# Design Workshop

*Mechanical Systems*

THEORY 6

TEAM 1241

RICK HANSEN SECONDARY SCHOOL

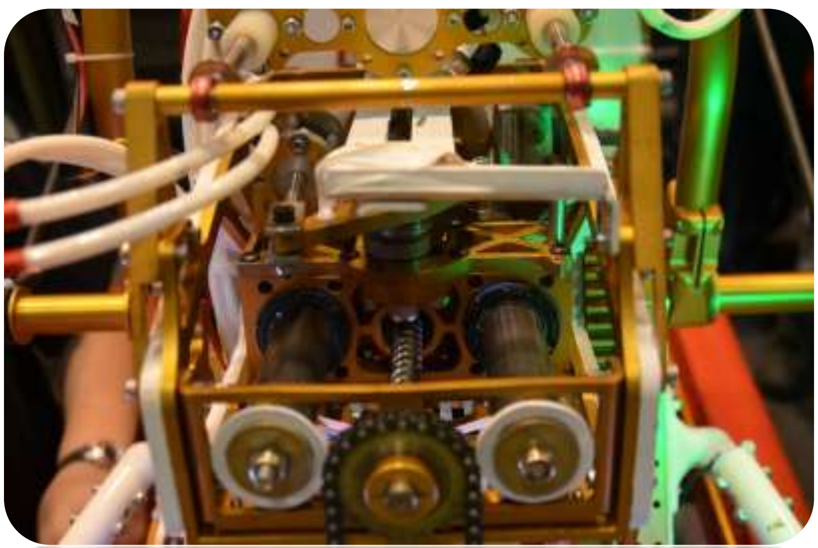
October 31, 2015

# Introduction

- Malavya Shah
  - Graduate of University of Waterloo
    - Bachelor of Applied Science in Mech. Eng. (2014)
- Joined FRC in 2007
  - Team 1241/1285
  - Student (2007-2009)
  - Lead Engineering Mentor
- Evertz Microsystems
  - Mechanical Design Engineer

# Objectives

- Types of Common Mechanisms Used in FRC
- Types of Motors Used in FRC
- Gears and Sprockets
- Example Problems

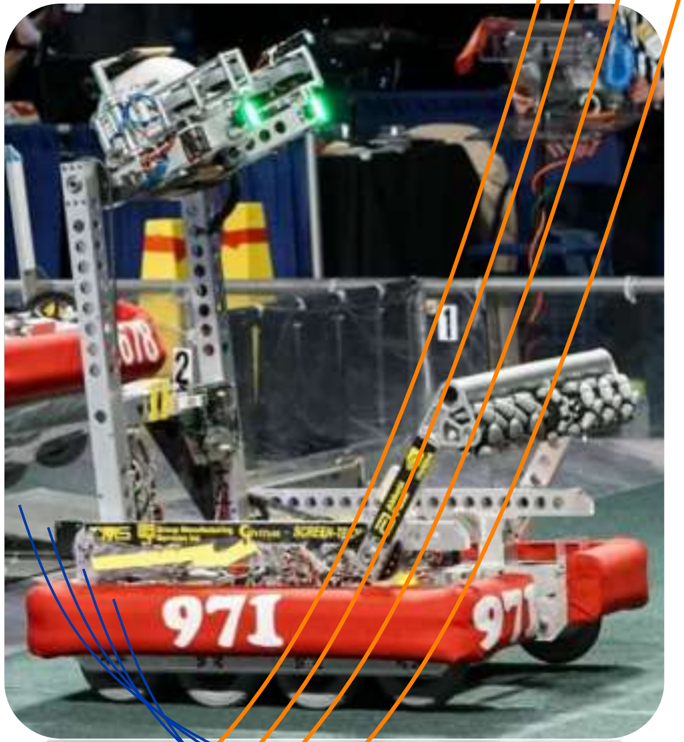


# Tips for Designing

- There is no right answer for an FRC game!
- Keep things simple
- Pay attention to orientation of game piece
- Possess Game Piece easily and quickly (touch and go)
- Try and take off load on motors when using arms
- Use sensors wherever possible. Tool operator shouldn't struggle trying to control the mechanisms.
- Prove your designs through prototyping not assumptions.
- Pay attention to your team's skill level, and resources.

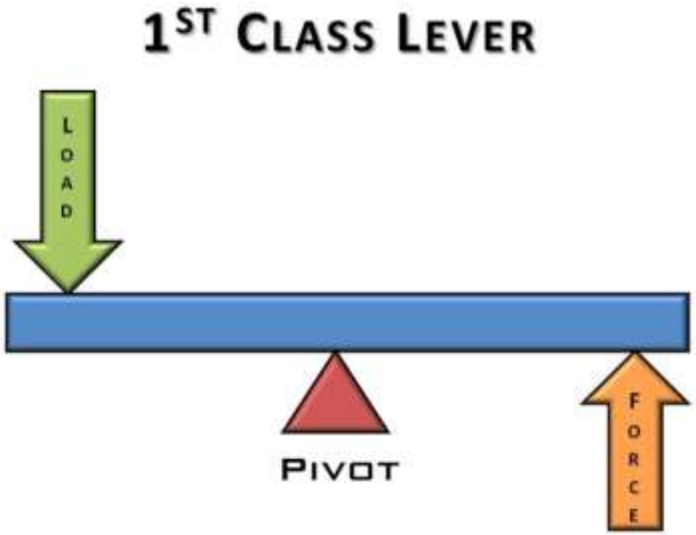
# Types of Mechanisms

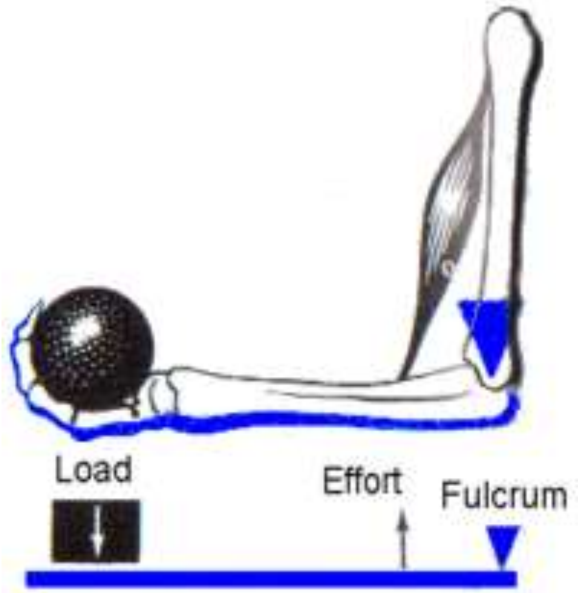
- Levers/Arms
    - Simple Bar Linkages
    - Four Bar Linkages
- Flywheels/Rollers
- Cam mechanisms
- Pulley Systems
- Rack and Pinion
- Pneumatics Systems
- And more!



# Levers & Arms

- Levers are long bars that spin on a pivot point called fulcrum. They also have a load and an effort.
- Torque arm Challenge

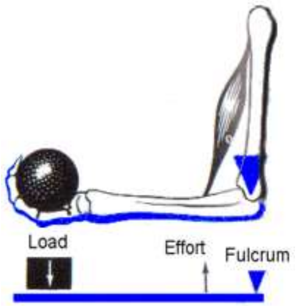


# Torque Arm Challenge

- Competitor 1 has their elbows at their hips with their arms out with palms facing up.
- Competitor 2 tries to push down on the arms!
- Competitor 1 now has their arms straight out.
- Competitor 2 tries to push down on these arms now.

NOW SWITCH ☺




# Simple Bar Linkages

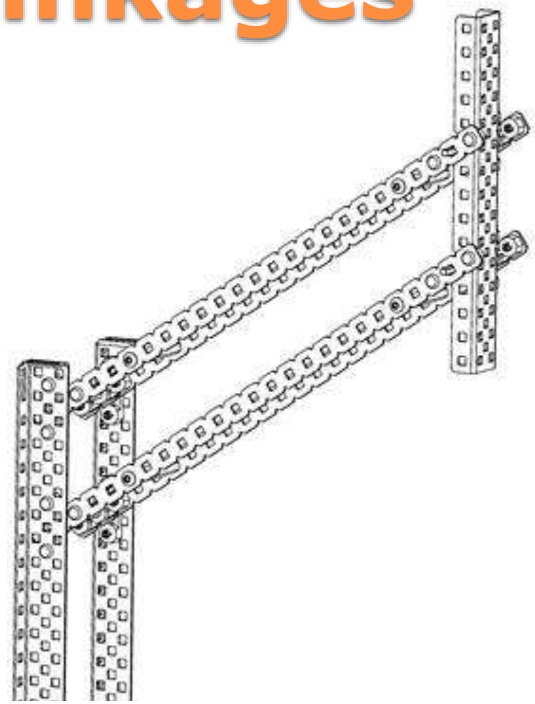
- Have 1 or 2 joints
- Both joints can be independently controlled

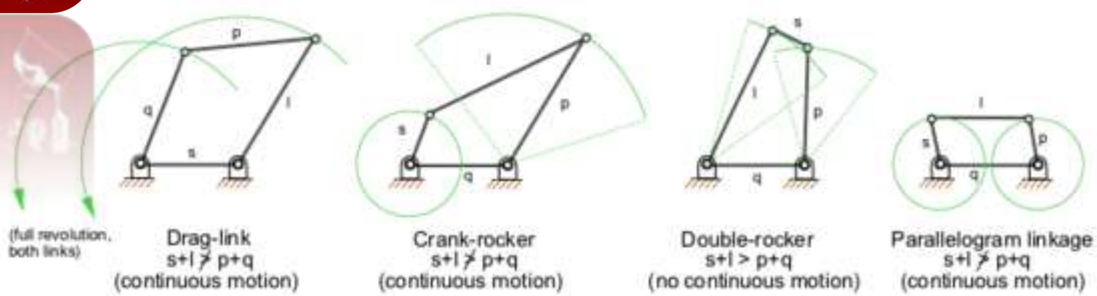


Special Tips:

- Use Sensors at each joint
- Try and take away as much load from the motor using springs, gas struts, elastic tubing

# Four Bar Linkages



# Flywheels / Rollers

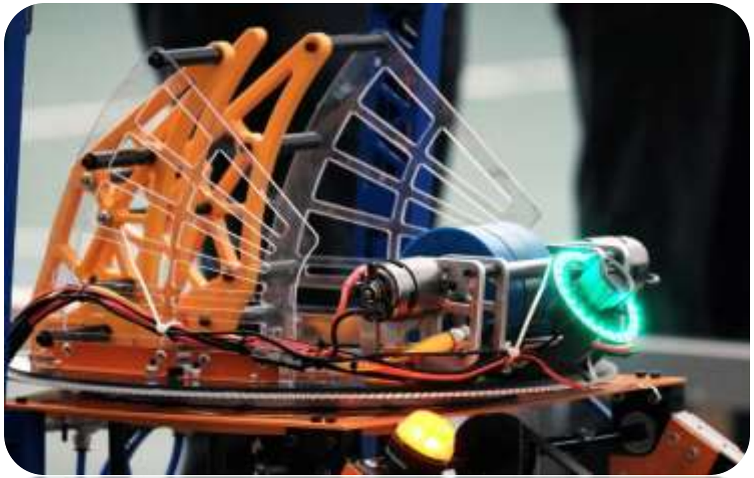
- Composed of a rotating structure. Sometimes designed with weighted structures on perimeter to increase moment of inertia.
- Usually accompanied by a hood (like snow blower) or another wheel.
- Perhaps the fastest way to possess or release a game piece.

## Special Tips:

- If used as a scoring mechanism, you must be able to control the rotational speed with precision. It is very difficult to predict the behavior without an encoder, or a light sensor, and proper programming.
- If used for intake, try and gear it to be faster than your drive speed, so that you can possess game pieces while driving away from it.

# Turret Mechanisms

- Composed of a rotating structure to allow for robot tool to articulate independently of drive train.
- Turrets can be powered using gears, sprockets/chain, or belt/pulley.
- Needs some sort of bearing configuration in order to rotate smoothly.
- Perhaps the fastest way to shoot at target without pressuring the driver.

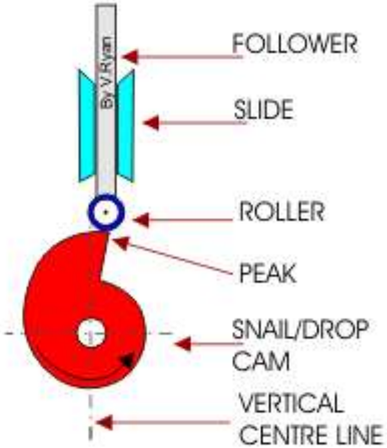


## Special Tips:

- You must be able to control the rotational speed and tolerances for precision. It is very difficult to predict the behavior without an encoder, or a light sensor, and proper programming.
- Only use a turret if absolutely necessary. It is a complex mechanism for programming. Always consistently feed the turret.

# Cam Mechanisms

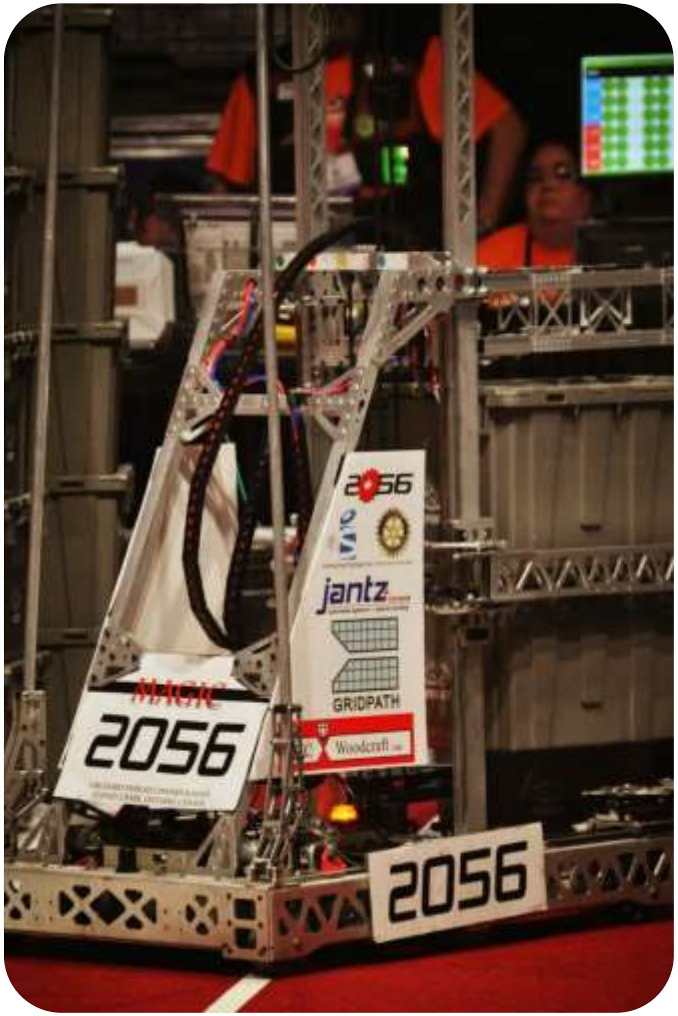
- Cam Mechanisms convert rotary to linear motion or vise versa.
  - Shooting Games
  - Kicking Games
  - Anything that requires repetitive motion



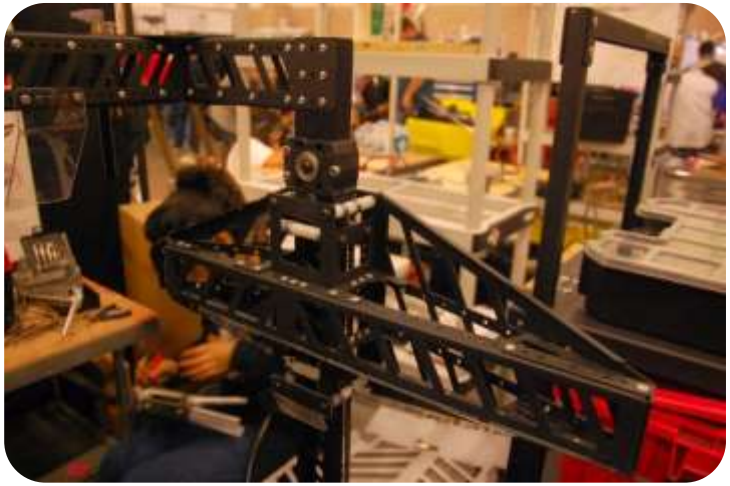


# Elevators

- Composed of a static tower structures and powered carriages.
- Carriages are raised and lowered using chain, belts, rack and pinion, or lead screws.
- Entire system is driven by a gearbox
- Great for pick and place games, motion of carriage is simplified because its completely linear.



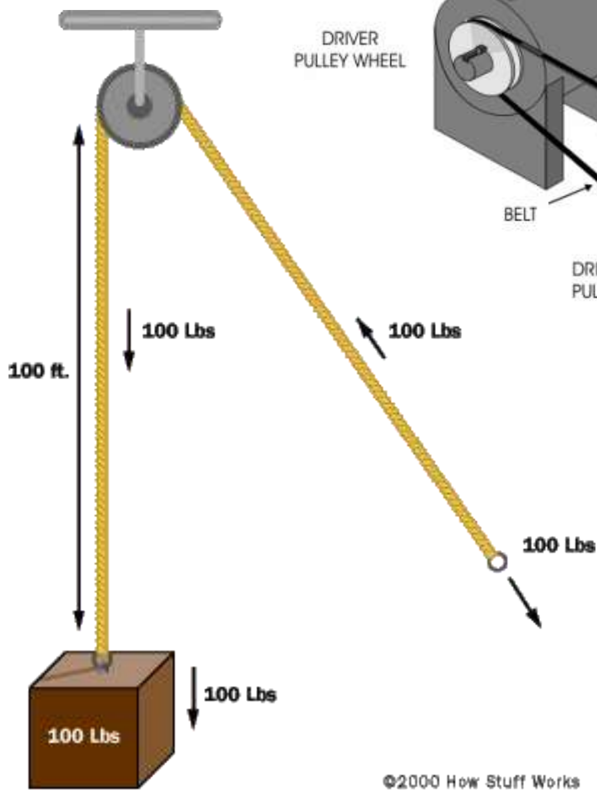
# Elevators

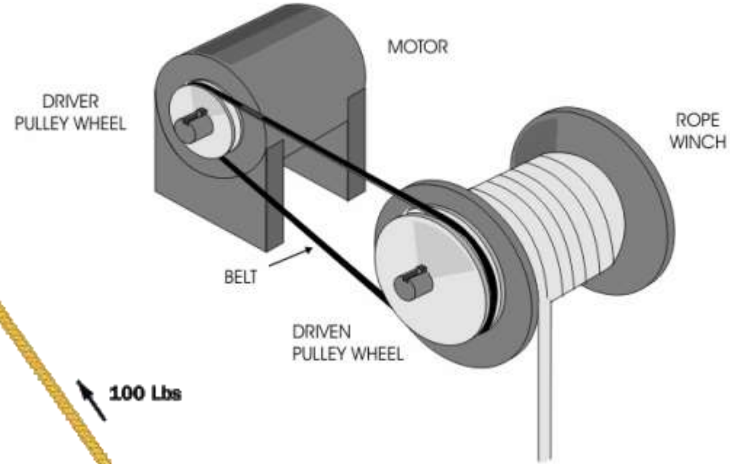



Special Tips:

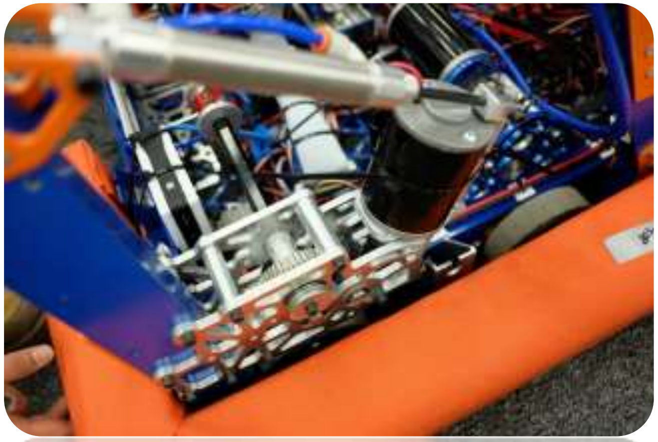
- Counter balance the weight of the carriage, so motor only has to lift game piece. Make sure motor does not have too much load.
- Include sensors to track position of elevator. PID control may need to be used for holding position.
- Make sure carriage is constrained on all 3 axis, so that it cannot jam and twist while moving up and down. BEARINGS BEARINGS BEARINGS

# Pulleys


100 ft.
100 Lbs
100 Lbs
100 Lbs
100 Lbs
100 Lbs
©2000 How Stuff Works


MOTOR
DRIVER PULLEY WHEEL
ROPE WINCH
BELT
DRIVEN PULLEY WHEEL


254
254

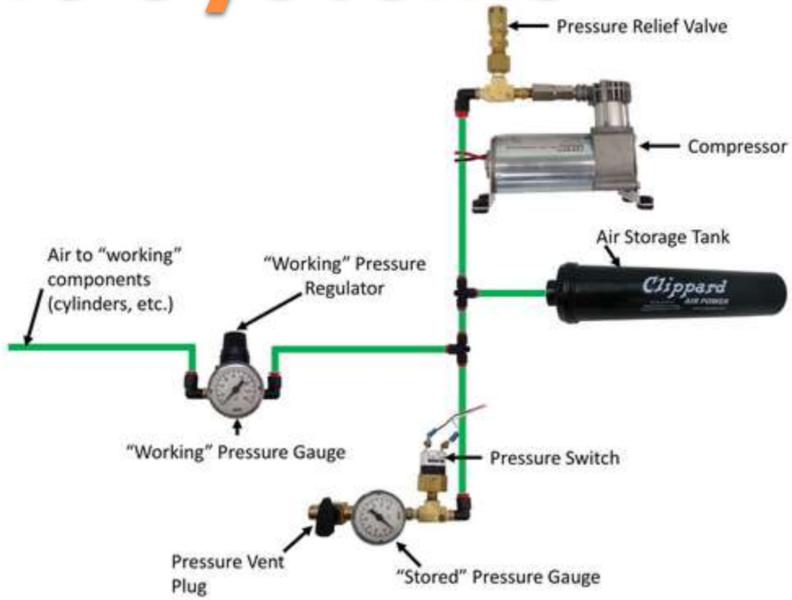


# Rack and Pinion

Notes:

- Precise Linear Motion with ability to hold position
- Usually pretty slow
- Difficult to implement because it requires precision machining for all parts

# Pneumatic Systems




## Several Components:

- Storage Tanks
- Compressor
- Pressure Gauge (120PSI)
- Regulator (60PSI)
- Solenoids
- Cylinders
- Pneumatic Lines

## Notes:

- 2 Position applications
- Force exerted depends on bore size & Pressure
- Force = Pressure x Area of Bore
- Retracting is less powerful than extending

# Motors

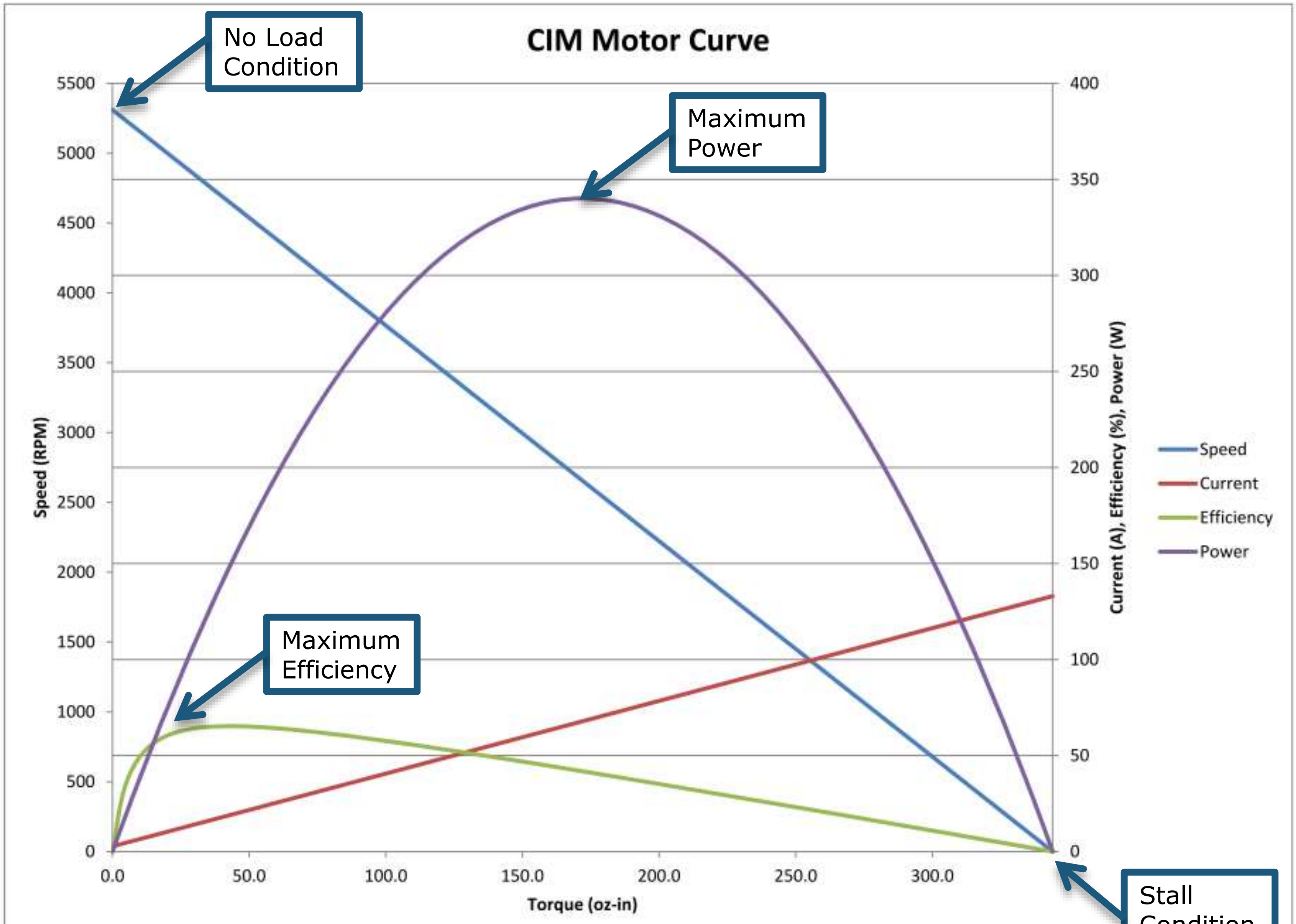
- Electrical DC Motors used in FRC
- Properties of a Motor:
  - Stall Torque [N*m or oz*in]
    - Torque at which motor speed is 0
  - Free Speed [rad/s or rpm]
    - Speed at which motor torque is 0
  - Terminal voltage [V]
    - Voltage required by motor
  - Efficiency
    - Power Out / Power In = $(T*\omega) /(V*I)$

# Motors

| Motor | Stall Torque (N m) | Free Speed (RPM) | Picture |
|---|---|---|---|
| CIM<br>Mini CIM<br>Vex Bag | 2.43<br>1.4<br>0.4 | 5310<br>6200<br>14000 |  |
| Andy Mark 9015 | 0.428 | 16000 |  |
| Denso Window | 10.6 | 84 |  |

# Motors

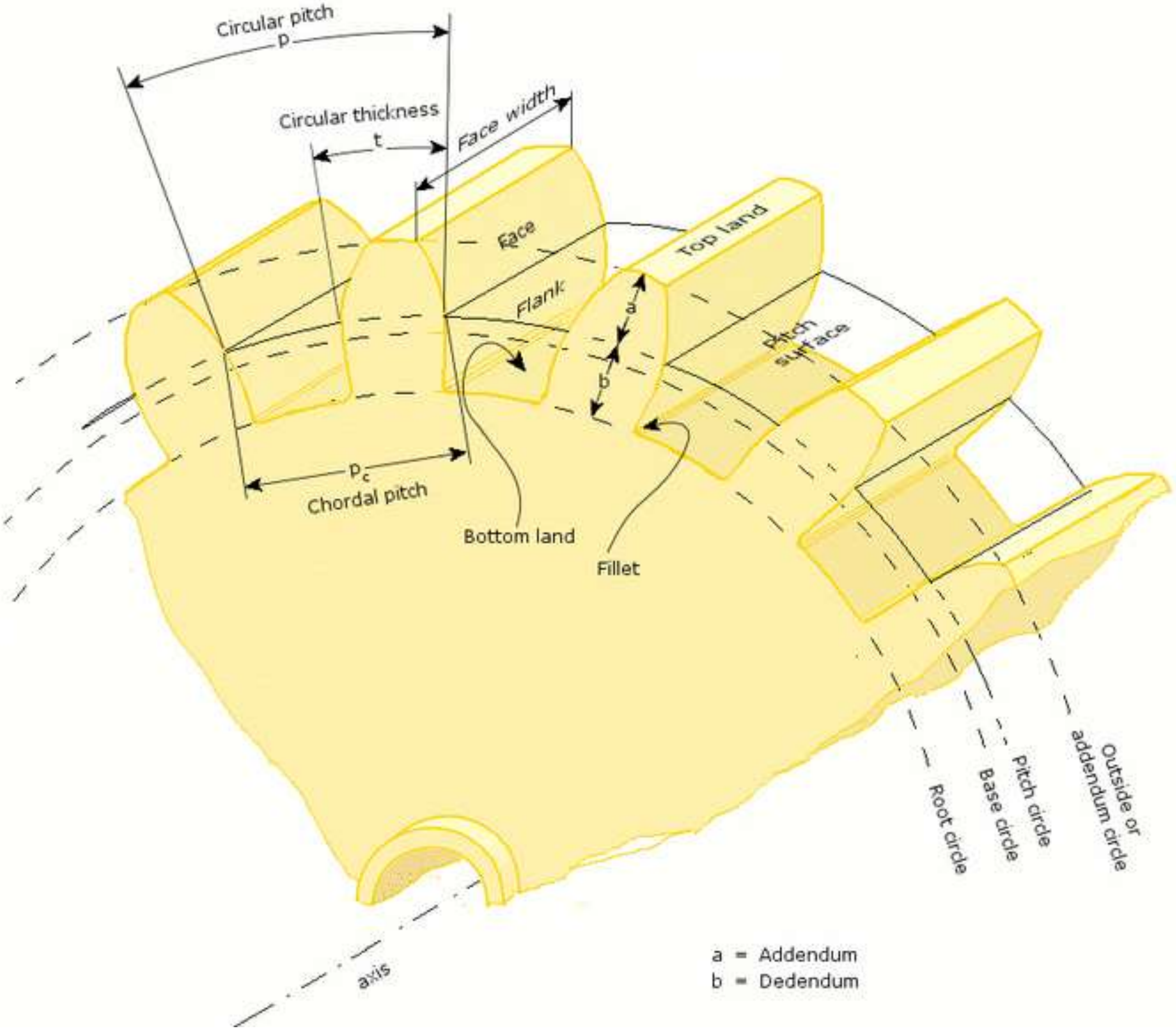
| Motor | Output Torque (N m) | Free Speed (RPM) | Picture |
|---|---|---|---|
| BaneBots 775Pro | 0.710 | 18730 |  |
| 775 –18V | 1.177 | 19500 | |
| 550 | 0.486 | 19300 | |
| 540 | 0.279 | 16800 | |
| 395 | 0.118 | 15500 | |
| Servo Motor | | |  |



CIM Motor Curve
No Load Condition
Maximum Power
Maximum Efficiency
Stall Condition
Speed (RPM)
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Current (A), Efficiency (%), Power (W)
400
350
300
250
200
150
100
50
0
Torque (oz-in)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Speed
Current
Efficiency
Power

# Gears

- Pinion Gear –or “Driving Gear”
- Driven Gear
- Pitch – Number of Teeth Per Inch
- Pitch Diameter – Circle at which the two gears meet

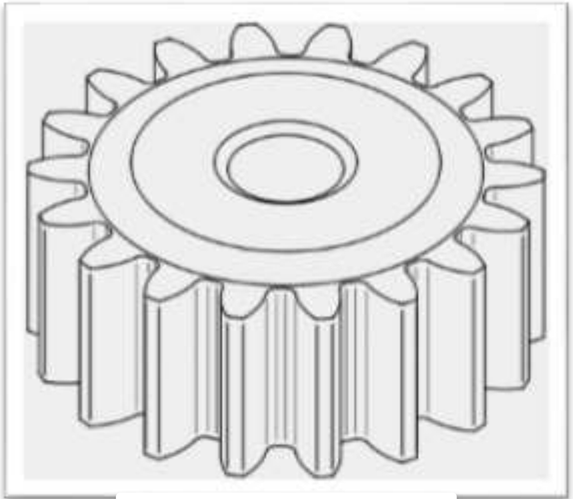



P=N/d

Where:

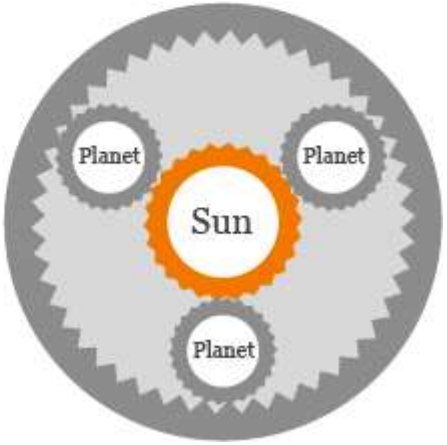
- P= diametral pitch (teeth per inch)
- d = pitch diameter (in)
- N = number of teeth

# Types of Gears



Spur Gears

Helical Gears




Planetary Gears

Bevel Gears

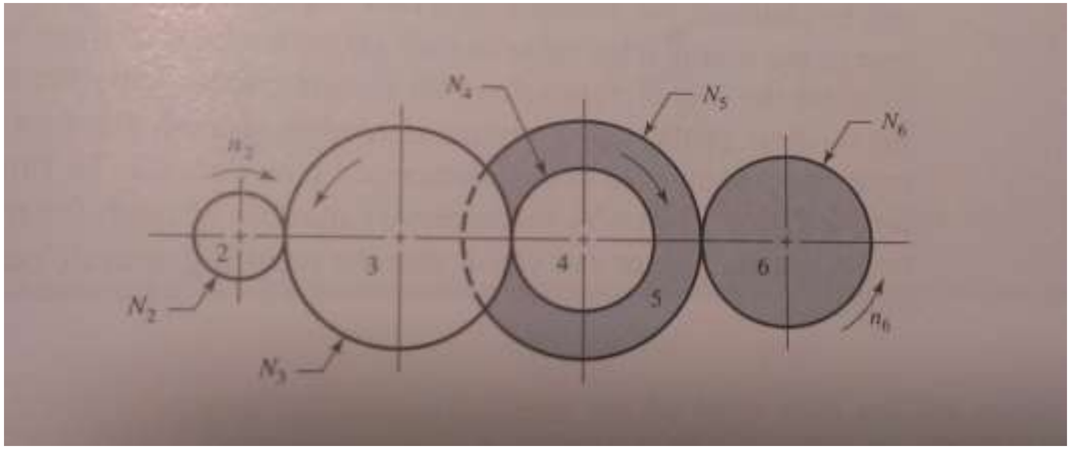
Worm Gears

# Gear Ratios

GR = N2/N1 = T2/T1 = ω1/ω2

If N2>N1 Torque is increased, speed is decreased

If N2<N1 Torque is decreased, speed is increased

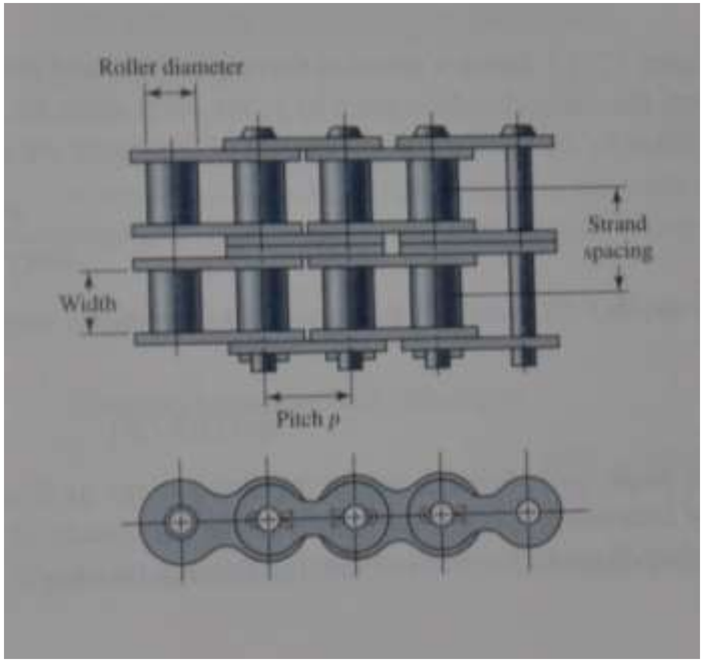


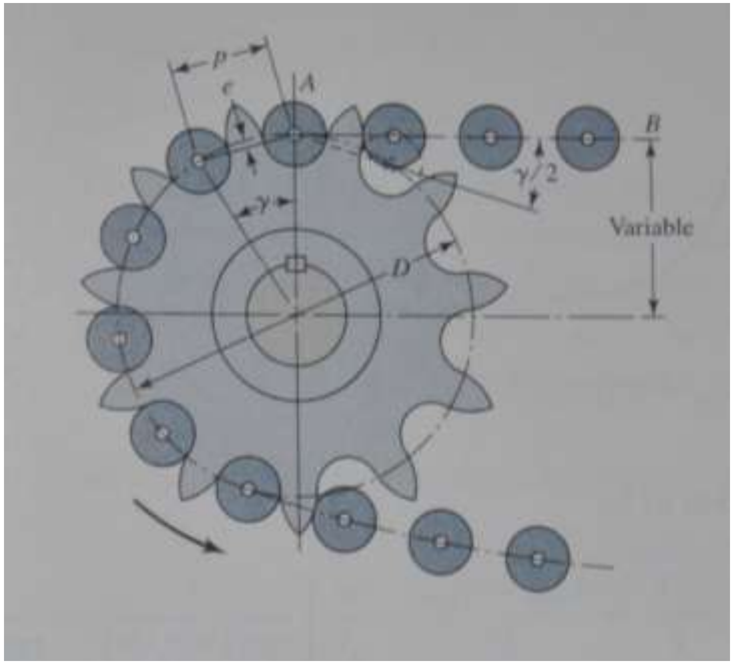
Gear Train:

GR = (N3/N2)(N4/N3)(N6/N5)

# Roller Chain / Sprockets

- Pitch – Distance between rollers
- Pitch Diameter – Circle at which the roller chain sits on the sprocket




D=p/(sin(180°/N)) where: D=diameter, p=pitch, N = teeth

| ANSI B29.1 roller chain standard sizes | | | | |
|---|---|---|---|---|
| Size | Pitch | Roller diameter | Tensile strength | Working load |
| 25 | 0.250 in (6.35 mm ) | 0.130 in (3.30 mm) | 781 lb (354 kg) | 140 lb (64 kg) |
| 35 | 0.375 in (9.53 mm) | 0.200 in (5.08 mm) | 1,758 lb (797 kg) | 480 lb (220 kg) |

## Calculating Center to Center Distances Between Sprockets:

$$C = \frac{p}{4}\left[-A + \sqrt{A^2 - 8\left(\frac{N_2 - N_1}{2\pi}\right)^2}\right]$$

$$A = \frac{N_1 + N_2}{2} - \frac{L}{p}$$

OR

$$\frac{L}{p} = \frac{2C}{p} + \frac{N_1 + N_2}{2} + \frac{(N_2 - N_1)^2}{4\pi^2 C/p}$$

Where:

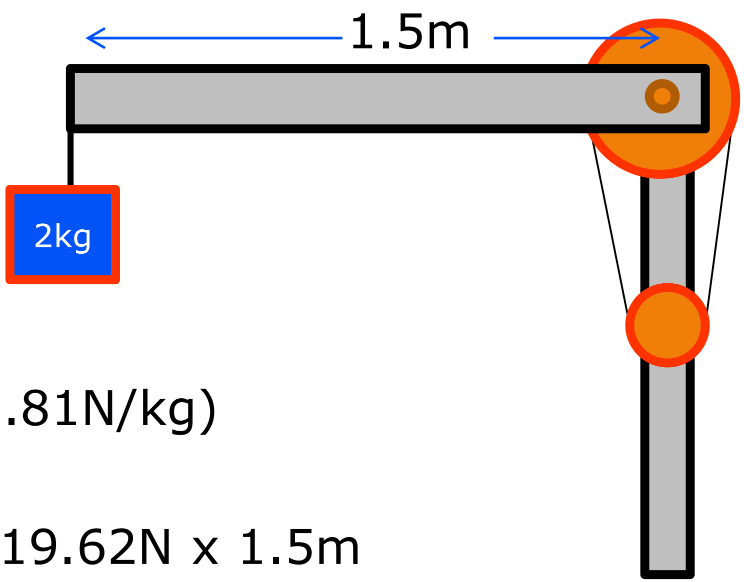
C=center to center distance
L=length of chain
N1=# of teeth on driving sprocket
N2=#of teeth on driven sprocket
p=pitch

## Chain Link Calculators:

http://www.islandpondrailroad.com/chain.htm
http://www.botlanta.org/converters/dale-calc/sprocket.html

# Torque Example

- Determine Gear Ratio for a motor that has output torque of 2 N-m and is used to rotate an arm 1.5m long with a mass of 2kg at the end of it.




Given:
Tm = 2 N-m
Larm = 1.5m
M=2.0kg

Solution:
Force = Mass x Gravity = 2.0kg*(9.81N/kg)
= 19.62N

Torque = Force x Length of Arm = 19.62N x 1.5m
= 29.43 N-m ~ 30 N-m

Gear Ratio:
GR = Load Torque / Torque Motor = 30N-m / 2N-m = 15:1

You need to have a safety factor so that you don't stall the motor!

# Speed Example

- Determine Gear Ratio for a motor that Rotates at 5000 rev/min to drive a 4 in wheel 16 ft/s

Given:
n = 5000rpm
Dwheel = 4in
V=16ft/s

Solution:
V=n*п*D so
Wheel Speed n = v/(D* п)
= 16/((4/12)*3.14) = 15.27 rps x 60= 916.2 rpm

Gear Ratio:
GR = Motor Speed/ Wheel Speed = 5000rpm / 916.2 =
<u>5.45</u>

# Questions?

# THANK YOU

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