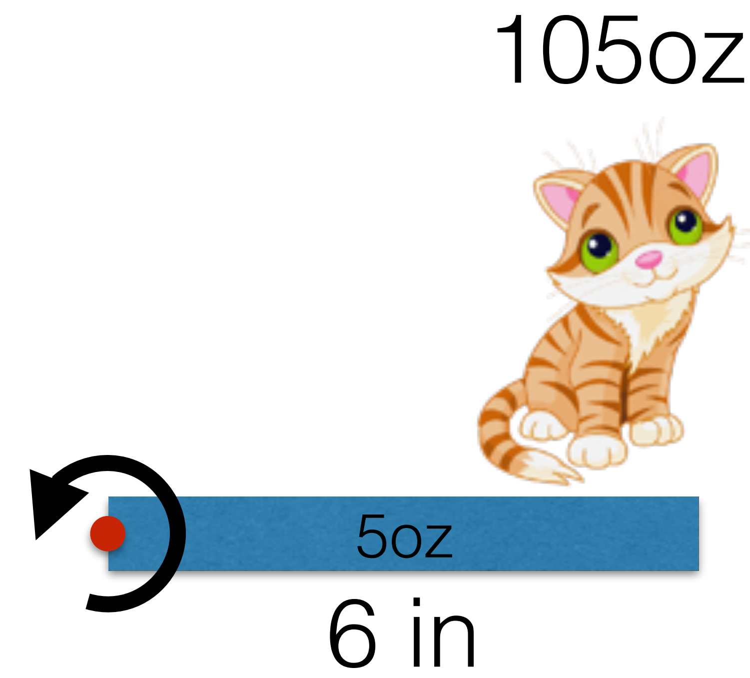
Rotational-Gears

Torque_motor*Velocity_motor = Torque_new*Velocity_new

NeveRest 60 Gearmotor (am-3103)

<u>Theoretical Performance Specs</u>:

- Gearbox Reduction: 60:1
- Voltage: 12 volt DC
- No Load Free Speed, at gearbox output shaft: 105 RPM
- Gearbox Output Power: 14W
- Stall Torque: 593 oz-in
- Stall Current: 11.5A
- Output counts per revolution of Output Shaft (cpr): 1680 Pulses



$$\overrightarrow{M_o} = \overrightarrow{r_{oF}} \times \vec{F}$$

$$\left|\overrightarrow{M_O}\right| = (\text{Force})\cdot(\text{Perpendicular distance})$$

M=(105oz*6in)+(5oz*3in)

M=645 oz*in

Rotational-Gears

Torque_motor*Velocity_motor = Torque_new*Velocity_new

291.5 oz*in*52.5 RPM = 645 oz*in*Velocity_new

Velocity_new= 23.73 RPM

gear ratio = (Torque_new/Torque_motor)

gear ratio =645 oz*in/ 291.5 oz*in

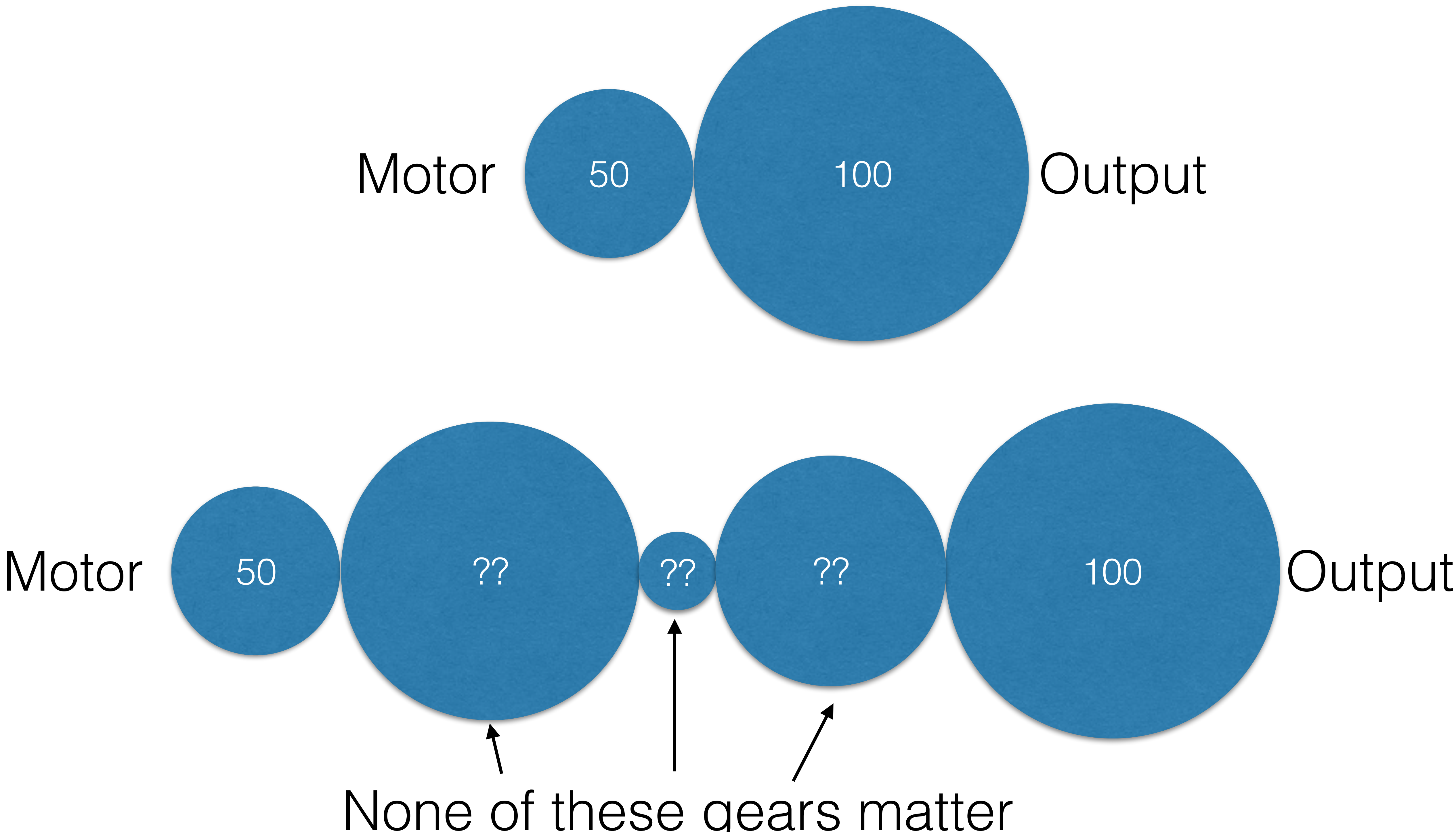
gear ratio ~= 2.2

gear ratio = (Torque_new/Torque_motor)* inefficiency

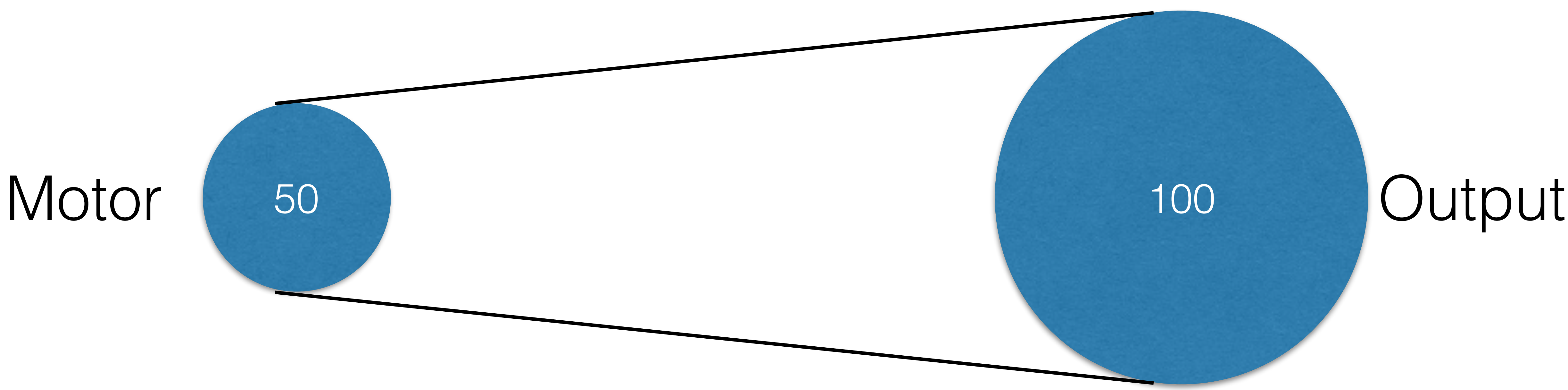
gear ratio =(645 oz*in/ 291.5 oz*in)*.9

gear ratio ~=2

Rotational-Gears



Rotational-Belts/Chains



Keep in mind you will get different efficiencies from chains, belts, and gears

Rotation-Wheels

- Drive Trains
  - 2 Wheel Drive
  - 4 Wheel Drive(Tank)
  - 5 Wheel Drive (Slide
  - 6+ Wheel Drive
  - Holonomic
- Manipulating Game Obje
  - Floor Roller Single
  - Floor Roller Double
  - Rollers
  - Conveyors

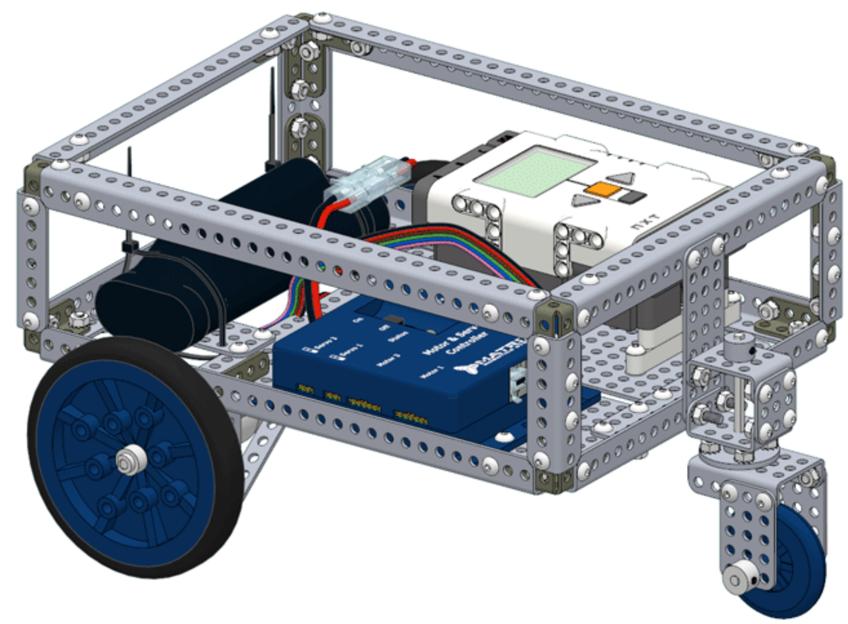
Drives Trains-2 wd

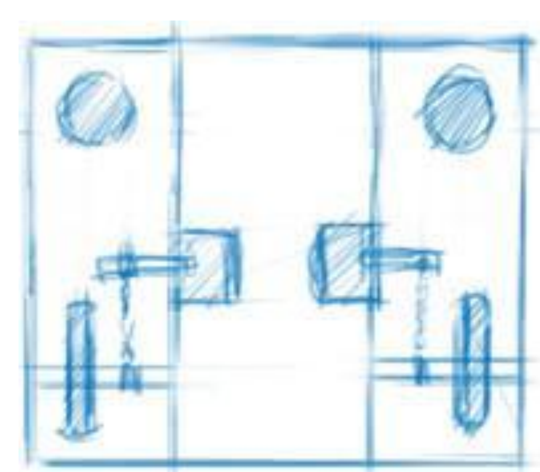
- Two Powered Wheels with a Caster/Omni wheel on end

- Difficult to drive

- Highly Maneuverable

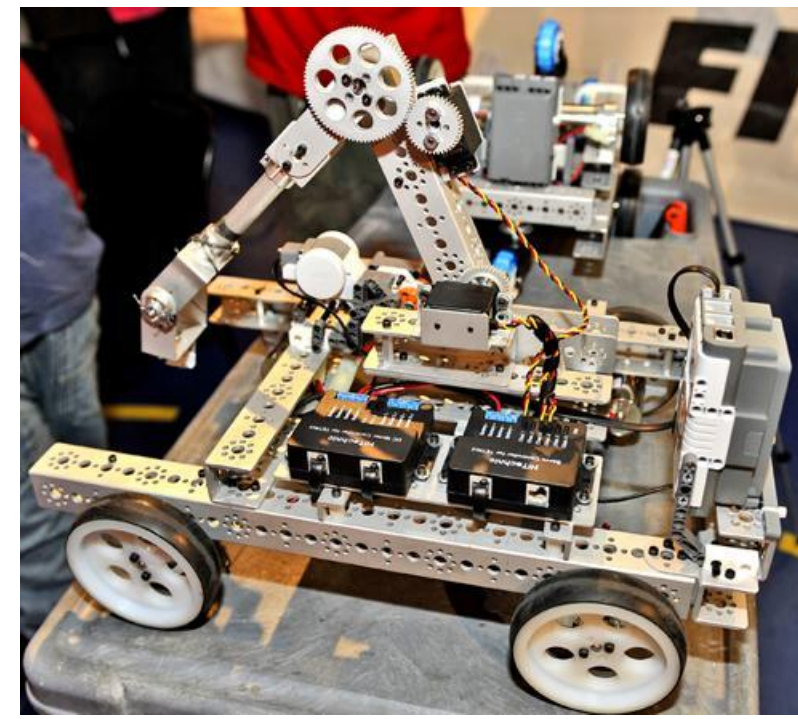
- Easy to be pushed

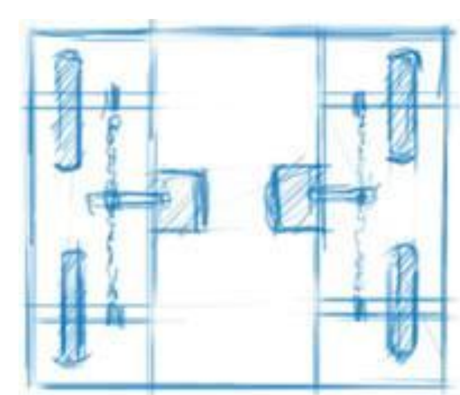




Drives Trains-4 wd

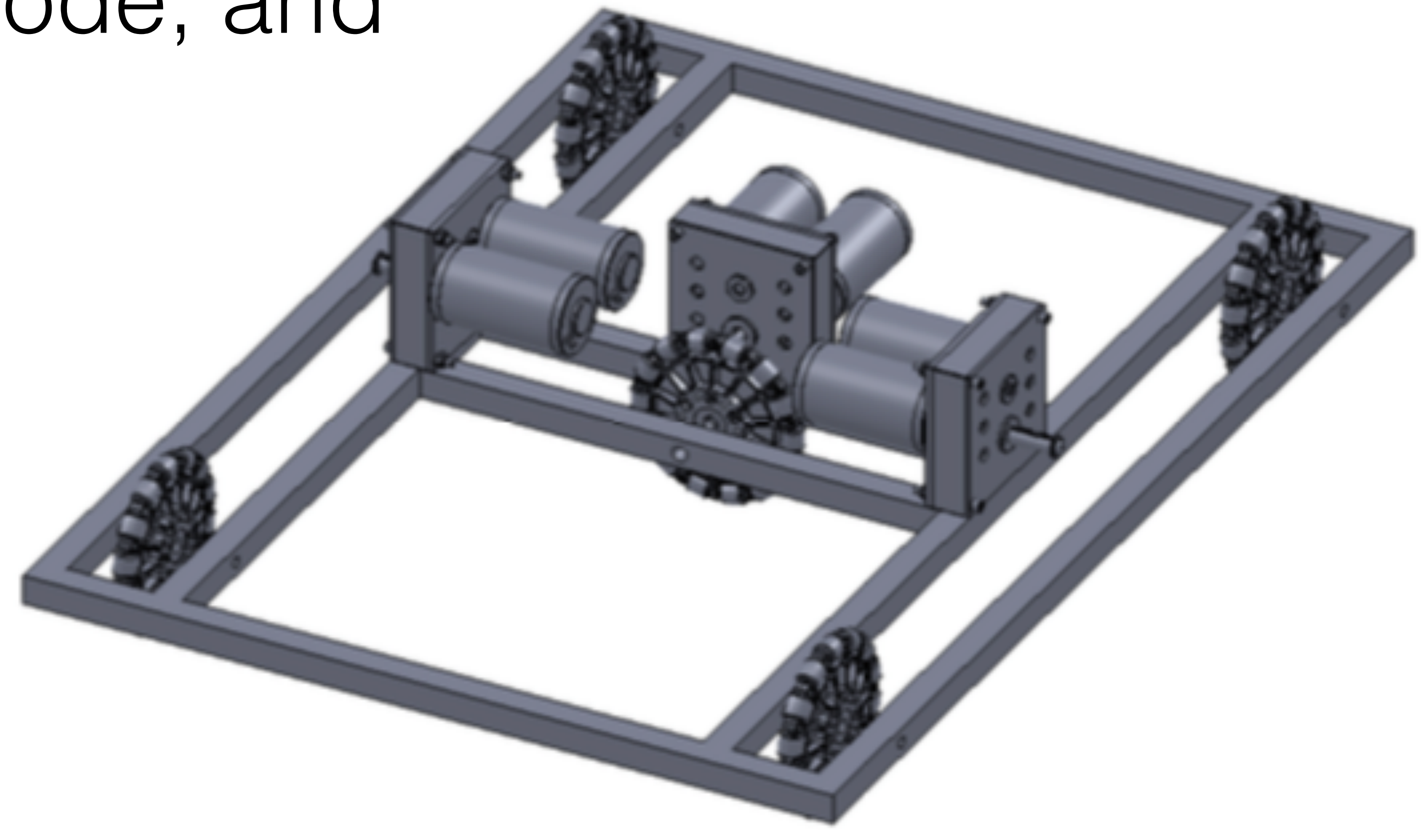
- Four Powered Wheels
- Easy to drive
- Less Maneuverable, forced to deal with skid forces when turning
- Difficult to push
- Easy to balance weight





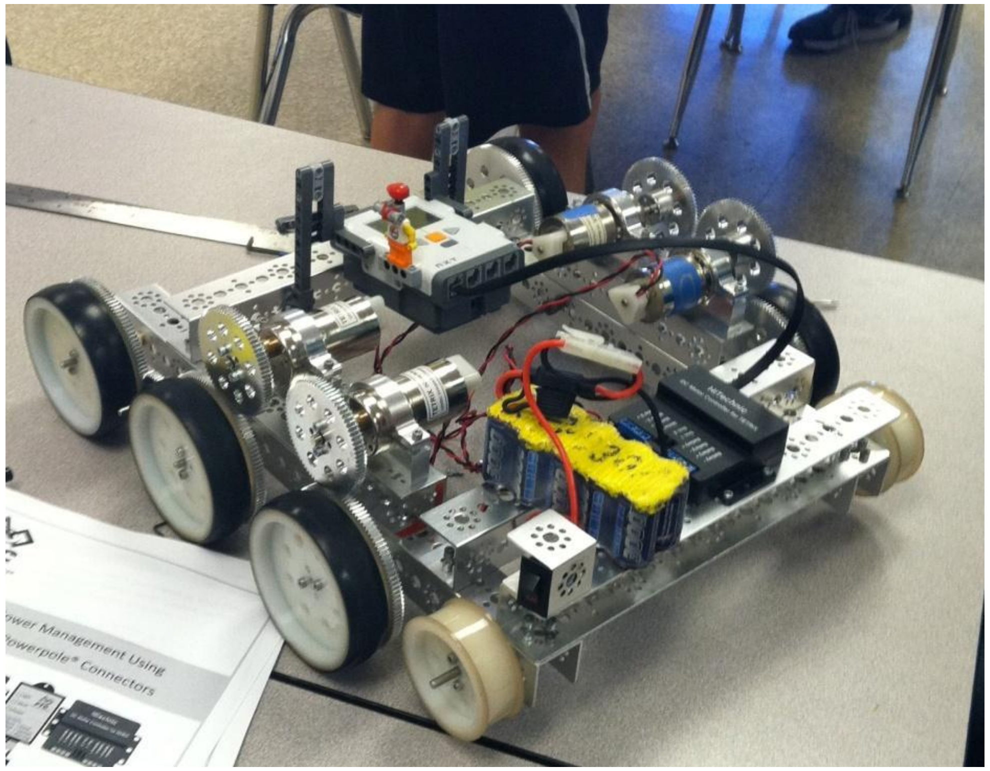
Drives Trains-5 wd

- Five Powered Wheels
- More complex to build, code, and drive
- Easy to push around
- Easy to balance weight



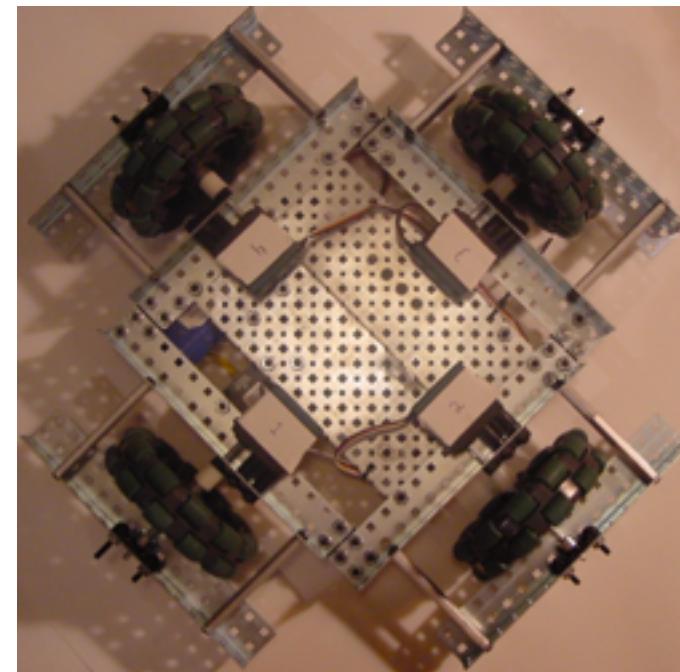
Drives Trains-6+ wd

- Six or more Powered Wheels
- Drop center wheel increases maneuverability
- Difficult to push
- Easy to balance weight
- Easy to drive



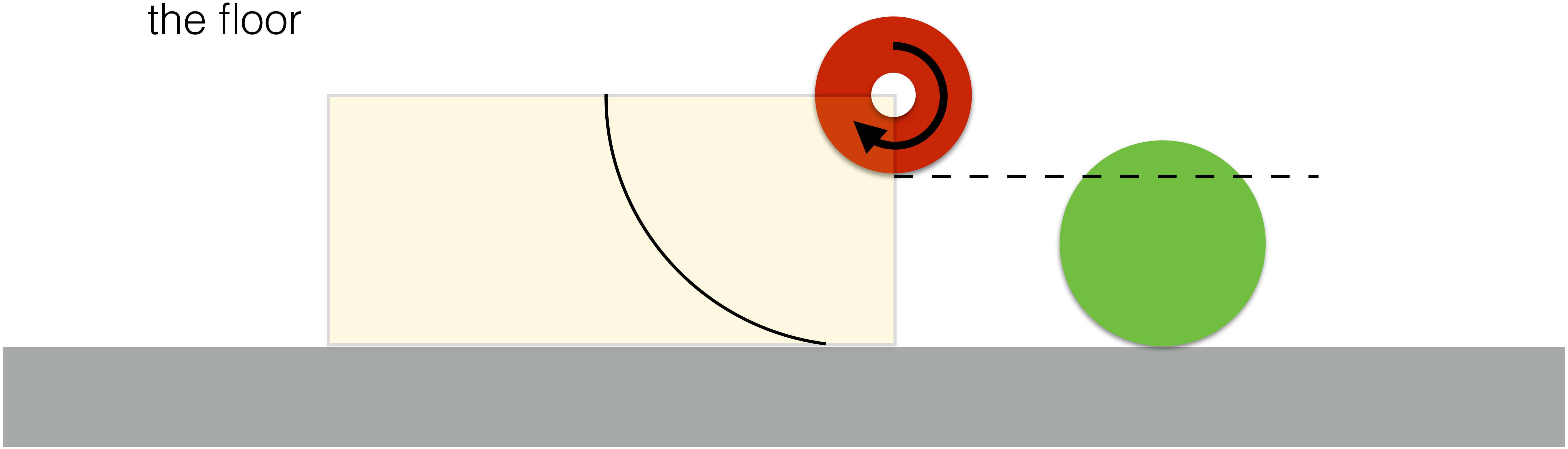
Drives Trains- Holonomic

- Four Powered Wheels
- Maximum maneuverability
- Difficult to code and drive
- Easy to push
- Complex design



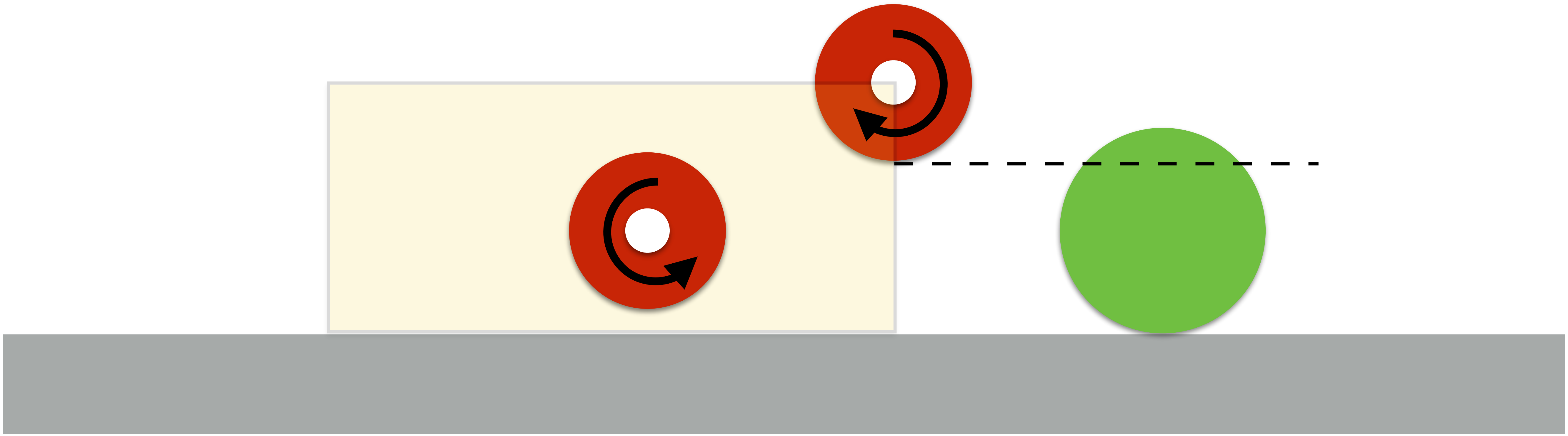
Floor Roller-Single

- Simple
- Single Motor
- Requires additional mechanism to lift
- Effective for dumping balls back onto the floor

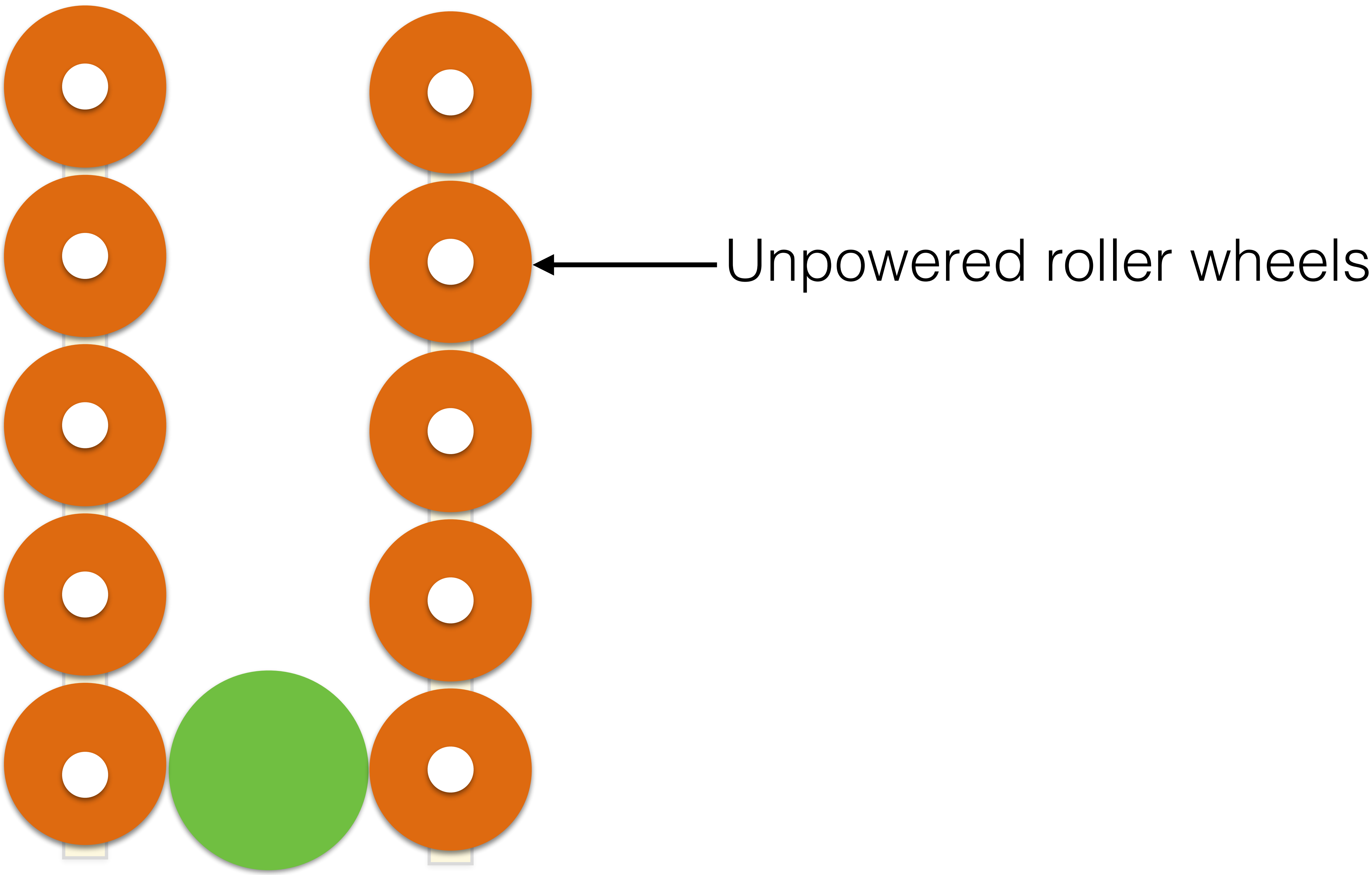


Floor Roller-Double

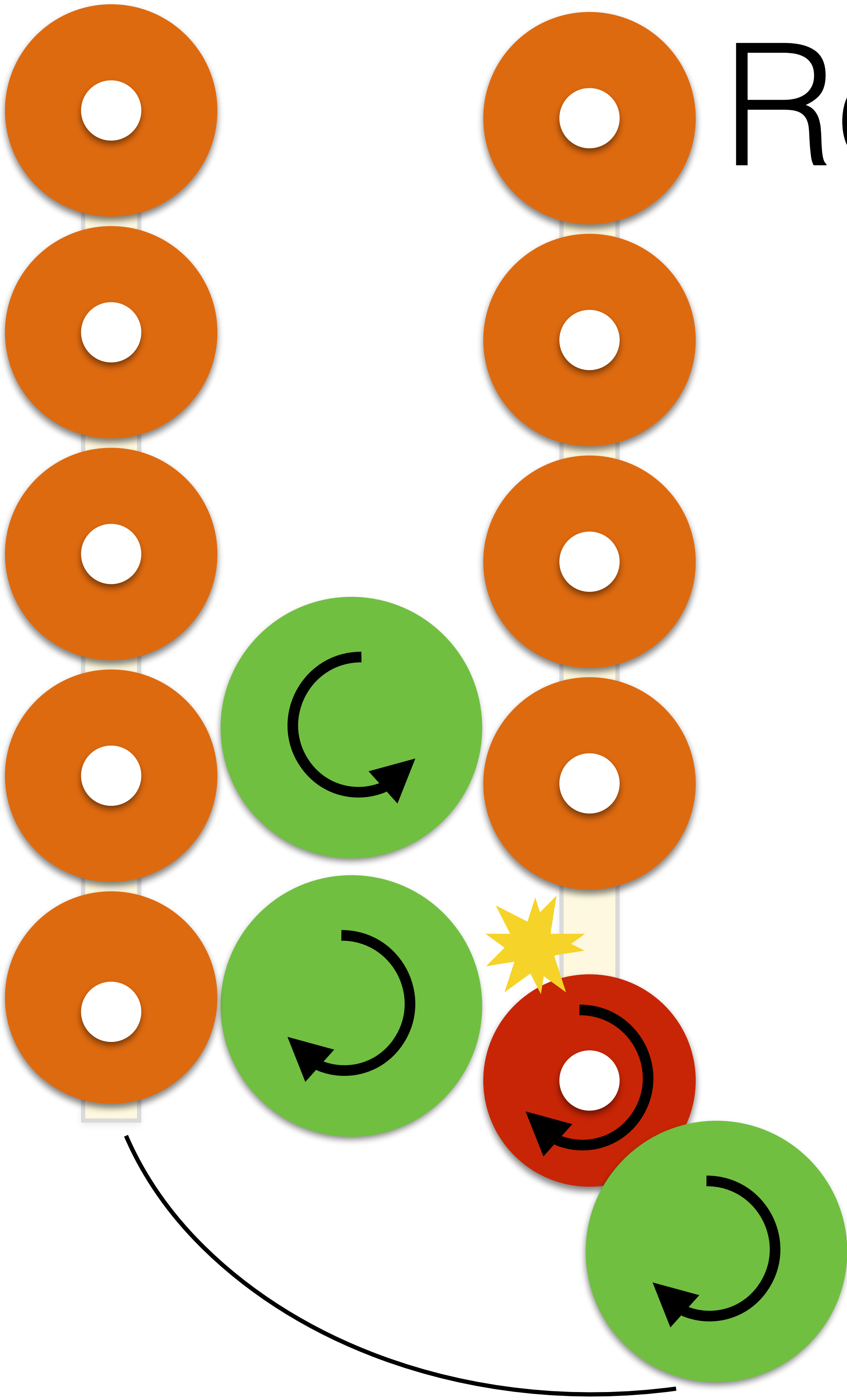
- Double Motor
- Single motor with more mechanics
- Can be effective at exposing of balls
- More space needed over the single



Rollers



Rollers



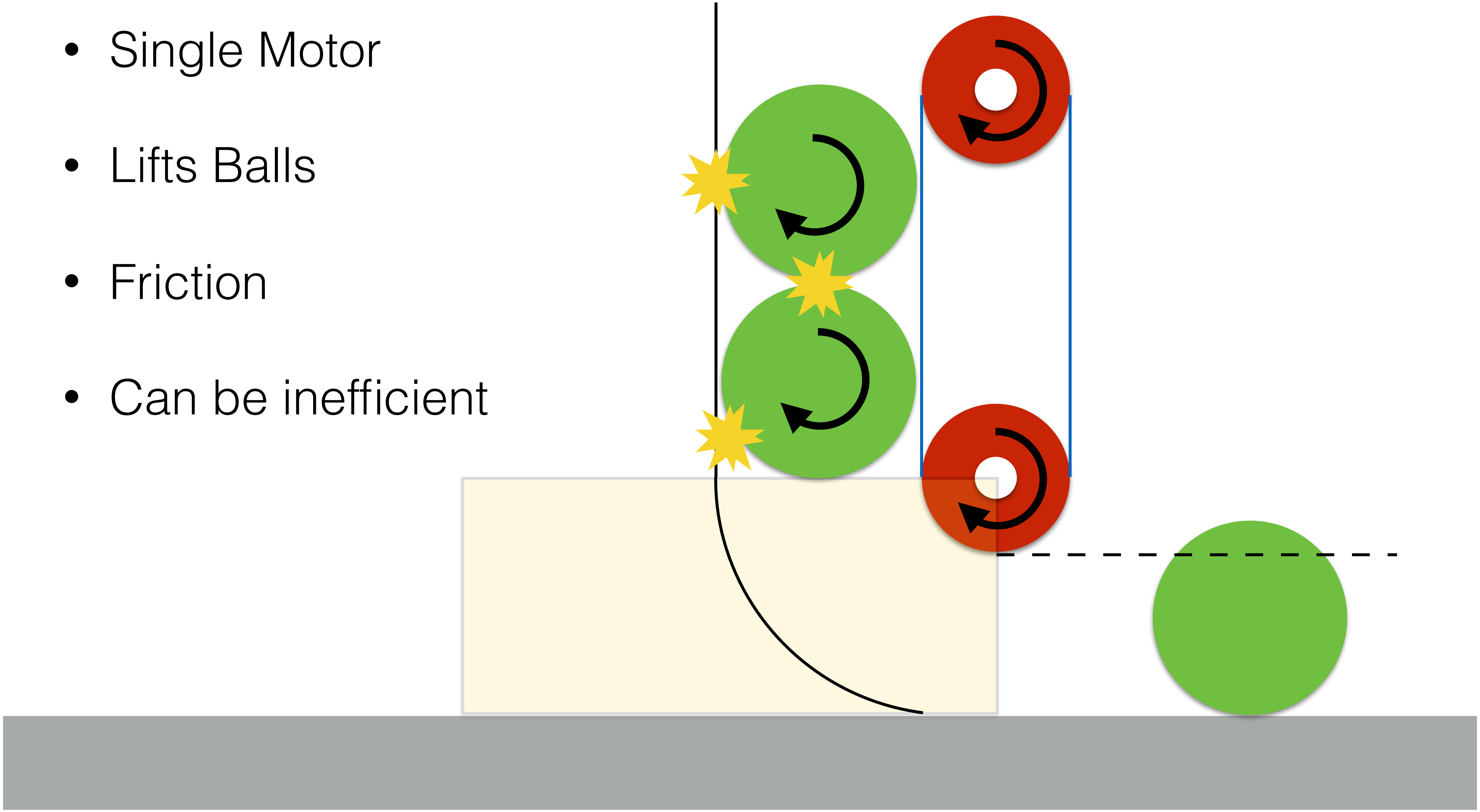
Team 1902- 2006

Rotation-Belts/Conveyors

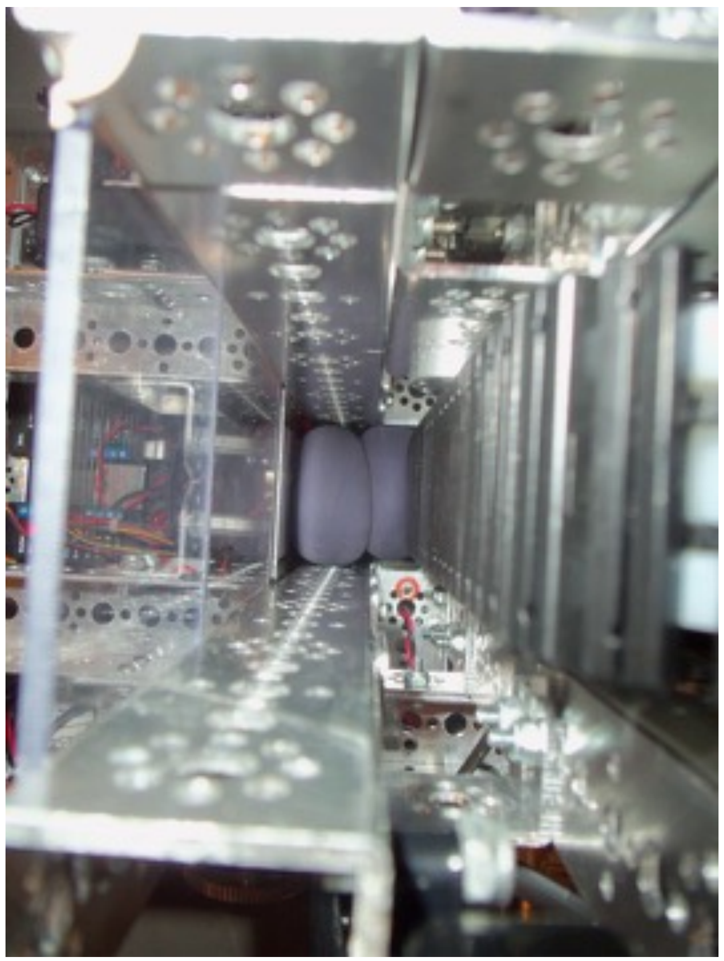
- Manipulating Game Objects
  - Single Belt/Conveyor
  - Double Belt/Conveyor

Conveyor-Single

- Single Motor
- Lifts Balls
- Friction
- Can be inefficient



Conveyor-Single



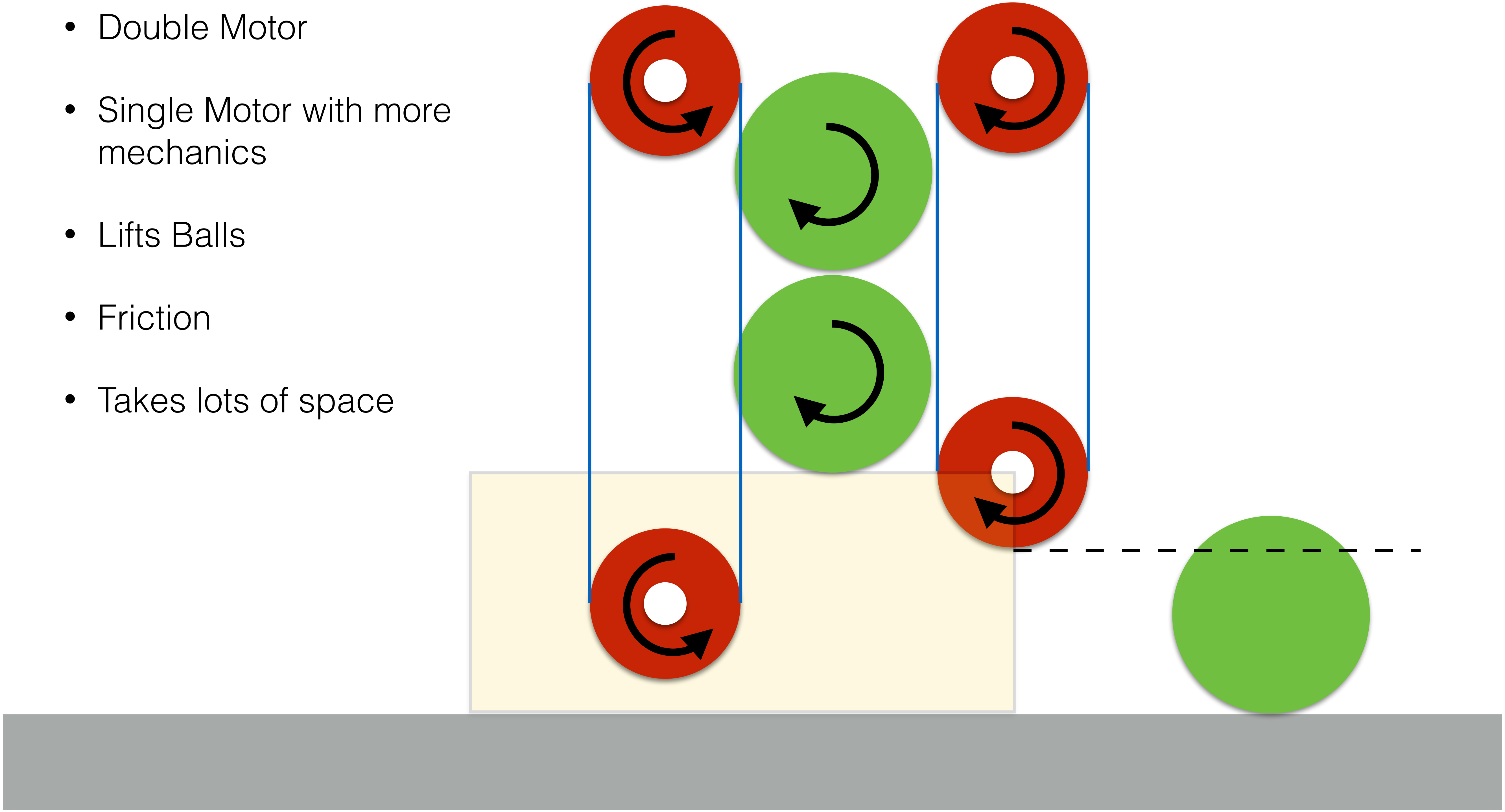
Team 5454

Team 254- 2006

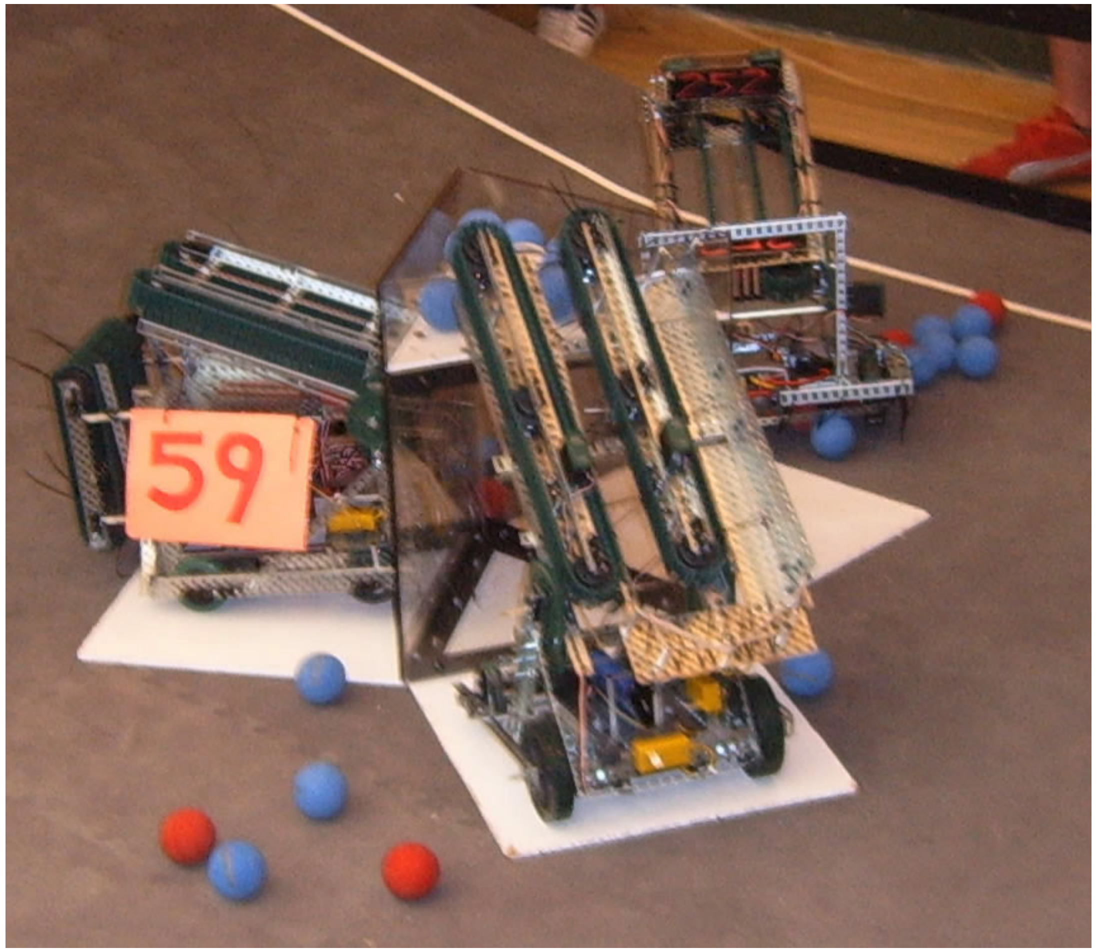
Team 173- 2002

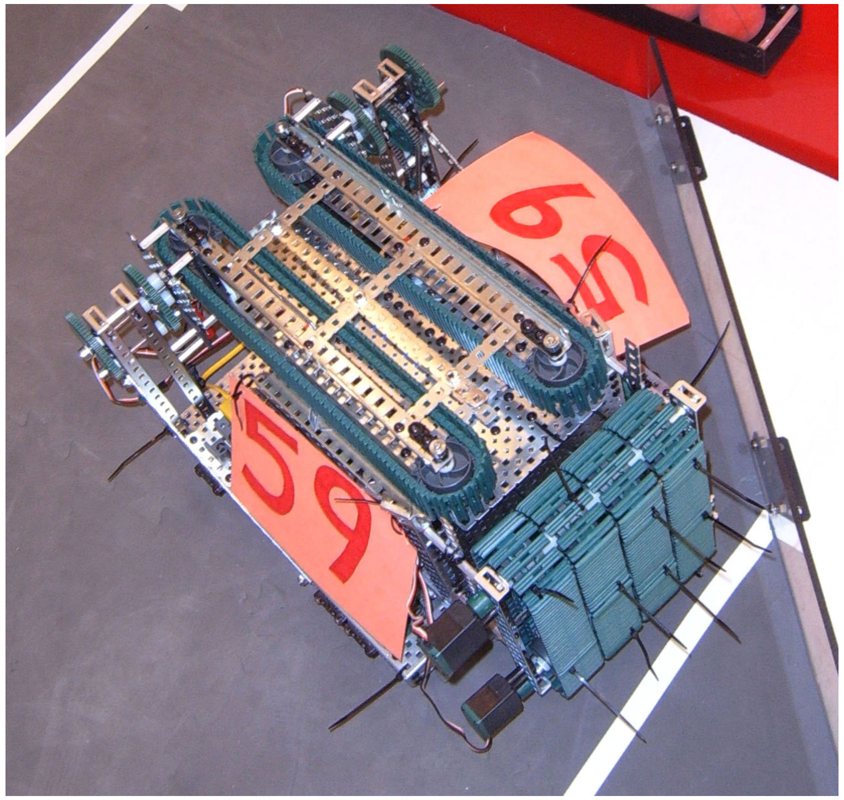
Conveyor-Double

- Double Motor
- Single Motor with more mechanics
- Lifts Balls
- Friction
- Takes lots of space



Conveyor-Double





FVC-2005-2006

Rollers vr. Conveyors

Roller

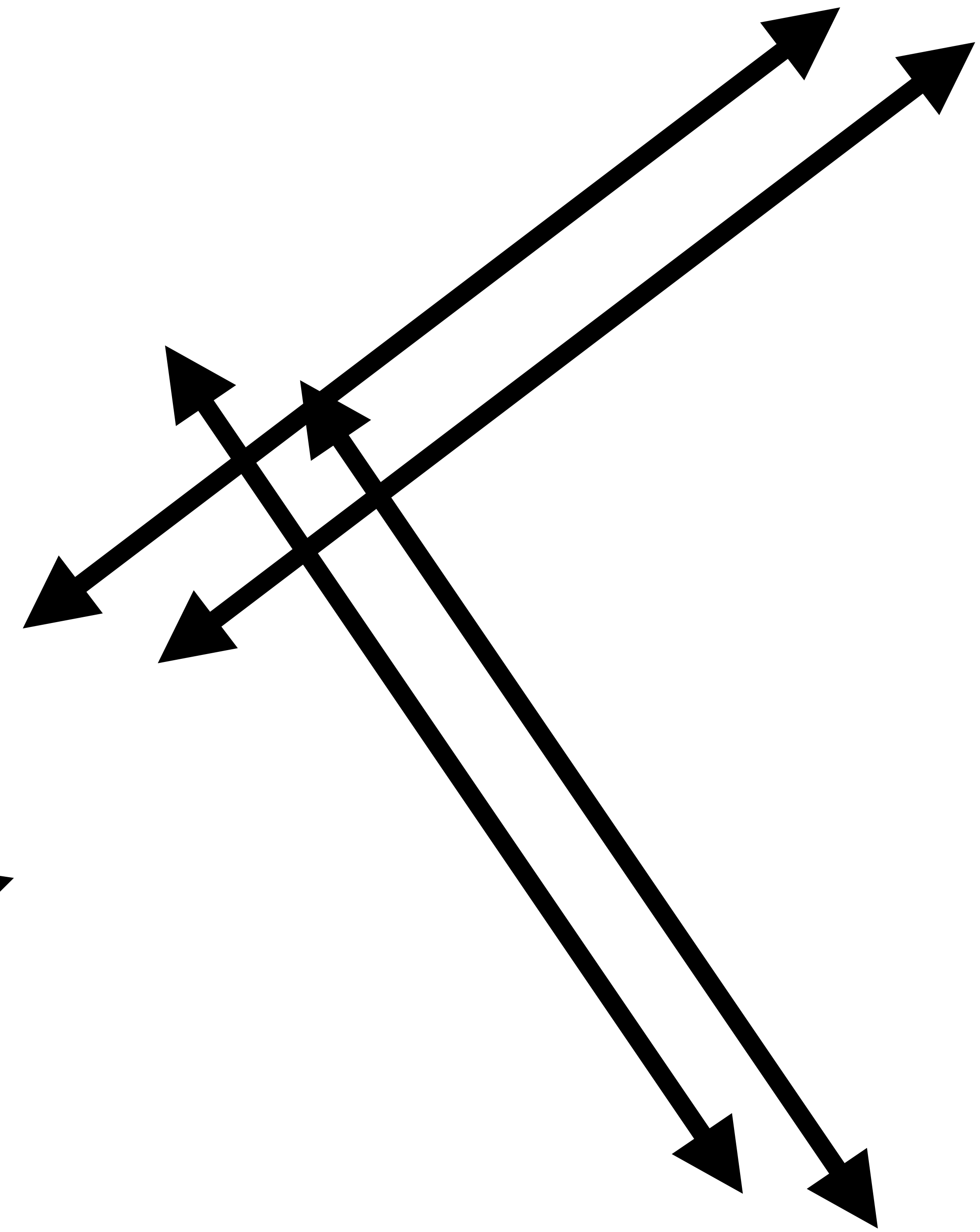
- Less Friction
- Lift from the bottom
- Difficult to get tall stacks
- Deploy to floor

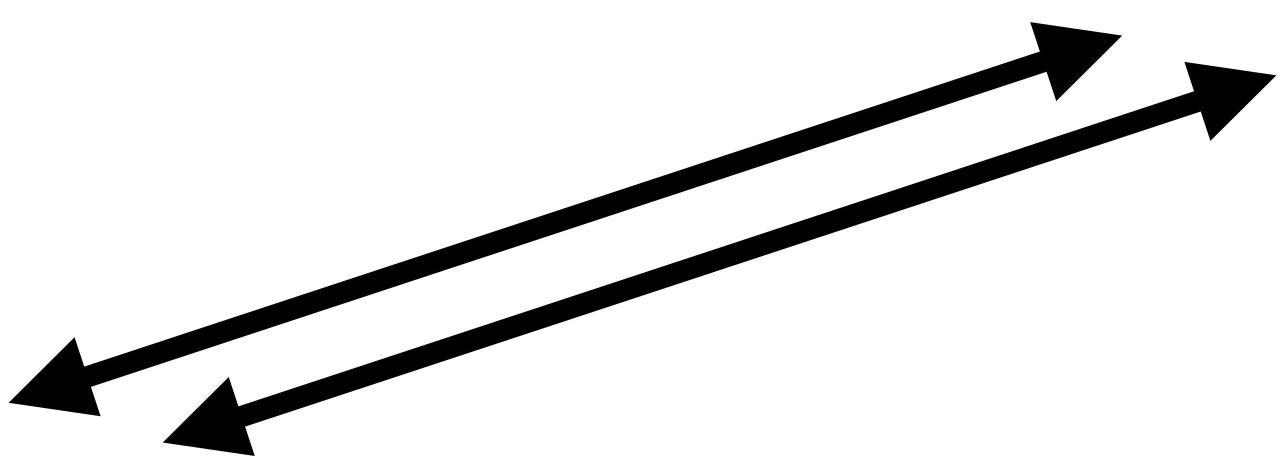
Conveyors

- More Friction
- Lift full height
- Requires high torque
- Deploy at height

Linear Motion

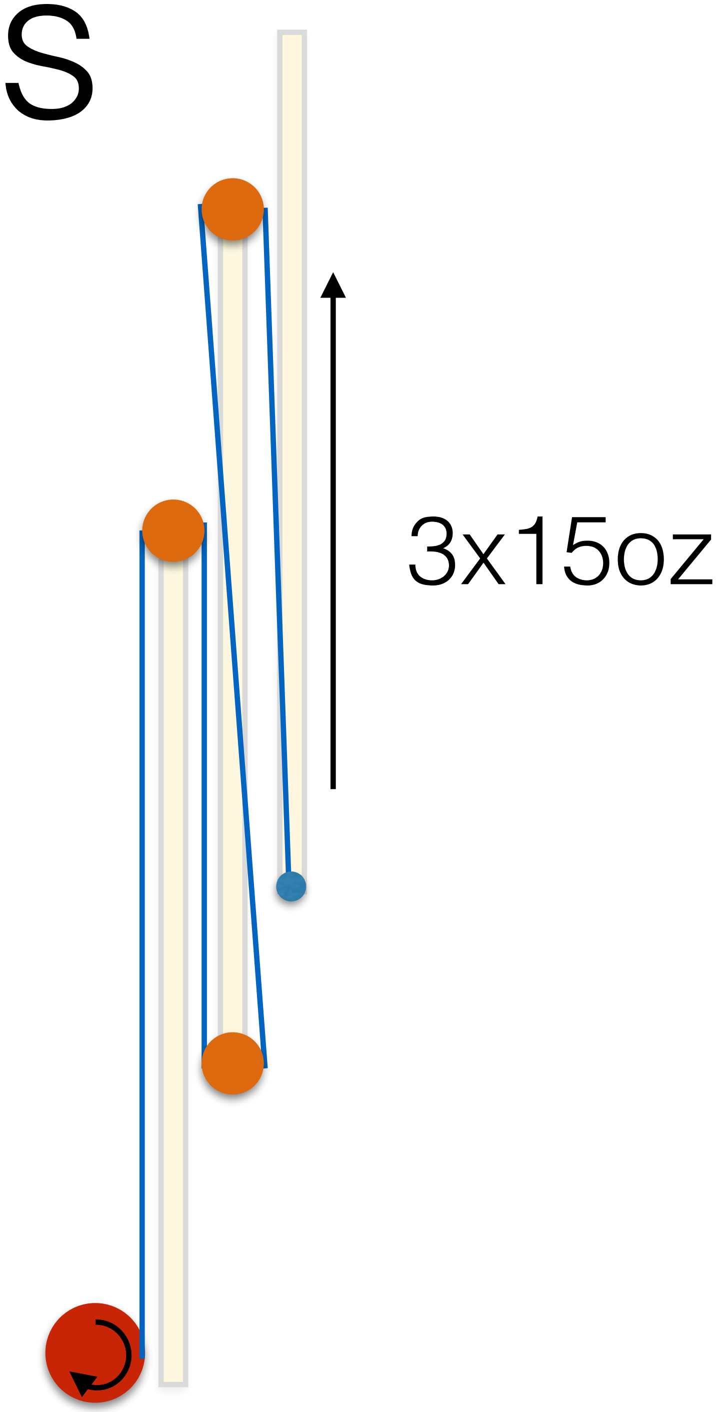
- Pulleys
- Rack and Pinion
- Linkages





Linear- Pulleys

- Telescoping boons/arms
- Motor torque is based on the tension in the cable
- Lots of power lost to friction



Tension=Friction*number of stages*total moving weight
Motor_torque= Tension* radius of pulley

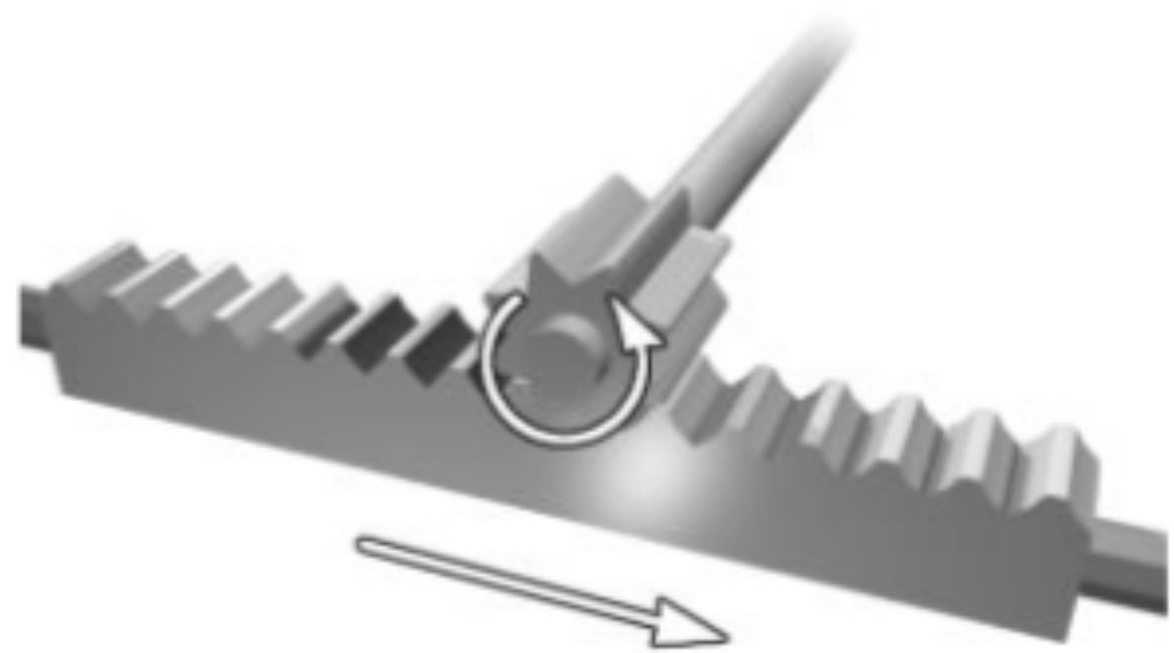
Linear- Rack and Pinion

- Simular to a linear gear
- Rotating the pinion moved the rack up and down
- Force calculation:

F=Torque/ Radius

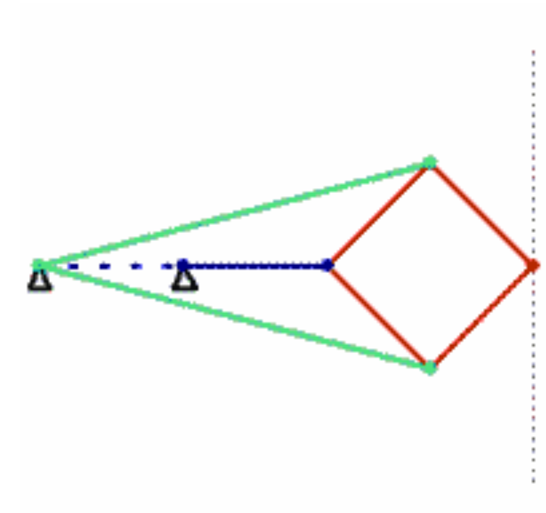
- Velocity calculation:

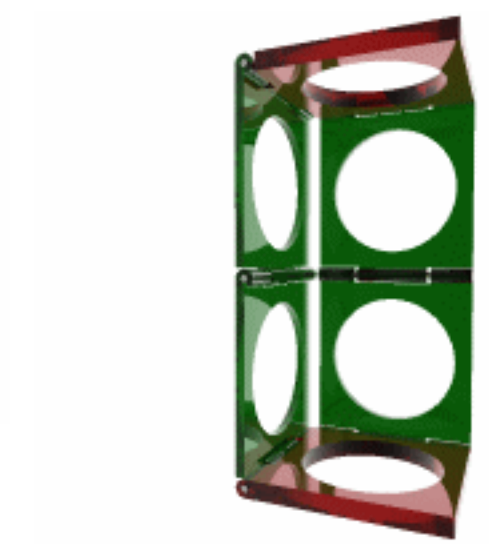
V=V_angular*Diameter*pi

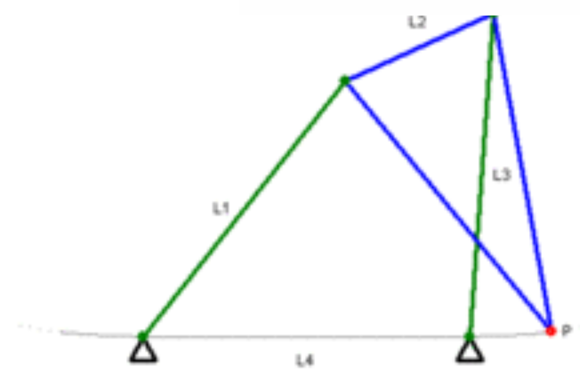


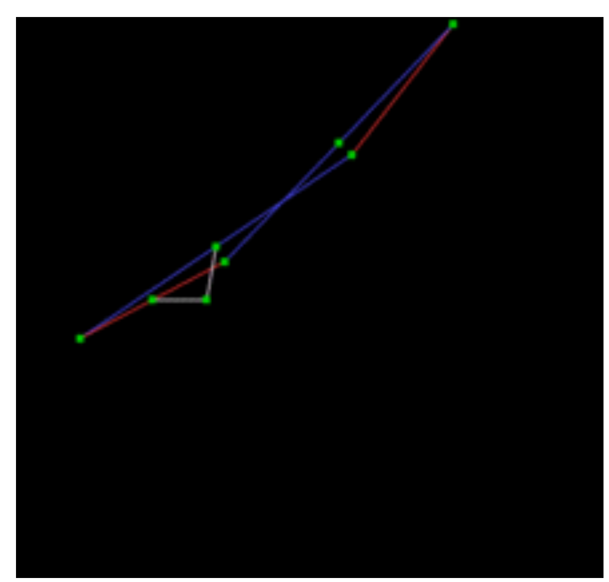
Linear-Linkages

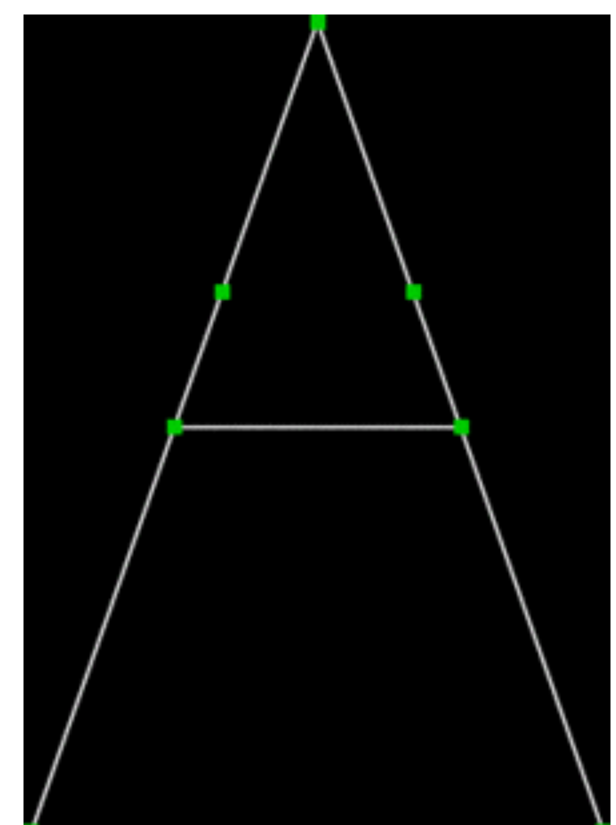
- Scissor Lift
- Peaucellier-Lipkin linkage
- Saris linkage
- Roberts linkage
- Hart's Inversor/A-frame





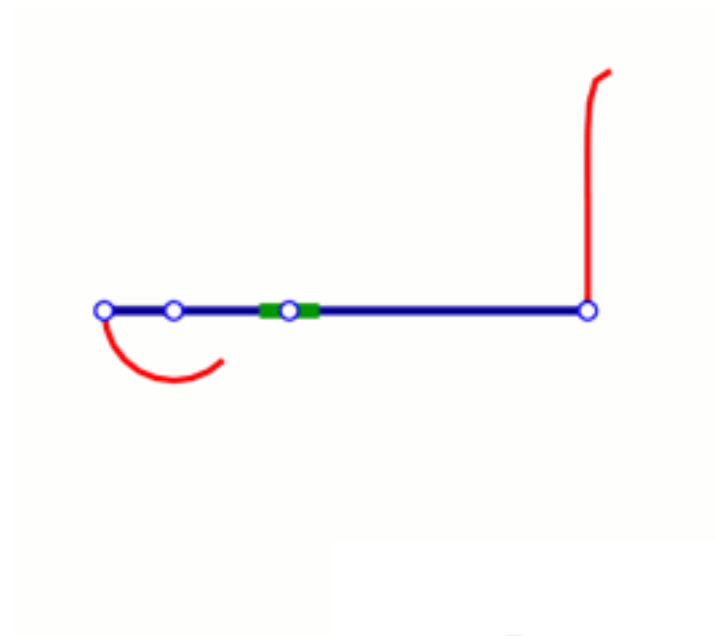


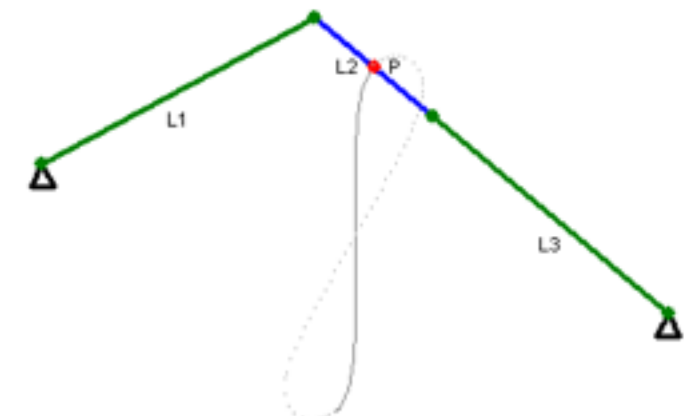


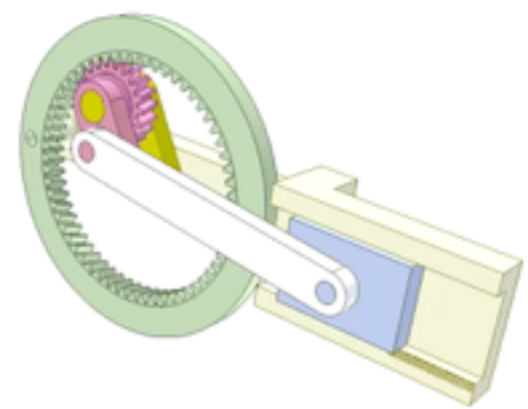


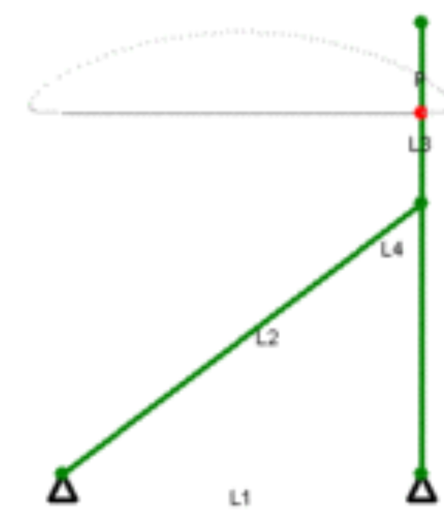
Linear-Linkages 2

- Chebyshev linkage
- Watt's linkage
- Hoefkens linkage
- Level luffing crane
- Slider Crank



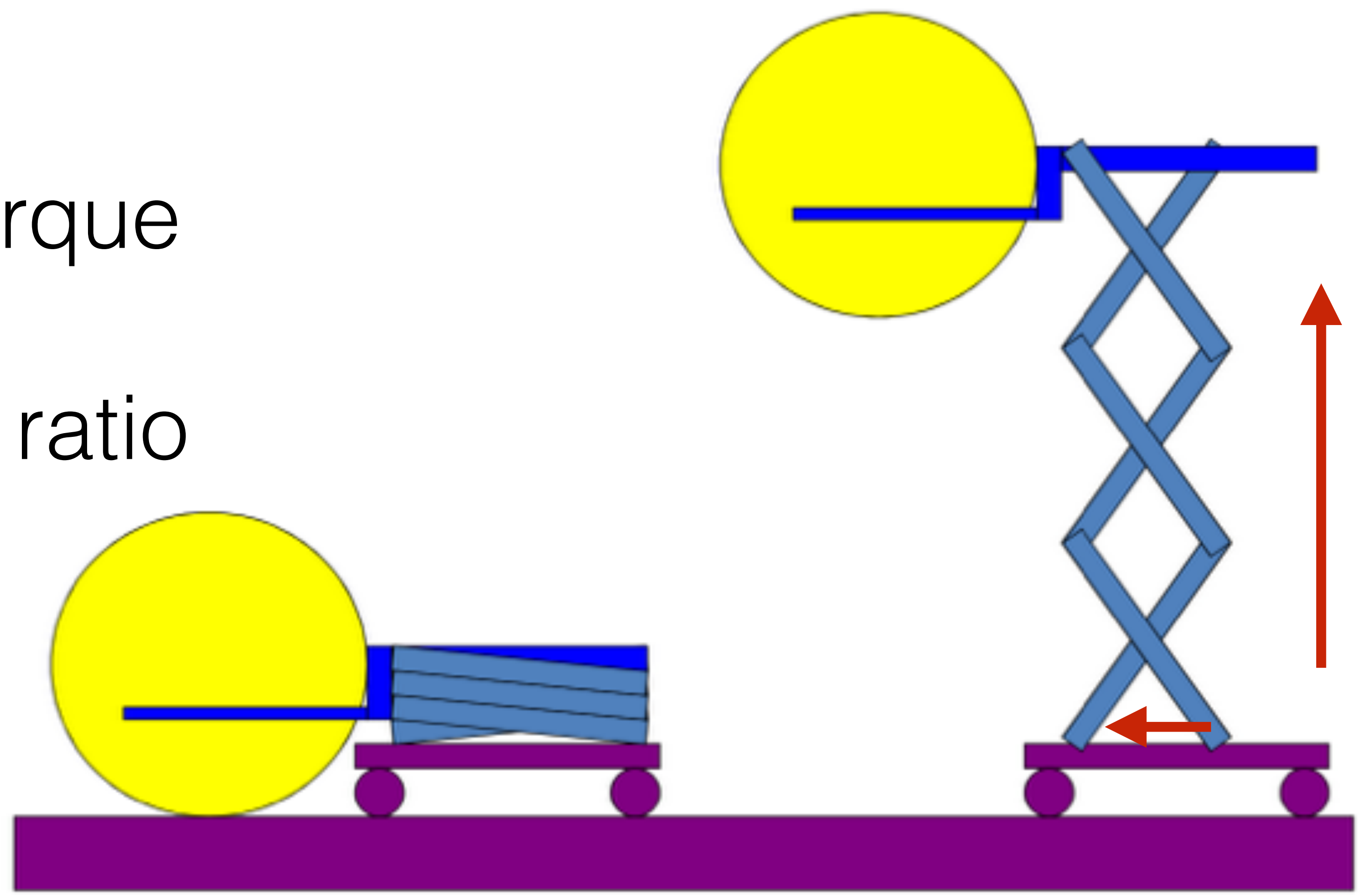




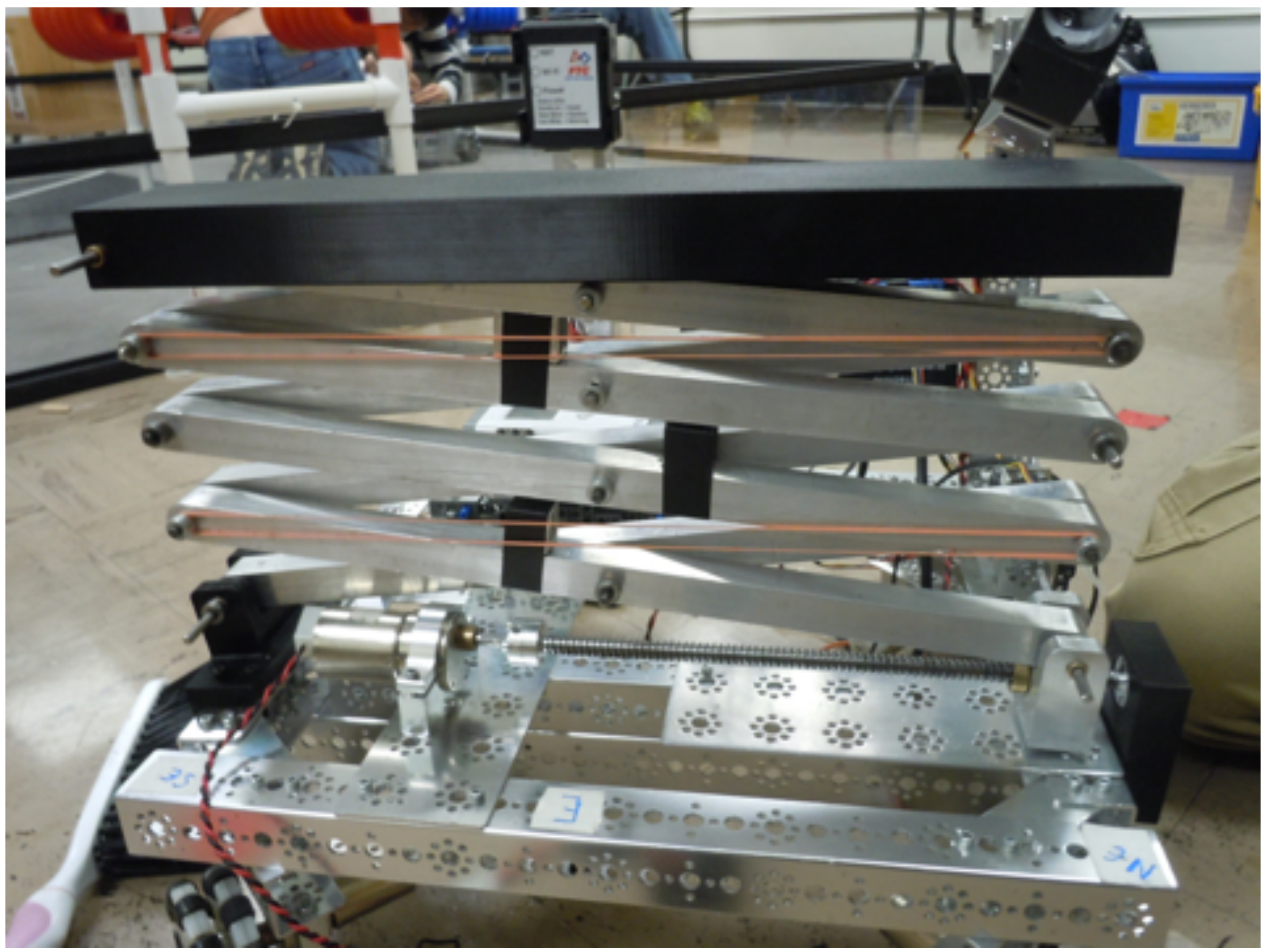


Linear-Scissor Lift

- Tend to be heavy
- Doesn't deal well with side loads
- Requires a lot of torque
- Size to height gain ratio is good

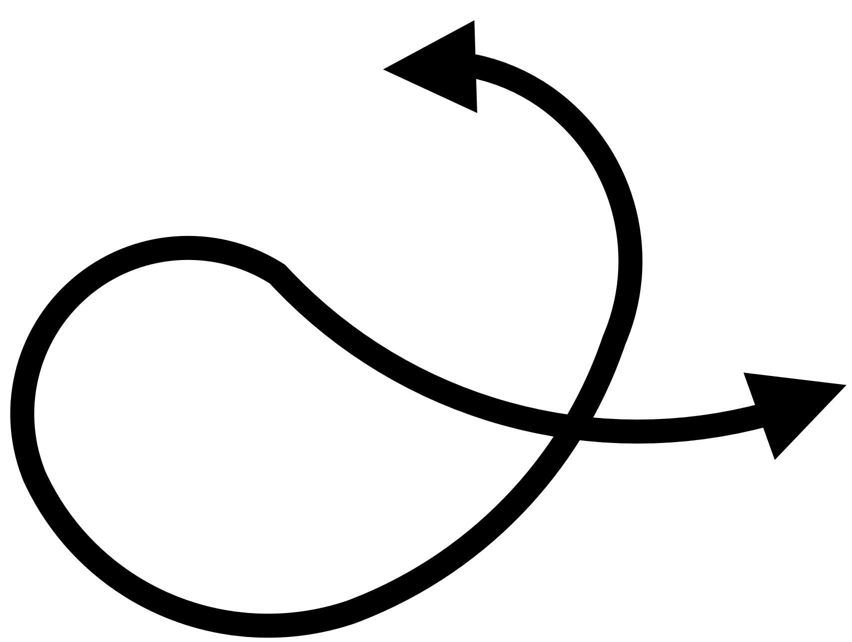


Linear-Scissor Lift



Complex Motion

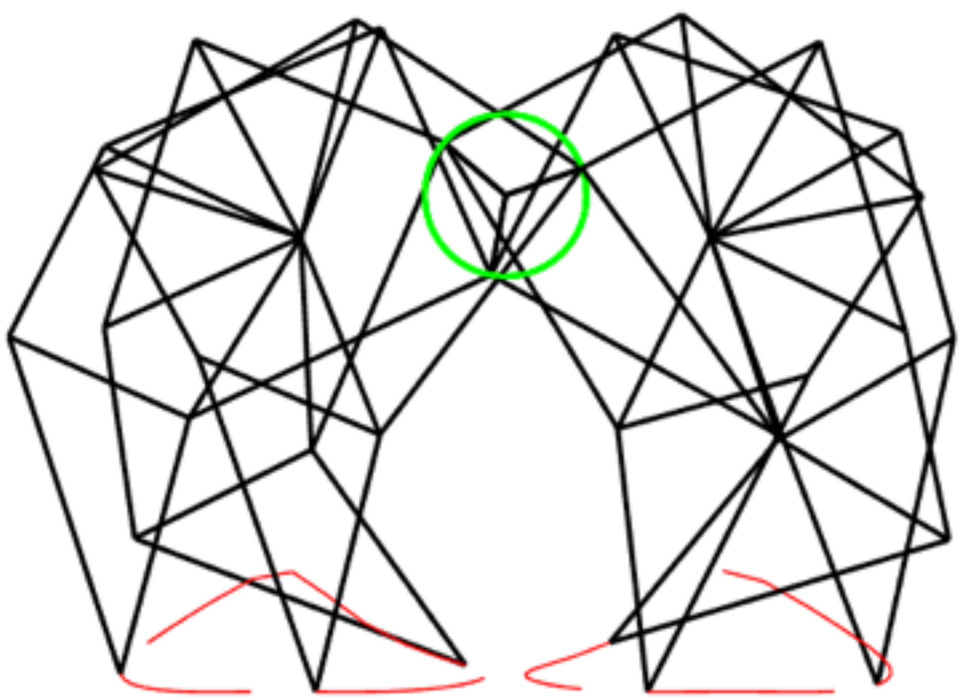
- Screws
- Linkages
- Cams

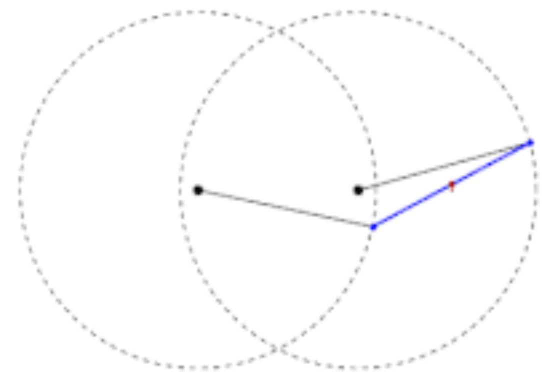


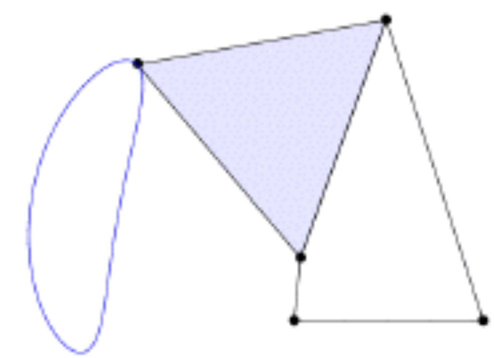
Complex-Screws

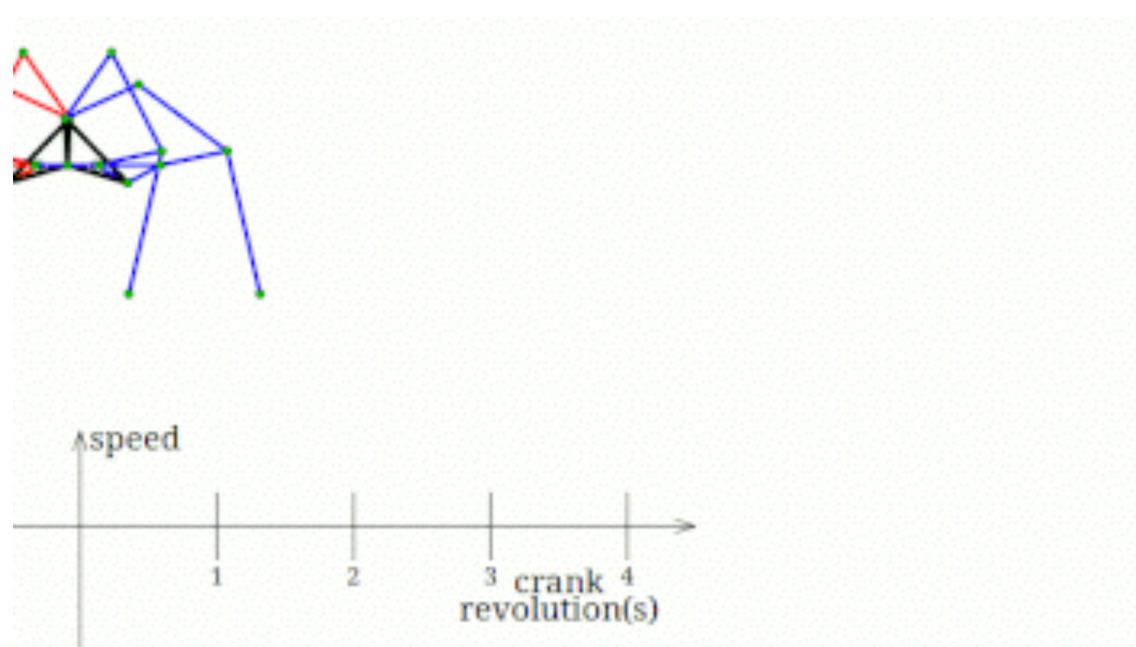
- Combine rotational and linear motion
- Can be a simple way to move game objects upward

Complex-Linkages







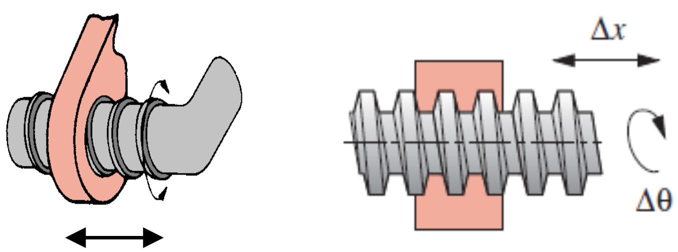


Linkages

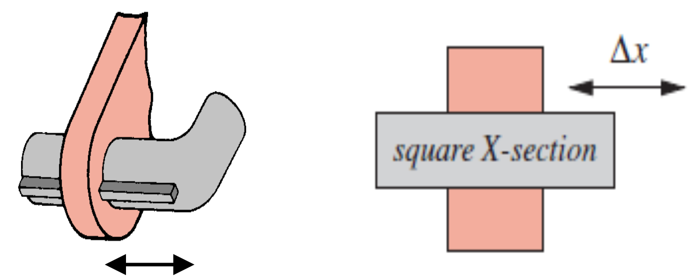
- The simplest Mechanism is a lever and fulcrum. This lever is a link.
- A linkage is a system of links connected through a series of joints

- These links can have as many nodes as desired

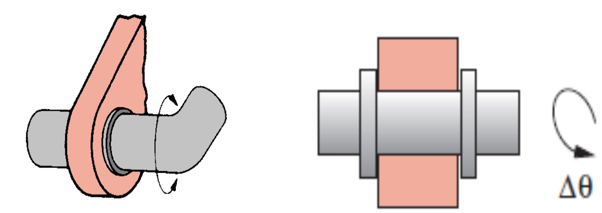
Types of Joints



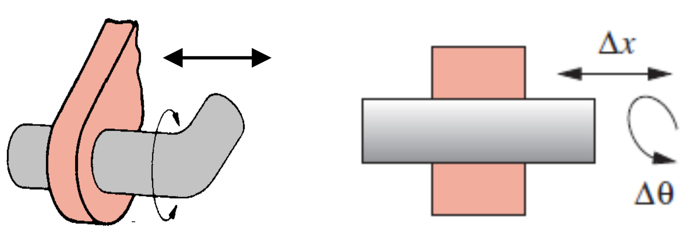
Helical (H) joint



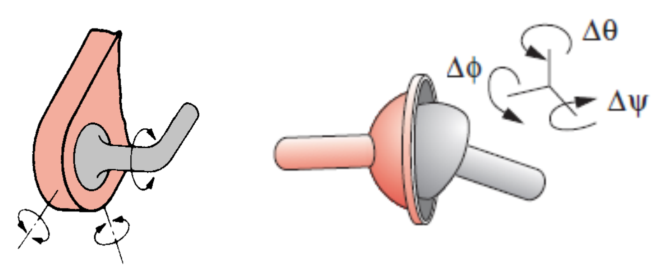
Prismatic (P) joint



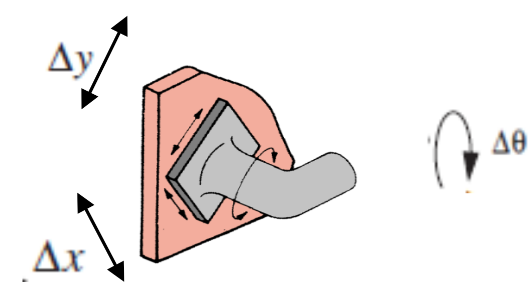
Revolute (R) joint



Cylindrical (C) joint



Spherical (S) joint

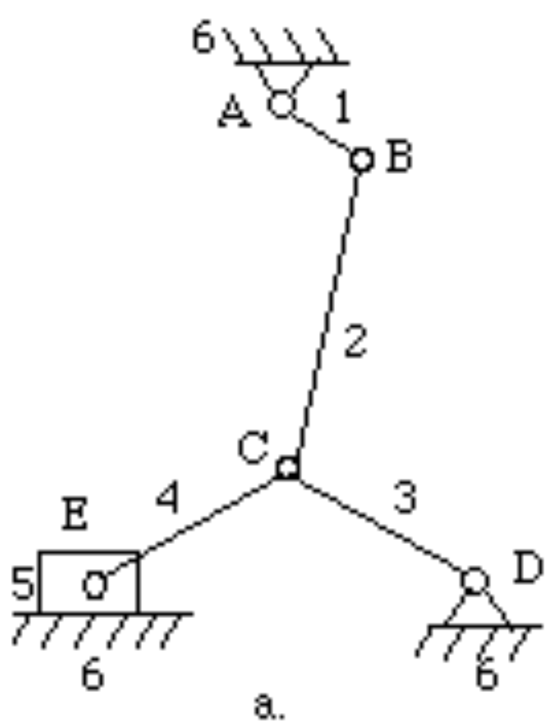


Flat (F) joint

Gruebler's Equation

$$F = 3(n-1) - 2l - h$$

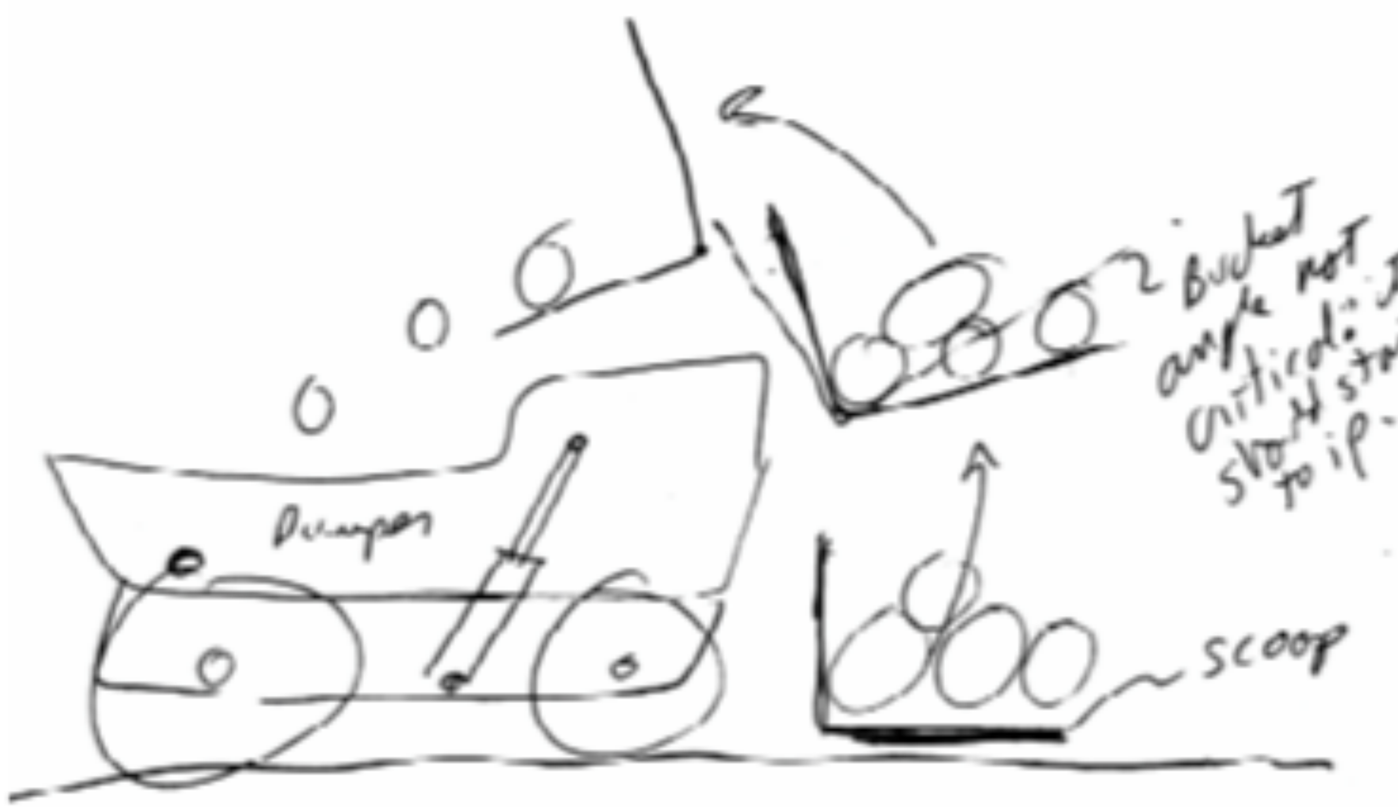
F = total degrees of freedom in the mechanism
n = number of links (including the frame)
l = number of lower pairs (one degree of freedom)
h = number of higher pairs (two degrees of freedom)



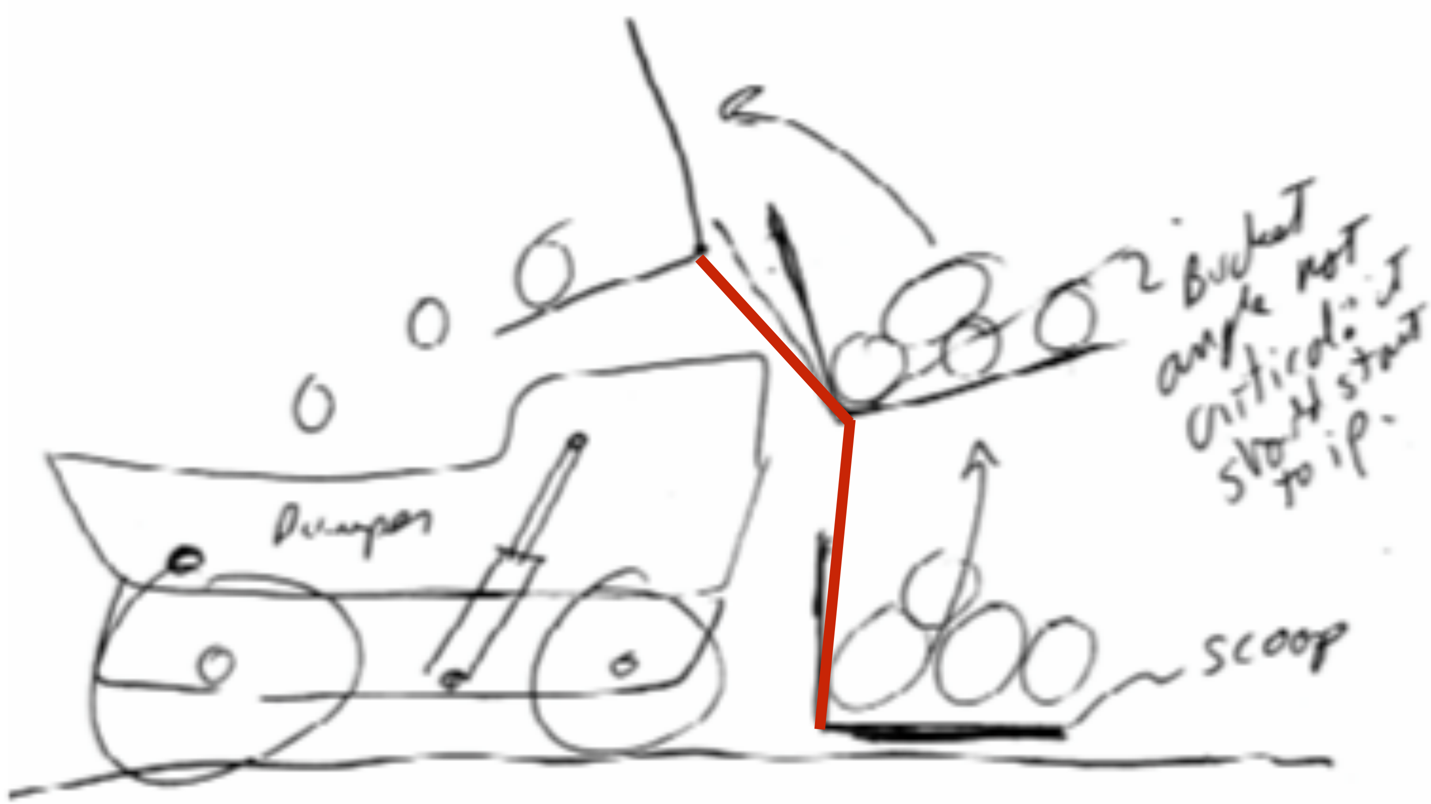
$n = 6, l = 7, h = 0$

$$F = 3(6-1) - 2 \times 7 - 1 \times 0 = 1$$

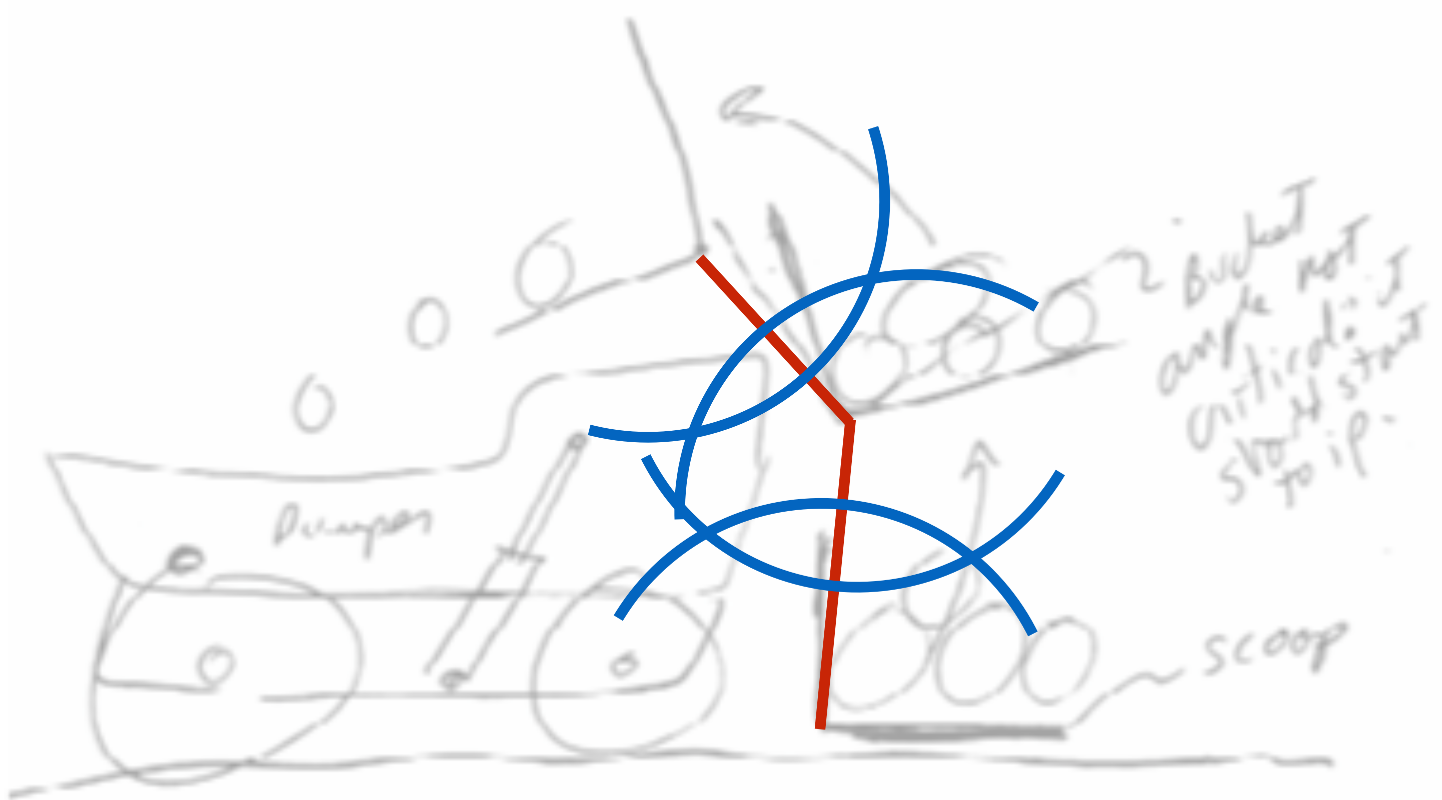
4-bar Linkage Design



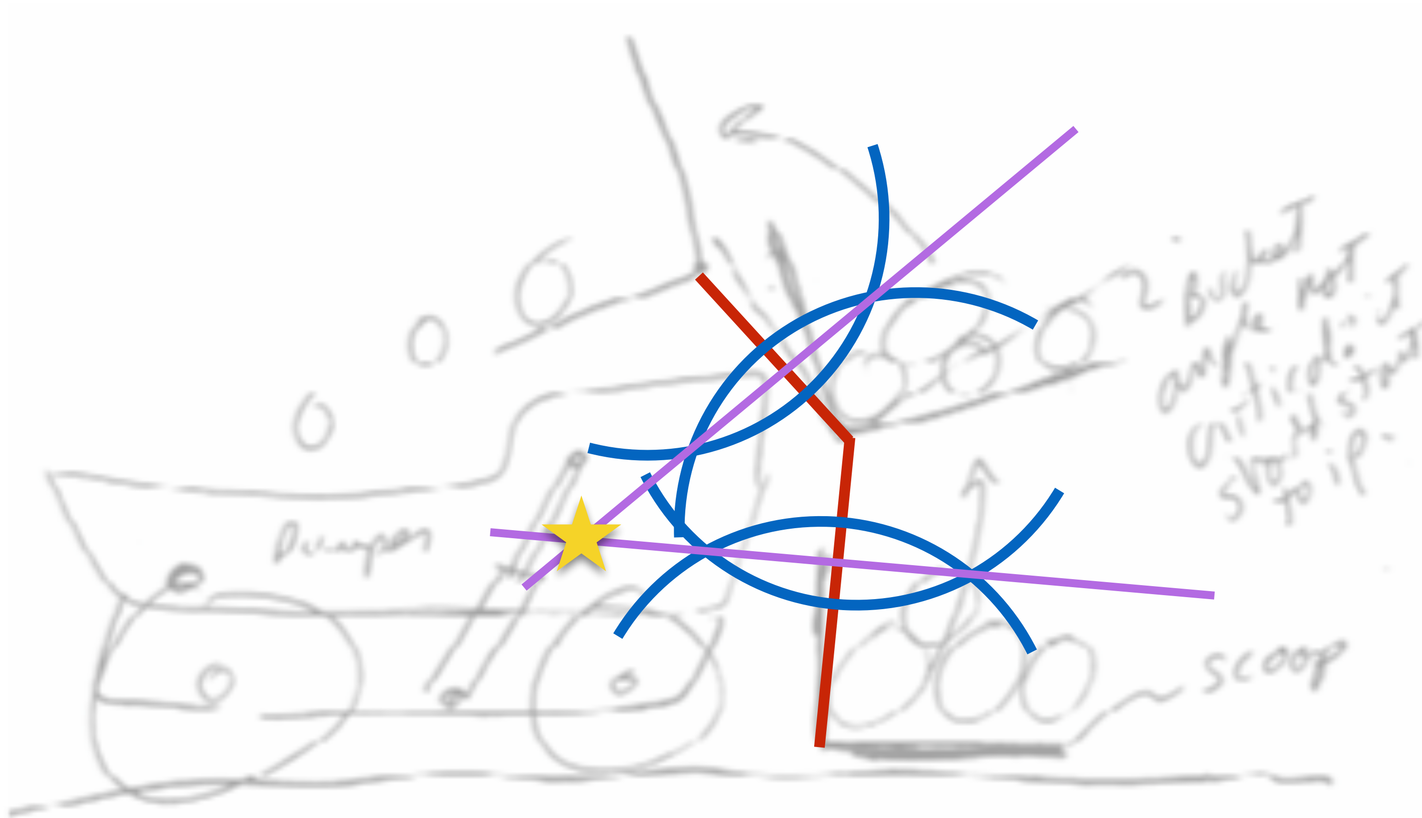
4-bar Linkage Design



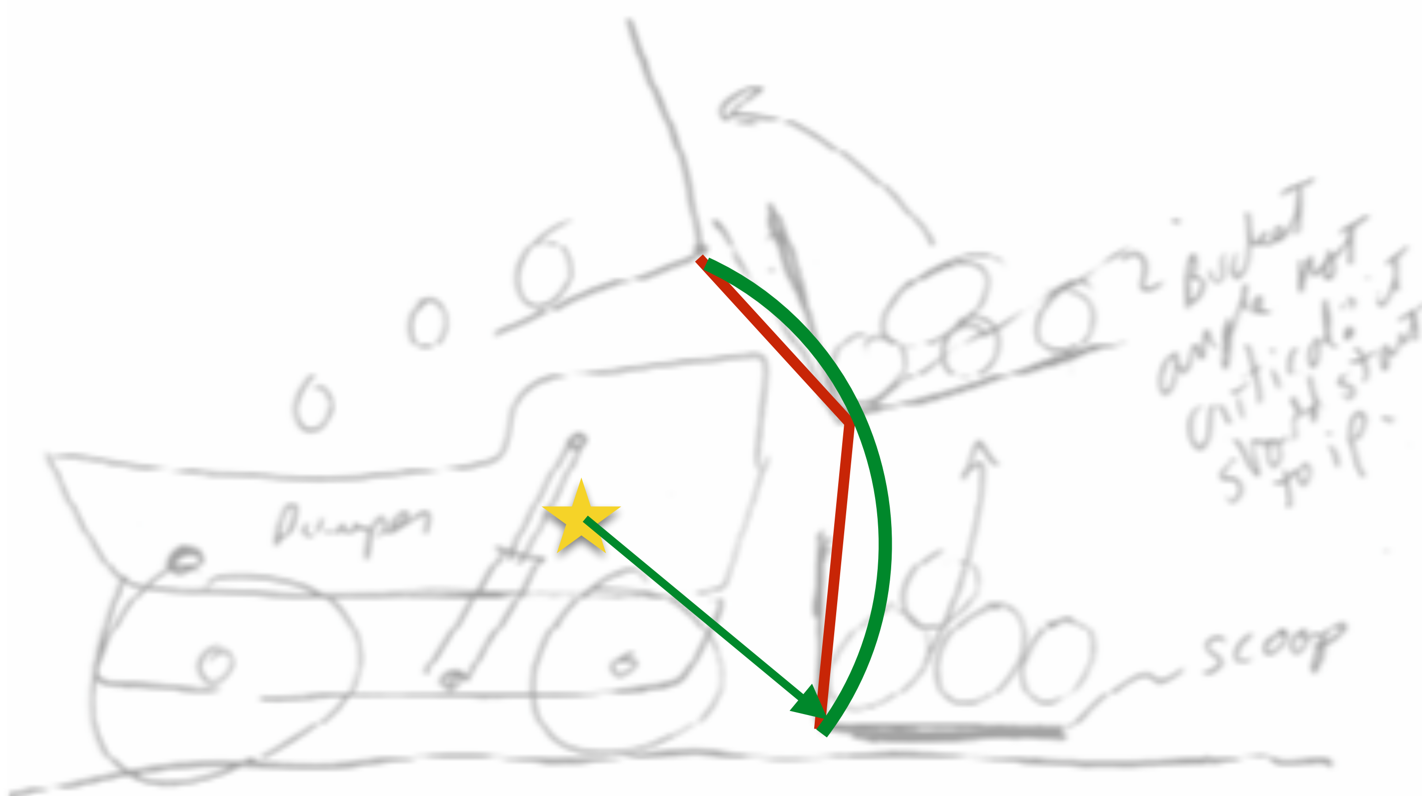
4-bar Linkage Design



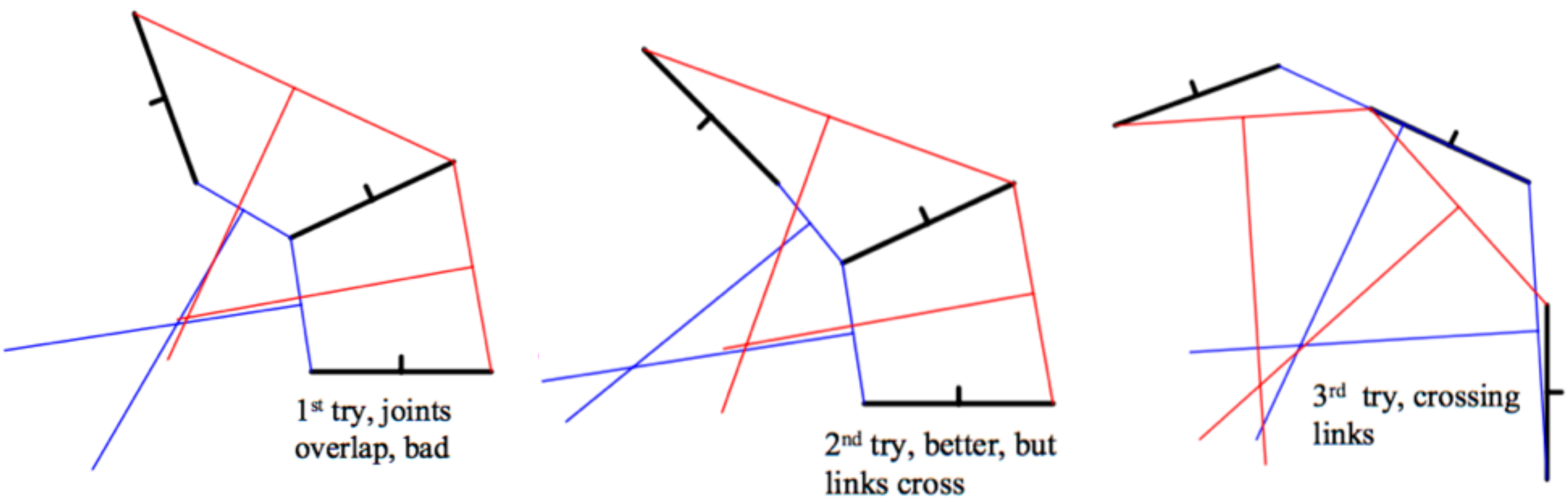
4-bar Linkage Design



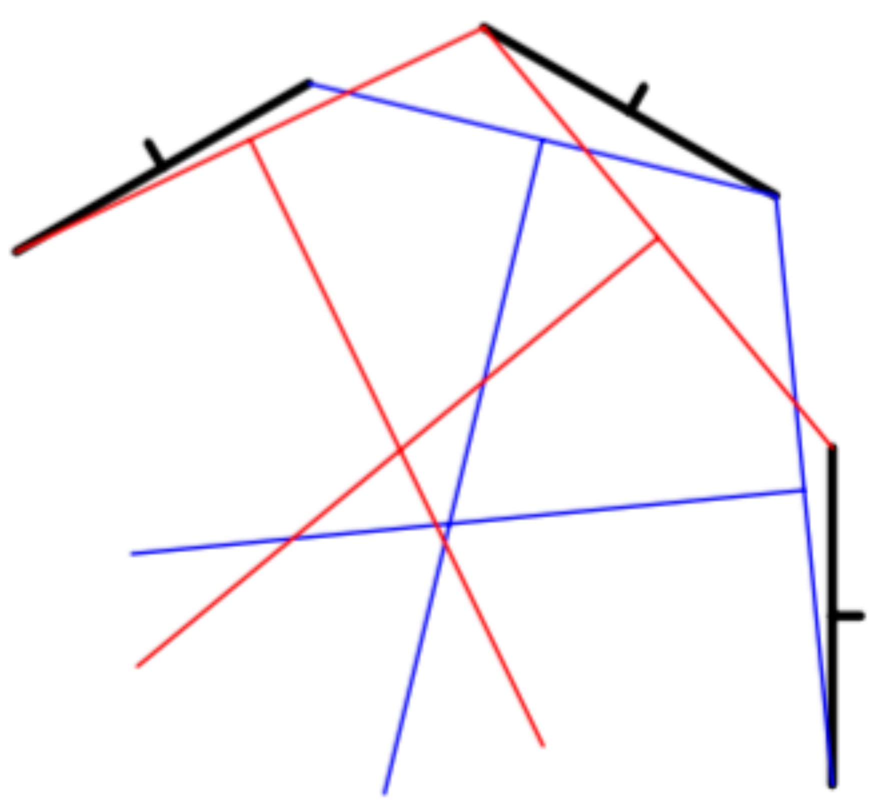
4-bar Linkage Design

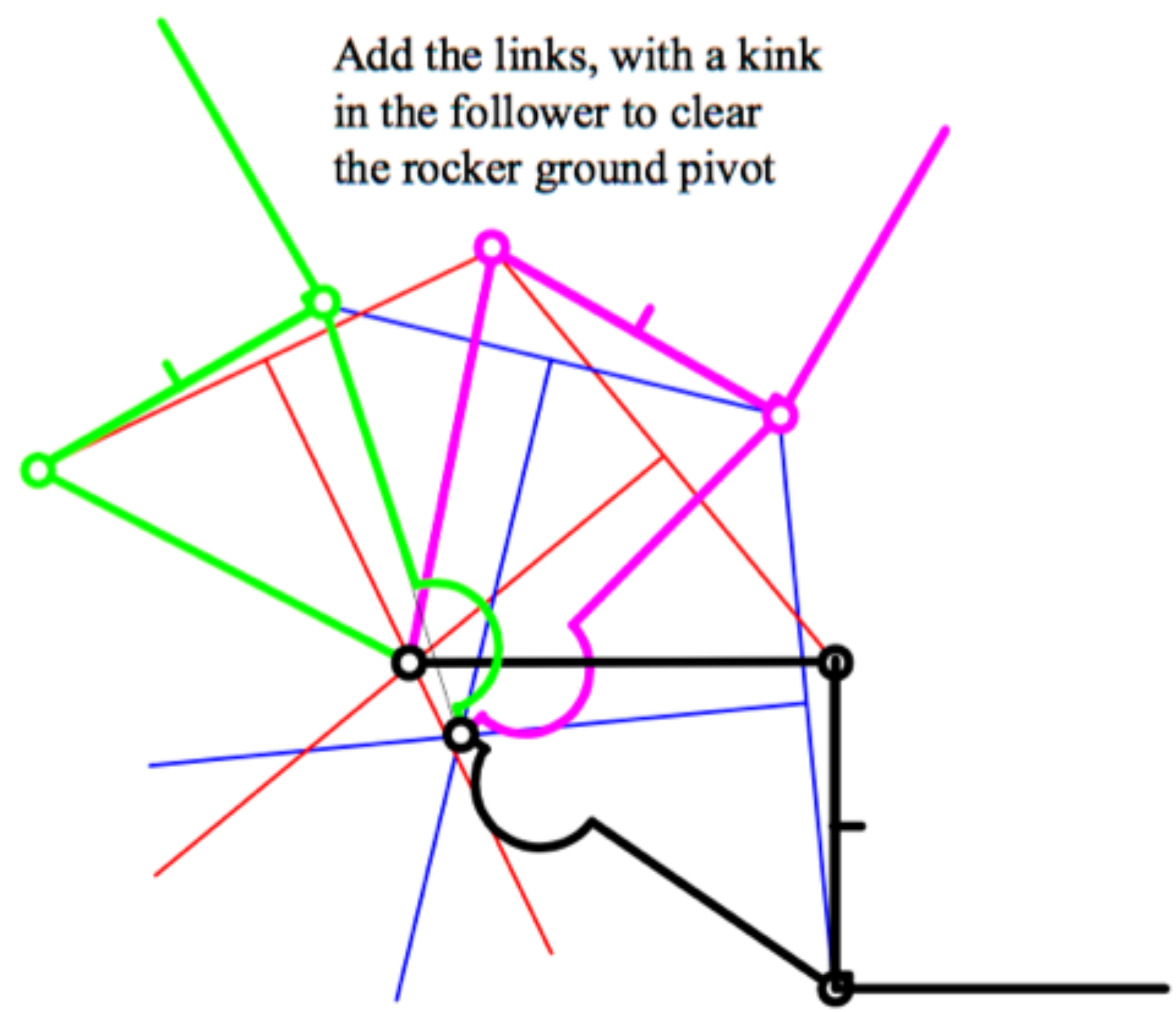


4-bar Linkage Design



4-bar Linkage Design





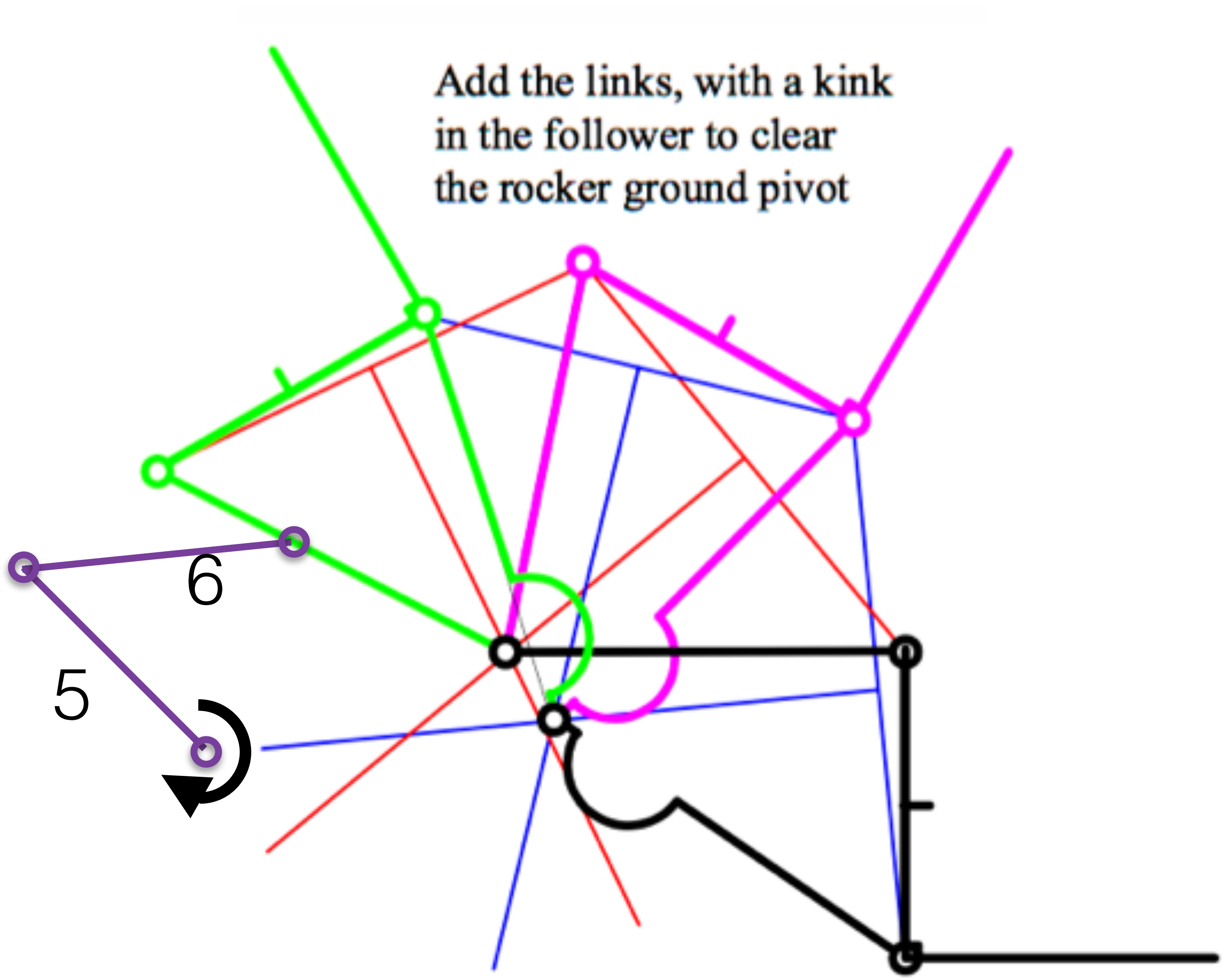
4-bar Linkage Analysis

Garshof criteria

- The sum of the shortest (S) and longest (L) links of a planar four-bar linkage can't be greater than the sum of the remaining two links(P,Q) if there is to be continuous relative motion

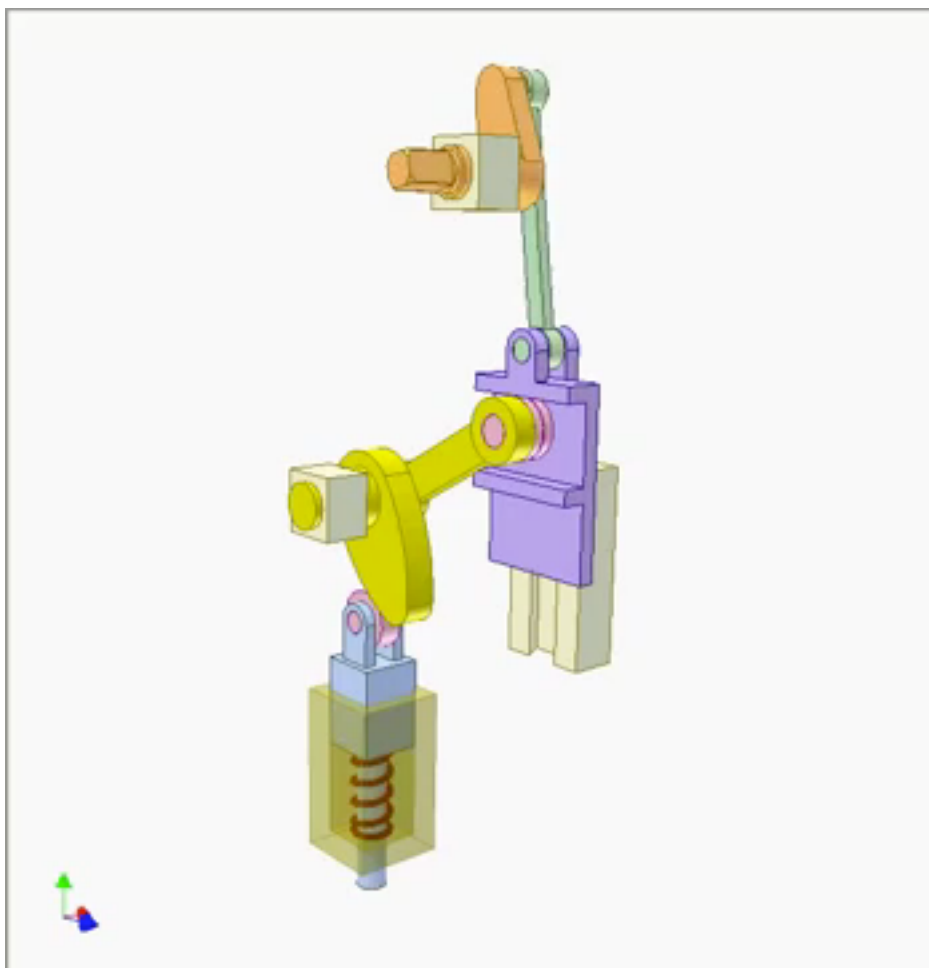
- $L+S<P+Q$

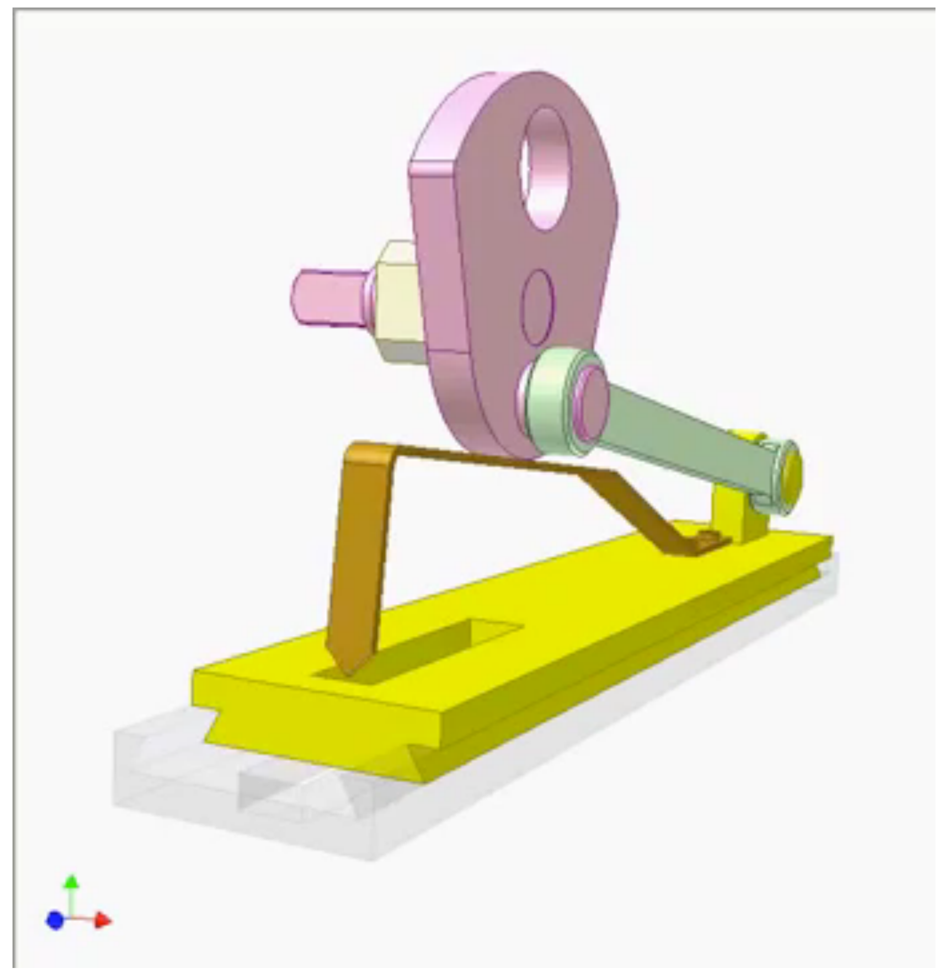
4-bar Linkage Analysis



Cams

Combinations





Some Design Mantras

- Simple IS better
- You don’t have to prototype everything…. Just the parts you want to work
- Assume nothing
- Sometimes wild ideas lead to champions

Questions?