RoboJackets

FIRST - IGVC - BattleBots - RoboCup

2008 TE Sessions Supported by

CATERPILLAR®

NATIONAL INSTRUMENTS™

Rockwell Automation

The George W. Woodruff School of Mechanical Engineering

Georgia Tech College of Computing

Mechanical Power Transmission

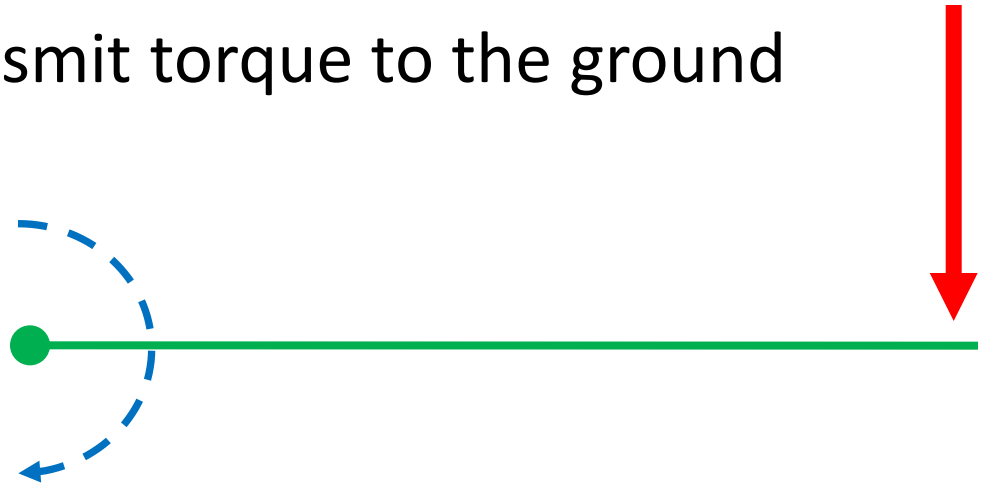
September 16, 2008

Goals

- Hand out kits to teams that don’t have one.
- More physics concepts and terms
- Understanding key devices for transmitting power
  - Gears, Sprockets, Chain, Belts, Pulleys
- Purpose for bearings and which to use
- Making it all spin with your shaft

Rotation

- Key to most machines and a moving robot
- Torque = Force acting at a distance
  - Motors transmit torque to gears
  - Gears transmit torque to wheels
  - Wheels transmit torque to the ground

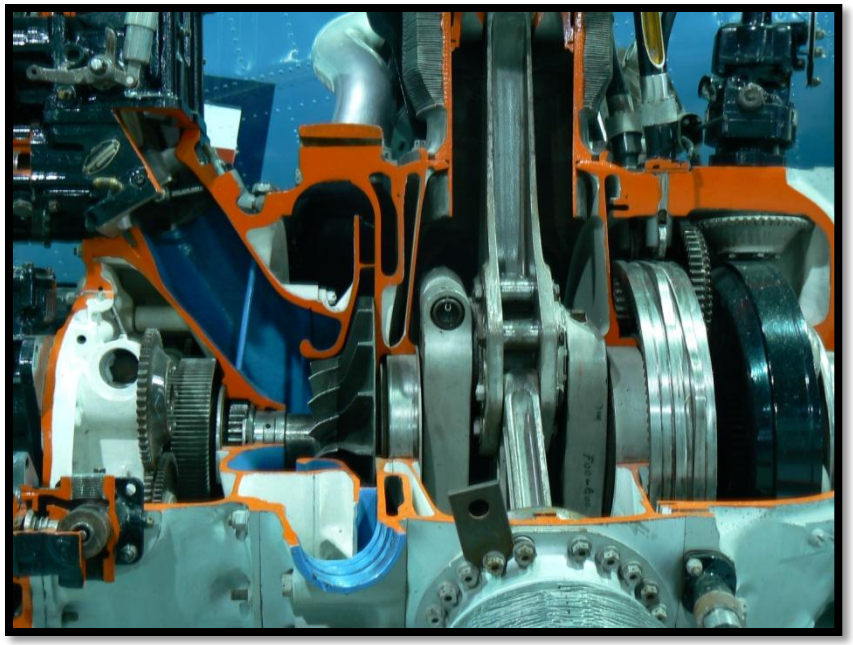


Power

- Physics
  - Work / time
  - Torque x angular speed
  - Force x velocity
- Idea
  - Your robot in motion
  - Make your motors useful

Power (Cont)

- Factors
  - Force
  - Torque
  - Velocity
- Implications
  - Heat
  - Efficiencies
    - Noise = Bad vibrations



Work & Energy

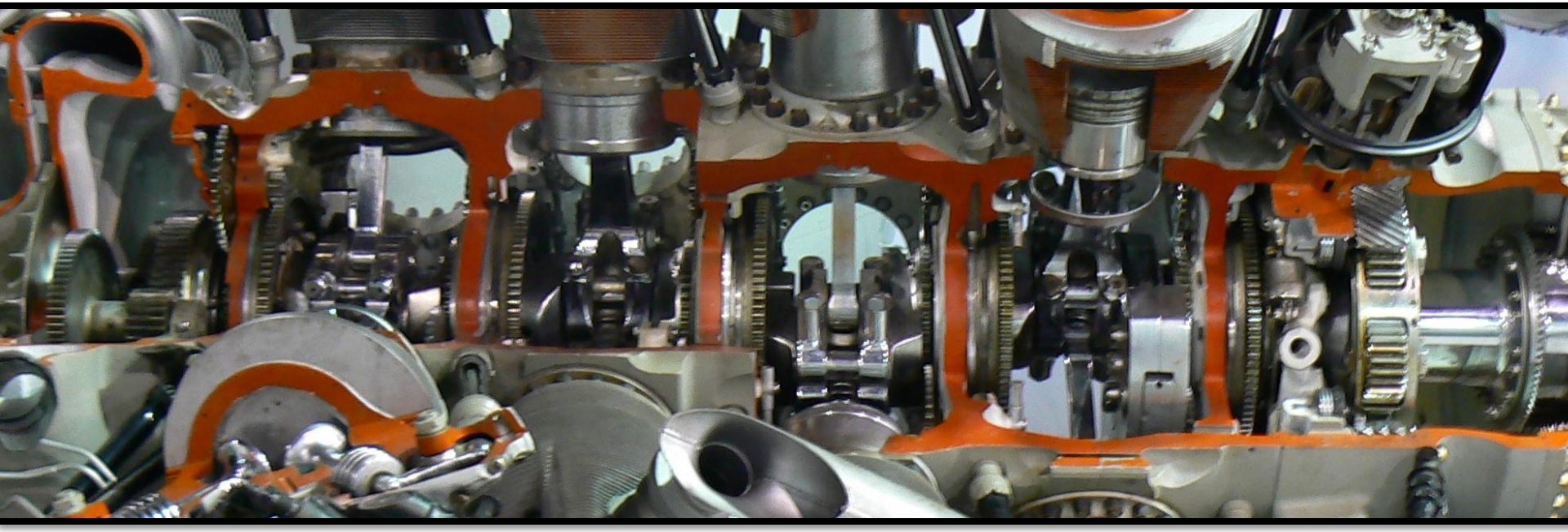
Work

- Applied force x distance
- Δ Energy

A tugboat pulling a ship

Energy

- Mechanical
  - Kinetic
  - Potential
- Is conserved
- Losses to:
  - Efficiency issues
  - Friction
    - Sound
    - Heat

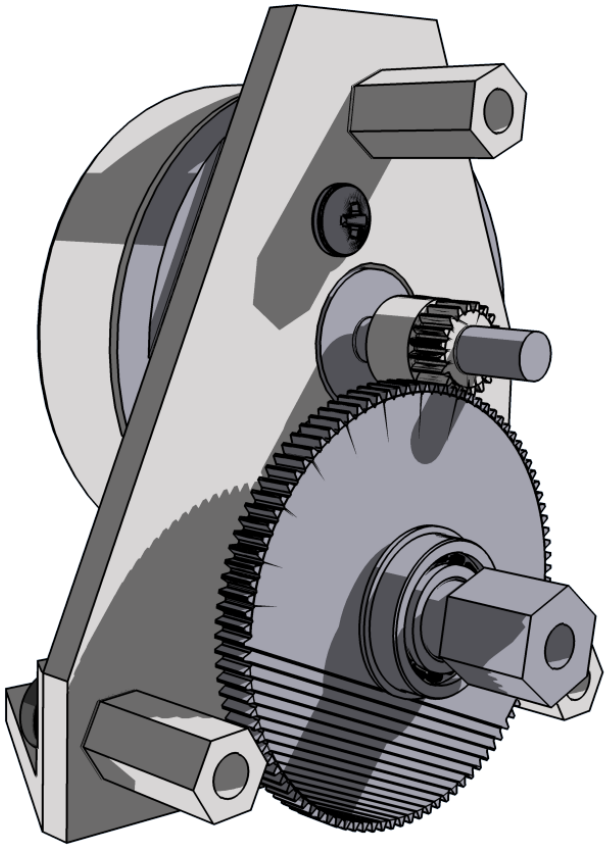


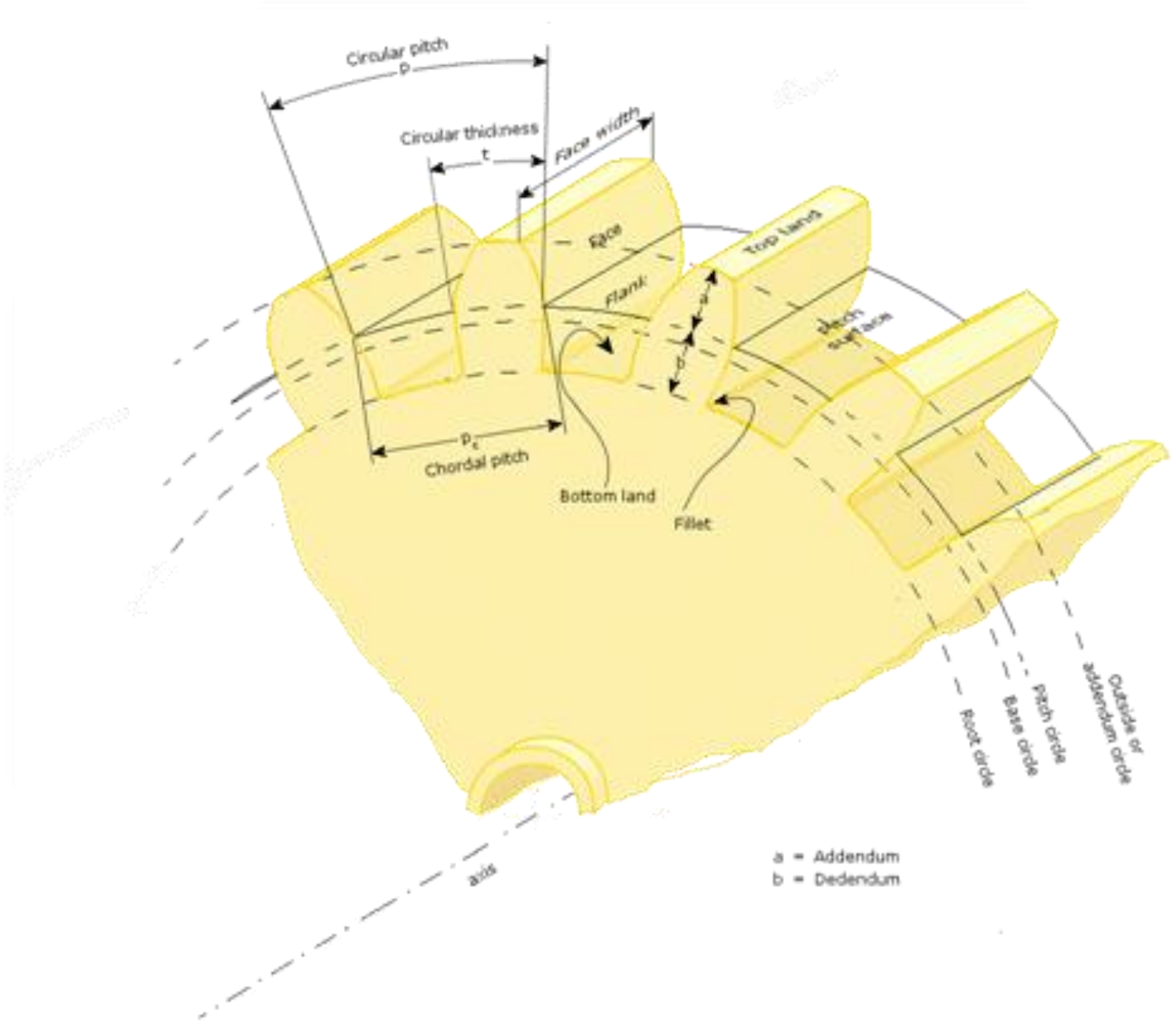
MECHANISMS

*Pratt & Whitney R-4360

Gears

- Types
  - *Spur*, Helical, Bevel, Internal
- How they work
  - Teeth
  - Pitch Diameter
    - Center line of meshing
  - Diametrial Pitch
    - Must have same size teeth



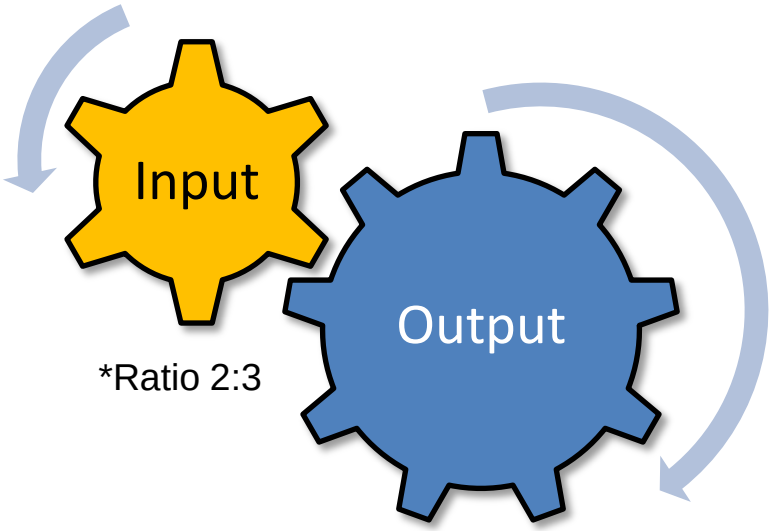


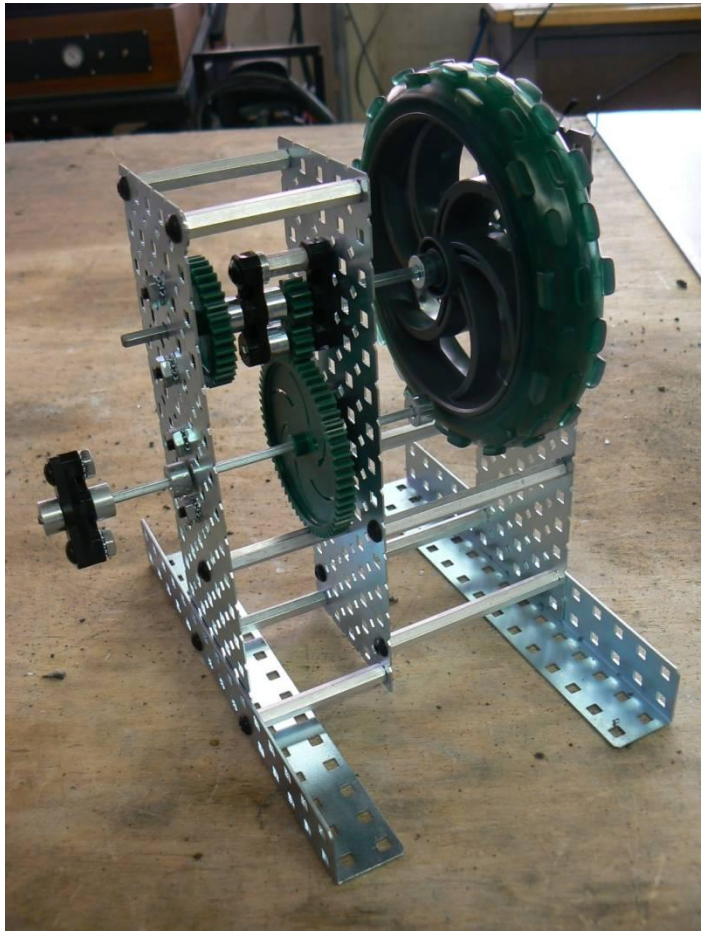
Gear Ratio

- Input : Output or input/output
- Gears and Sprockets
  - Teeth : teeth
- Pulleys and Belts
  - Diameter : Diameter
    - Can be used in all instances

Gear Ratio (Cont'd)

- Big Input : Small Output
  - Speed Faster
  - Torque Less
- Small Input : Big Output
  - Speed Slower
  - Torque More
- Same In and out
  - Direction Changes

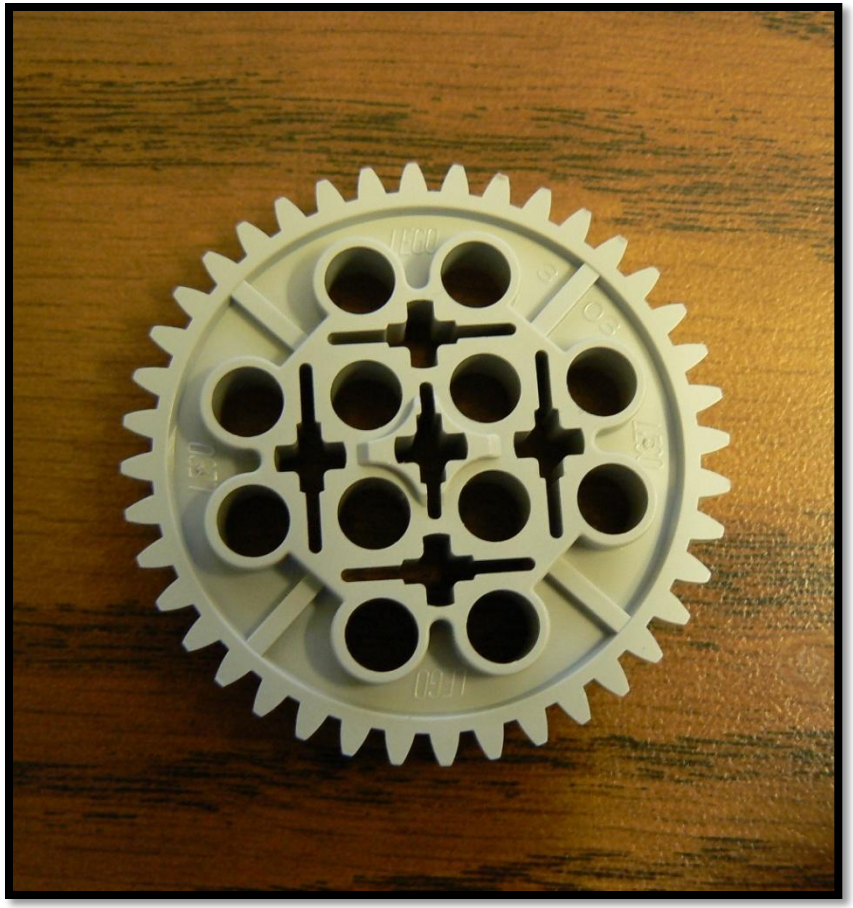




Gears Demo

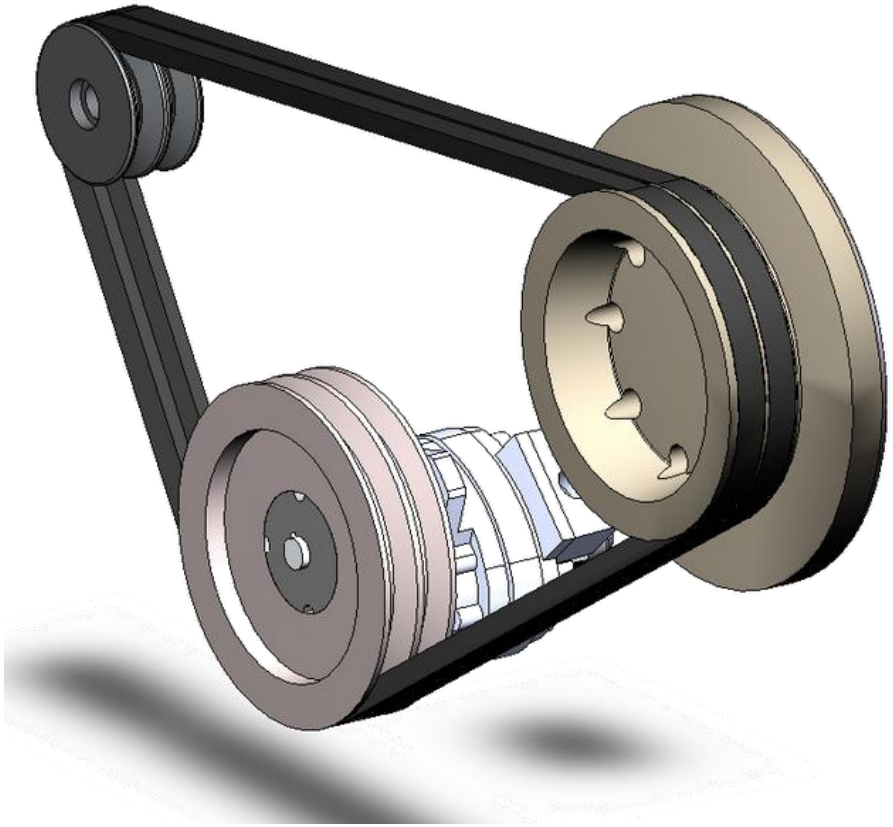
Activity – Spur Gearbox

- Build a Gear Box
  - 5 : 1
  - 1 : 5
  - 5 : 3
  - 1:15



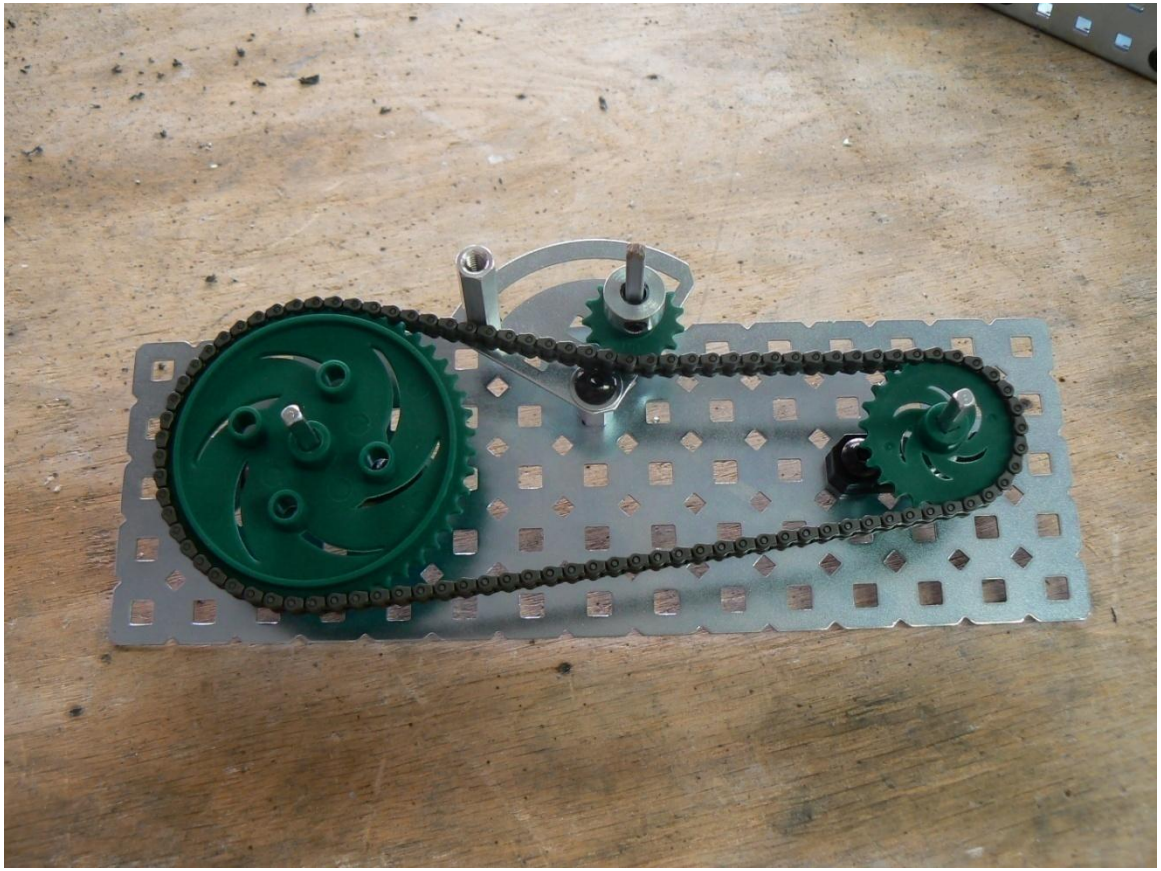
Belts & Pulleys

- Types
  - V-Belts
  - Timing Belts
- How they work
  - V-Shaped Groove
  - Notches
  - Pitch diameter
    - (outside pulley)



Chains & Sprockets

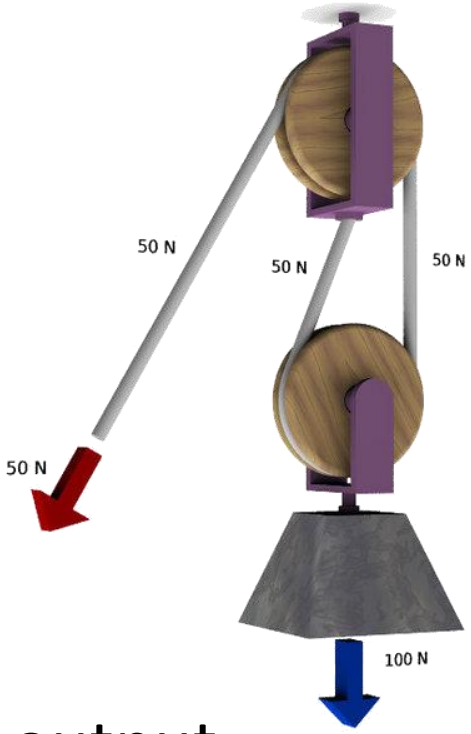
- How they work
  - Links
  - Master Link
    - Connects ends / links (Full and half)
  - Chain Numbering
    - 35 Larger stronger, but less efficient
    - 25 Smaller, lighter, weaker, but more efficient.
  - Pitch diameter (chain centerline)
- Tools
  - Chain break (& chain puller)



Chain Demo

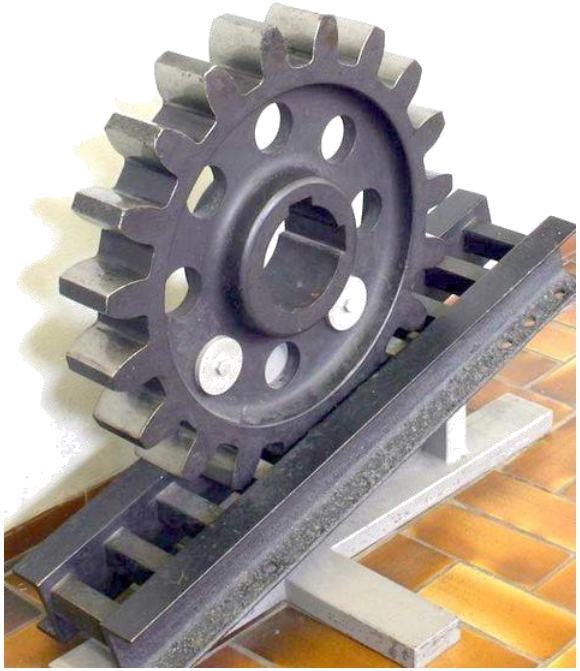
Cable & Pulleys

- Note
  - Increase force
  - A potentially easy way to gain mechanical advantage
- Other
  - Need constant tension
  - Location – Motor can be far from output
  - Travel distance increase

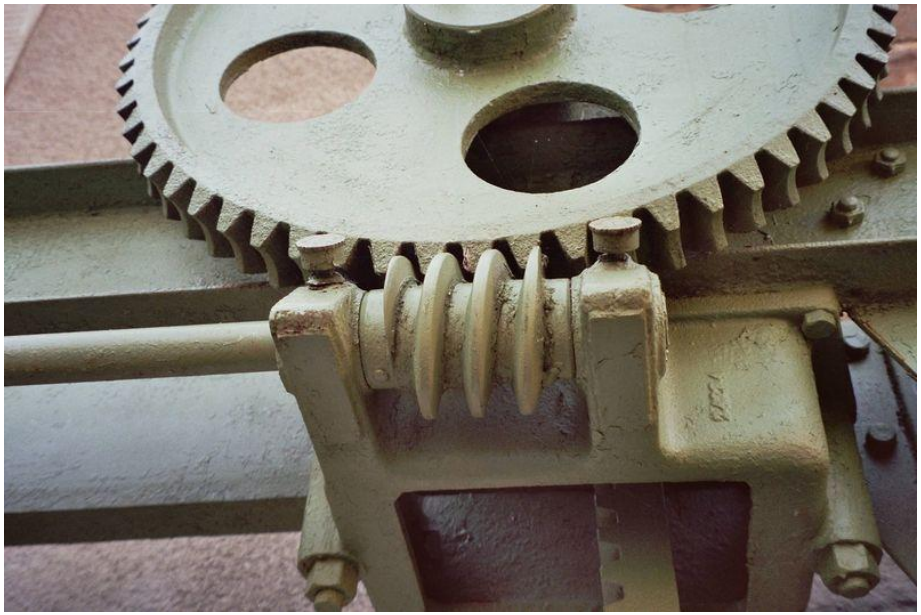


Special Configurations

Rack and Pinion



Worm and Worm Gear



Activity – Worm Gearbox

With NXT Kit build a worm gear box

DESIGN CONSIDERATIONS

Gears

- Good
  - Easy to design with (no tensioning)
- Bad
  - Weight – You will be removing mass
  - Backlash
- Other
  - Location – Motor is close to output

Chains & Belts

- Good
  - Weight – Much less than gears
- Bad
  - Less efficient transfer compared to gears
- Other
  - Location - Motor can be far from output
  - Tensioning
    - Loose - could skip
    - Tight – Drains battery, moves slow, loads motors
  - Need to wrap around pulley / sprocket

Special Configurations

Rack and Pinion

- Maintaining alignment

Worm and Worm Gear

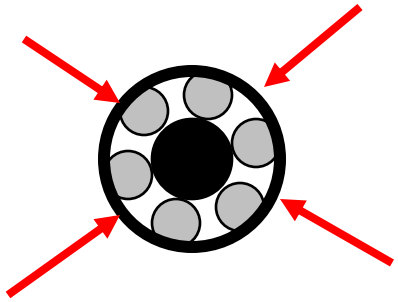
- Back drive impossible
  - unless failure occurs
  - If worm spiral allows
- High gear ratios (30:1)
  - Very slow output relative to input
  - One stage

BEARINGS

Radial Bearings

Radial Load bearings

Radial bearings handle loads in the radial direction



Radial loads are applied from wheels to shaft

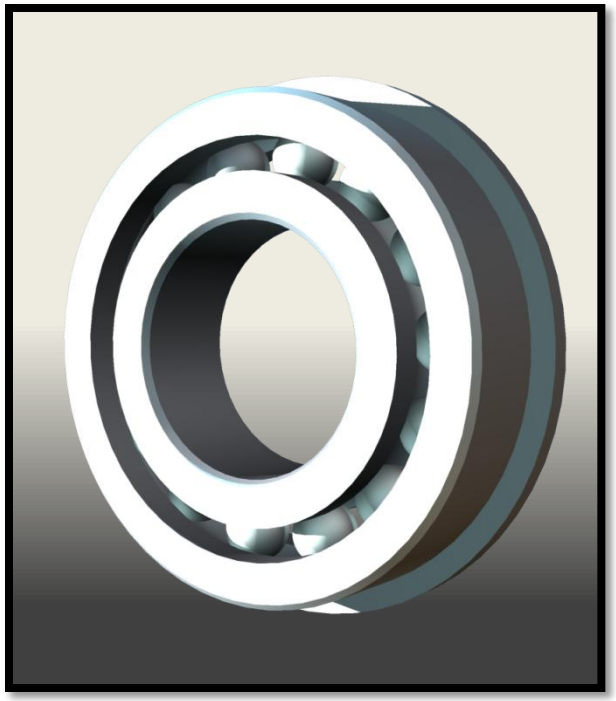
Why even use bearings?

Bearings are essential in rotating machines

Bearings reduce drag and handle forces

Without bearings, the shaft would heat up so much that it would swell and seize in its housing

Radial Bearings



- Types
  - Flanged or not flanged
  - Double shielded, unshielded
  - Packed with grease or oil
- Rating via ABEC 1 → 9
  - 1 ←→2 good for FIRST
  - Informs you how much it will / can wobble.
    - Higher number more efficient, but cost more.
    - As bearings get smaller they only come in higher ABEC #'s.
      - ISO's # are reverse

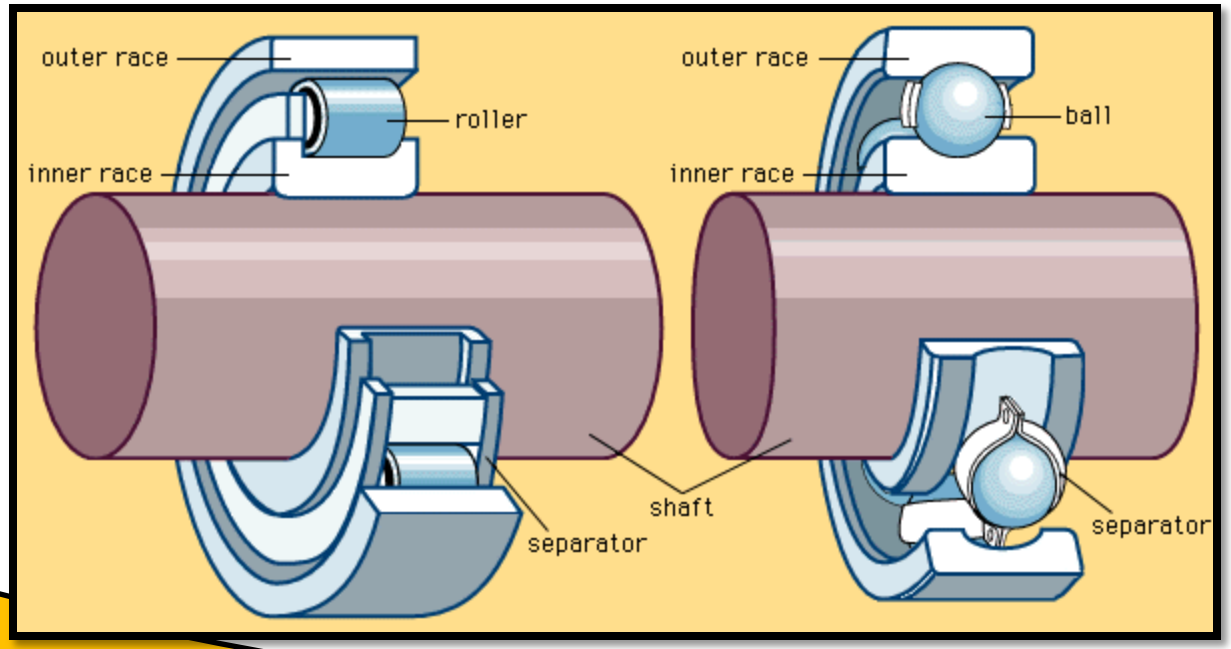
Radial Bearing Types

Roller

- Higher radial loads

Ball

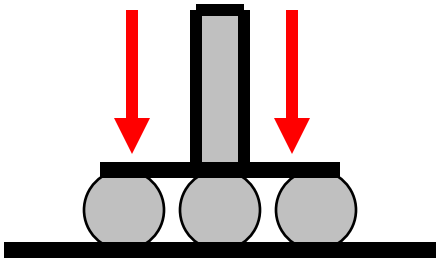
- Higher shaft speeds
- Common in FIRST



Thrust Bearings

Thrust Load bearings

Thrust bearings handle loads in the axial direction



Radial loads are applied from shaft to housing or support

Why even use bearings?

Thrust bearings are good for supporting a rotating arm assembly…

Cars use combination radial/thrust bearings to handle cornering loads

Bushings

- What's the difference?
  - Act like bearings
  - No moving parts
  - Low speed apps
  - Less $$$$
  - For FIRST typically
    - Plastic
    - Brass
  - Below 1000 rpm

MATERIAL CONSIDERATIONS & USE

Wheel Setups

Overhanging Loads

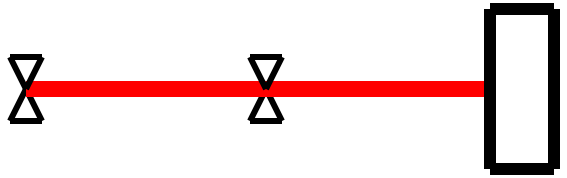
Analog to beam bending

Wheels can be placed on the end of a shaft

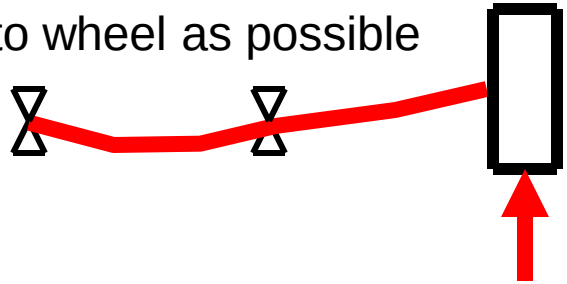
Shaft **MUST** be supported in two places

Shaft **MUST** be supported in two places

Overhanging wheels:



Put bearings as close to wheel as possible



Wheel Setups

Centered Loads

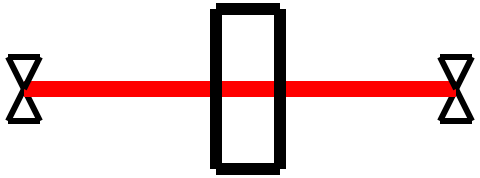
Analog to beam bending

Wheels can be placed at the center of shaft

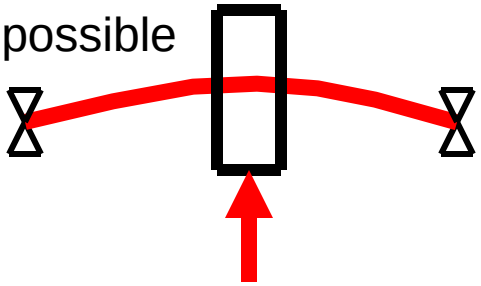
Shaft **MUST** be still supported in two places

Shaft is supported on both sides of wheel

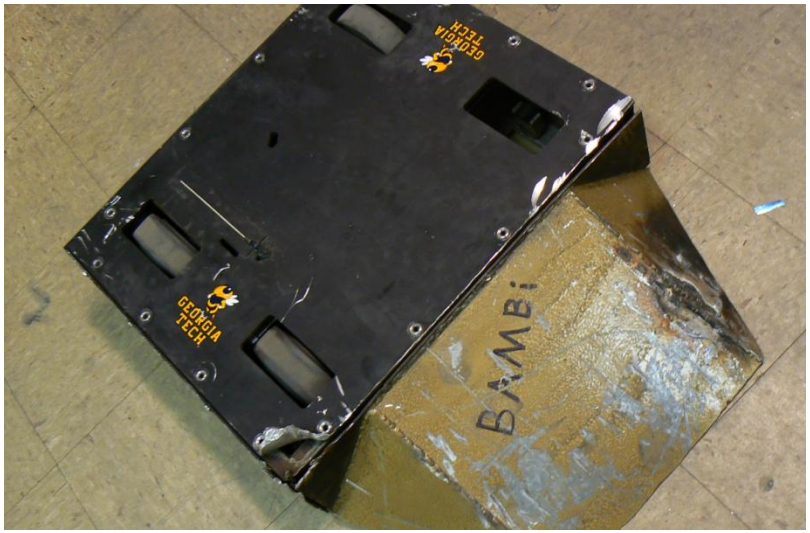
Centered wheels:



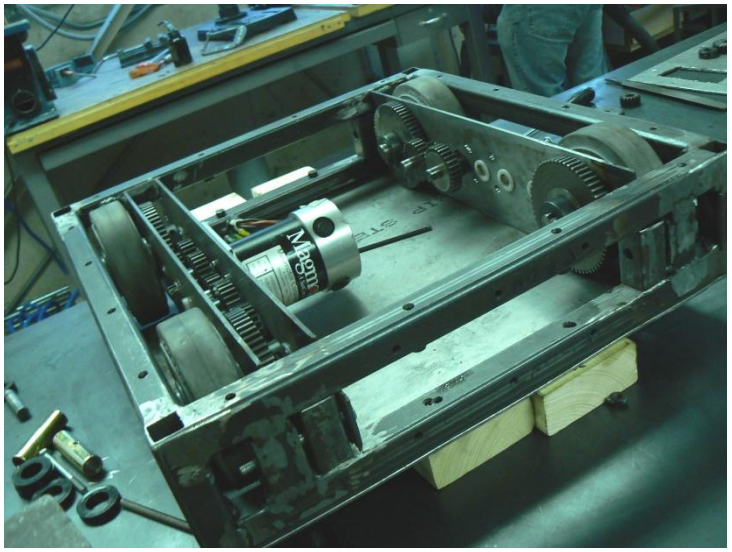
Put bearings as close to wheel as possible



BattleBots



2007



2008

Note: Doing these things makes your design more compact and potentially saves room for other components.

Wheel Setups

Wheels spinning on shaft

- Advantages
  - Wheels are passive components
  - Useful for unpowered wheels
  - Simple for unpowered applications
- Thoughts
  - Wheels must have bearings inside hub

Wheels spinning with shaft

- Advantages
  - Wheels are actively driving the vehicle
  - Wheels can be mounted directly to gearbox
  - Or driven by chains or belts at a distance
- Thoughts
  - Wheels must be coupled to shaft
  - Keyed shafts are most effective way to couple

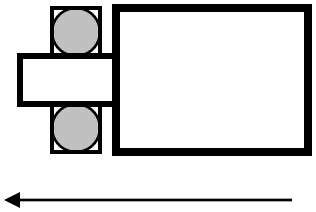
Shaft Restraints

Reasons

Shafts can still move axially within bearings

Solutions:

Shoulders



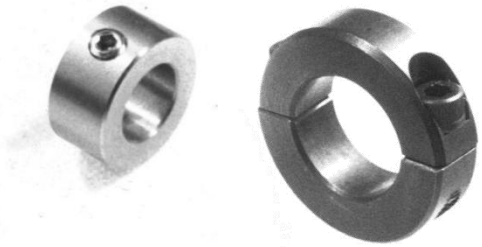
Prevents motion in one direction

Snap Rings & E-Clips

Clip onto grooves in shaft to prevent motion

Shaft Collars

Grip onto shaft by friction or set screws



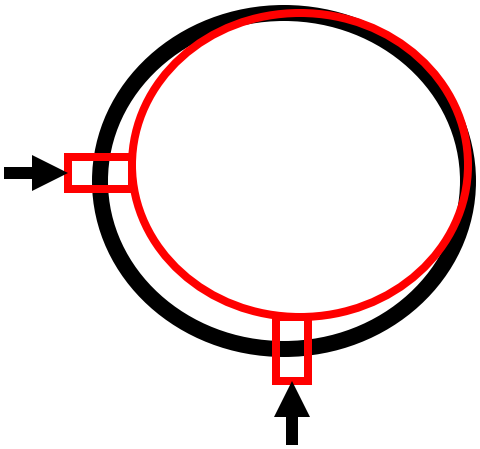
Shaft Restraints

Set Screws

Set screws seize the shaft onto a hub

Set screws work best when applied at 90 degrees

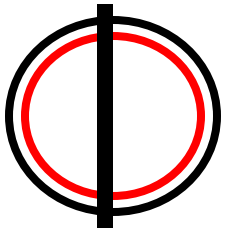
Application



Even though the shaft is off-centered, the set screw clamping force is effective

Note: A shaft should have flats at any planned set screw contact.

Pinning



Pinning is simple but can shear

LUBRICANTS

Lubricants

- Uses
  - Smooth out motion
  - Keeps gear surface clean
  - Will tell you how something failed
  - Can catch small debris
  - Increase efficency

CLOSING

What to expect

- Gear boxes
  - More than one stage
- Combinations
  - Mostly chain

Not just to move a robot!!

- Applications
  - Spinning a roller
  - Pivoting / rotating an arm
  - Opening / closing a gripper

Further Resources

- Wikipedia's Page on Gears
  - http://en.wikipedia.org/wiki/Gears
- WM Berg's pdf on gears, bearing, etc
  - http://wmberg.smartcats.com/pdf/techsessionpdf.pdf
- TIMKEN's presentation on bearings
  - http://www.timken.com/AntiFriction/player.html

Legal

These slides and more are available at

http://www.robojackets.org

For more information contact the RoboJackets.
(contact info available via the web)

Legal

Title 17 Chapter 1 107. Limitations on exclusive rights: Fair use

Notwithstanding the provisions of sections 106 and 106A, the fair use of a copyrighted work, including such use by reproduction in copies or phonorecords or by any other means specified by that section, for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research, is not an infringement of copyright. In determining whether the use made of a work in any particular case is a fair use the factors to be considered shall include—

(1) the purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes;
(2) the nature of the copyrighted work;
(3) the amount and substantiality of the portion used in relation to the copyrighted work as a whole; and
(4) the effect of the use upon the potential market for or value of the copyrighted work.

The fact that a work is unpublished shall not itself bar a finding of fair use if such finding is made upon consideration of all the above factors.