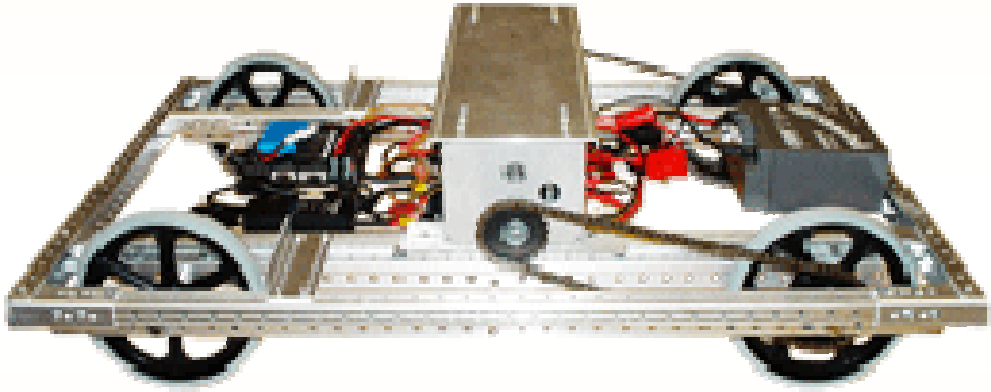
# Chassis Design



## 2007 FIRST Rookie Workshop

Zan Hecht
Manchester, NH
Jan 5th, 2007

# Outline (modified)

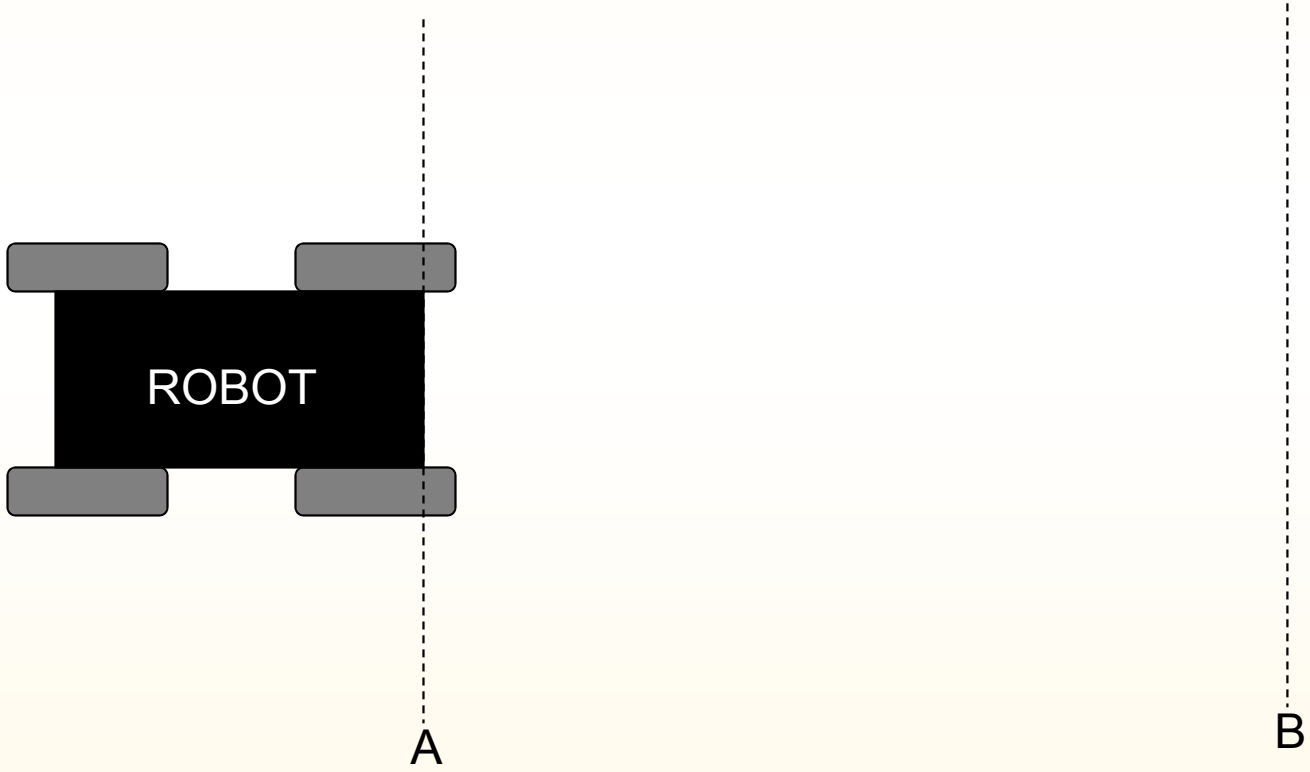
- Basic Robot Design Theory
- Building a Chassis
- Building a Driveline
- What's in the KOP?
- Moving from VEX to FRC
- Final Advice
- Questions?



# Basic Robot Design Theory

# Basic Robot Design Theory

## Skid (Tank) Steering



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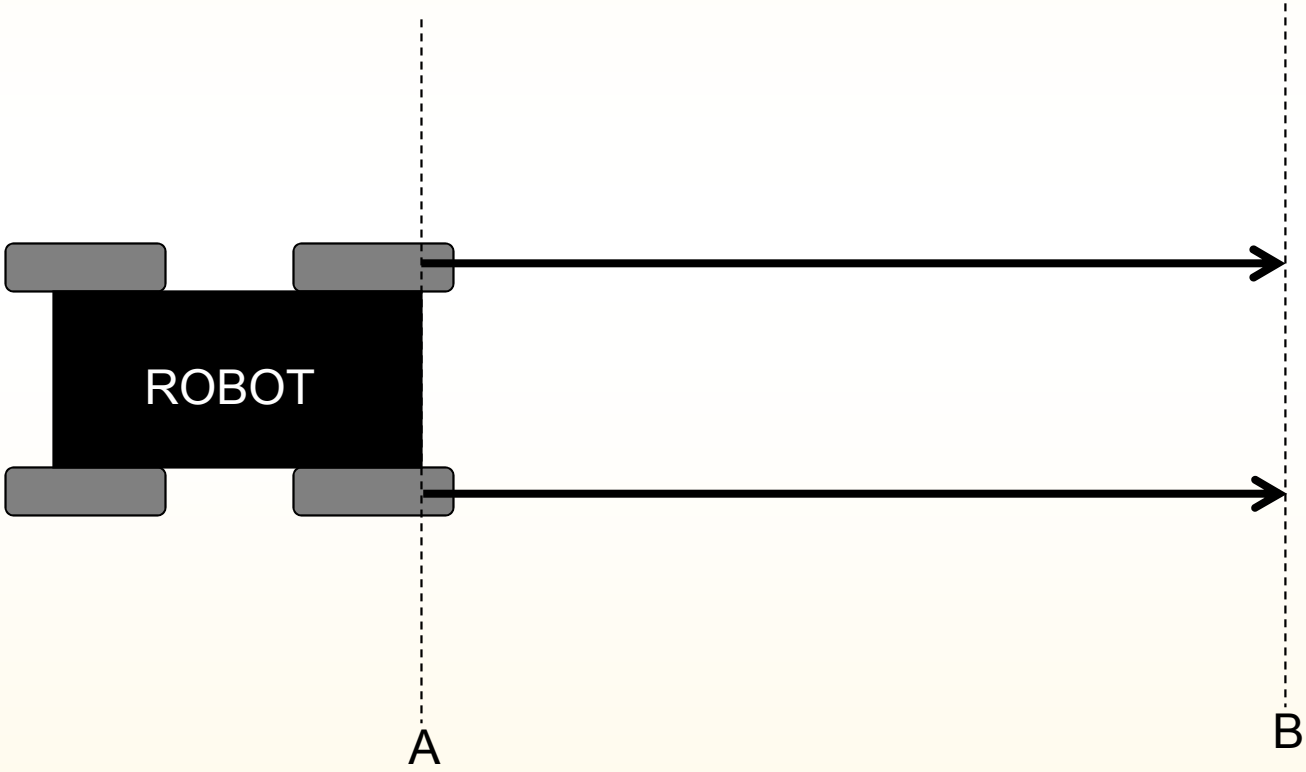

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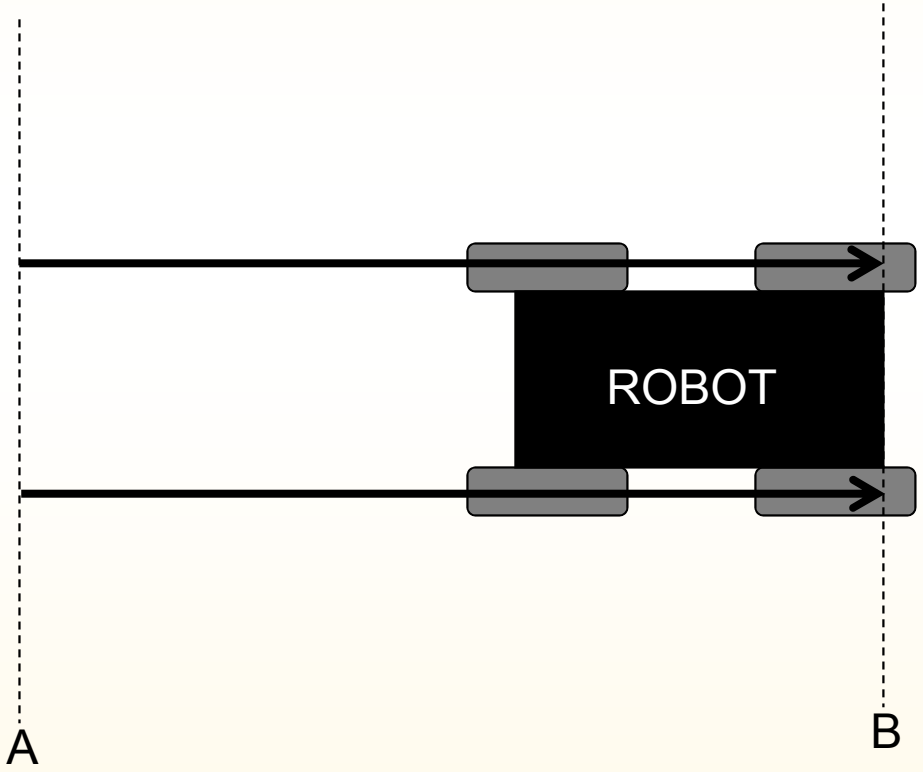

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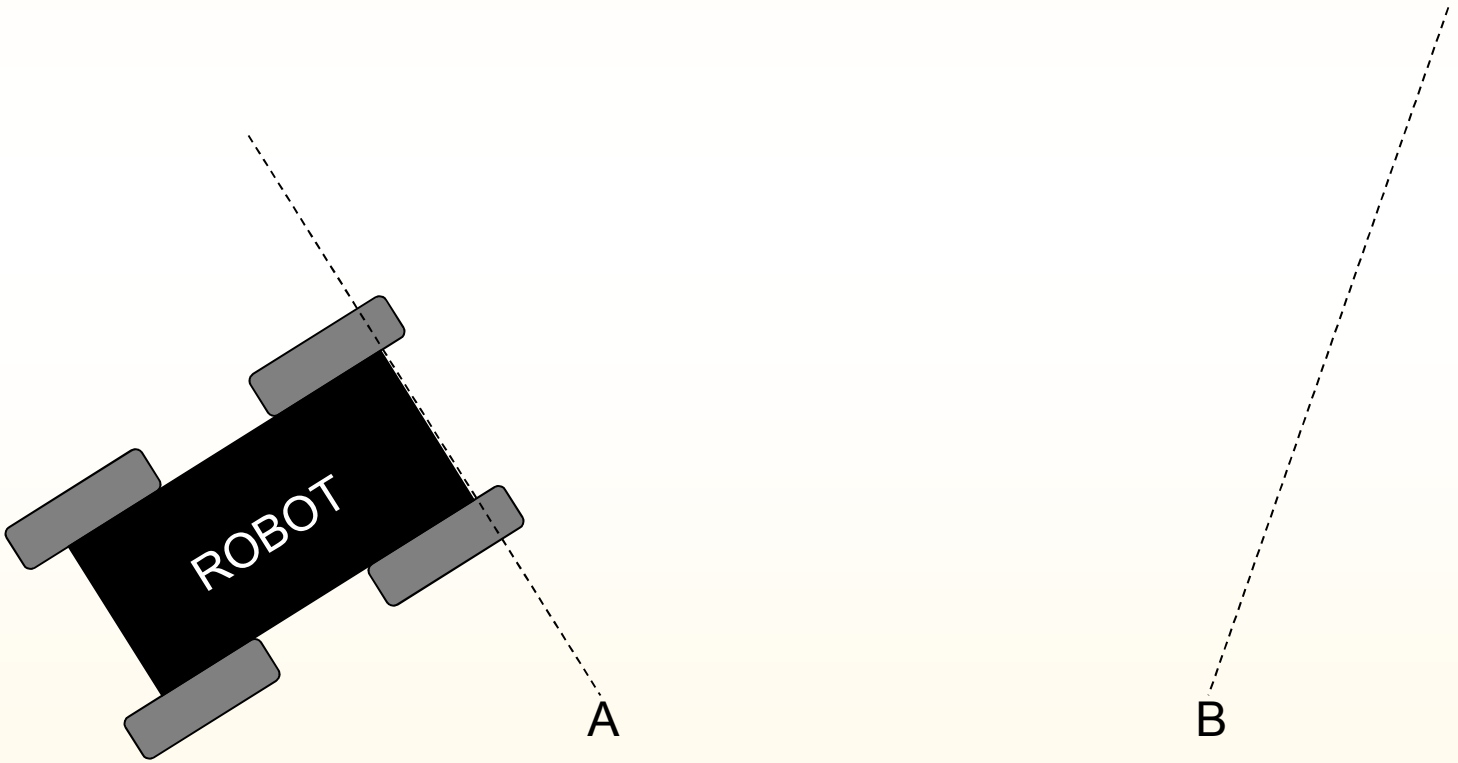

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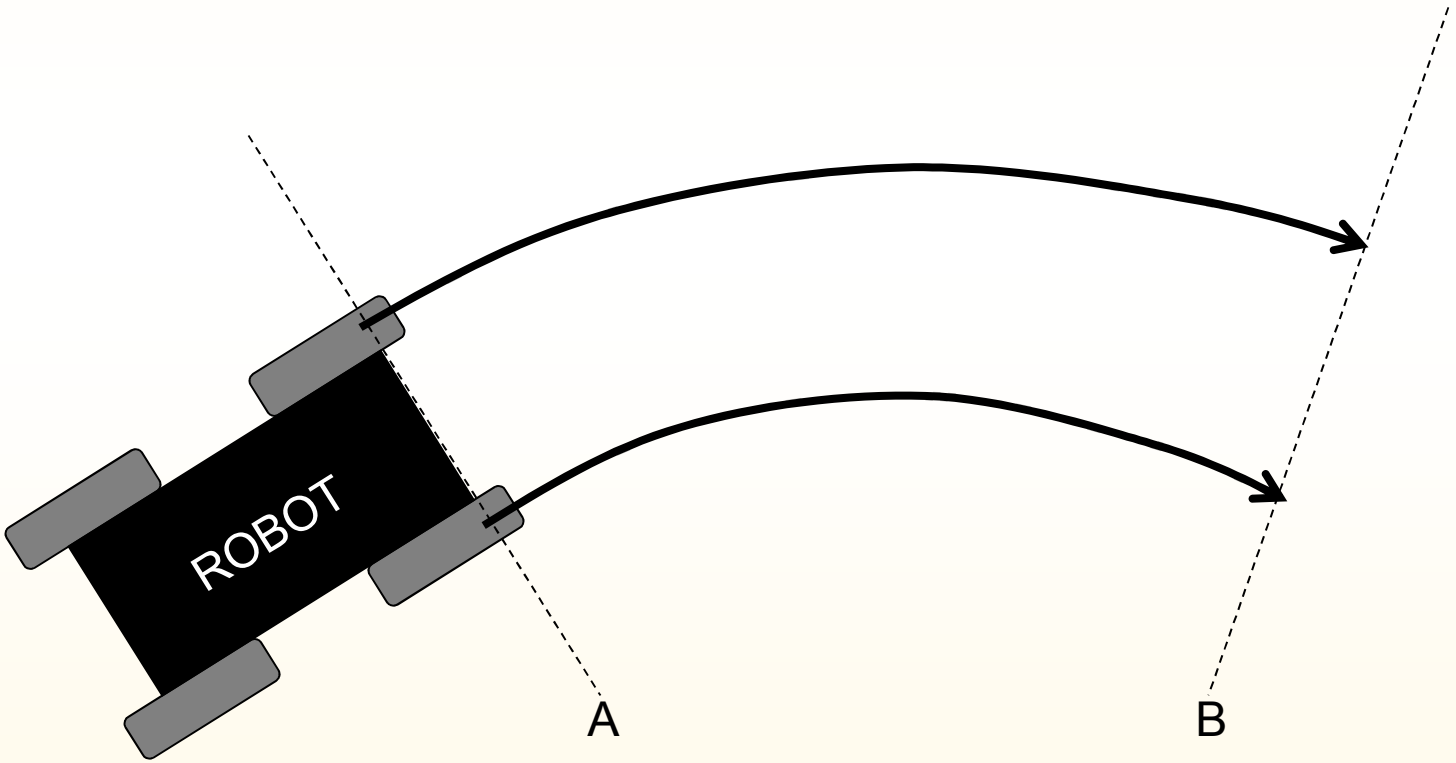

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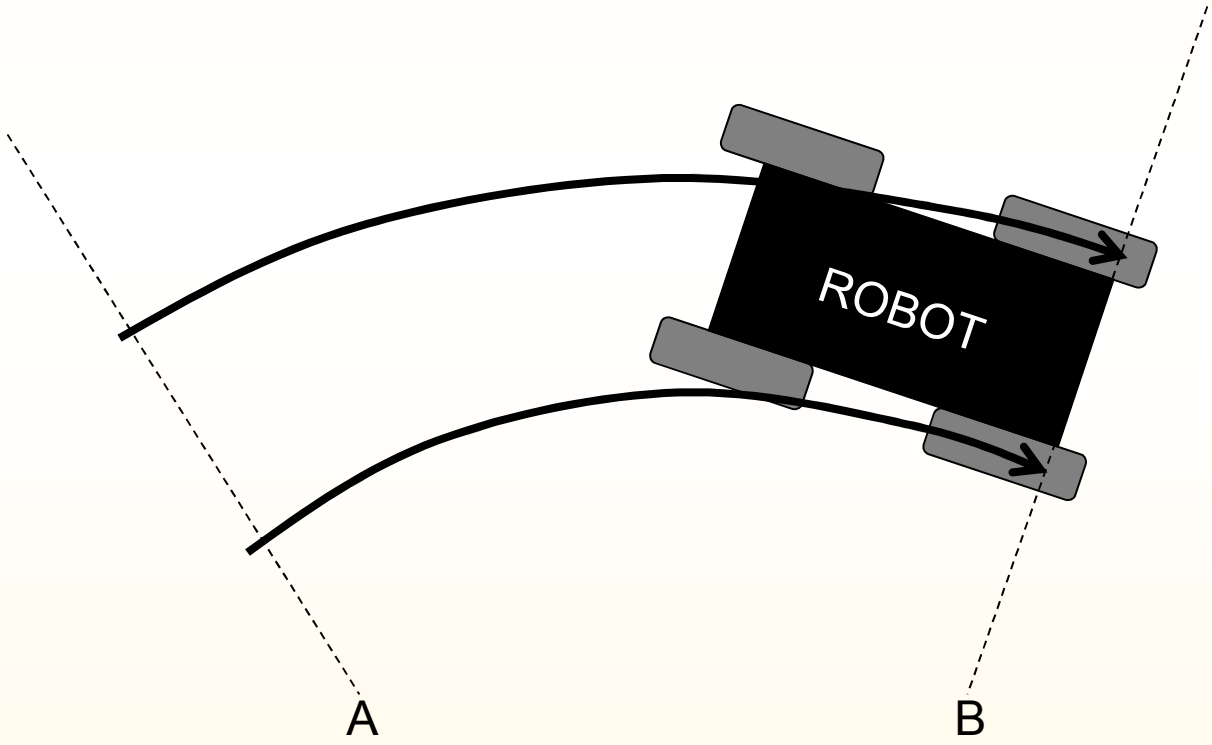


# Basic Robot Design Theory

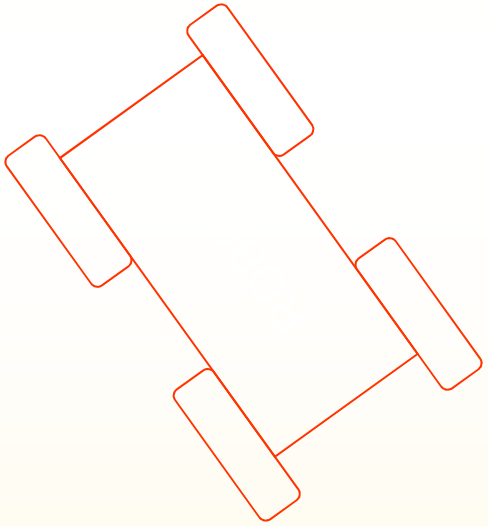
## Steering Suggestions

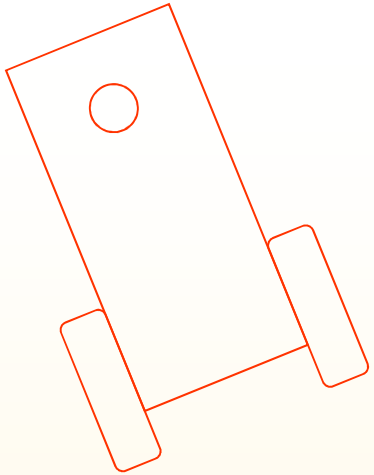
- Skid steering is easy
- Single-joystick controls are great for new drivers
- Two-joystick controls gives drivers more control



# Basic Robot Design Theory

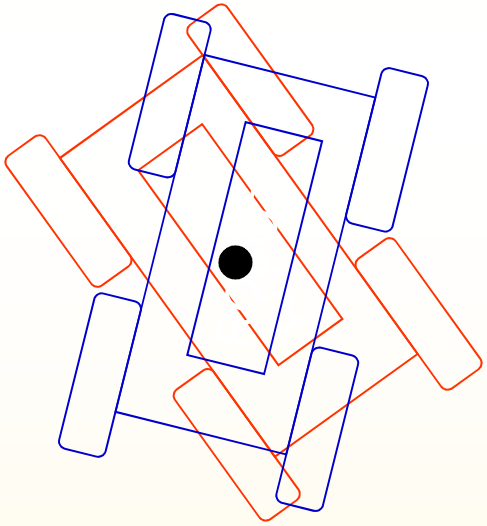
## 4 Wheels vs. 2 Wheels

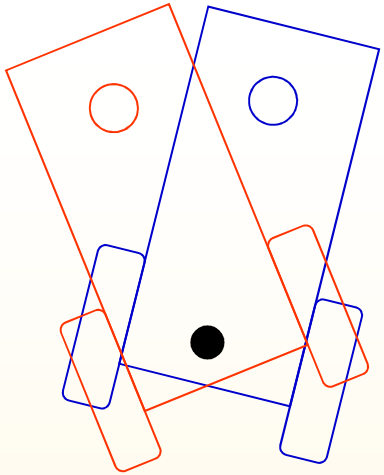




# Basic Robot Design Theory

## 4 Wheels vs. 2 Wheels





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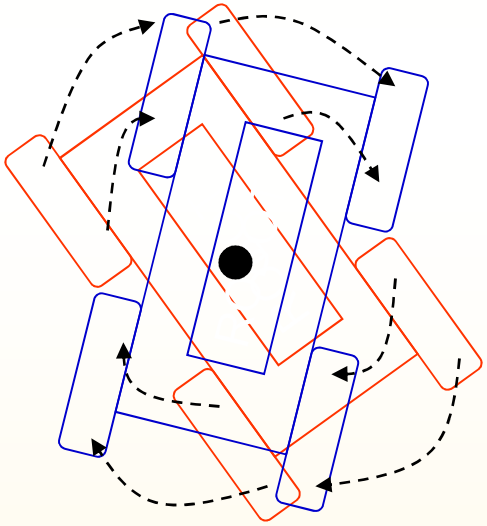
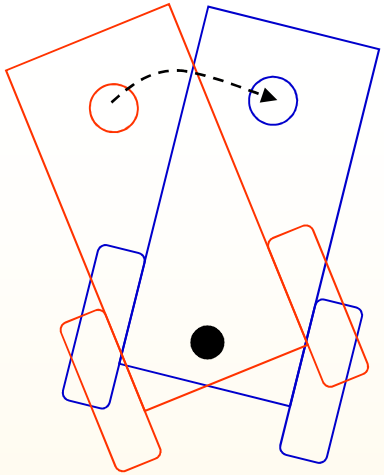
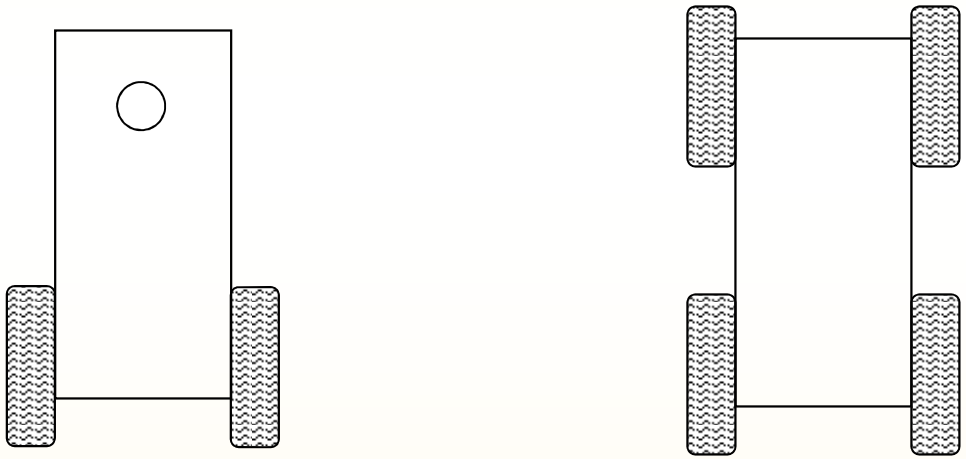
## 4 Wheels vs. 2 Wheels





# Basic Robot Design Theory

## Slicks vs. Grips



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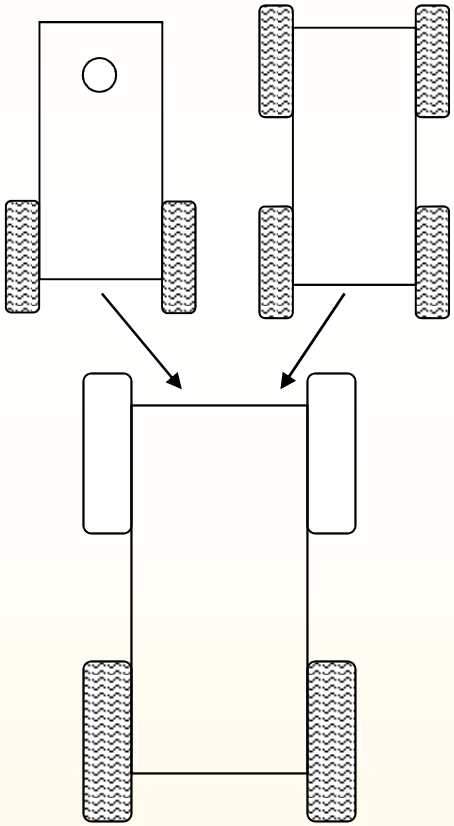

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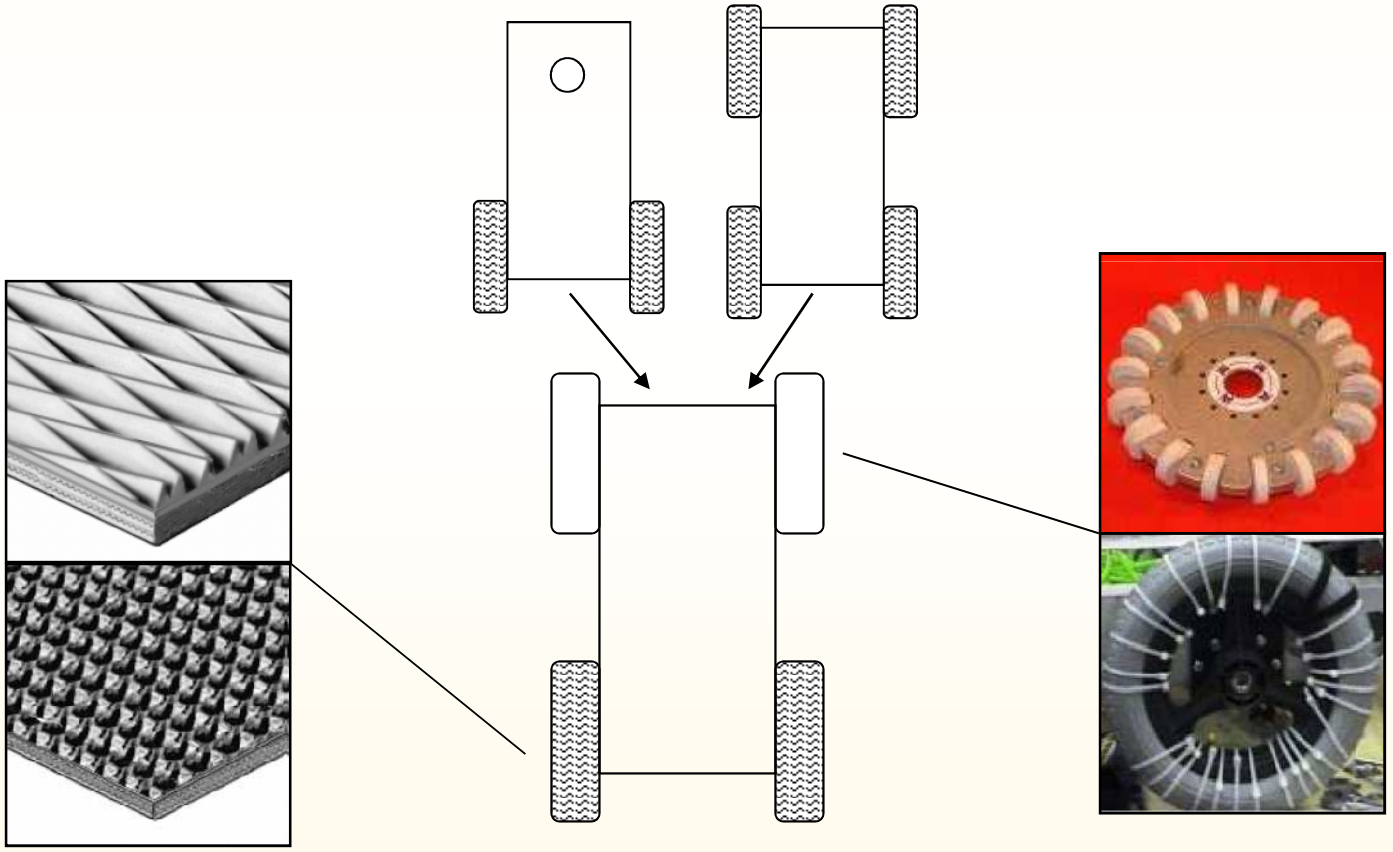


# Basic Robot Design Theory

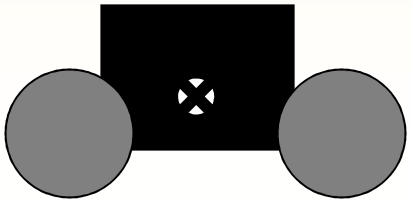
## Wheel Suggestions

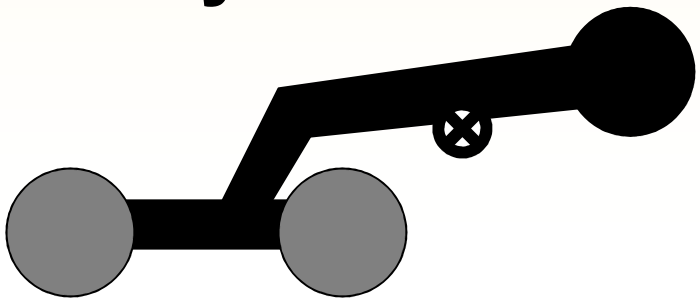
- It doesn't matter how many wheels you have, as long as they all are driven
- If you plan to turn, you should only have two "grippy" tires
  - Incline Conveyor Belt (wedge-top, rough-top)
  - Pneumatic Tires
  - Soft Rubber Tires
- Remaining wheels should be slick
  - Hard rubber or plastic
  - Omni-wheel/Wonder-wheel
  - Zip ties (in case of emergency only!)

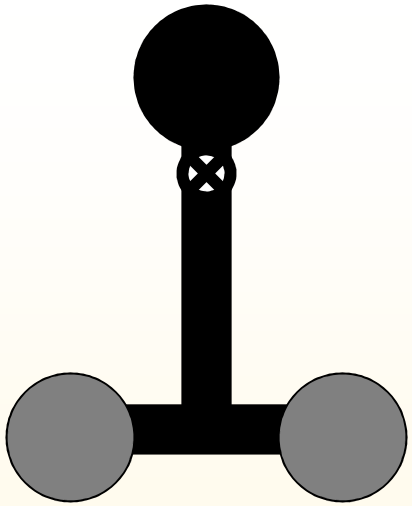


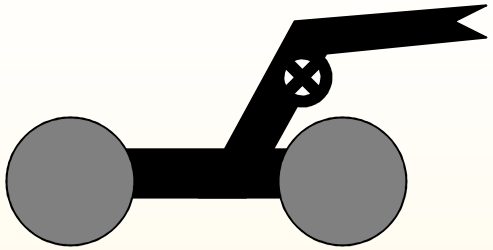
# Basic Robot Design Theory

## Center of Gravity



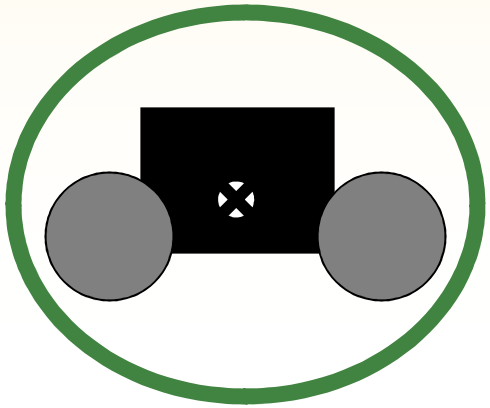


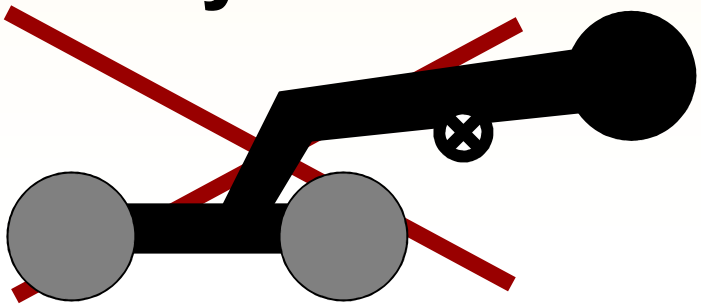


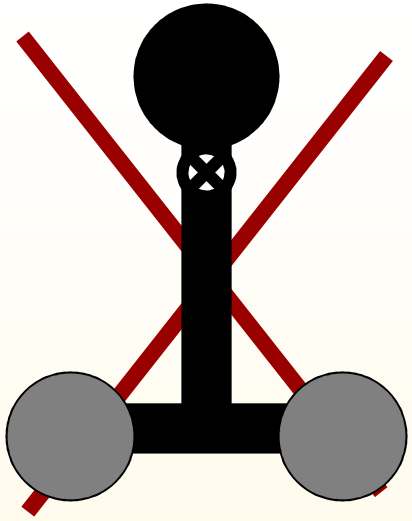


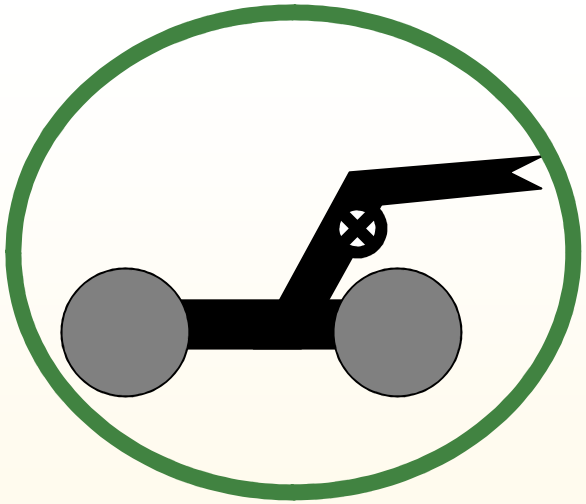
# Basic Robot Design Theory

## Center of Gravity









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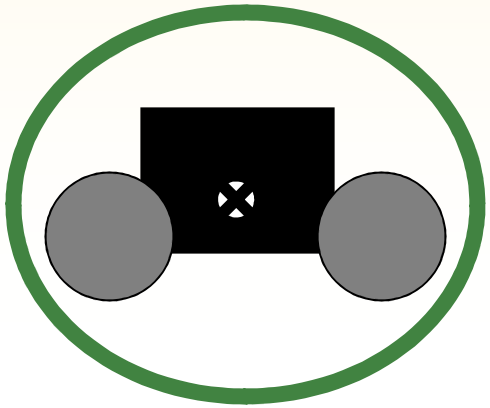

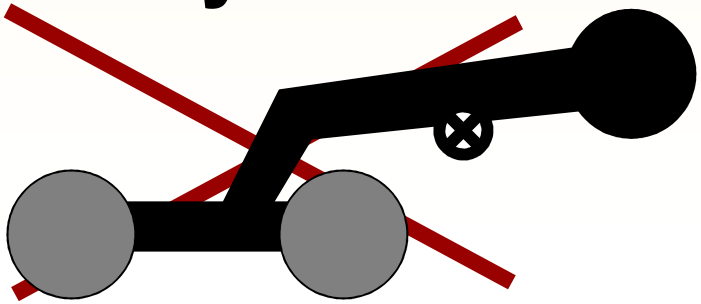

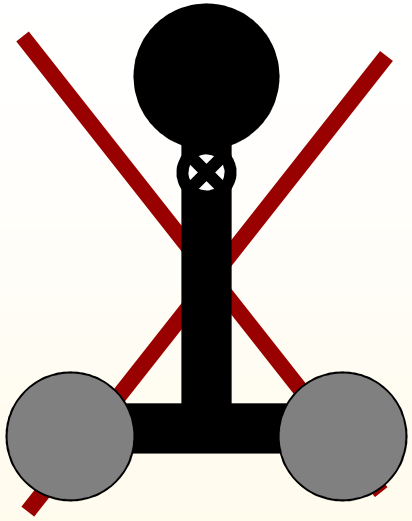

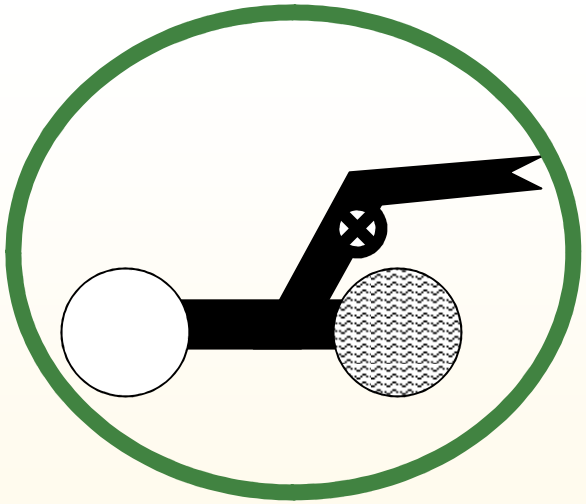

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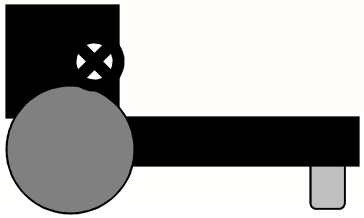

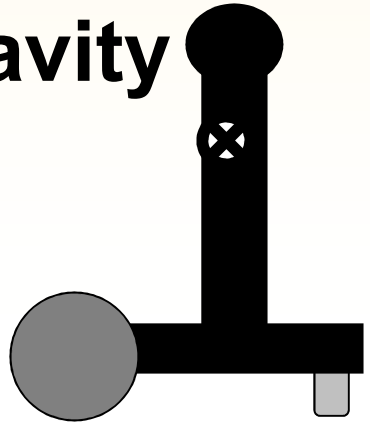

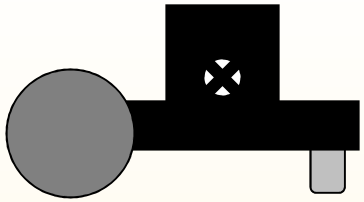

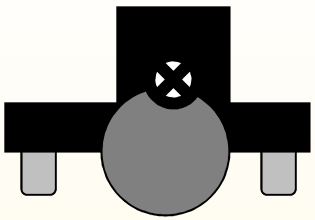

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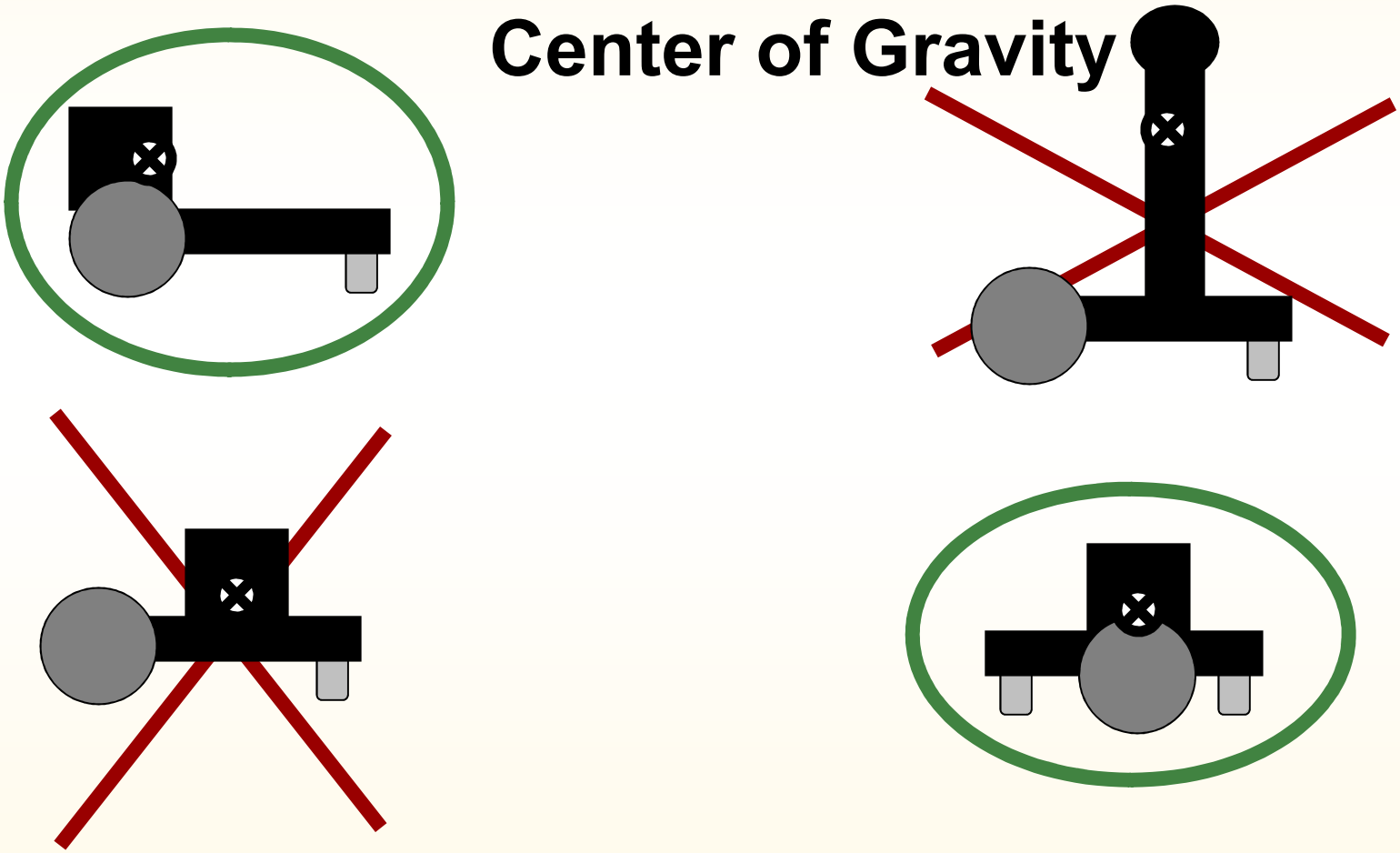

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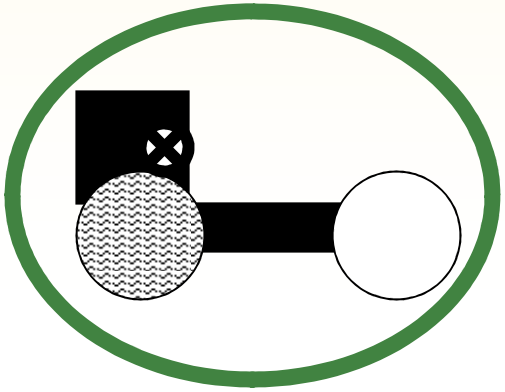
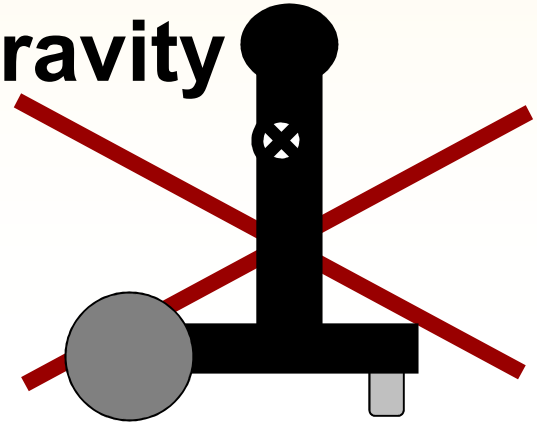
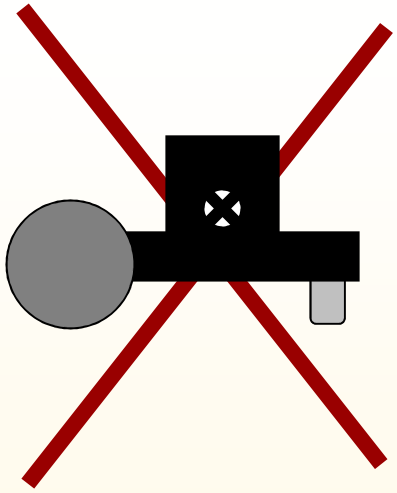
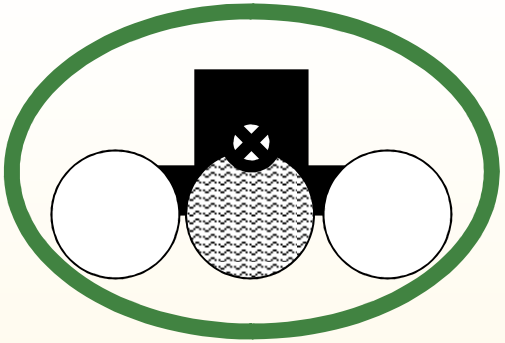








# Basic Robot Design Theory

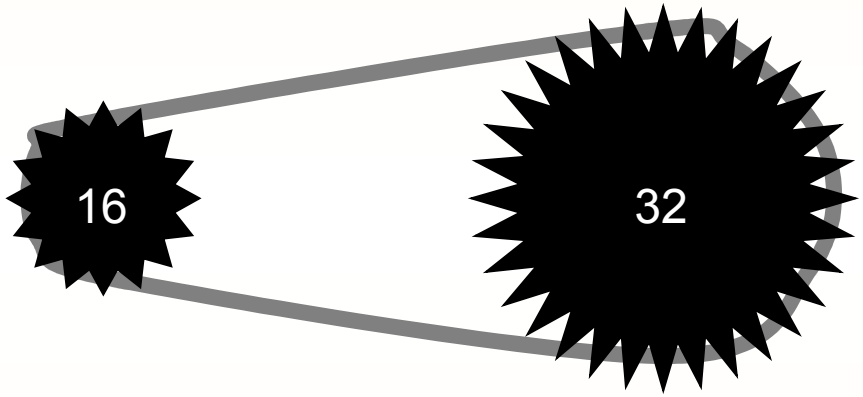
## Weight Distribution Suggestions

- Your center of gravity must be between your wheels
- Your center of gravity must be between your wheels even when your robot is at an angle
- The wheels closest to your center of gravity should be grippy



# Basic Robot Design Theory

## Chain Theory



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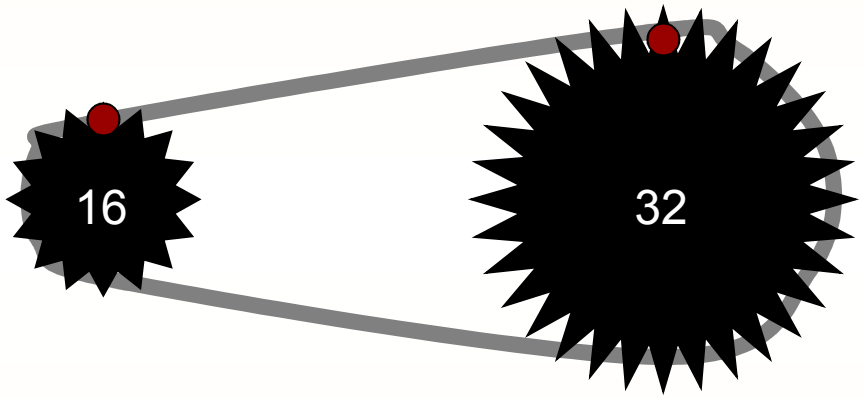

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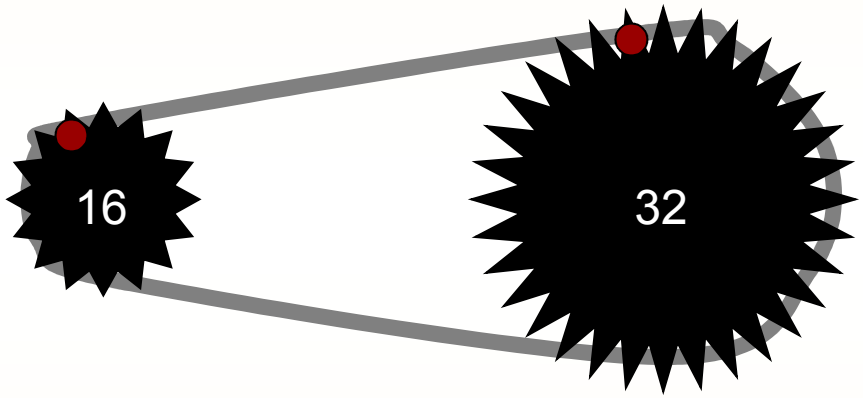

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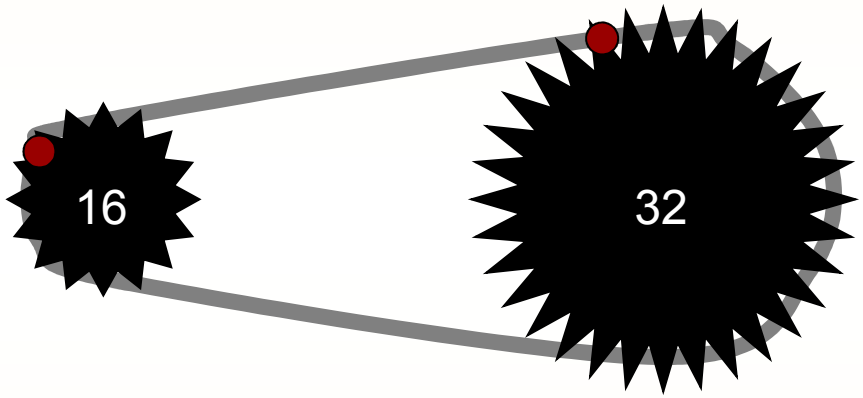

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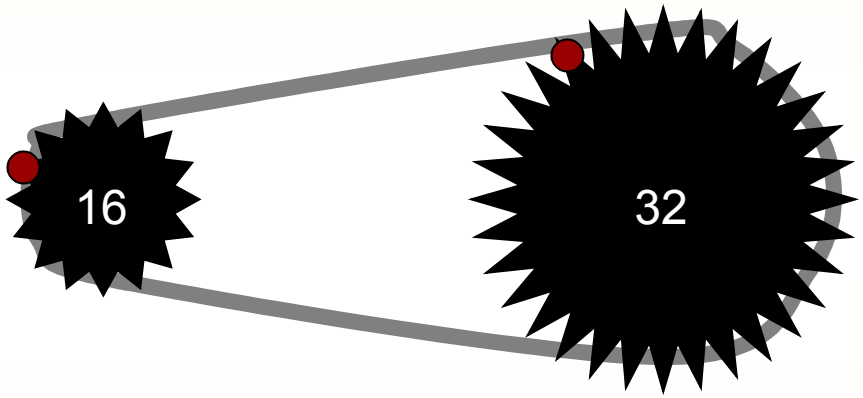

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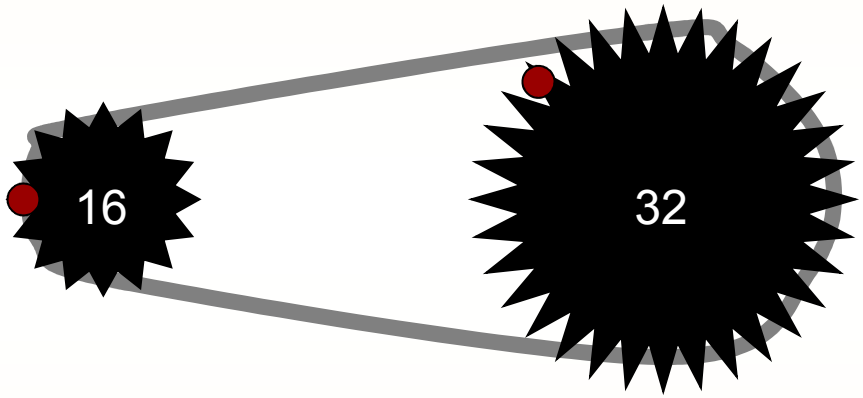

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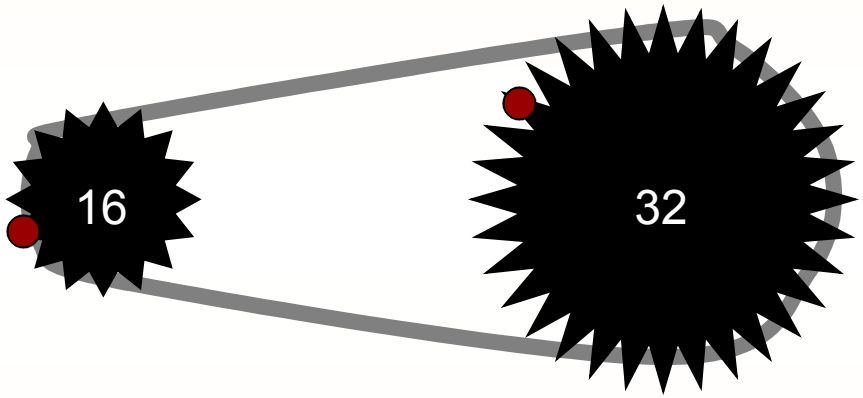

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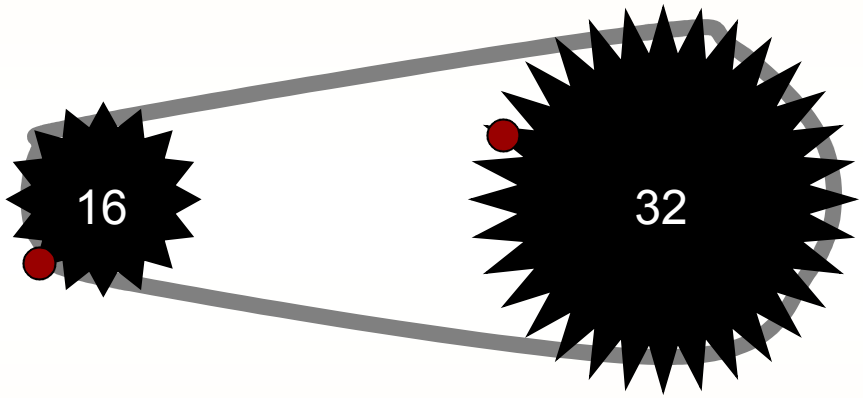

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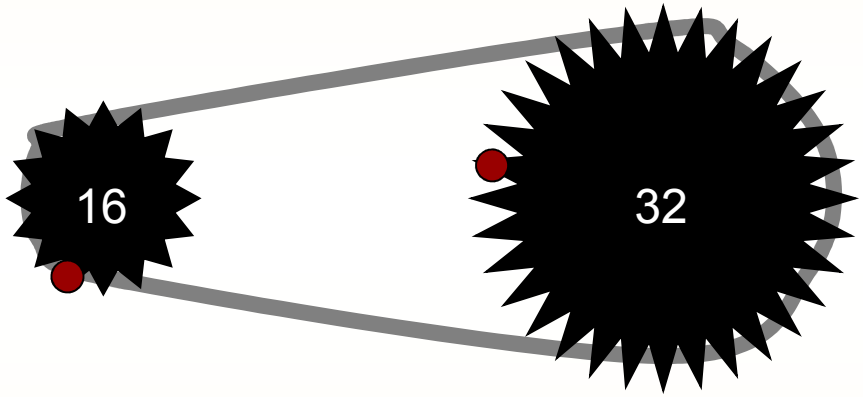

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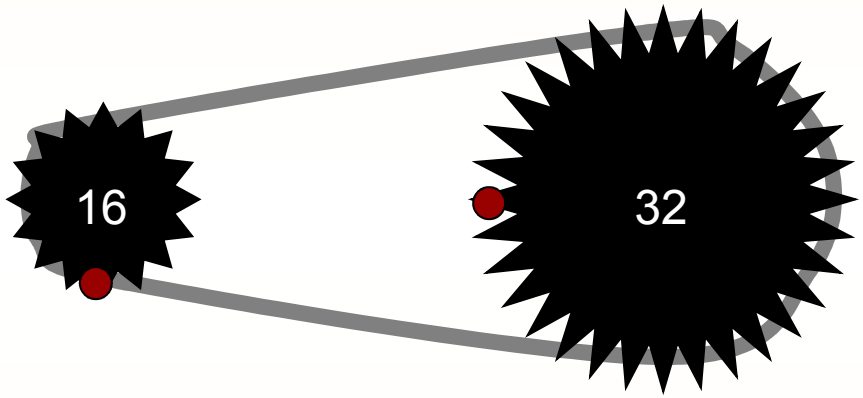

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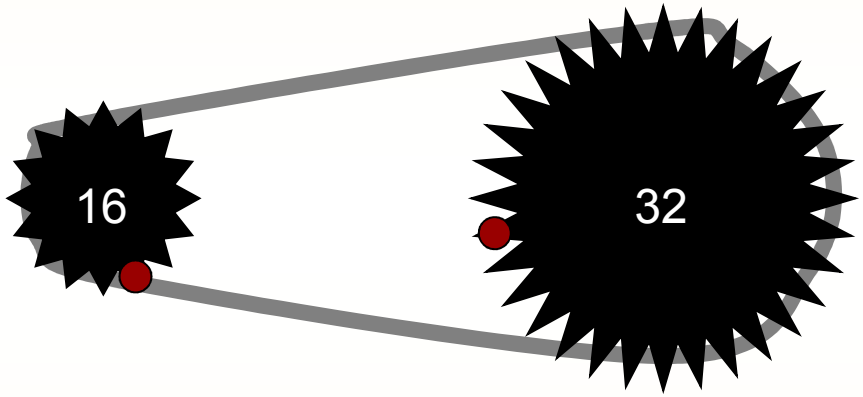

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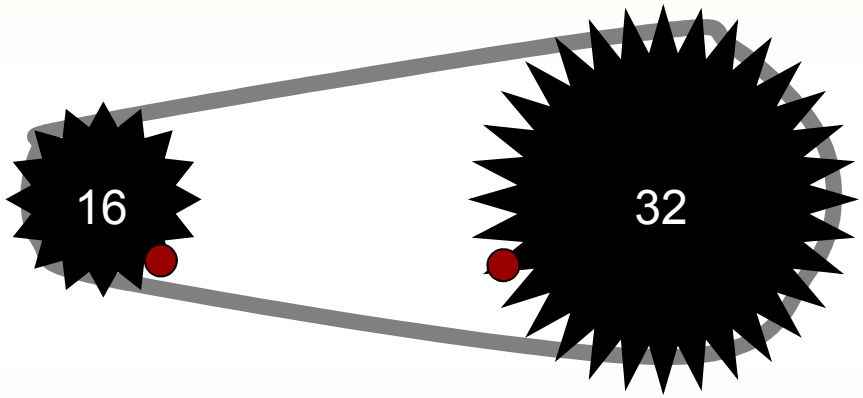

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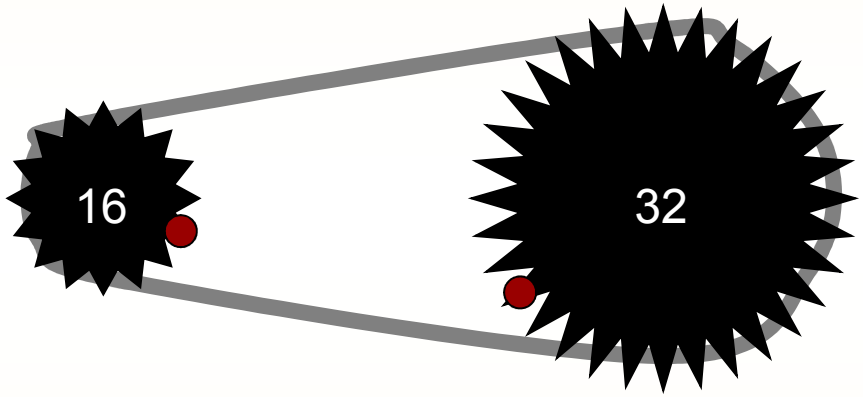

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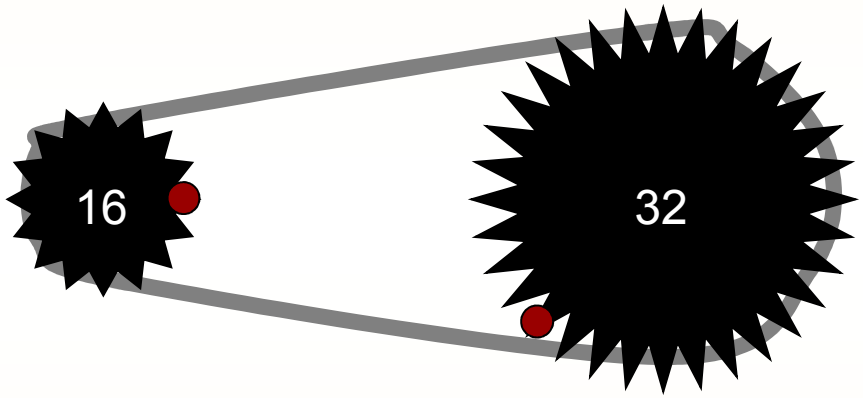

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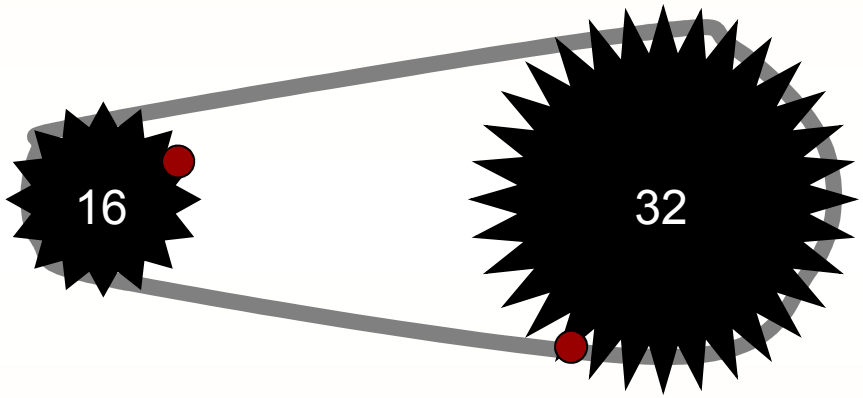

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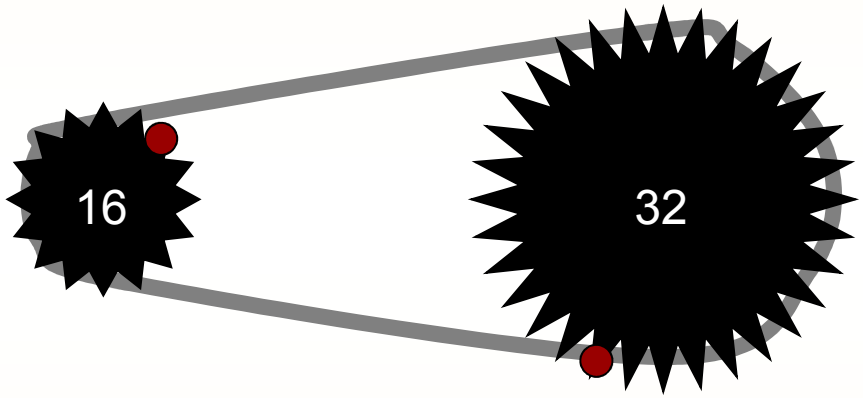

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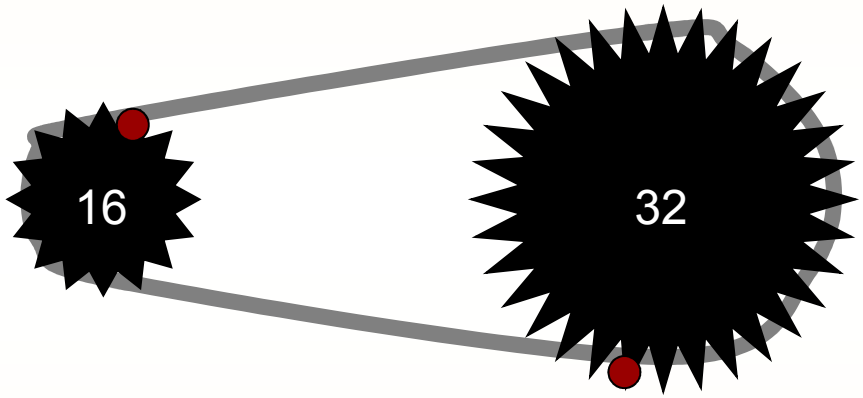

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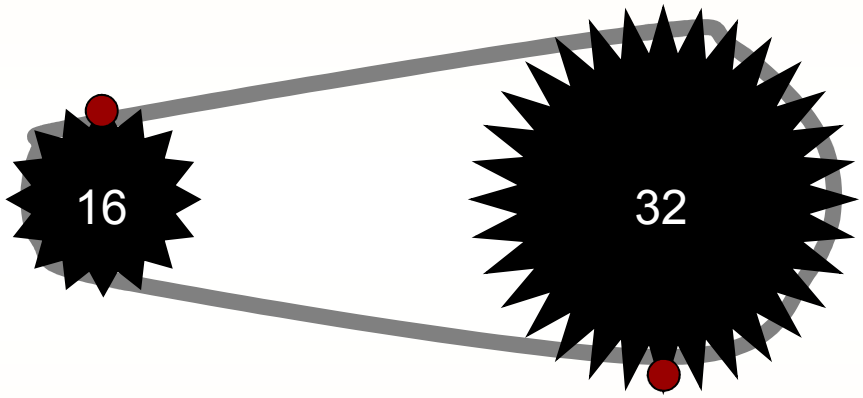


# Basic Robot Design Theory

## Chain Theory

$$rpm_{output} = rpm_{input} * ?$$

$$torque_{output} = torque_{input} * ?$$



# Basic Robot Design Theory

## Chain Theory

$$rpm_{output} = rpm_{input} * \frac{teeth_{input}}{teeth_{output}}$$

$$torque_{output} = torque_{input} * ?$$



# Basic Robot Design Theory

## Chain Theory

$$rpm_{output} = rpm_{input} * \frac{teeth_{input}}{teeth_{output}}$$

$$torque_{output} = torque_{input} * \frac{teeth_{output}}{teeth_{input}}$$



# Basic Robot Design Theory

## Robot Speed

$$speed_{robot} = ?$$



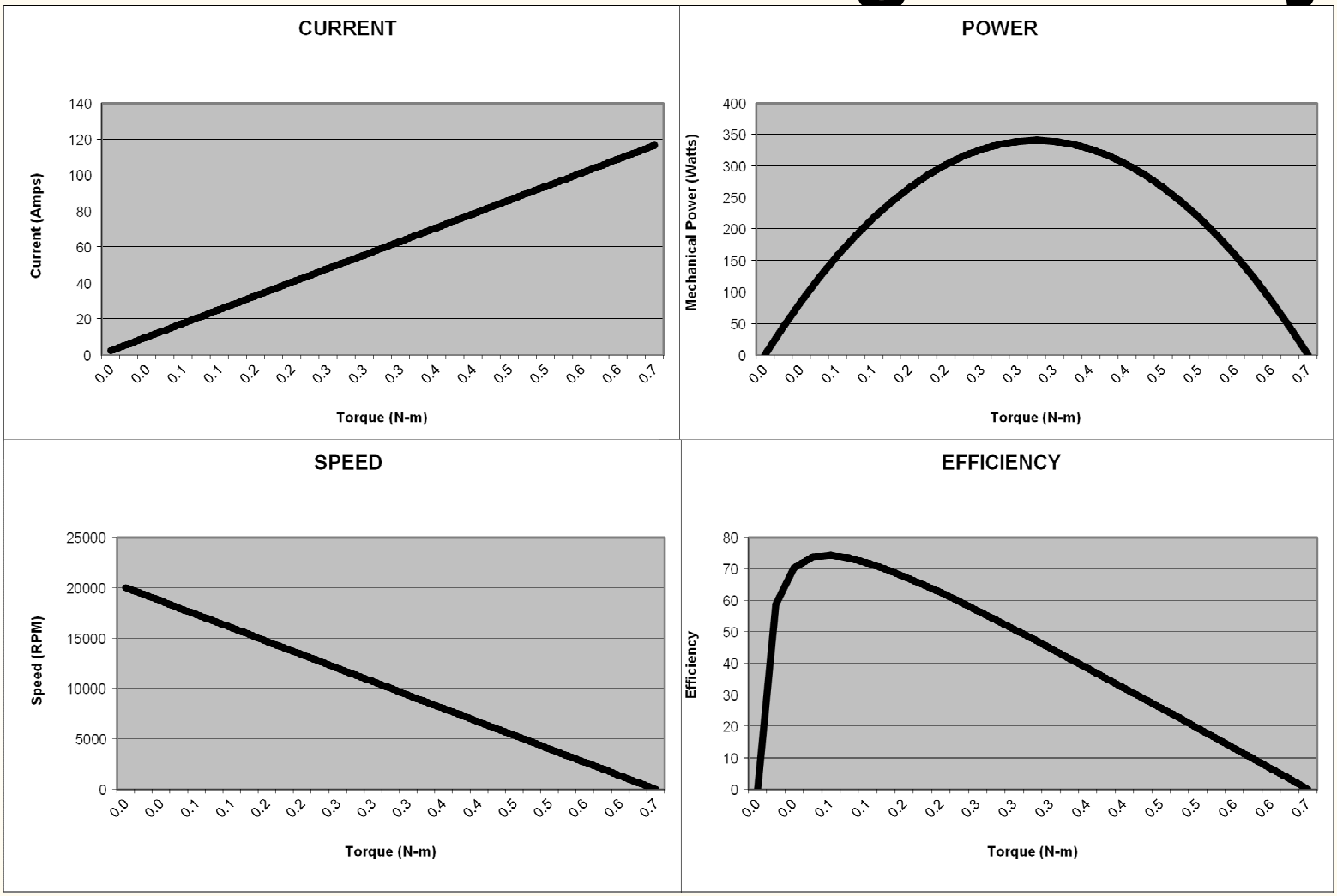
# Basic Robot Design Theory

## Robot Speed

$$speed_{robot} = \frac{rpm_{wheel}}{60} * Diameter_{wheel} * \pi$$



# Basic Robot Design Theory



# Basic Robot Design Theory

**Motor Performance Data**

| Speed (RPMs) | Torque (oz. in.) | Current (Amps) | Power Out (Watts) | Efficiency | Heat (Watts) |
|---|---|---|---|---|---|
| 170 | 0.00 | 0.1 | 0.0 | 0% | 1 |
| 159 | 4.68 | 0.3 | 0.5 | 26% | 2 |
| 147 | 9.35 | 0.4 | 1.0 | 34% | 2 |
| 136 | 14.03 | 0.5 | 1.4 | 36% | 2 |
| 125 | 18.71 | 0.6 | 1.7 | 36% | 3 |
| 113 | 23.38 | 0.7 | 2.0 | 34% | 4 |
| 102 | 28.06 | 0.8 | 2.1 | 32% | 4 |
| 91 | 32.73 | 0.9 | 2.2 | 29% | 5 |
| 79 | 37.41 | 1.0 | 2.2 | 26% | 6 |
| 68 | 42.09 | 1.1 | 2.1 | 23% | 7 |
| 57 | 46.76 | 1.2 | 2.0 | 19% | 8 |



# Basic Robot Design Theory

## Robot Speed

**What size wheel should I use if I want my robot's maximum speed to be 3 feet per second?**



# Basic Robot Design Theory

## Robot Speed

**What size wheel should I use if I want my robot's maximum speed to be 3 feet per second?**

$$3 = \frac{\sim 120}{60} * Diameter_{wheel} * \sim 3$$



# Basic Robot Design Theory

## Robot Speed

**What size wheel should I use if I want my robot's maximum speed to be 3 feet per second?**

$$Diameter_{wheel} \approx \frac{1}{2} \qquad (6 \text{ inches})$$



# Basic Robot Design Theory

## Robot Speed

**If the 6” wheels are the largest I can fit onto my robot, how would I make my robot’s maximum speed 6 feet per second?**



# Basic Robot Design Theory

## Robot Speed

**If the 6” wheels are the largest in the kit, how would I make my robot’s maximum speed 6 feet per second (without damaging the motor or making custom wheels)?**

**Put a sprocket on the motor that is half the size of the sprocket on the wheel.**



# Basic Robot Design Theory

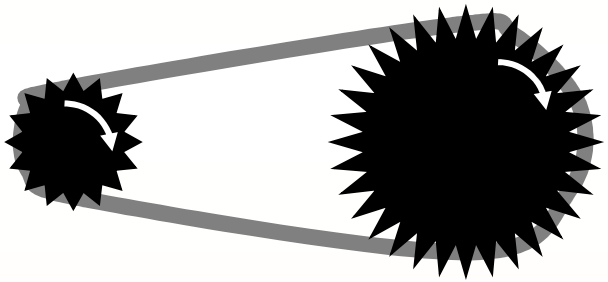
## Sprockets vs. Gears

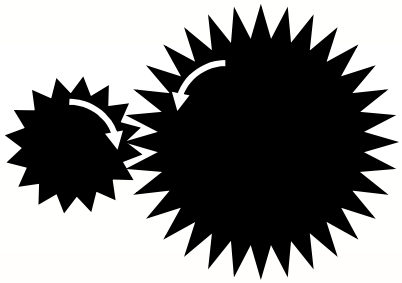
Sprocket

Gears

# Basic Robot Design Theory

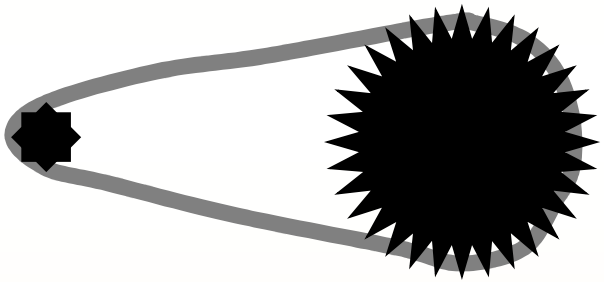
## Sprockets vs. Gears





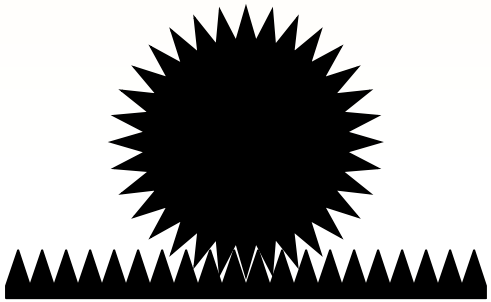
# Basic Robot Design Theory

## Sprockets vs. Gears



Maximum ratio 8:1

9–72 teeth



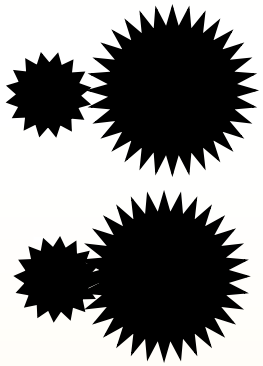
Infinite Ratio Possible

13 – ∞ teeth (<18 not recommended)

# Basic Robot Design Theory

## Sprockets vs. Gears

Face Alignment Critical



Spacing Critical

# Basic Robot Design Theory

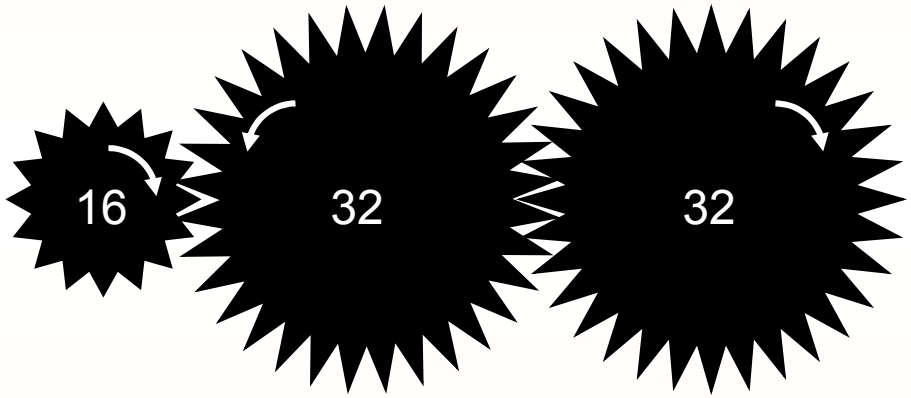
## Gear and Sprocket Recommendations

- Sprockets are used with chains, gears mesh with each other
- Sprockets and gears are NOT interchangeable
- Sprocket and chain systems are easier to build than gear systems
- Gear systems can be smaller and lighter than chains and sprockets



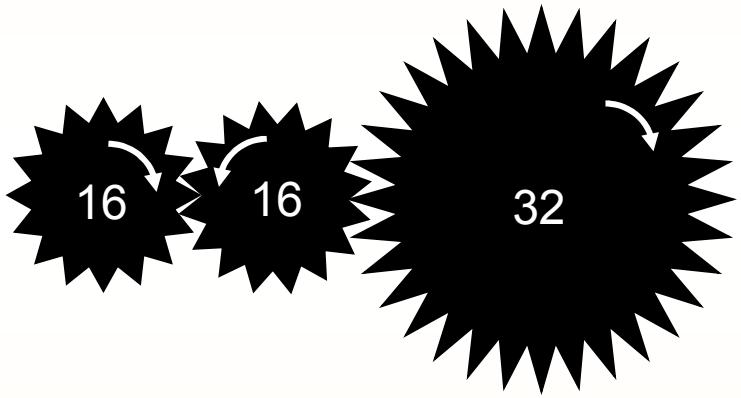
# Basic Robot Design Theory

## Idler Gears



# Basic Robot Design Theory

## Idler Gears



# Basic Robot Design Theory

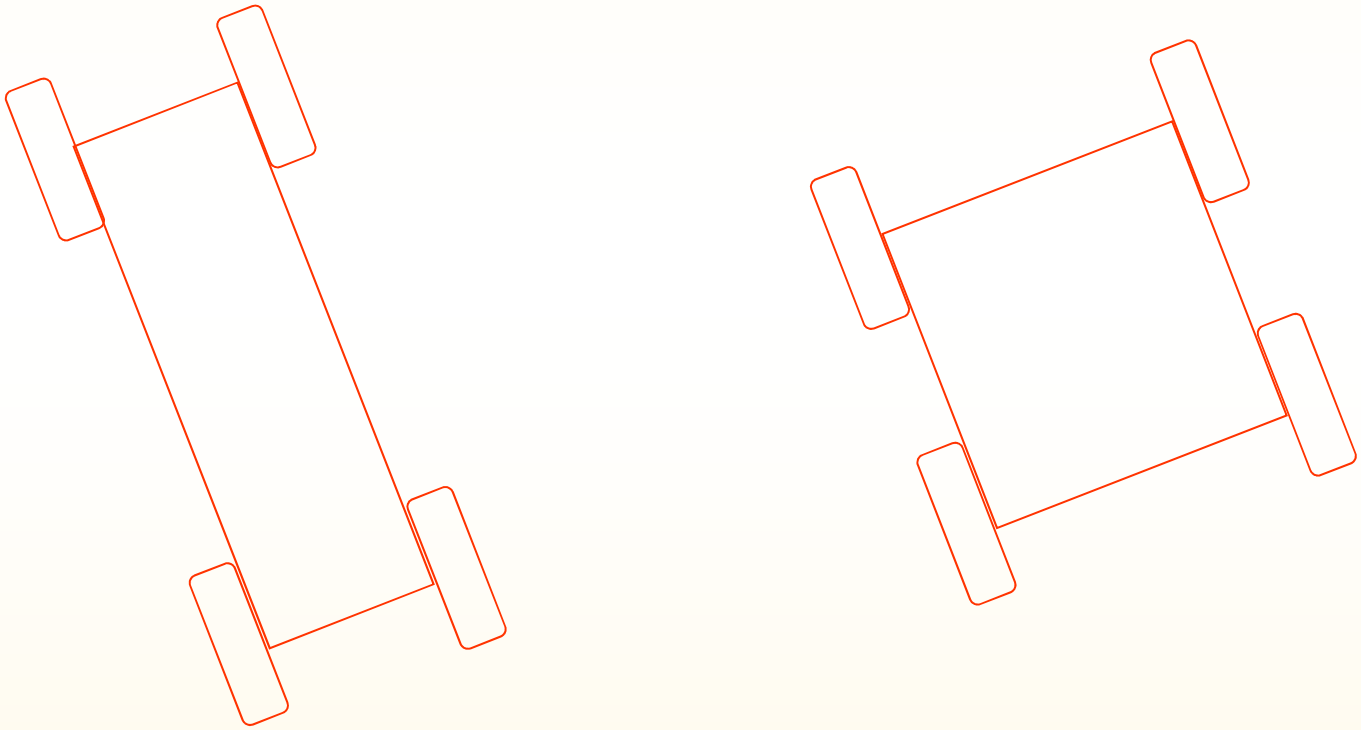
## Further Gear and Sprocket Recommendations

- Idler gears change direction of motion, but don't change gear ratio
- Properly designed gear or chain and sprocket systems are ~97% efficient at each gear/sprocket, so idlers don't effect much if you don't go overboard



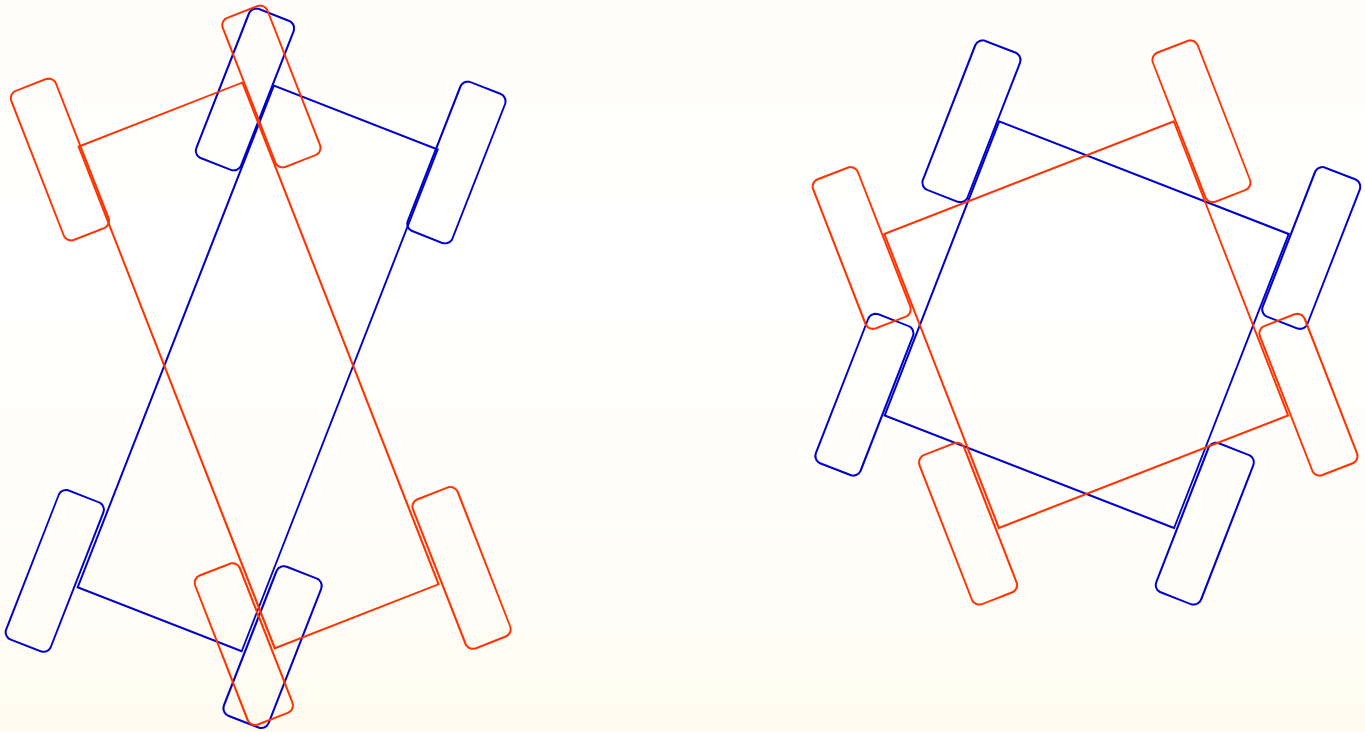
# Basic Robot Design Theory

## Wheelbase

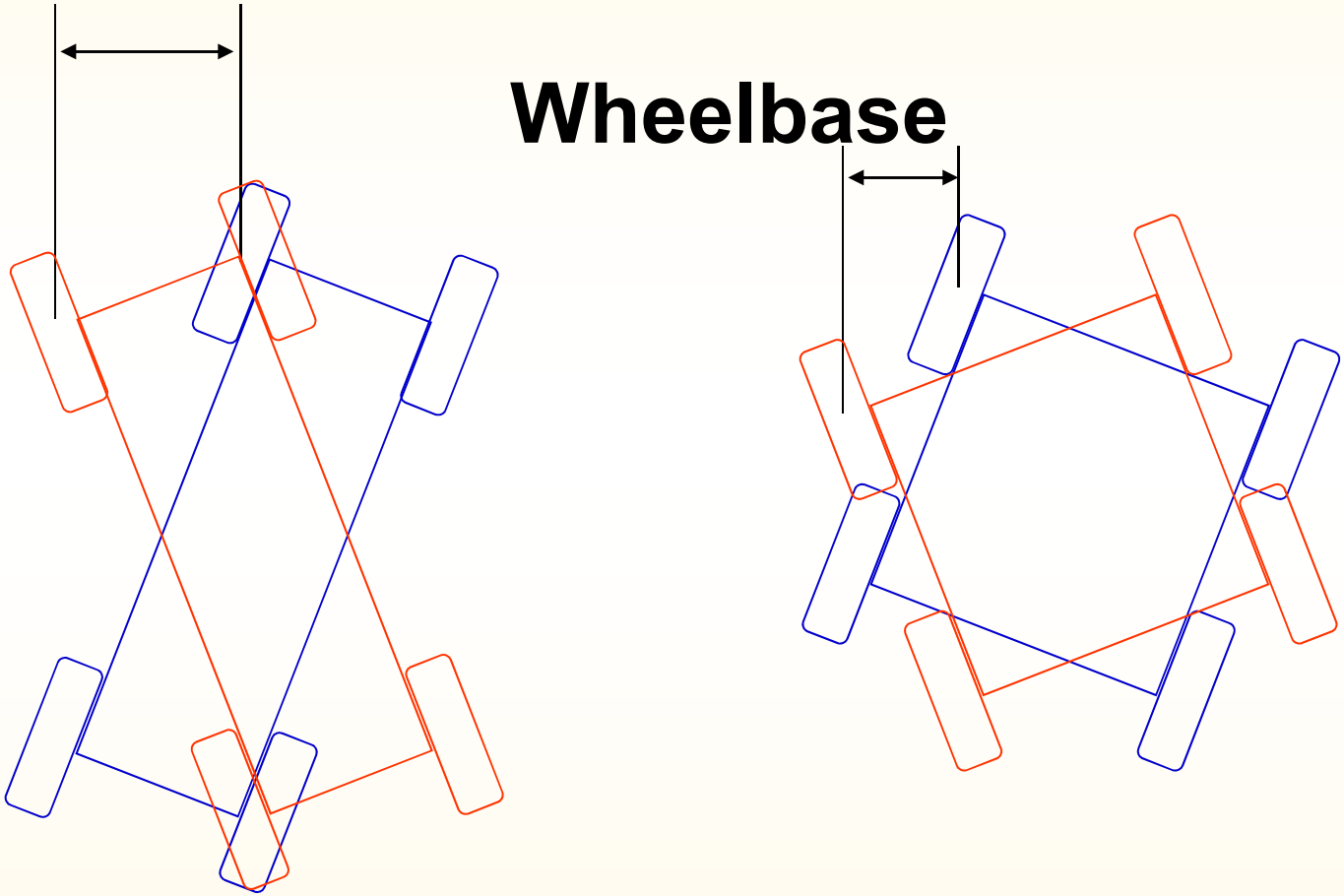


# Basic Robot Design Theory

## Wheelbase

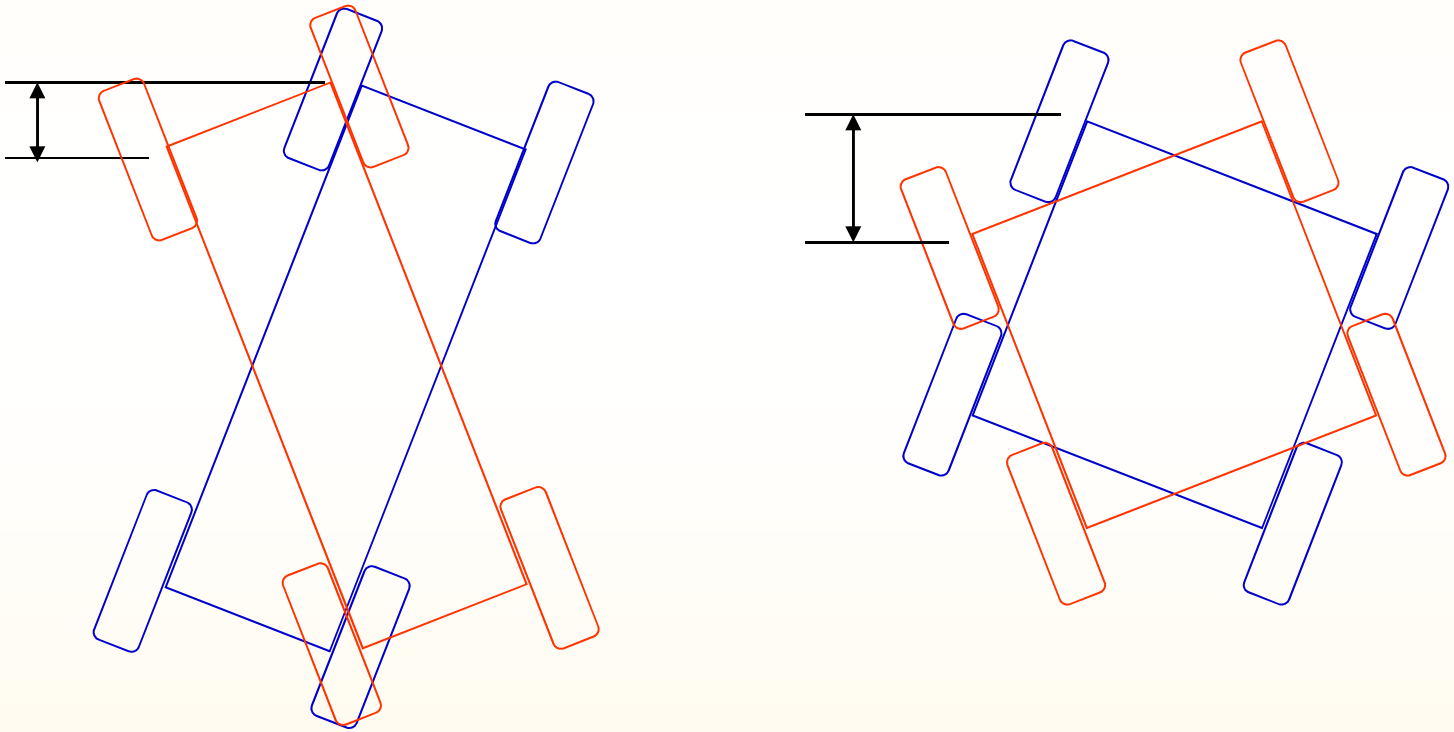


# Basic Robot Design Theory



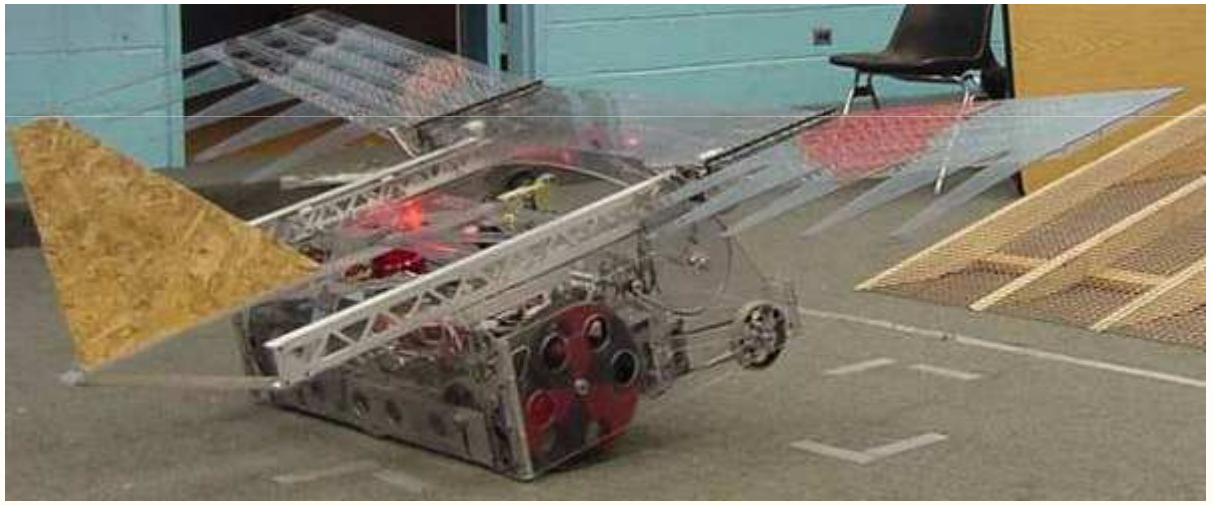
# Basic Robot Design Theory

## Wheelbase



# Basic Robot Design Theory

## Wheelbase

# Basic Robot Design Theory

## Wheelbase Recommendations

• Short and wide robots turn easily and have lots of control, but will tend to not drive straight

•Long and narrow robots will not turn easily and will have poor turning control, but will tend to drive very straight

•Depending on the task, you should balance the two



# Building a Chassis

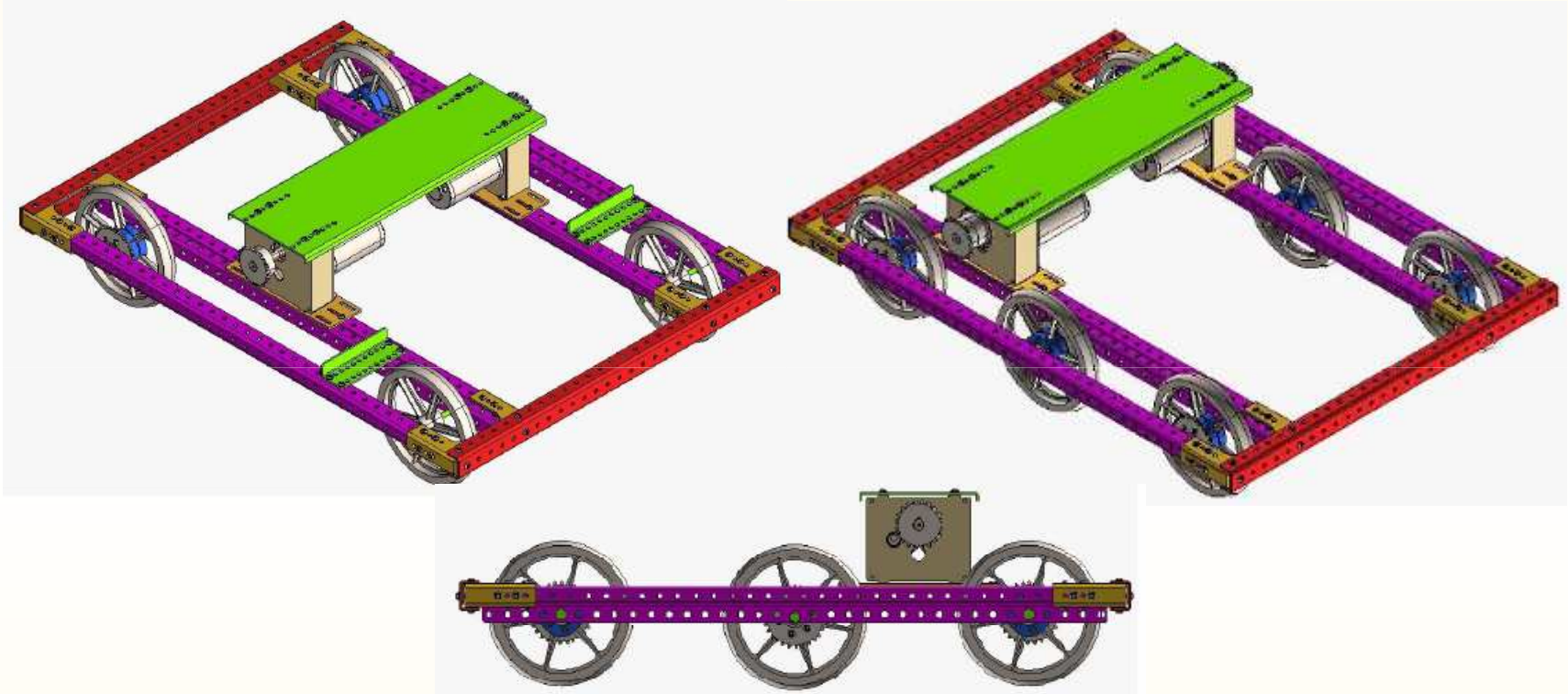
# Building a Chassis

## Design Tradeoffs

- Stable vs. Maneuverable
- Accessible vs. Compact
- Strong & Rigid vs. Light
- Manufacturable & Affordable vs. Everything



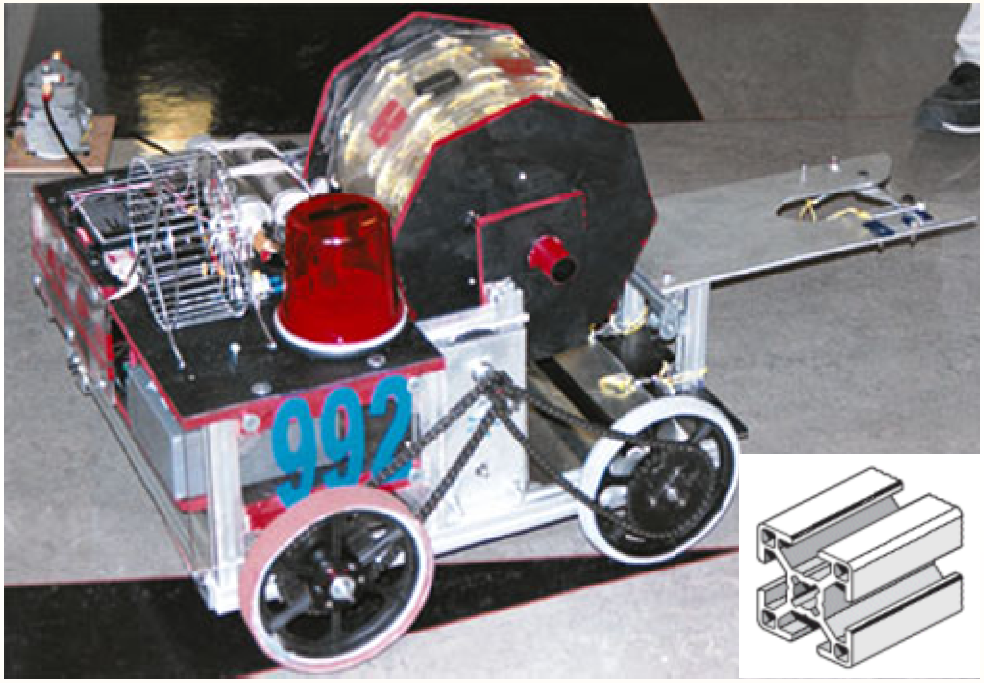
# Building a Chassis
## Kit Chassis



- **Advantages: lightweight, quick to build, uses standard parts**
- **Disadvantages: may not fit your design, requires added structure (that will most likely be put on anyway)**

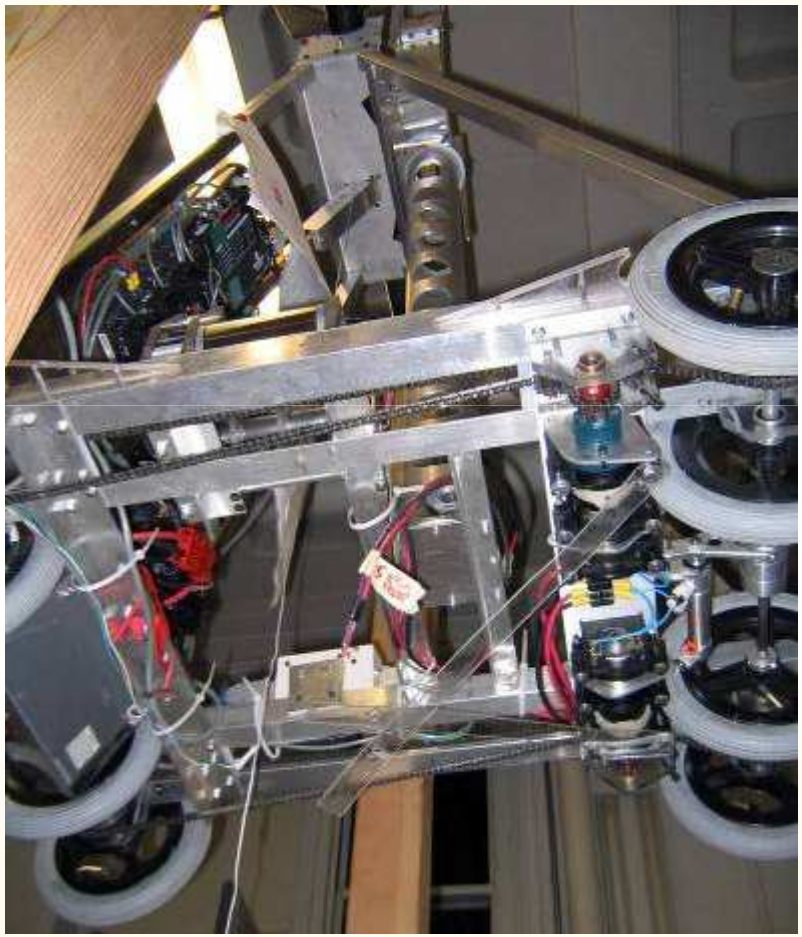
# Building a Chassis

## T-Slot Extrusion (80/20)




- Advantages: quick to build, standard parts, easy to create tension and to add fastening points
- Disadvantages: heavy, expensive

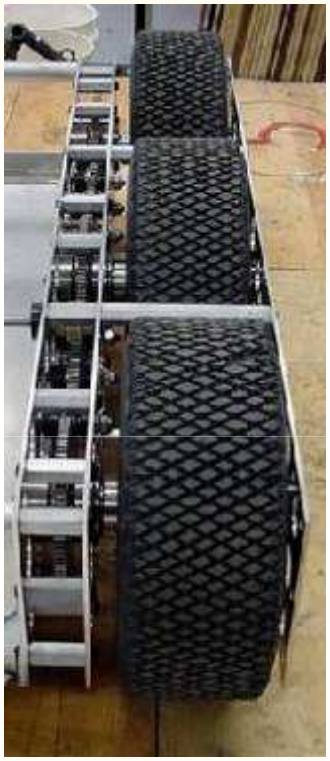
# Building a Chassis
## Aluminum Tube and Plate



- **Advantages: lightweight, strength, fits your design**
- **Disadvantages: takes time, requires skill, non standard parts**

# Building a Chassis

## Miscellaneous

- Advantages: fits your design, unique
- Disadvantages: takes much time, requires skill, non standard parts

# Building a Chassis

## Materials

- **Aluminum Extrusion**
  - 1/16” – 1/8”: usable but will dent and bend
  - T-slot: use 1” sized profiles or higher
- **Aluminum Plate, Bar, and Angle**
  - 3/16” – ¼” used often
- **Plastic Sheet**
  - Spans structures, provides bracing
  - Polycarbonate (LEXAN, etc.) NOT Acrylic (Plexiglas, etc.)
- **Wood**
  - Lightweight and easy to use
  - Will splinter and fail but can be fixed
- **Steel Tube and Angle**
  - Strong, but heavy, 1/16” wall thickness is plenty strong
- **Misc**
  - Extruded fiberglass, PVC tubing, etc. Use your imagination!



# Building a Driveline

# Building a Driveline

## Design Tradeoffs

- Speed vs. Power
- Traction vs. Maneuverability

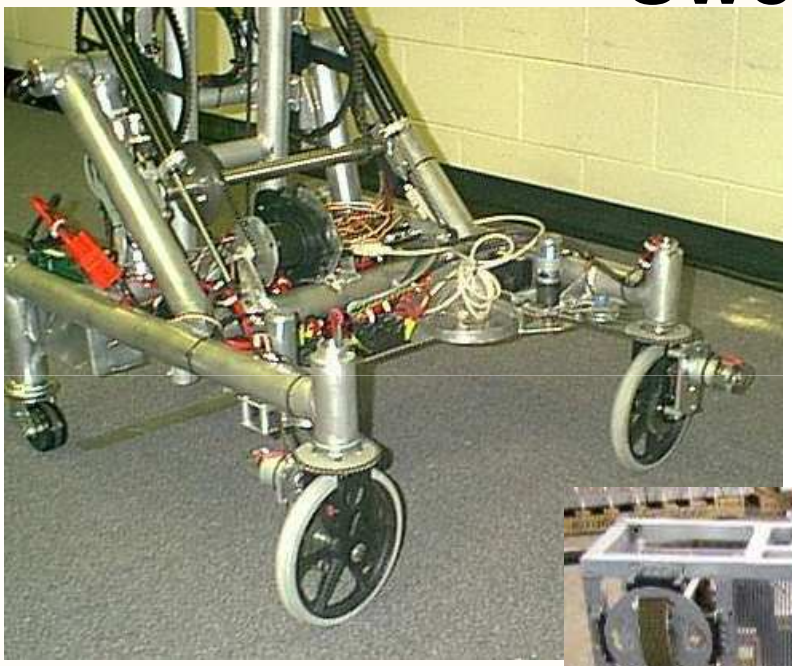


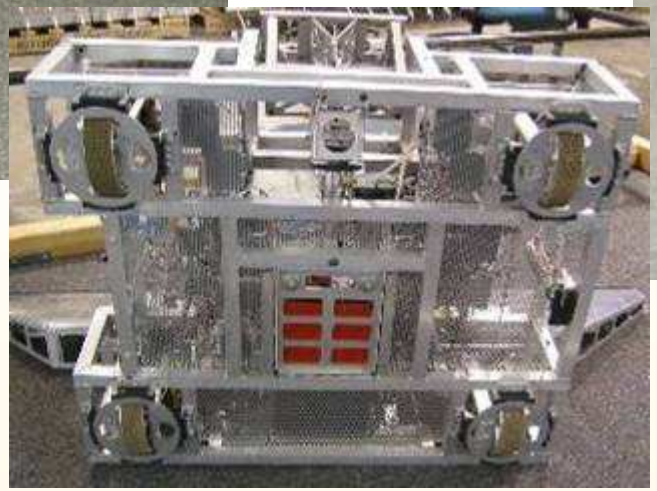
# Building a Driveline

## 6-Wheel Drive

# Building a Driveline

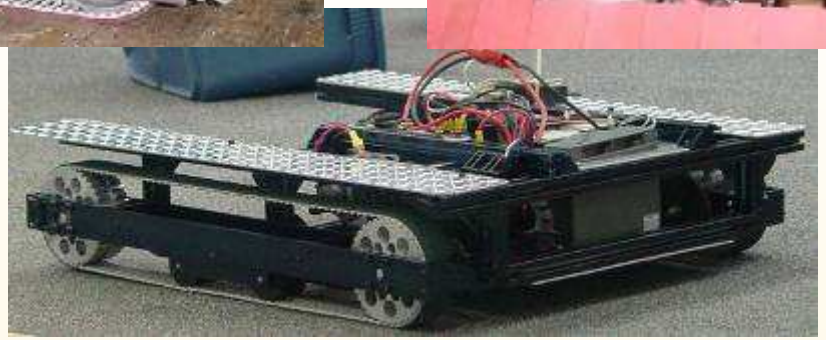
## Swerve Drive





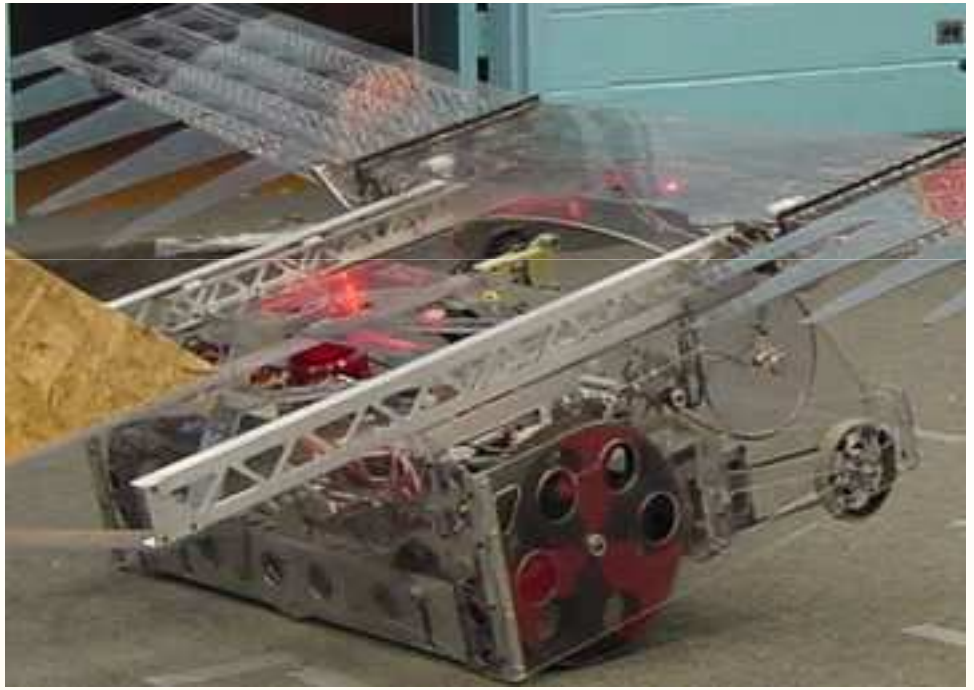
# Building a Driveline

## Treads



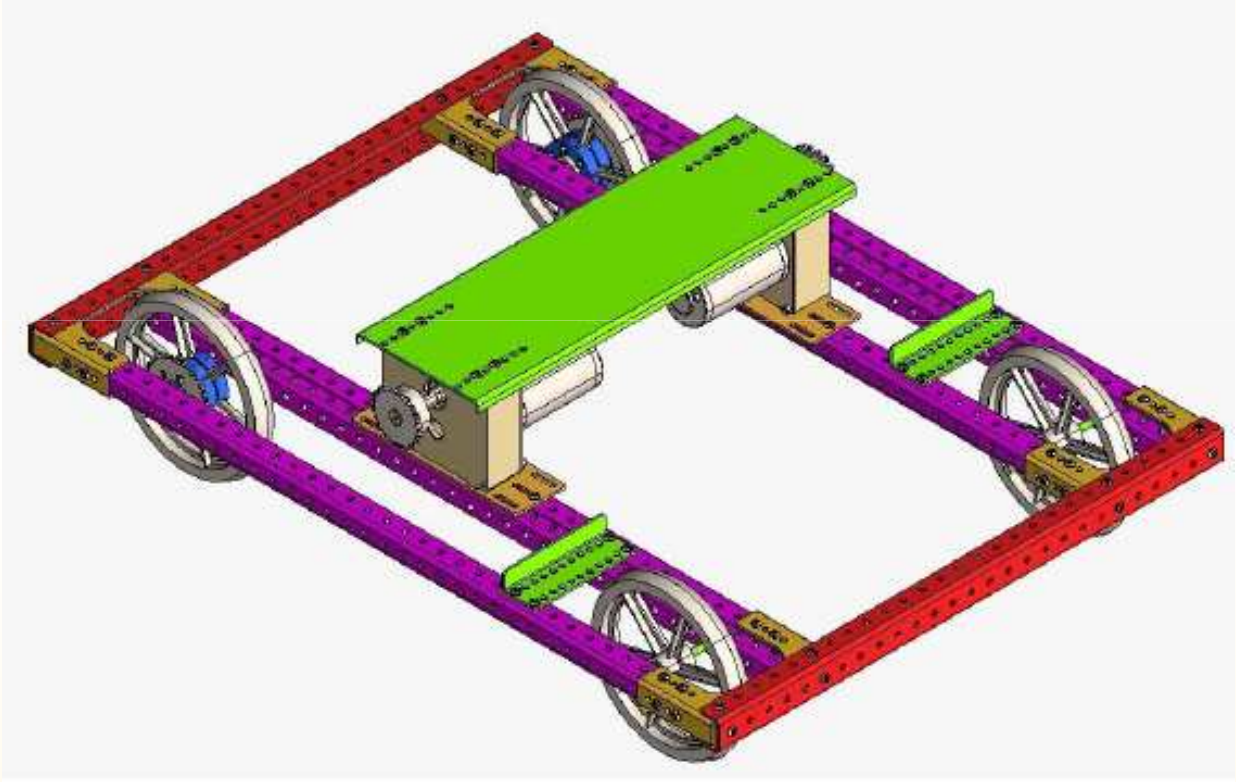
# Building a Driveline

## Other Wheel Configurations



# Building a Driveline

## Standard 4-wheel Tank Drive



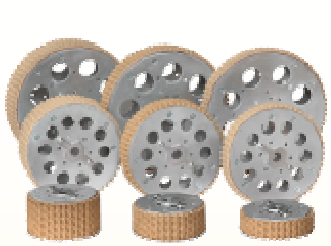
# Building a Driveline

## Wheel Sources

- Kit of Parts Skyway wheels (more available at FIRST team discount from 800-332-3357)

- Colson Casters (available from many places, including http://www.robotmarketplace.com/)

- FIRST Specific wheels (high traction wheels, omniwheels, etc)
  - http://andymark.biz/
  - http://ifirobotics.com/



- Make your own (can be made from aluminum, wood, HDPE, lexan, etc.)

# Building a Driveline

## Driveline Recommendations

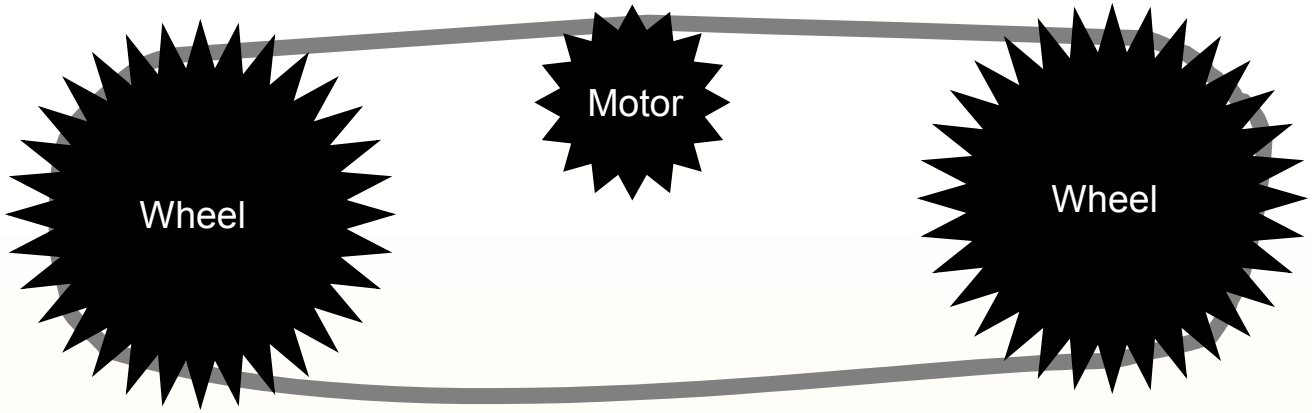
• There are many types of drivelines, choose the one that best fits your specific game strategy.

• A well driven, reliable, “vanilla” driveline will beat a complex and unreliable driveline in competition.



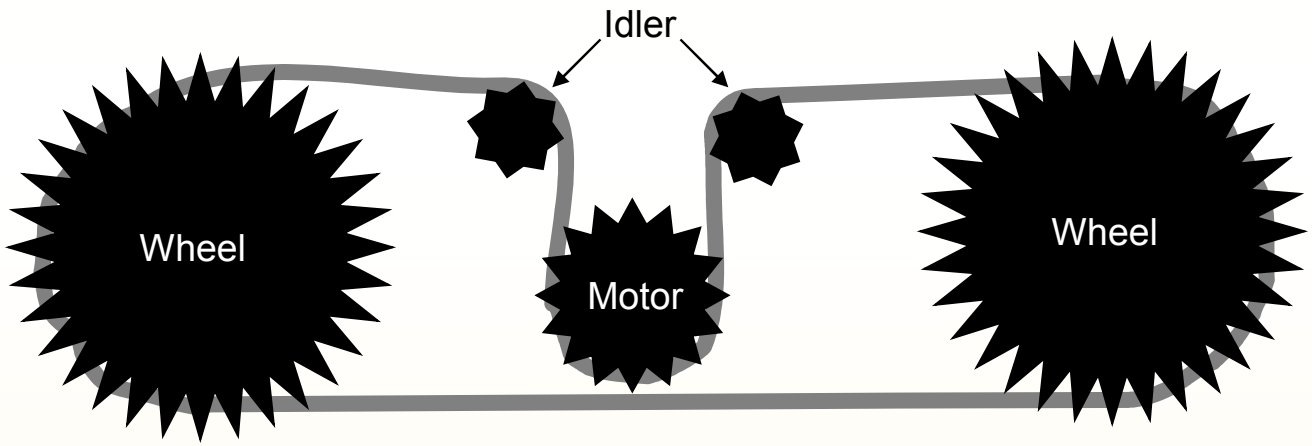
# Building a Driveline

## Chain Wrap



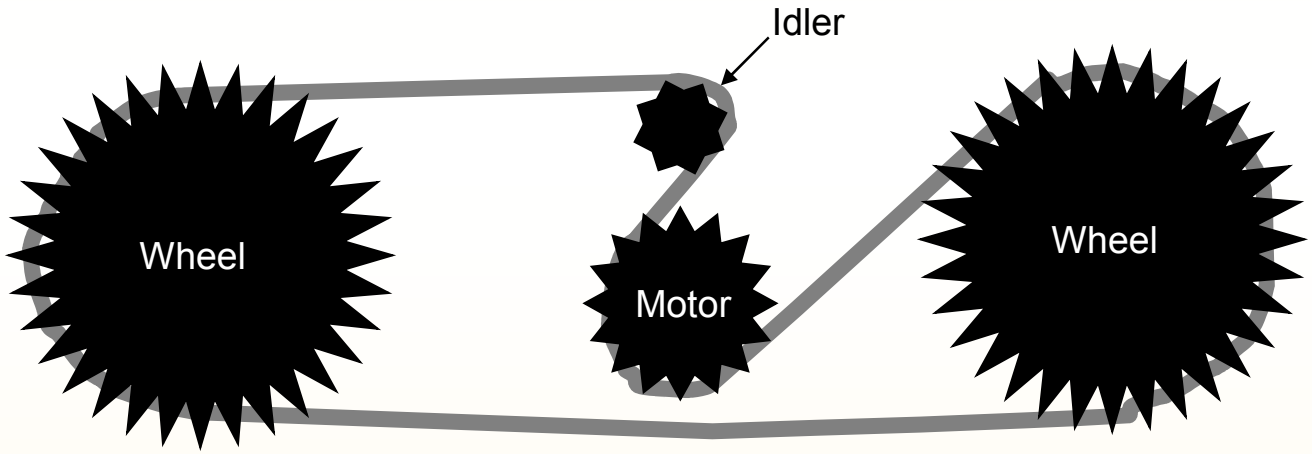
# Building a Driveline

## Chain Wrap



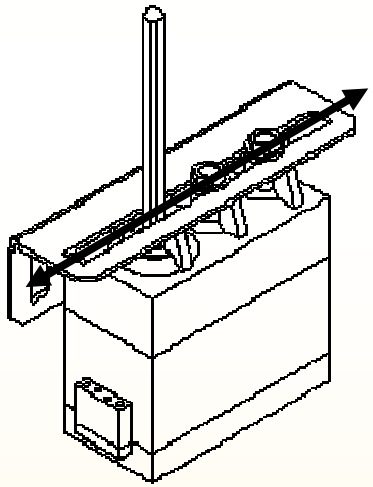
# Building a Driveline

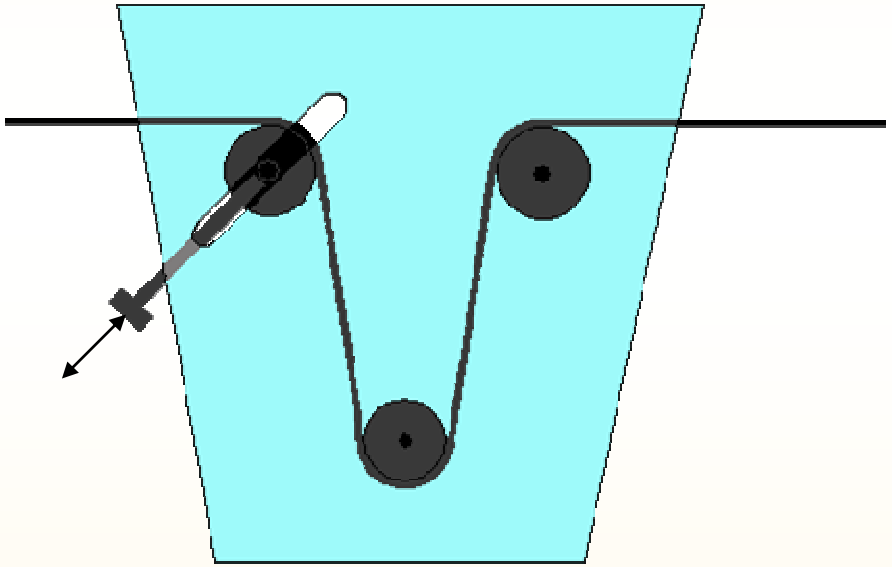
## Chain Wrap



# Building a Driveline

## Chain Tension





# Building a Driveline

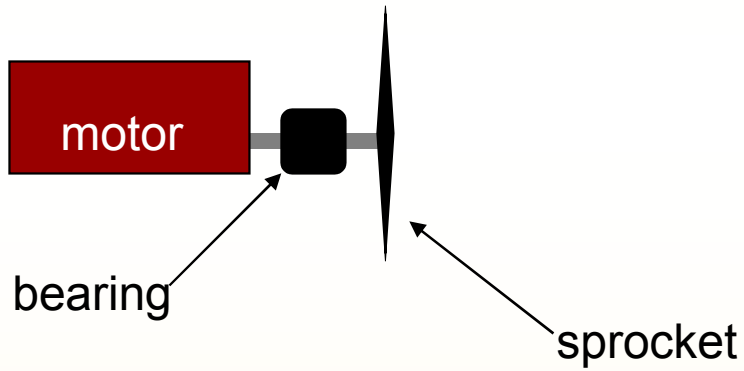
## Further Gear and Sprocket Recommendations

- All sprockets must have >120º of chain wrap (180º is better)
- Chains “stretch” as they wear, have a way to adjust tension



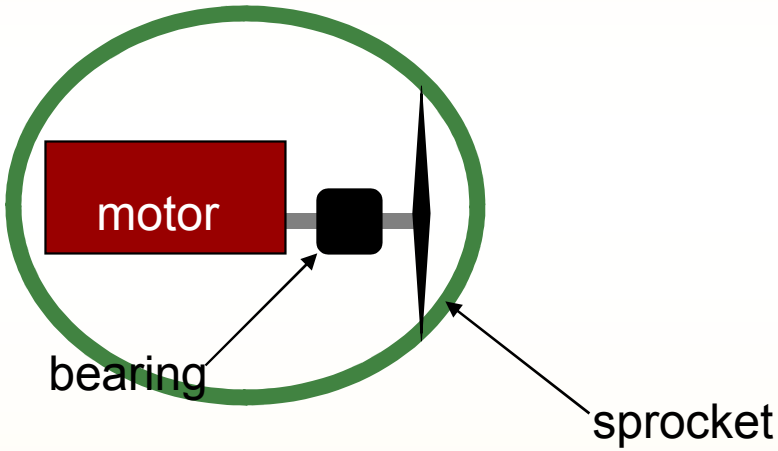
# Building a Driveline

## Supporting Shafts



# Building a Driveline

## Supporting Shafts



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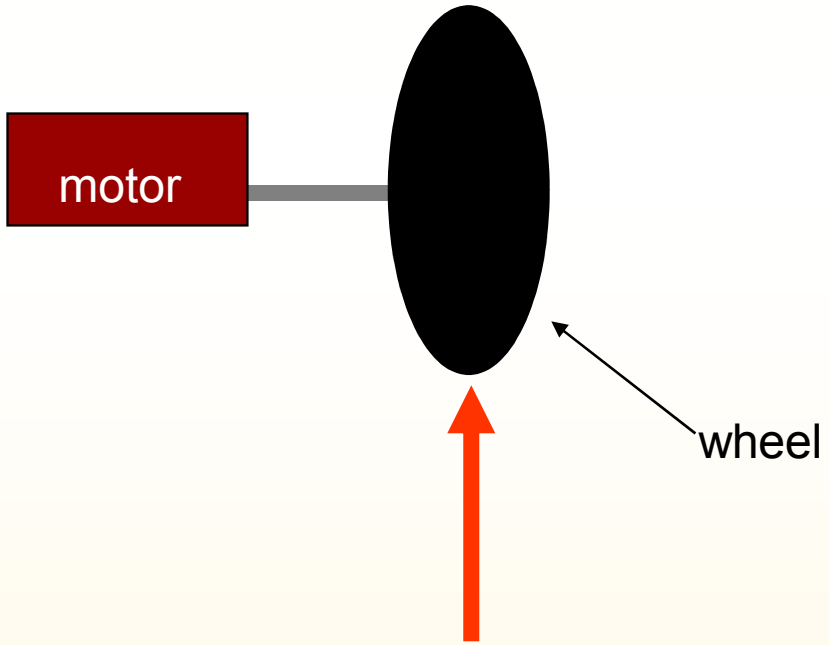
## Supporting Shafts



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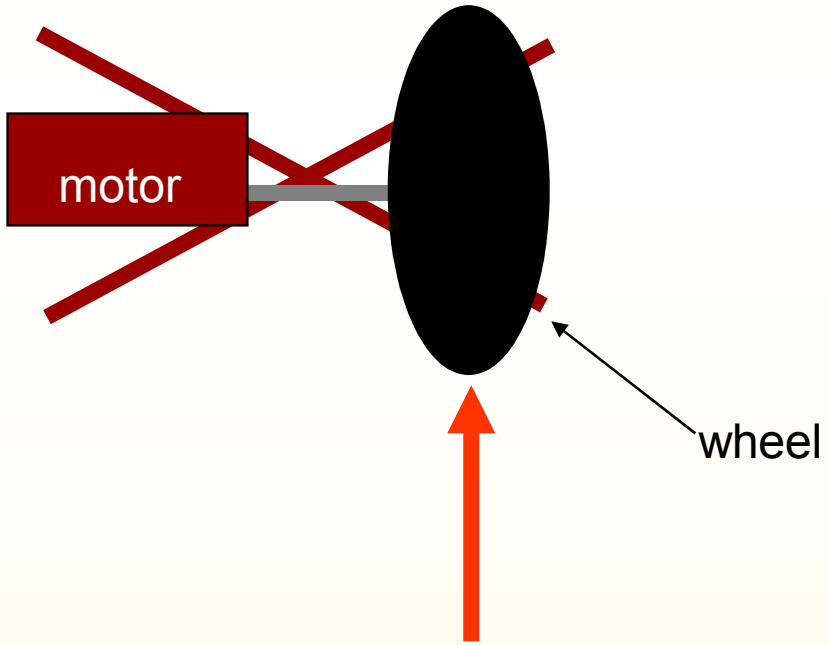
## Supporting Shafts



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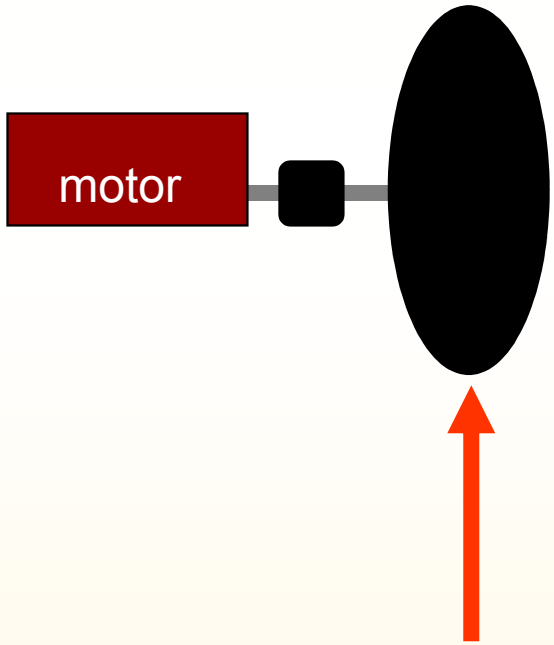
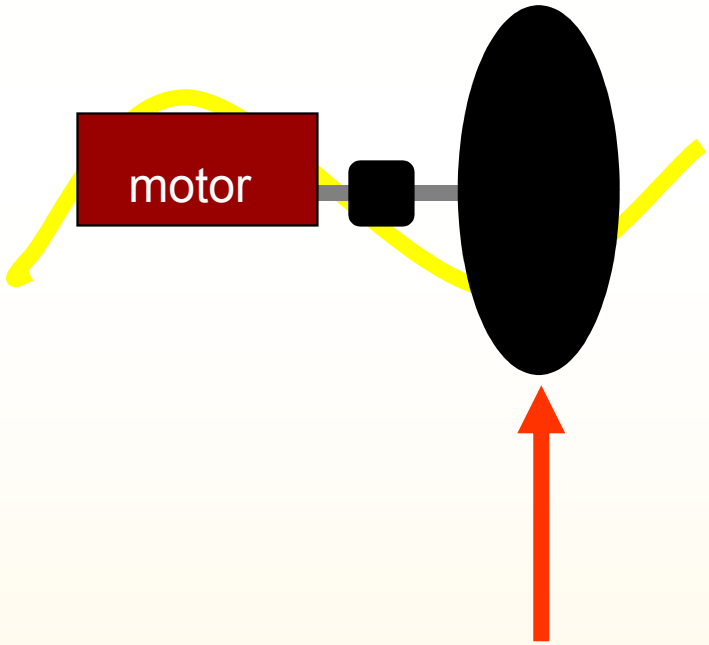
## Supporting Shafts



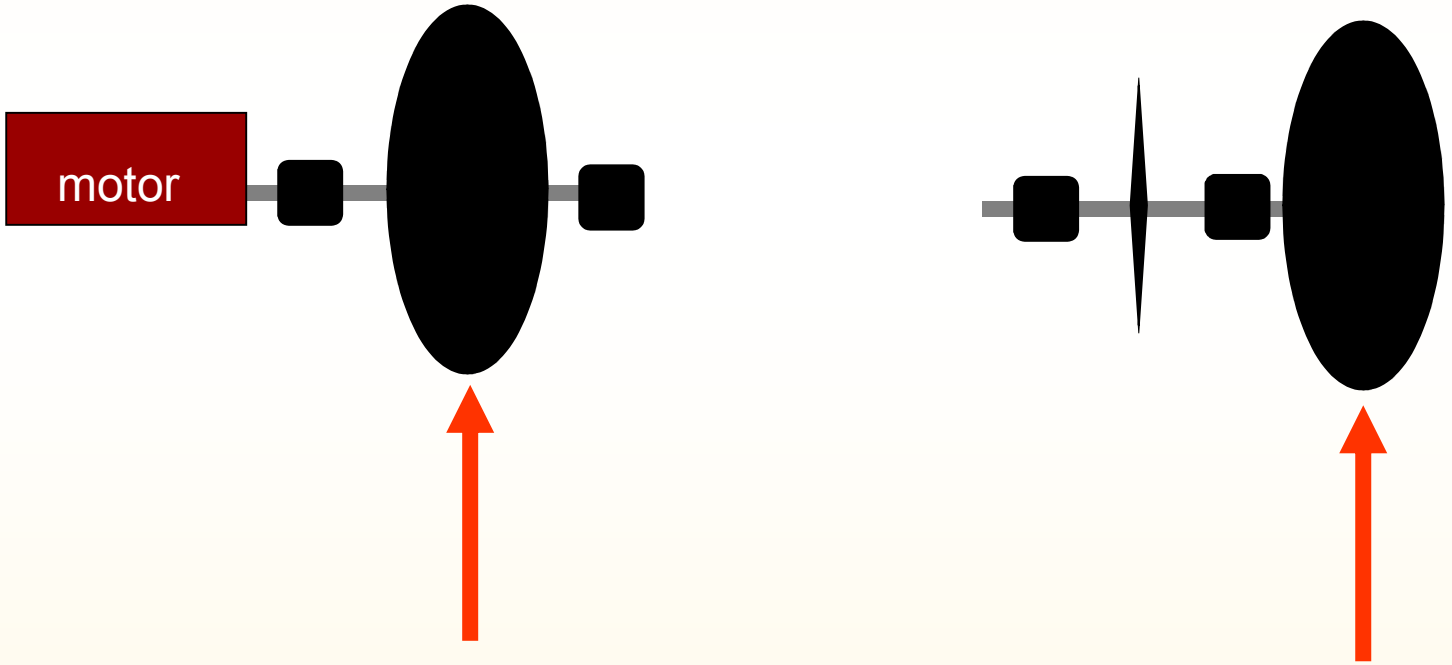
# Building a Driveline

## Supporting Shafts



# Building a Driveline

## Supporting Shafts



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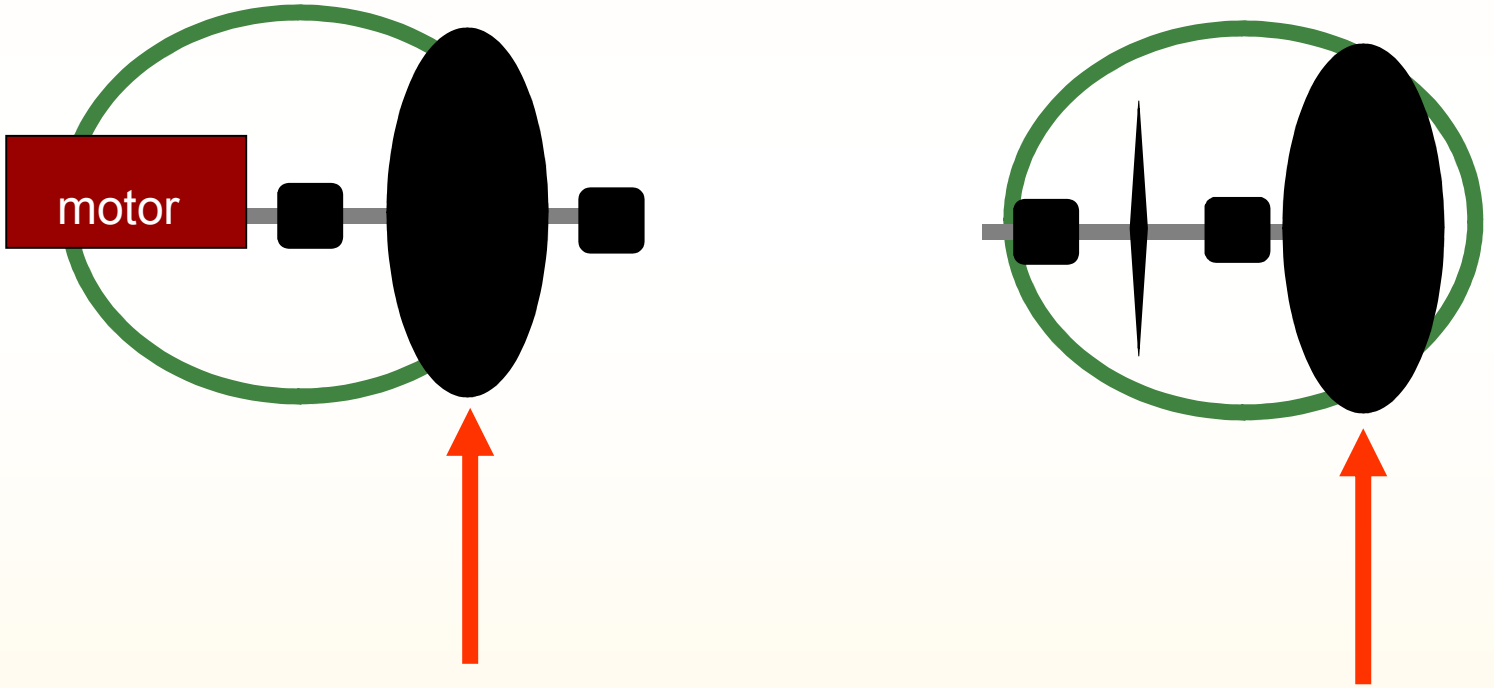
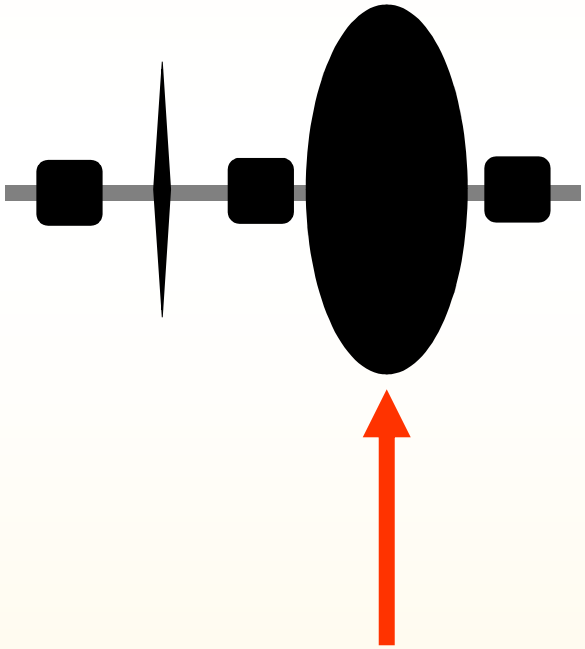
## Supporting Shafts



# Building a Driveline

## Supporting Shafts



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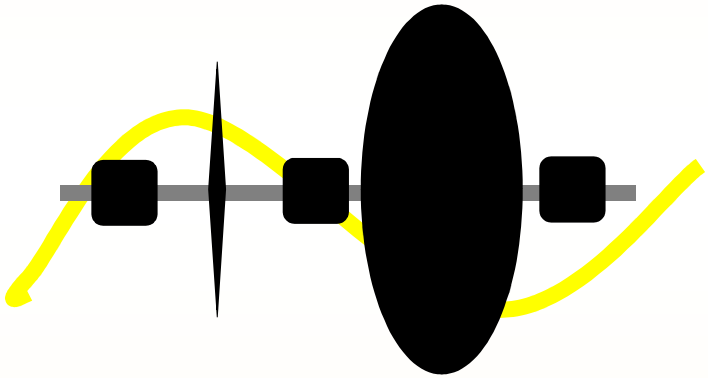
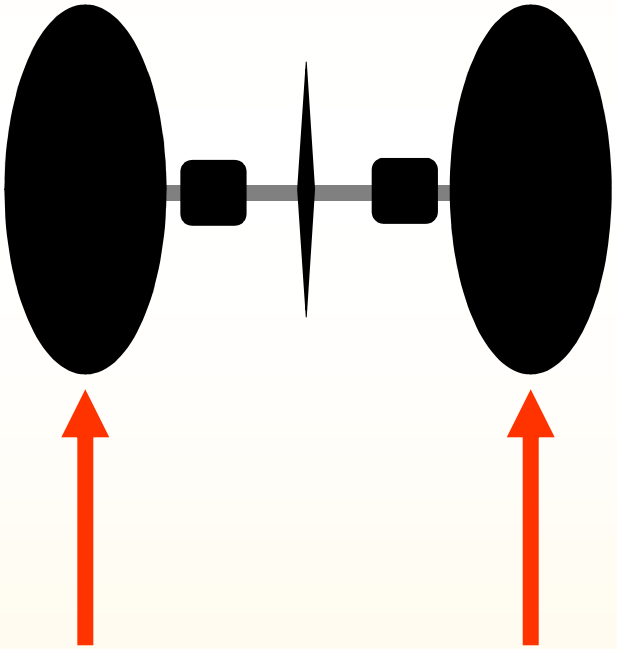
## Supporting Shafts



# Building a Driveline

## Supporting Shafts



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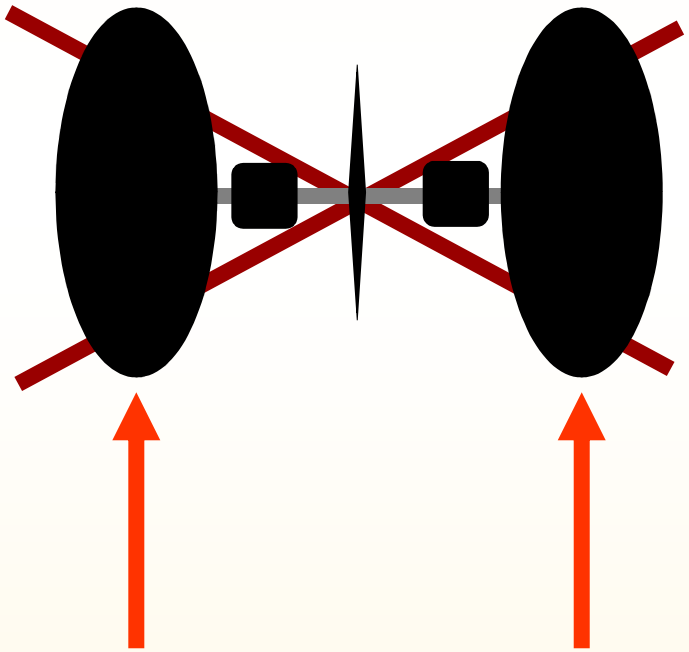
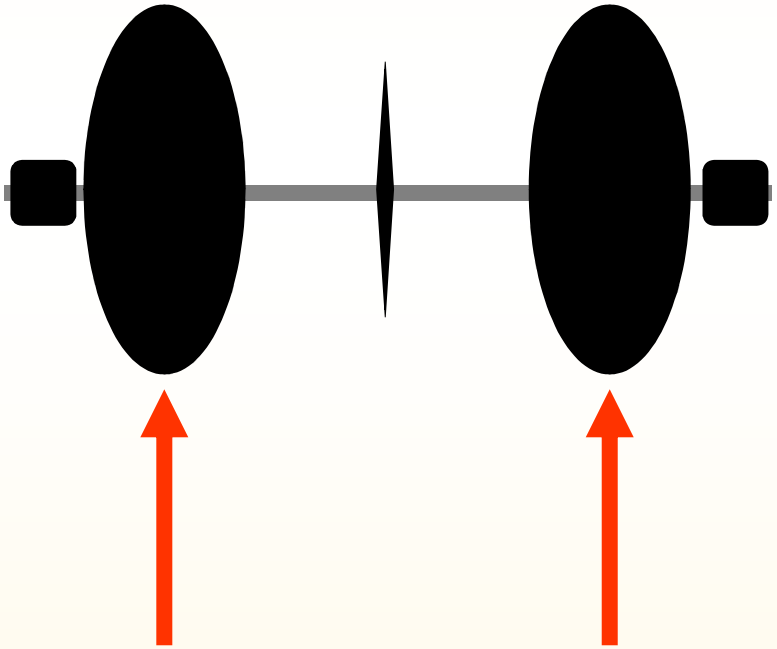
## Supporting Shafts



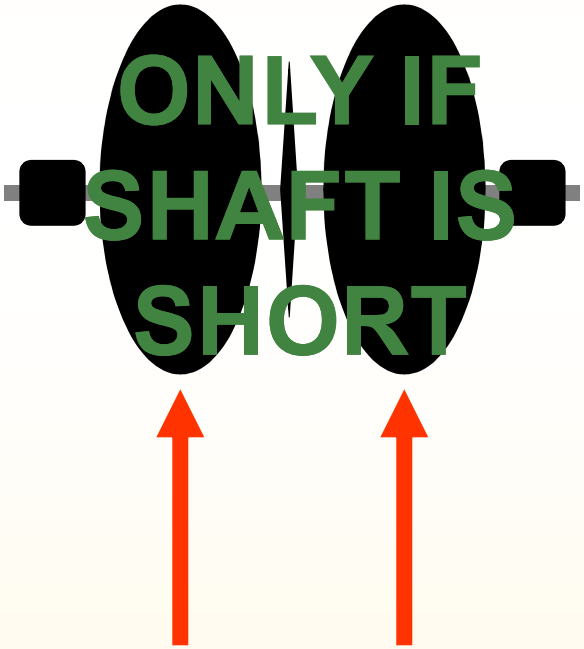
# Building a Driveline

## Supporting Shafts



# Building a Driveline

## Supporting Shafts



# Building a Driveline

## Shaft Support Recommendations

• Never side-load your motors – they're not designed for it. Always have at least one bearing on the output, and try to have two whenever possible.

• If your shaft is supporting weight, support *it* in two places.

• Try to avoid supporting a shaft in three or more places – a misalignment will lead to a loss of power.



# Questions?