Building LEGO® Robots for FIRST™ LEGO League

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Version 1.1

Legal Stuff

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- Professionally, the open source software movement has shown that far flung software developers can cooperate to create robust and widely used software. The open source process is a model High Tech Kids wants to emulate for much of the material we develop. The open source software license is a key enabler in this process. That is why we have chosen to make this work available via a Creative Commons license. Your usage rights are summarized below, but please check the complete license at: http://creativecommons.org/licenses/by-nc-sa/2.0/.

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Credits

This class material is based on *"Building LEGO Robots for FIRST LEGO League"* by Dean Hystad. This presentation material was put together by Fred Rose. But Dean deserves all the credit.

Building LEGO Robots

- **Objective**
  - **Learn the basics of LEGO design and construction**
- **Structure**
  - **Theory**
  - **Examples specific to language**
  - **Hands-on**
- **What this class is**
  - **Meant to teach an approach to building solid robots**
- **What this class is not**
  - **Not an exhaustive reference**
  - **A Constructapedia**

Class Agenda

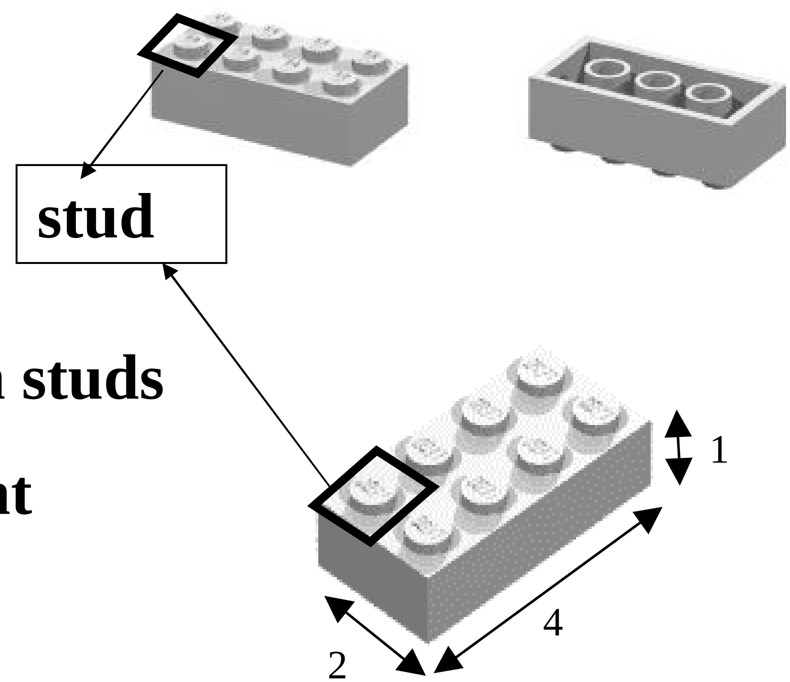
- LEGO Construction Basics
- Gears and pulleys
- Motors and sensors
- Drives

- We'll practice as we go along and have a couple working sessions to build some things.

LEGO Construction Basics

Bricks

Basic LEGO brick



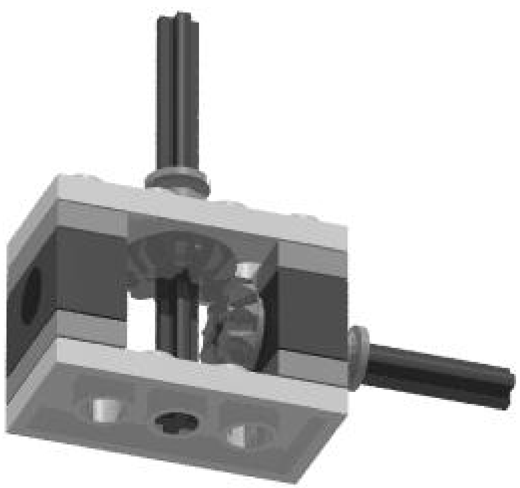
Lego dimensions given in studs

- **Width, length, height**
  - **2 x 4 x 1**
- **In metric dimensions**
  - **16mm x 32mm x 9.6mm**
  - **Studs are 8mm wide, bricks are 1.2 studs high**

Plates

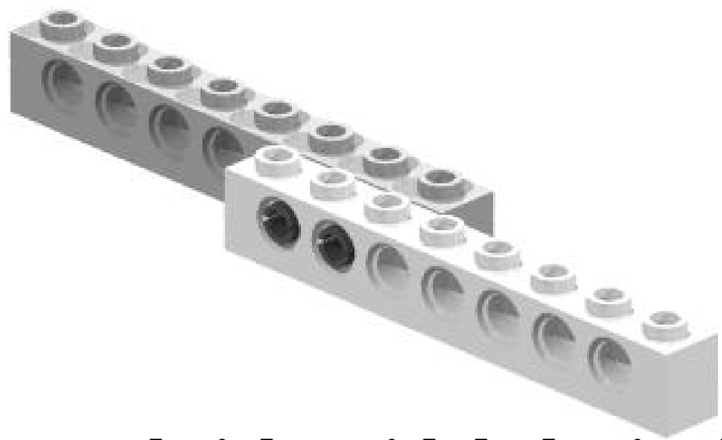
- **Plates are 1/3 the height of bricks**
  - **3.2 mm or .4 stud**

3 plates stacked = 1 brick in height



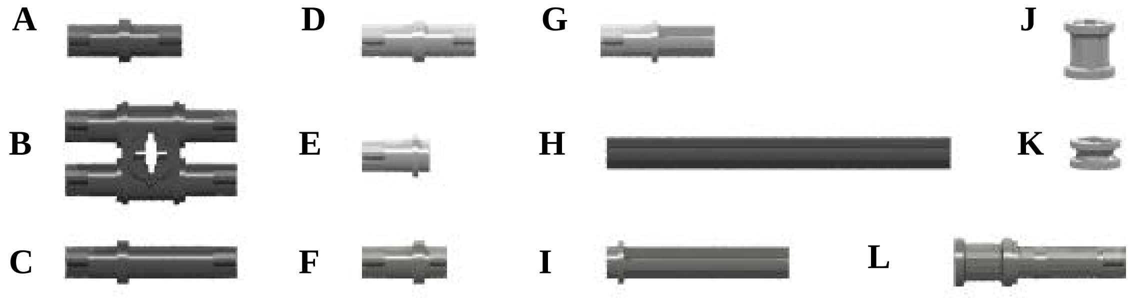
Some plates have holes (called technic plates) which fit axles and connector pins

Beams



- Beams are 1x bricks with holes in their sides
  - Holes at 1 stud intervals and spaced between studs on top of beam
- Connector pins allow beams to be connected side by side
  - Black (tighter fit) and grey pegs (not as tight)
- Beams are crucial to sturdy robots

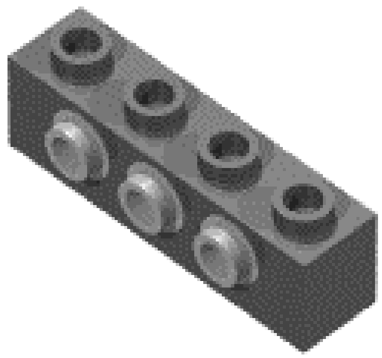
Pins



A. Pin with Friction
B. 3L Double Pin
C. Long Pin with Friction
D. Technic Pin
E. Half Pin
F. ¾ Pin
G. Axle Pin
H. 6L Axle
I. 3L Pin with Stud
J. Full Bushing
K. Half Bushing
L. Long Pin with Stop Bushing

- **The most commonly used of these is the black Technic pin with friction, or friction pin**
- **The gray Technic pin has a slightly loose fit. The gray pin is a good choice for pivots or hinges.**

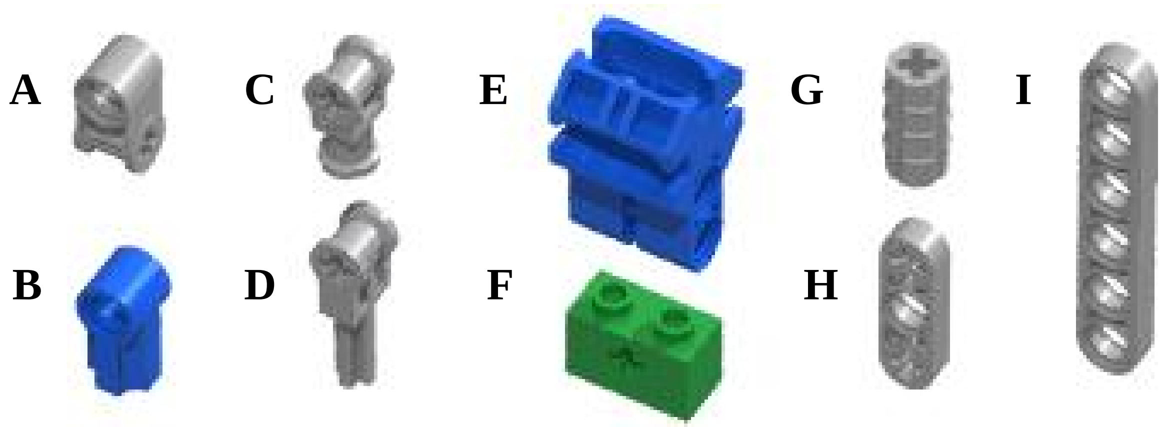
Half Pins and Axles



• The gray half pin can be used on the side of a beam to mimic studs.

• Axles come in different lengths measured by studs.

More Part Names

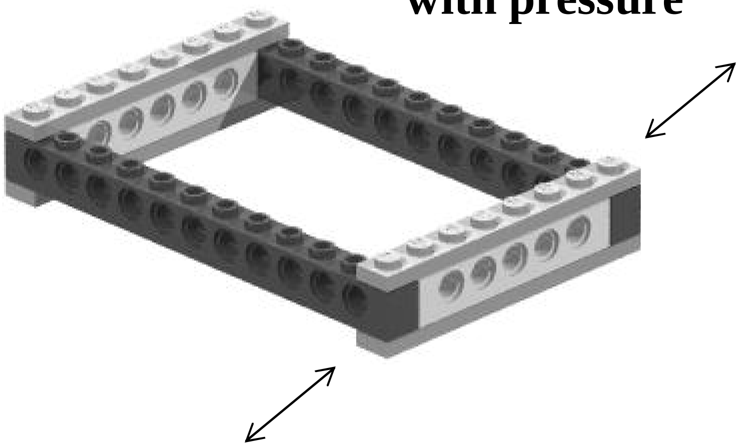


A. Axle Jointer Perpendicular
B. Angle Connector #1
C. Connector with Axlehole
D. Pole Reverser Handle
E. Connector Block 3 x 2 x 2
F. Beam 1 x 2 with Axlehole
G. Axle Joiner
H. Liftarm 1 x 3
I. Liftarm 1 x 6

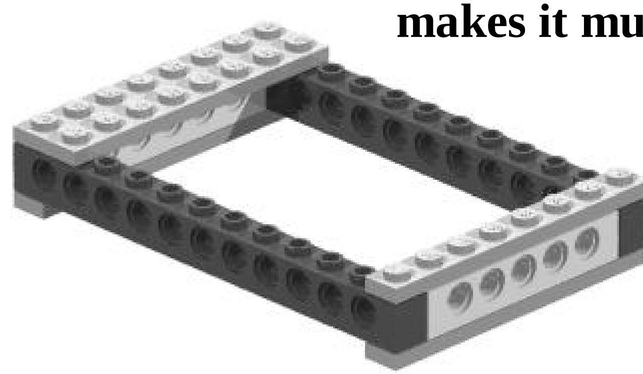
Frames

- **Robots need a frame**

This one twists with pressure

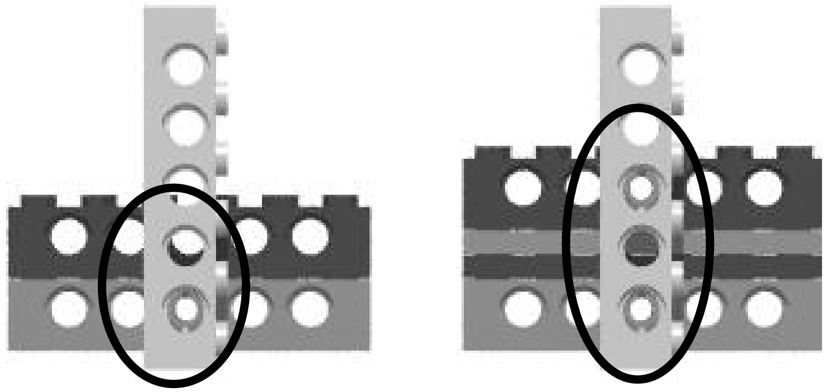


Replacing the 1x8 plate with a 2x8 plate makes it much stiffer



- **Text has an example of making this frame even sturdier**

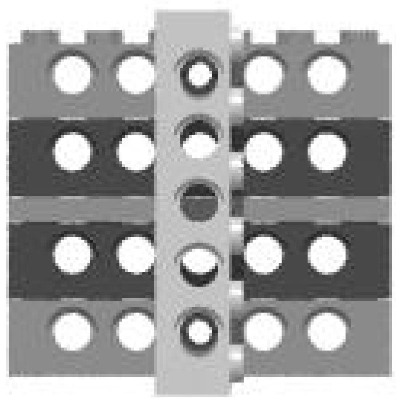
Cross Bracing

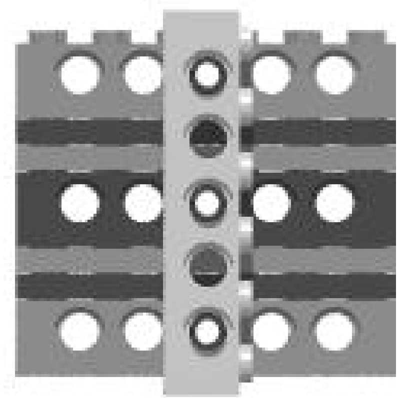


To brace, remember, 1 beam and 2 plates!!

- In the assembly on the left, the 1x6x1 beam is 1.2 studs high, which causes a problem when simply stacked. The cross brace beam holes do not line up.
- In the assembly on the right, 2 1x6 plates are added, the holes align perfectly. This is because a beam and 2 plates are exactly 2 studs apart (1.2 + .4 +.4 = 2 studs).

Cross Bracing



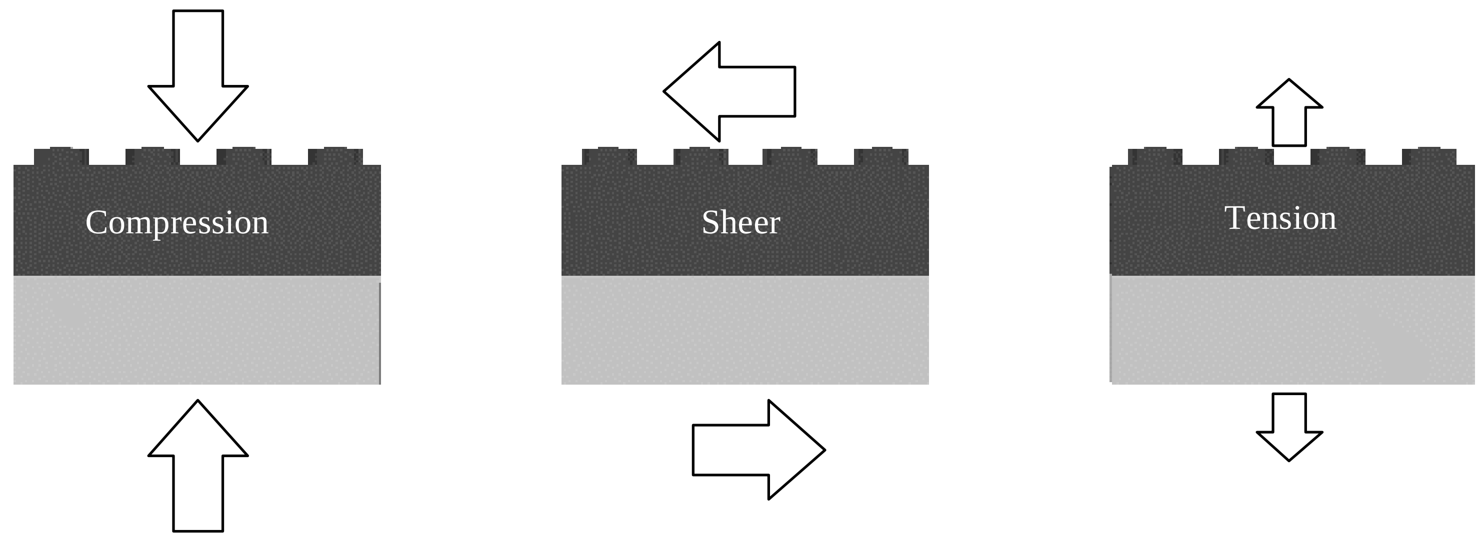


Better as it allows a mid point for a connector and provides better spacing for gears

To brace, remember, 1 beam and 2 plates!!

1 - 2 -1

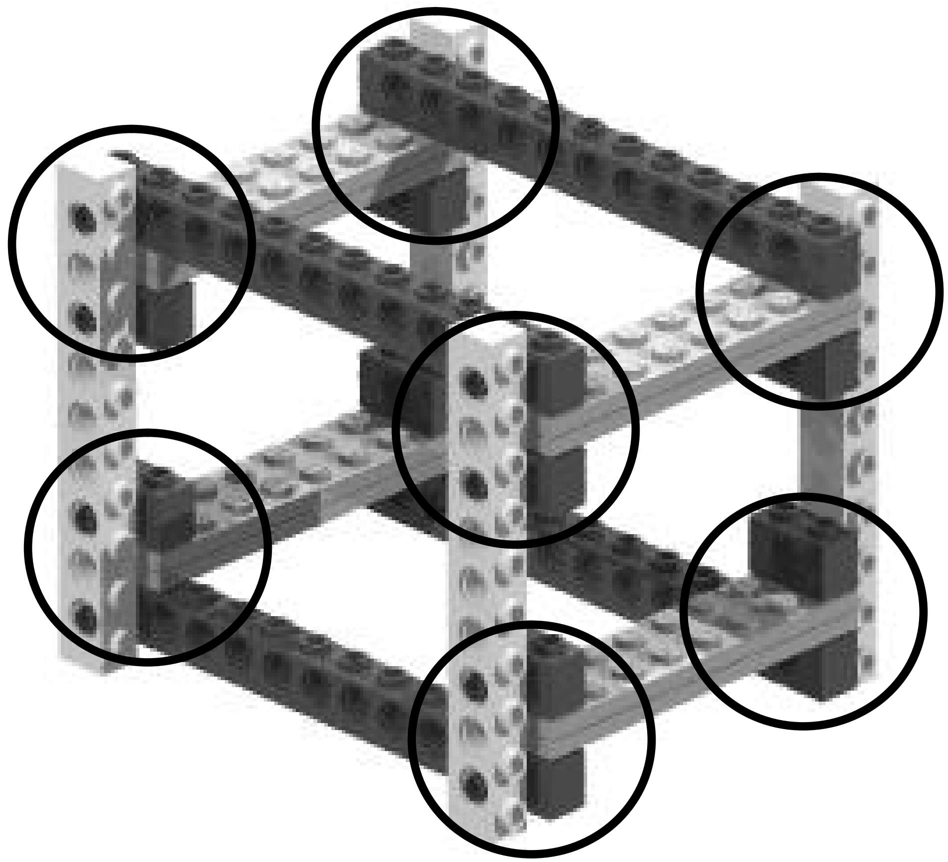
Forces on Brick Connections



- **Snap on connections are strong in compression and sheer but weak in tension**

- Cross bracing adds sheer strength (the vertical brace) to strengthen the weak point (the tension) of the horizontal structure.

1 Beam - 2 Plates - 1 Beam



Another Geometry Convention

- 5-6-2
- The vertical unit is precisely 6/5 the horizontal unit.
- A height of a stack of 5 LEGO bricks is precisely equal to the length of a 6 stud LEGO beam.
- One beam and two plates would be 2 units in the vertical
- Either notation is fine.
- We use studs in this presentation as the measuring unit.

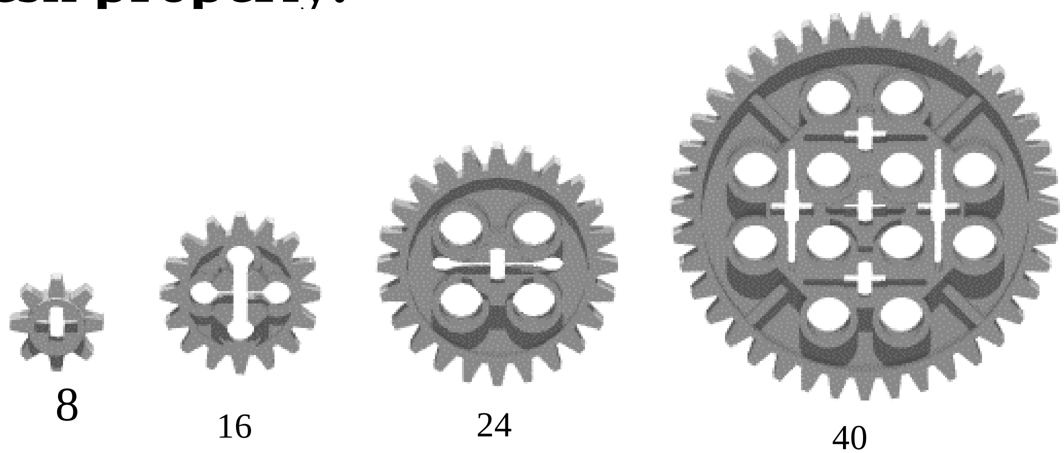
Gears

Why Use Gears?

- **To transmit torque from one axle to another**
- **To increase or decrease the speed of rotation**
- **To reverse the direction of rotation**
- **To move rotational motion to a different axis**
- **To change rotary motion to linear motion**
- **To keep the rotation of two axles synchronized**

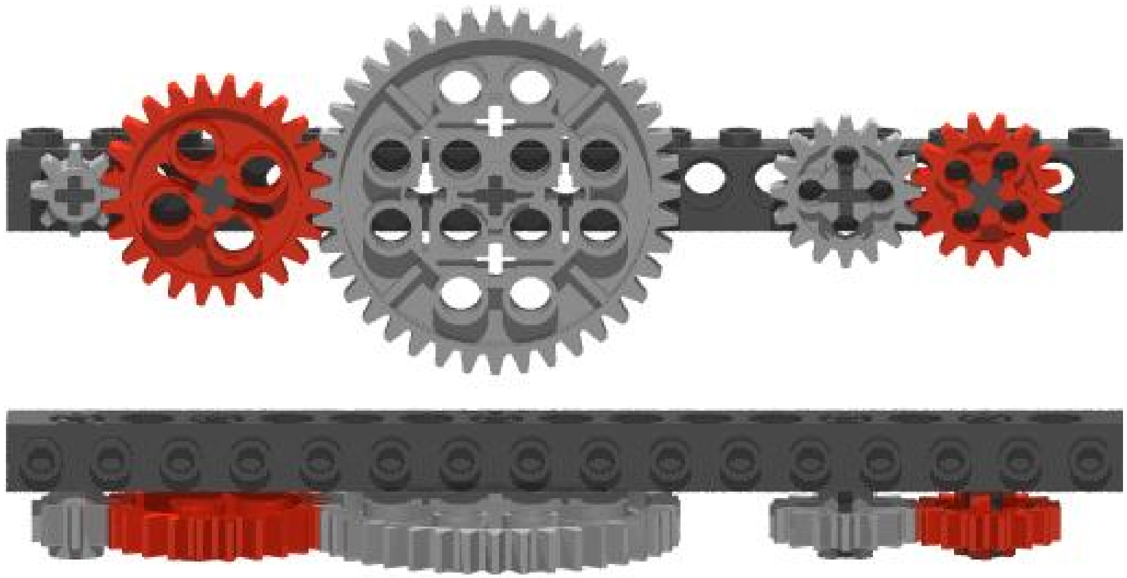
Spur Gear

- **Most common gear**
- **Used when shafts rotate in same plane**
- **Gear sizes counted by number of teeth**
- **All LEGO spur gears have the same size teeth so they can mesh properly.**



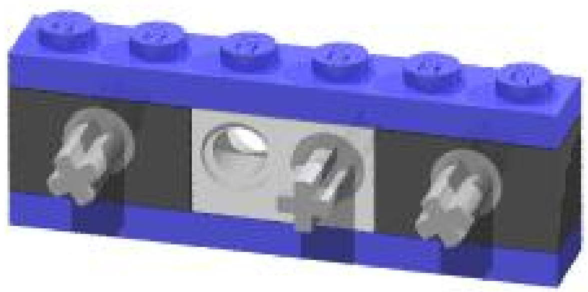
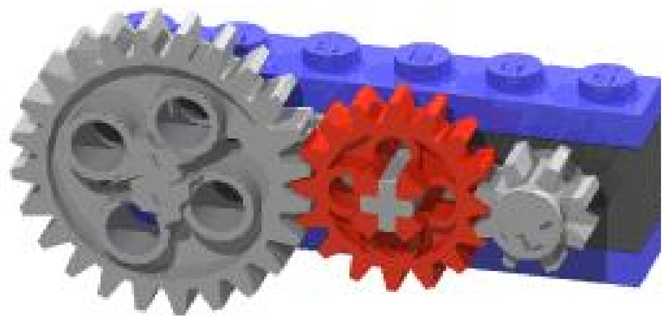
Teeth	8	16	24	40
Radius (studs)	0.5	1	1.5	2.5

Spur Gear Spacing



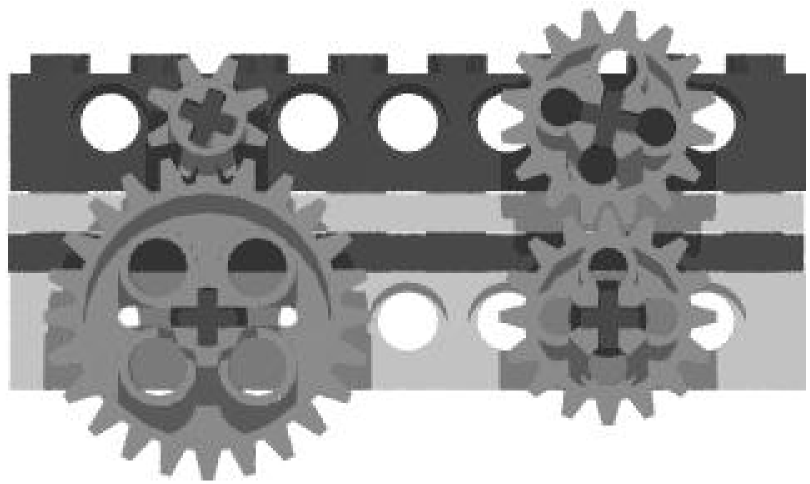
	8 tooth	16 tooth	24 tooth	40 tooth
8 tooth	1.0 studs	1.5 studs	2.0 studs	3.0 studs
16 tooth	1.5 studs	2.0 studs	2.5 studs	3.5 studs
24 tooth	2.0 studs	2.5 studs	3.0 studs	4.0 studs
40 tooth	3.0 studs	3.5 studs	4.0 studs	5.0 studs

Half-Stud Spacing

• **Here is a trick to get half-stud spacing using 2 holed 1 x 2 beam**

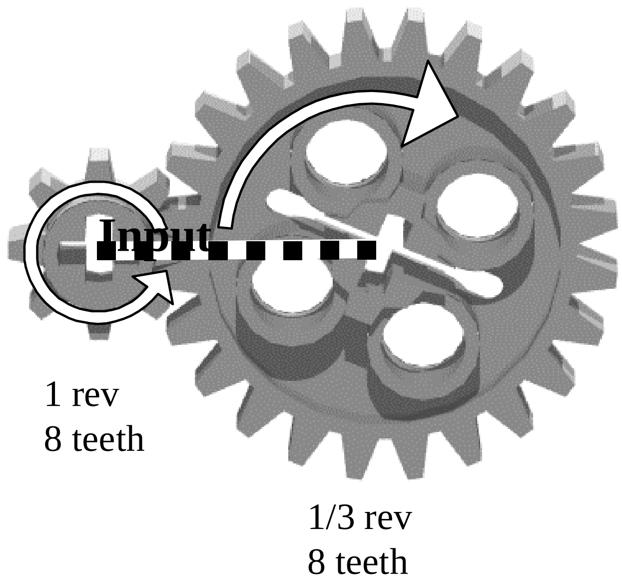
Vertical Gear Spacing



	8 tooth	16 tooth	24 tooth	40 tooth
8 tooth			2.0 studs	
16 tooth		2.0 studs		
24 tooth	2.0 studs			4.0 studs
40 tooth			4.0 studs	

- **Vertical spacing is difficult**
- **Really only 2 and 4 stud distances work well**
  - **Our old friend 1-2-1**

Gear Ratio



Output

The 24t gear turns 1/3 revolution for every turn of the input 8t gear.

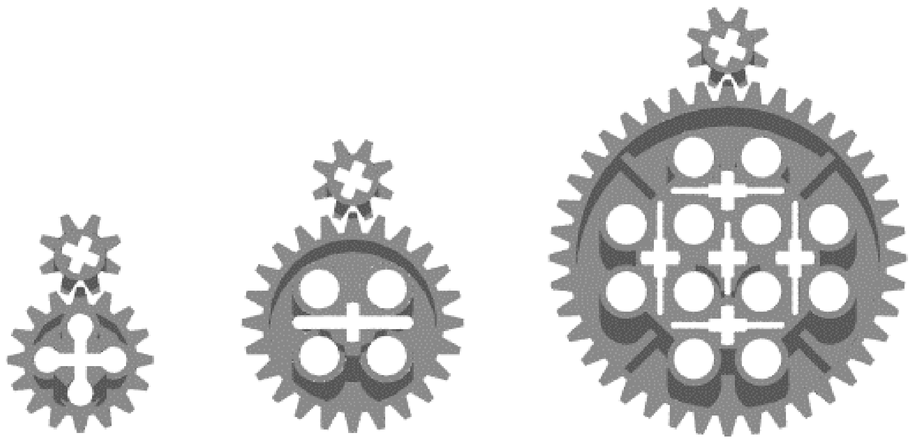
This is a 3:1 gear ratio

Gear ratio is defined as the ratio of how much the output shaft of a gearbox turns for a given rotation of the input shaft.

Gearing Up and Down

- **The 3:1 gear ratio tells us that the input shaft (attached to the 8t gear) has to complete three full revolutions for the output shaft (attached to the 24t gear) to rotate all the way around just once.**
- **Using gears to slow down rate of rotation or decrease the amount of rotation is called gearing down.**
- **If we were to switch the 8t and 24t gears around the output shaft would spin three revolutions for each revolution of the input shaft.**
- **This is gearing up, and the gear ratio would be 1:3**

Gear Ratios



16 : 8
or
2 : 1

24 : 8
or
3 : 1

40 : 8
or
5 : 1

Output Shaft or Driven Gear

Input Shaft or Driving Gear

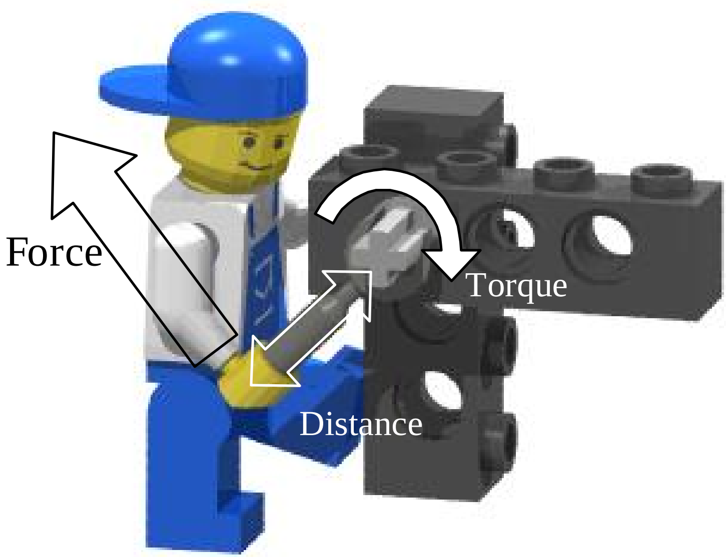
	Driven 8 tooth	16 tooth	24 tooth	40 tooth
Driving 8 tooth	**1:1**	**2:1**	**3:1**	**5:1**
16 tooth	**1:2**	**1:1**	**3:2**	**5:2**
24 tooth	**1:3**	**2:3**	**1:1**	**5:3**
40 tooth	**1:5**	**2:5**	**3:5**	**1:1**

Gear Ratio and Torque

- **Gears operate by transmitting forces at the teeth of the gear.**
- **When two gears mesh, the force that is transmitted can be multiplied by the radius to obtain the torque applied to the gear.**
- **Torque is a force that tends to rotate or turn things. For example, you generate a torque any time you apply a force using a wrench. When you use a wrench, you apply a force to the handle. This force creates a torque on the nut, which tends to turn the nut.**

Torque

- **A force applied to the teeth of a large gear will generate more torque than the same force applied to the teeth of a small gear. This also means that for a given torque, a larger gear will transmit less force than a smaller gear**



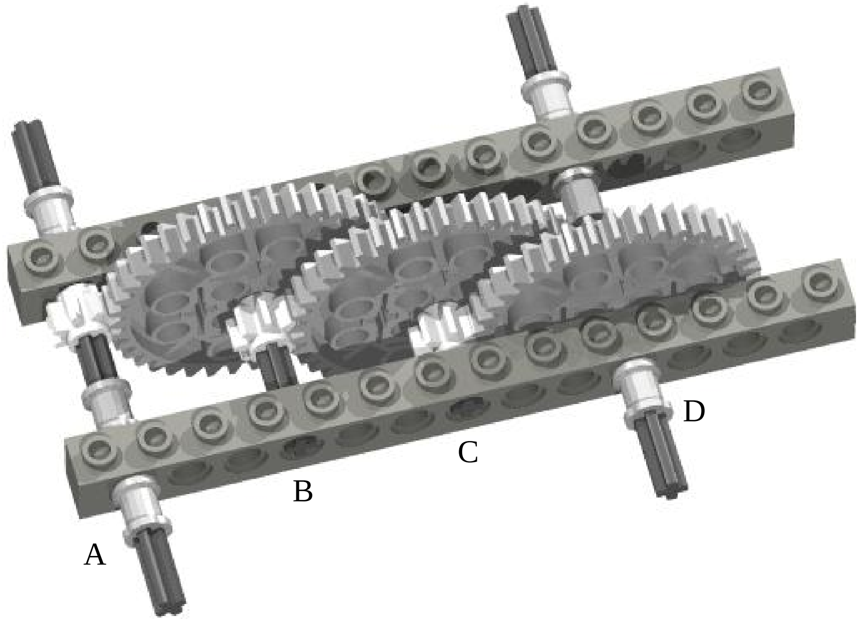
Torque = Force * Distance

Torque

- The teeth of a large gear travel faster than the teeth of a small gear at a given angular velocity.
- So there is no free lunch. If you gear down to get an increase in torque, you will also get a proportional decrease in angular velocity.
- The driven gear will turn stronger and slower.

Strong and Slow **or** **Fast and Weak**

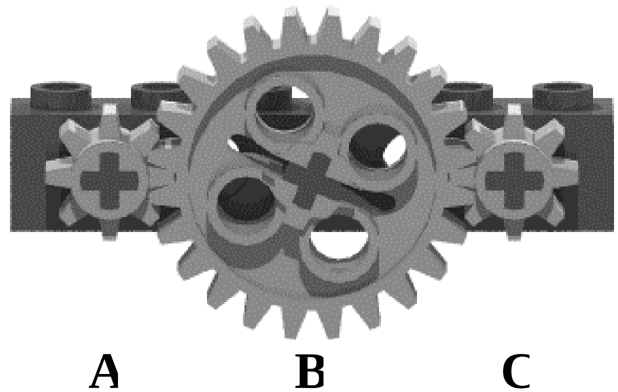
Gear Trains



A->B = 5:1
B->C = 5:1
C->D = 5:1
A->D = (A->B) x (B->C) x (C->D)
= 5:1 x 5:1 x 5:1
= 5 x 5 x 5:1 x 1 x 1
= 125:1

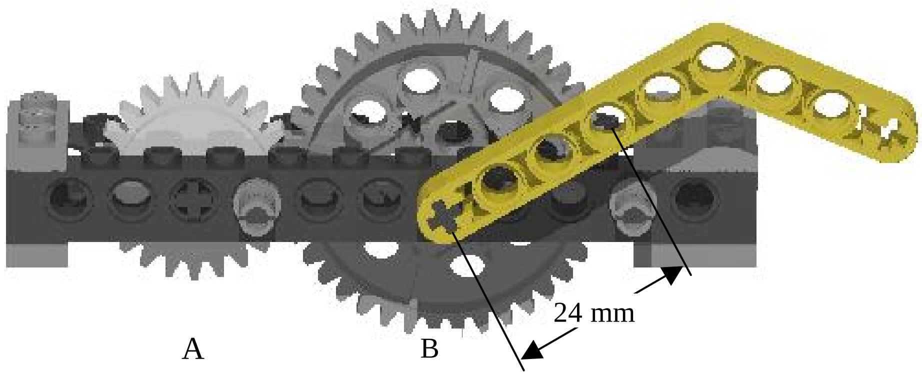
If you connect shaft A to a motor spinning at 300 revolutions per minute (rpm), shaft D will spin at 2.4 rpm or 1 revolution every 25 seconds. Shaft D will have a LOT OF TORQUE!!! It could break gear teeth or snap axles.

Idler Gear



- **The 24 tooth gear is an idler gear. An idler gear does not affect the gear ratio of a gear train**
- **Idler gears are quite common in machines where they are used to connect distant axles. Idler gears may also used to change the direction of rotation of the output shaft**

Clutch Gear

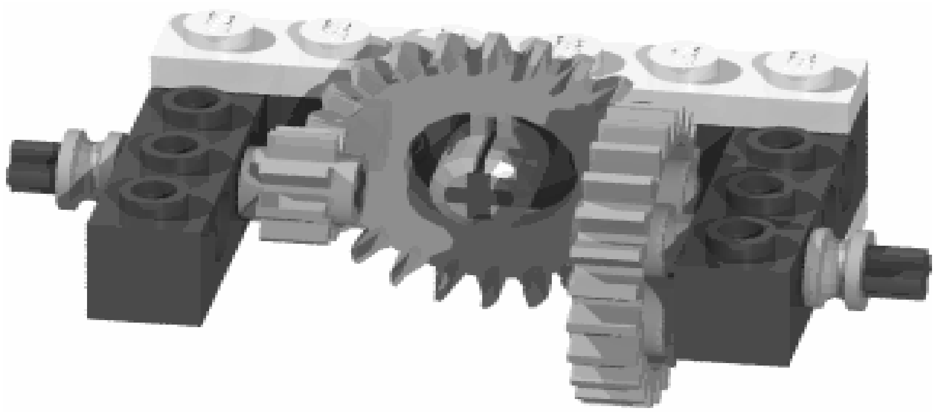


- **The white gear with writing on it is called a clutch gear**

- **The clutch gear is special in that the gear teeth are able to rotate about the shaft.**

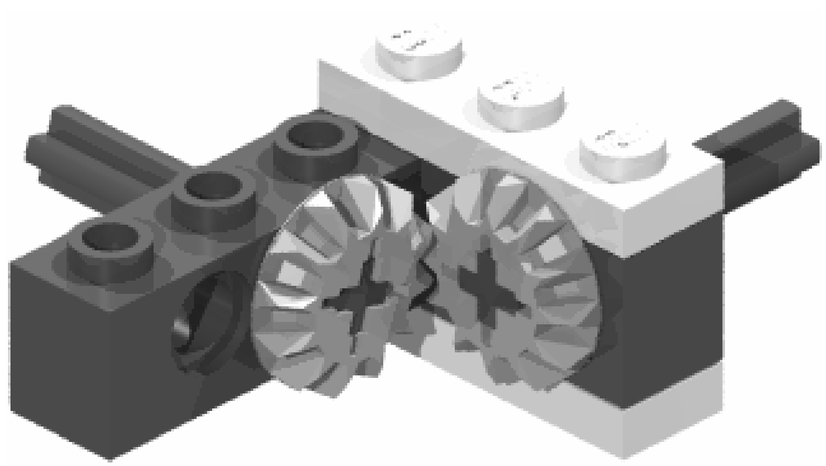
- **It has an internal clutch mechanism that starts to slip when its maximum rated torque is exceeded. The clutch gear is used to limit the torque of a geared system, saving motors and preventing your robot from tearing itself apart.**

Crown Gear



- **The crown gear has teeth that are raised on one side and rounded-off on the other to give it a crown-like appearance.**
- **Used when the shafts to be turned meet at an angle. It can be meshed to spur gears and worm gears, but it doesn't mesh well with other crown gears.**
- **Can also be used in place of a 24 tooth spur gear.**

Bevel Gear

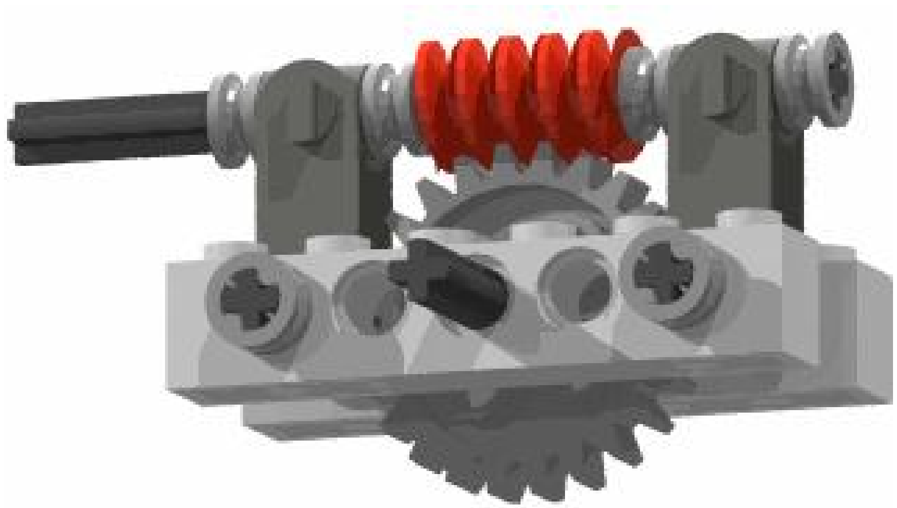


• The bevel gear has teeth that slope along one surface of the disc. It is used when the shafts to be turned meet at an angle.

• It has less friction than the crown gear, but can only mesh with another bevel gear.

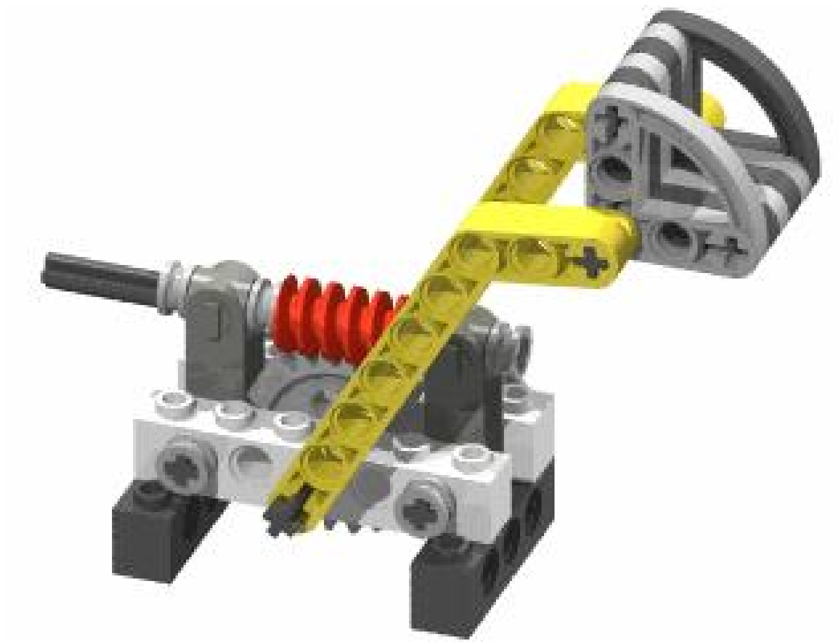
• Can also be used as a small wheel

Worm Gear



- **A worm gear is a screw which usually turns along a spur gear.**
- **Motion is transmitted between shafts that are at right angles.**
- **Can create very high gear ratio as each time the shaft spins one revolution, the spur gear moves one tooth forward.**

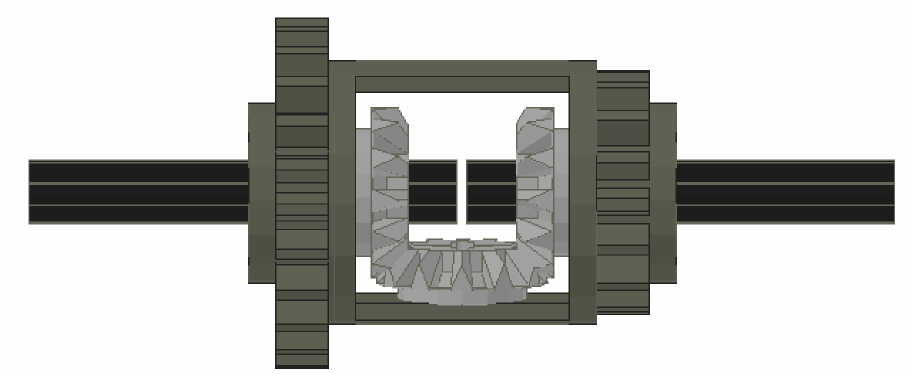
Worm Gear is Self Locking

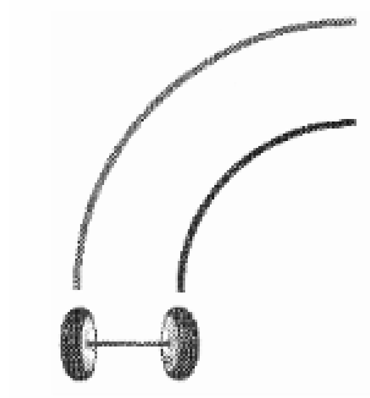


• Your can turn the input shaft to drive the output shaft, but you cannot turn the output shaft to drive the input shaft.

• Very useful for arms as no torque is required to keep it in place.

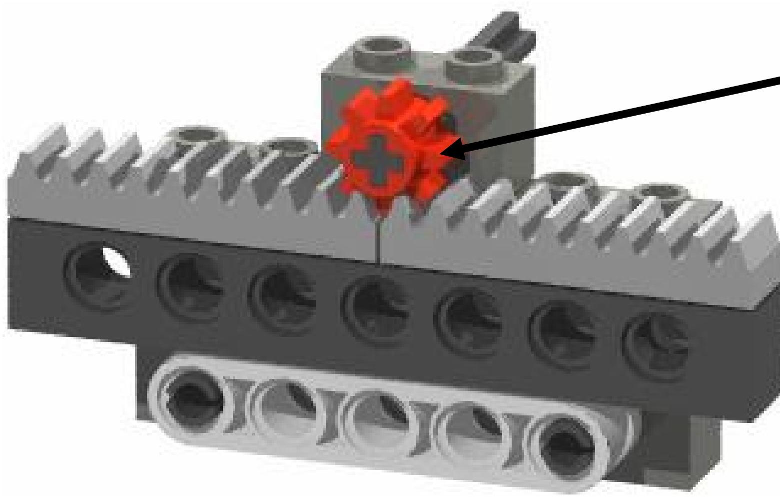
LEGO Differential





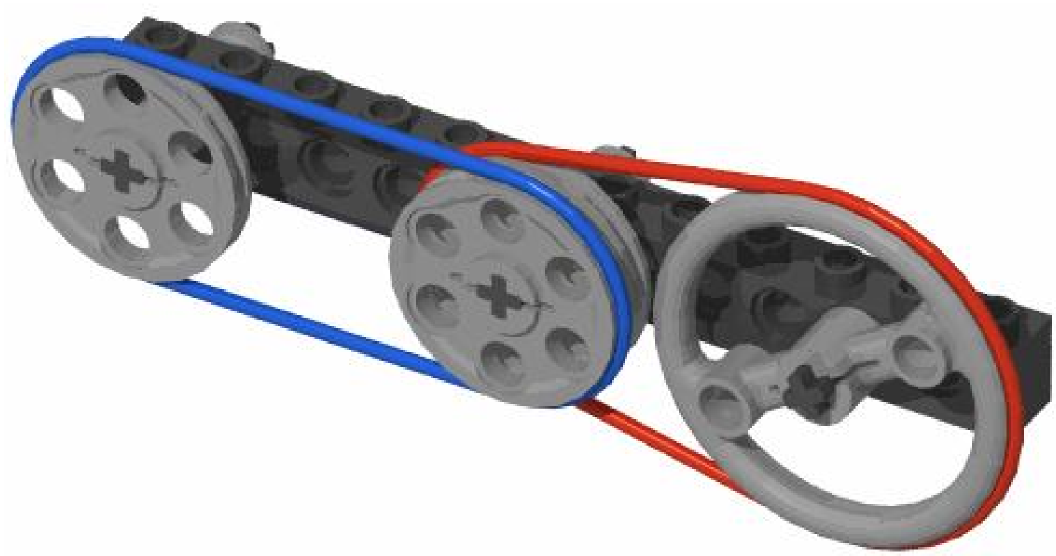
- A differential is a device takes a torque applied to its housing, and evenly distributes it to two output shafts, allowing each output to spin at a different speed.
- Necessary because going around a turn, car wheels turn at a different speed.

LEGO Gear Rack and Pinion



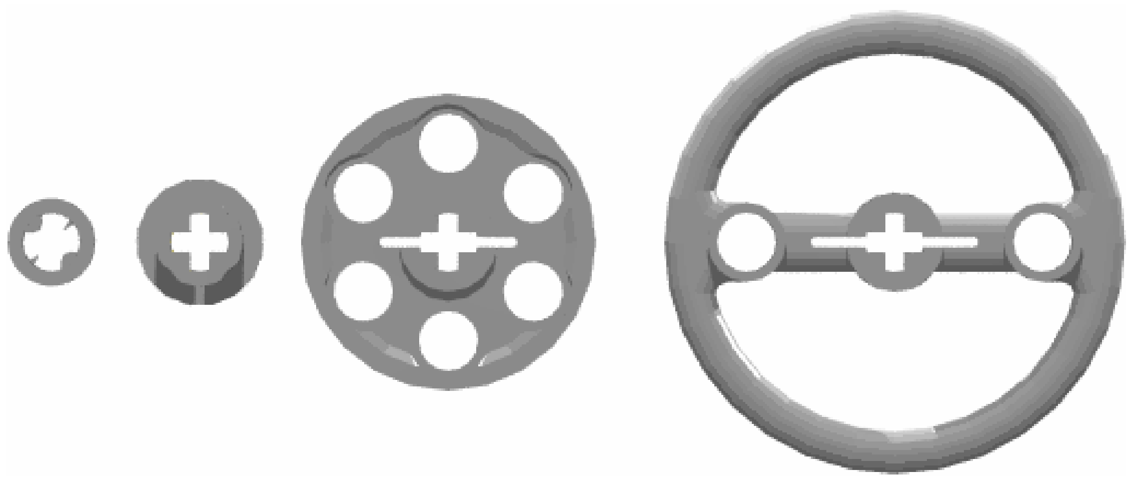
- The gear rack looks like a spur gear laid out flat. It is usually used in conjunction with a spur gear (which is referred to as the pinion).
- Used to convert rotation into linear motion.

Pulleys and Belts



- A pulley is a wheel with a groove about its diameter. The groove, called the race, accepts a belt which attaches the pulley to other pulleys.
- LEGO belts are color coded; small (white), medium (blue) and large (yellow).

Lego Pulleys



• **With four different sized pulleys, it is possible to "gear" up and "gear" down.**

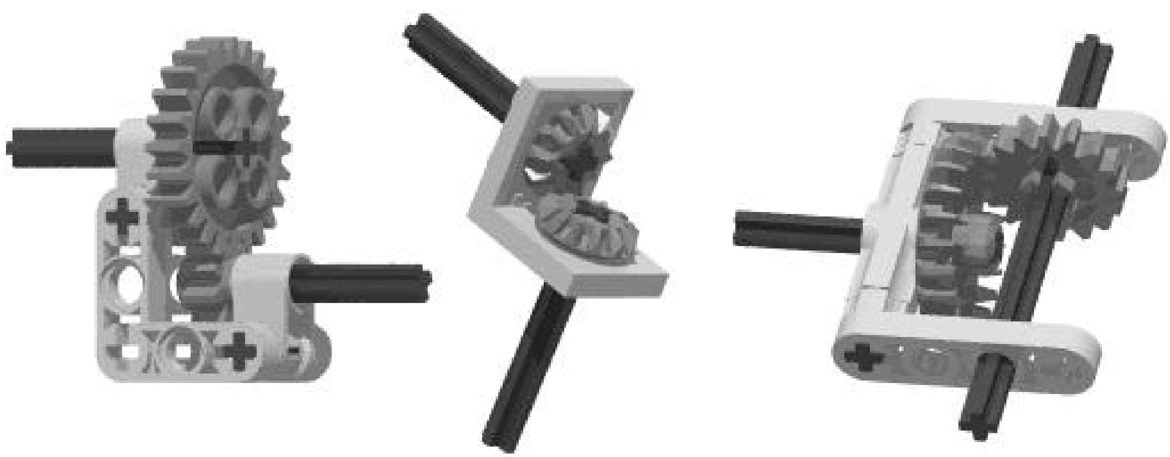
• **Pulleys may be used in place of gears in many applications. Since there are no teeth to mesh, placement is much more forgiving. But because it has no teeth a pulley cannot be used to transmit high torques. The belt will slip first.**

Pulley Ratios

	Half Bushing	Small Pulley	Medium Pulley	Large Pulley
Half Bushing	1:1	1:2	1:4	1:6
Small Pulley	2:1	1:1	1:2.5	1:4.1
Medium Pulley	4:1	2.5:1	1:1	1:1.8
Large Pulley	6:1	4.1:1	1.8:1	1:1

Reinforcing Gear Trains

- **Gears will undergo the biggest forces on your robots. Here are some simple examples of sturdy frames for gears.**



Lego Wheels and Tires

Small Solid
24mm x 7mm

Medium Solid
30mm x 10.7mm

Large Solid
43mm x 10.7mm

Large Balloon
81.6mm x 15mm

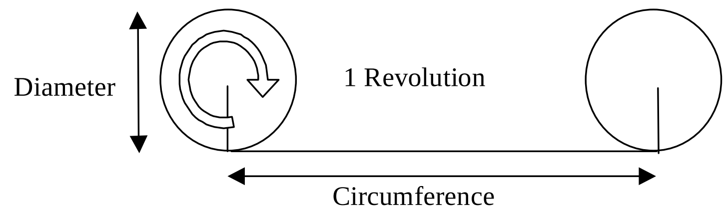
Small Balloon
30.4 mm x 14 mm

Medium Balloon
49.6 mm x 28 mm

Pulley Wheel
30 mm x 4 mm

- **Wheels affect your robot's speed, power, accuracy and ability to handle variations in terrain.**
- **What you choose will have a profound effect on your robot's success or failure.**

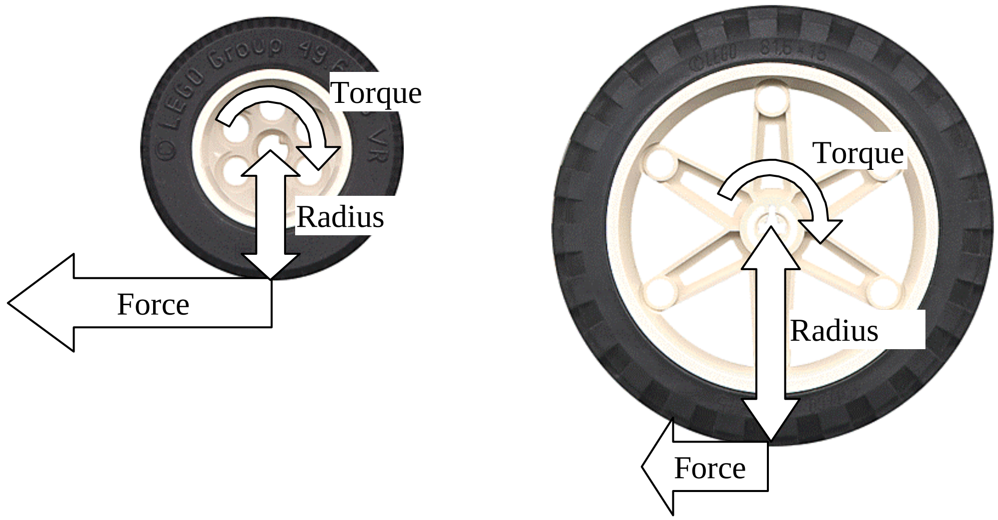
Speed Calculation



- **Circumference = pi x Diameter**
- **Use this to calculate speed and distance (details in slide notes)**

ω = Motor RPM x Gear Ratio
= 300 rpm x 3:1
= 900 rpm
v = ω x Pi x d
= 900 rpm x 3.14 x 81.6mm
= 230,601 mm per minute
or 8.7 mph ← **Wow!!!**

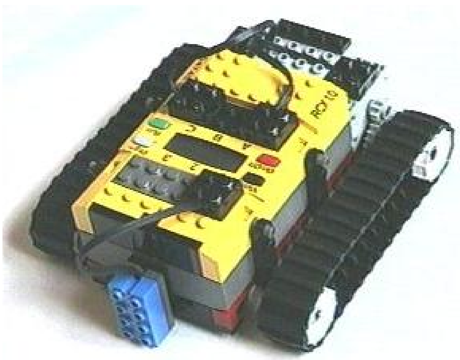
Force = Torque/Radius



• **Gears and wheels have the same relationship between force, torque, and radius.**

• **When you use big wheels to increase speed you have to give something up, and that something is force. A robot with big wheels cannot pull as much as a robot with small wheels can pull.**

Tracked Robot



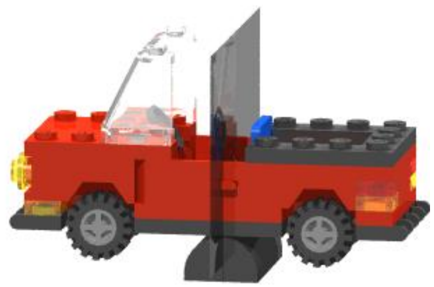
- Advantages:
  - Good traction on rough surfaces
  - Stable
  - Agile (turns in small space)
- Disadvantages
  - Poor traction on smooth surfaces (slips a lot), making some methods of navigation difficult
  - A lot of power loss due to bending of tread, etc.

Robot Balance

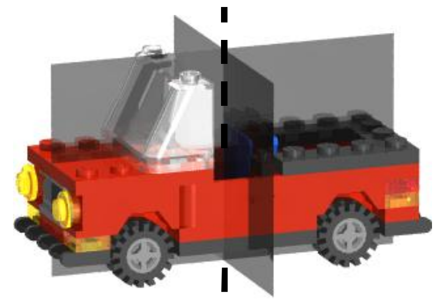
- Proper balance is very important in robot design. For your robot to move in a predictable and repeatable manner all wheels must be in contact with the ground at all times, and the weight carried by each wheel must be consistent.
- Balance is dependant upon two factors; wheel base and center of gravity
- Center of gravity should remain within the wheel base.

Finding the Center of Gravity

Lateral Balance Plane



Longitudinal Balance Plane



CG is on this line

• **Using the balance method you need to locate the balance point on the lateral, longitudinal, and vertical axes.**

• **You need a fulcrum, 2x4 curved top brick, that will support the weight of the robot while still allowing it to tip easily. Place the robot on the fulcrum such that the fulcrum is parallel to the balance plane you are trying to locate. Slowly adjust the position of the fulcrum until the robot balances. This is the balance point.**

Motors and Sensors

RCX basics

Infrared (IR) communications port

View to select display

On/Off switch

Display:

Motor status, sensor values, program status

3 Sensor Inputs

Program select (1-5)

Green means GO!!

3 Motor Outputs

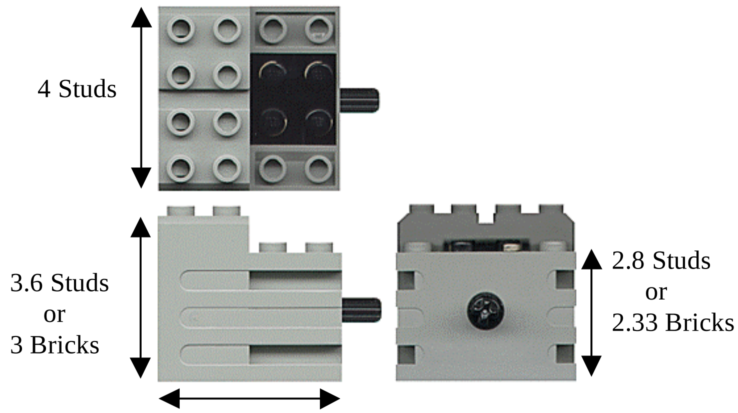
Processor: Hitachi H8 8 bit microcontroller running at 5to 20Mhz

Memory: 32K of RAM

Driving Motors

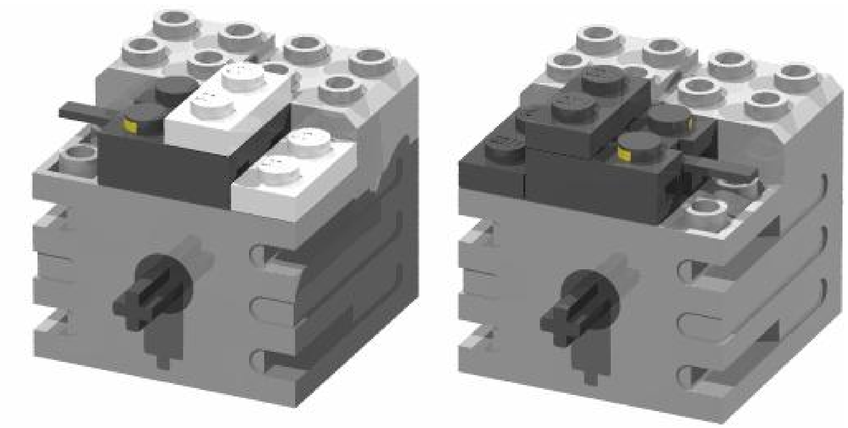
- **Making the motors move and do something is the point (the <u>output</u>) of your program. That's what makes your creation a robot!**
- **Formally called the 9 volt geared motor**
  - **Without load, motor shaft turns at about 350 rpm**
  - **With typical robots the power usage should allow 3-4 hours of use on a set of batteries**
- **FLL currently allows up to 3 motors on your robot**

Motor Details



- **Motor can be set to different power settings**
  - **5 settings in Robolab**
  - **8 settings in RCX code**
  - **Changing power settings is usually a poor substitute for gearing**
- **Turning the power setting up higher essentially makes the shaft turn faster**

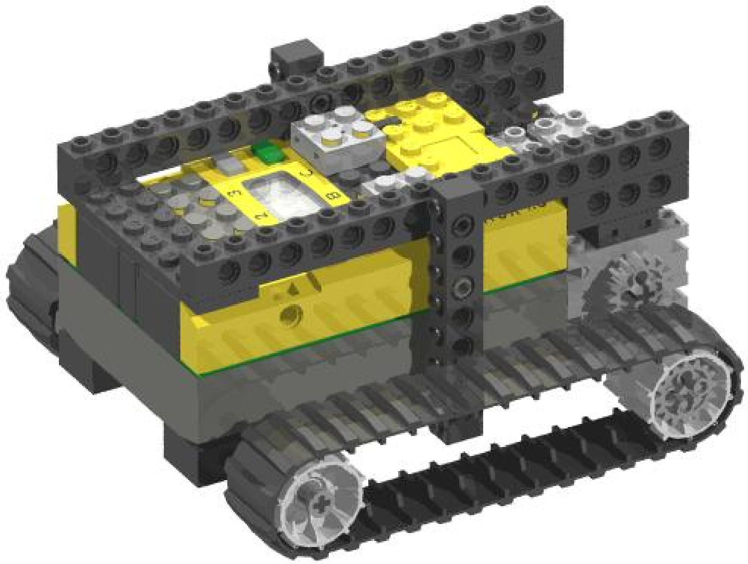
Motor Connections

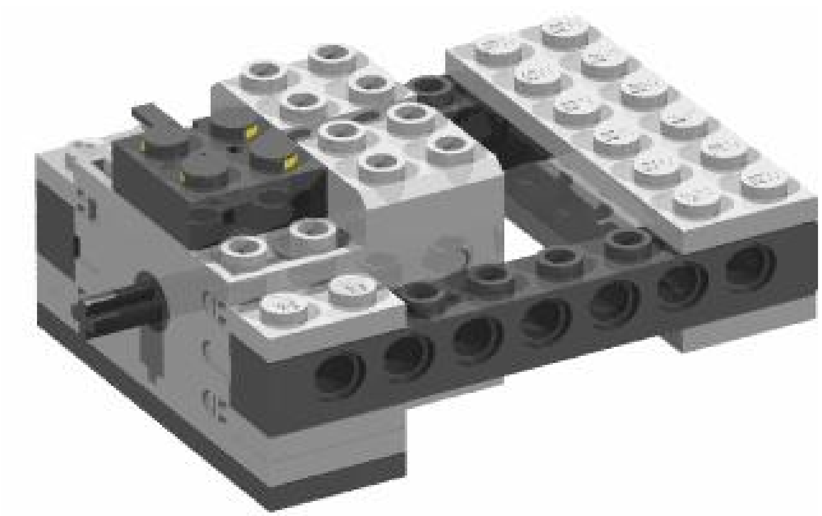


• A motor is attached to one of the three output connectors using a snap-on wire lead. You can reverse the rotation direction of the motor by changing the orientation of the connection.

• To make sure you always connect them in the same way try marking the connector leads and motor ports with color coded 1 x 2 plates as a reminder.

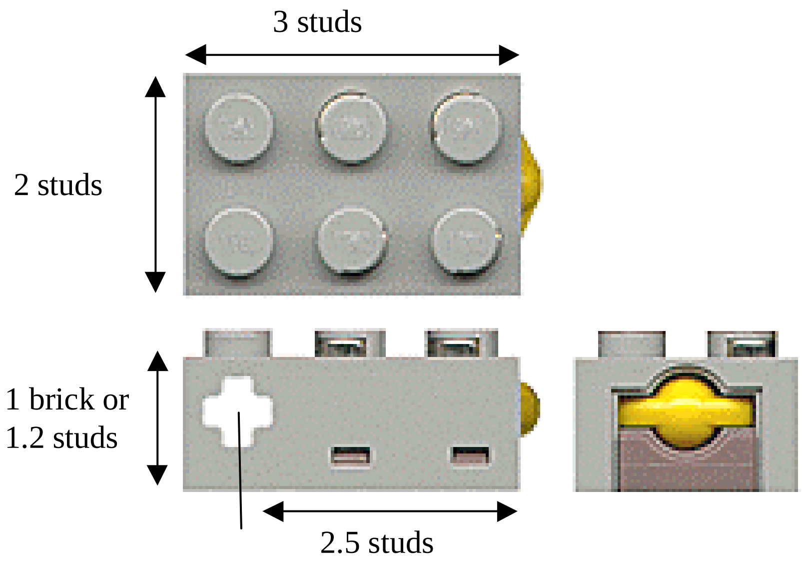
Strengthening Motor Mounts





Motors will fall off if they are just snapped on.

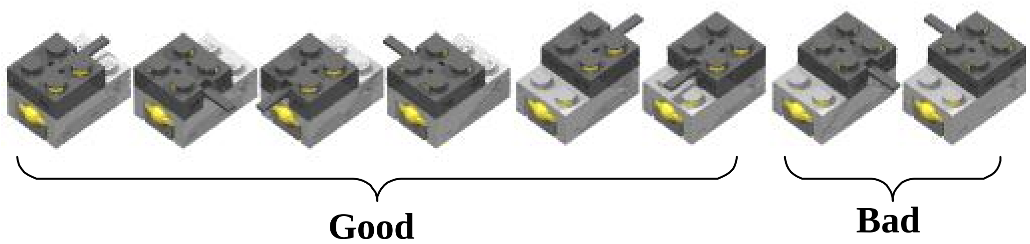
Touch Sensor



• **Allows robot to detect touching or bumping into something**

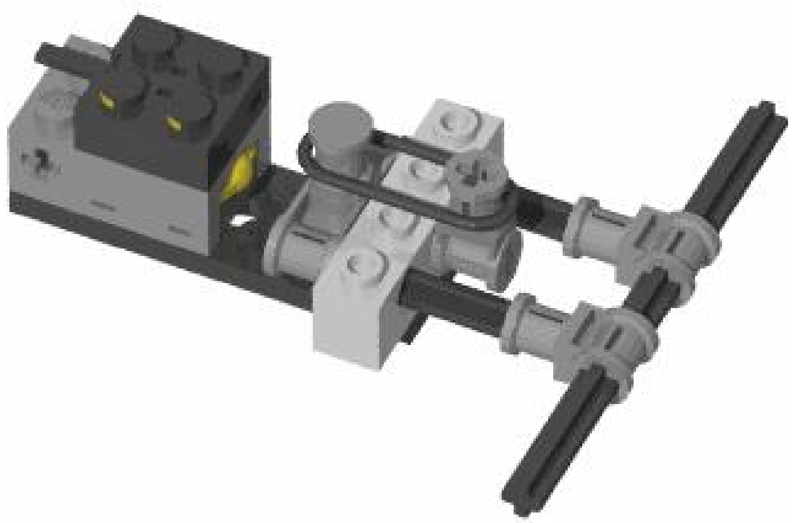
• **Good to detect robot arm movements (the sensor is activated when the arm moves far enough to push in the touch sensor). This is called a limit switch.**

Wiring the Touch Sensor



- **Orientation is not important if the lead wire is attached to all four contact studs.**
- **You can also make the connection using only two of the contacts, but when doing so the lead wire must be oriented as shown.**

A Simple Bumper



- **A bumper is a device that notifies your robot that you ran into an obstacle. When struck, the bumper moves and presses or releases a touch sensor, notifying your robot of the impact.**

- **Bumpers are the most common use for a touch sensor in FLL.**

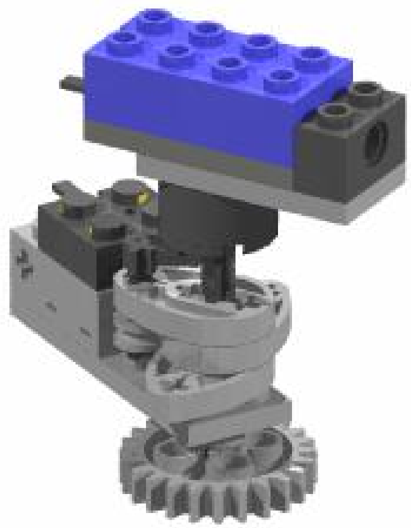
More Bumpers

<u>**Normally closed**</u> **- means that the touch sensor is normally <u>in</u> and is <u>released</u> by the bumper**

<u>**Normally open**</u> **- means that the touch sensor is normally <u>out</u> and is <u>pushed in</u> by the bumper**

You need to have a rubber band or something to return the bumper to its normal position after a collision

Position and Limit Switches



- **Another use for touch sensors**

•Limit and Position switches tell you when a component of your robot is in a certain location.

- **Useful in arm movements, etc.**

Light Sensor

• A light sensor detects reflected light from its red light emitting diode.

• Light sensors operate in "percent" mode, anywhere from 0 to 100 in value.

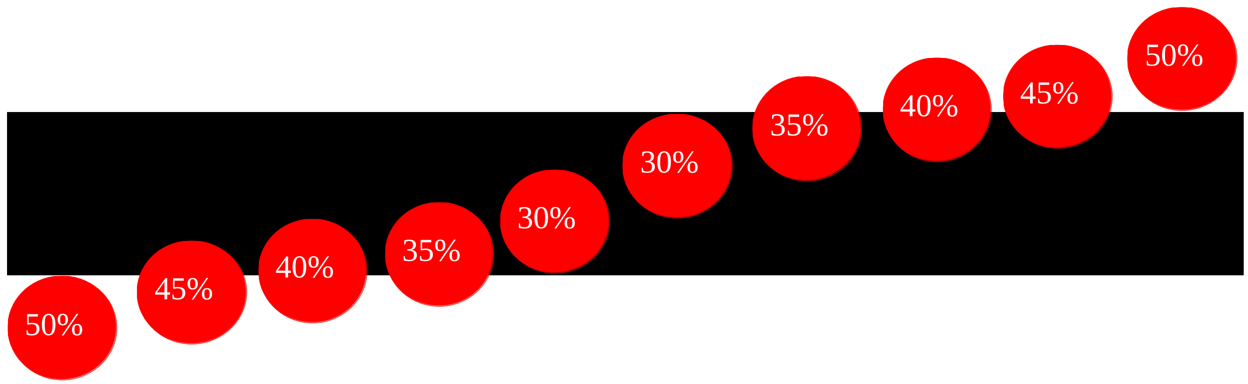
  • Higher the number, the brighter the light, hence the lighter the surface as more light is reflected back

• Light sensor can be the most frustrating sensor due to it's variability

Light Sensor Readings

- **Lowest reading likely 20% (in very dark room)**
- **Highest reading likely 100% (pointing directly at sun or incandescent light bulb)**
- **Normal operation values tend to be between 30-60%**
- **Readings also depend on the color of the surface**
  - **See text for extensive discussion of this**
  - **You can't always predict what this will be, you should experiment with your surfaces/colors**
- **Light sensor is extremely sensitive to the distance between the sensor and the reflecting surface. Even small variations can make the readings unusable. Try to keep the sensor close to the surface and shielded.**

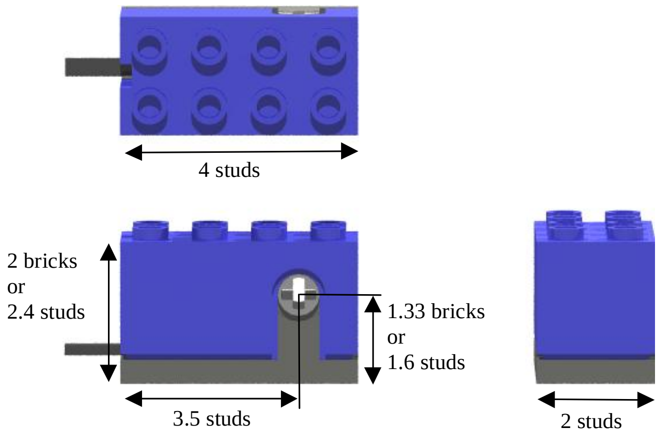
Light Sensor Readings



• **The light sensor averages its readings over roughly a circular area. Don't drive too fast or you will get inaccurate readings**

• **It is very sensitive to ambient light. Shield the sensor as much as possible and try it out under the conditions that you will compete in. Test it on competition day.**

Rotation Sensor

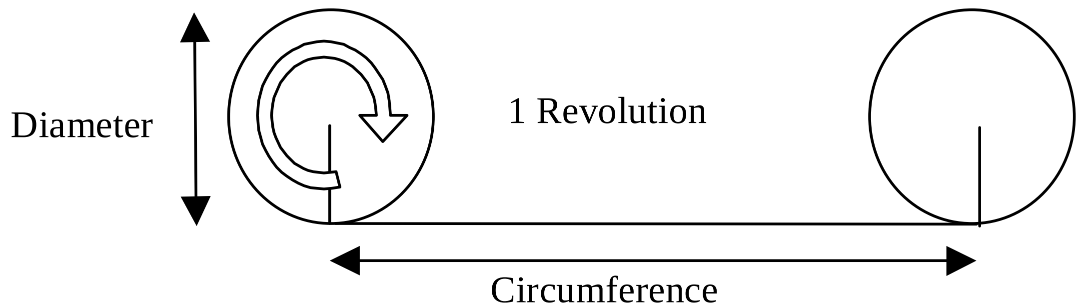


- **The rotation sensor is used to measure how far a rotating axle has turned. As the axle turns, a counter in the RCX is incremented or decremented.**

- **Each full rotation registers as 16 counts giving the sensor a resolution of 22.5 degrees (360/16). Hence it is sometimes called the angle sensor.**

Calculating Distance

- **The rotation sensor also brings in the possibility of doing some real math!**



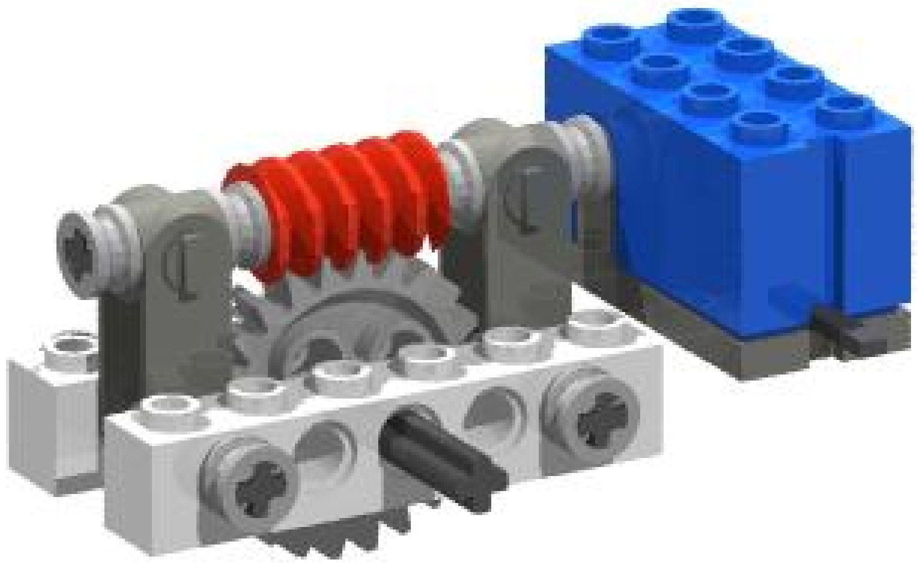
Circumference = pi x Diameter

- **We'll leave that as an exercise for the reader!**
- **Of course, trial and error also works.**
- **Sources of error in calculation - dirt on surface, using a skid rather than a wheel, backlash (poor fitting gears)**

More on Rotation Sensor

- Rotation sensor can count forwards or back, up to Absolute Value (32,767), then it rolls over to largest negative from largest positive (or vice versa), however this is really unlikely to occur in FLL.
- Increase sensor resolution with gear reduction
- Rotation sensor is quite reliable if shaft speeds are kept in 60-1000 rpm range, some accounting problems may occur at very high or very slow speeds.
  - Motors typically around 200 rpm.

Increasing Resolution



• **Extremely powerful for navigation (how far have you gone) but does have some error.**

• **Use gear reduction to increase resolution and decrease error.**

Debugging the Rotation Sensor

- **Common sources of repeatability problems for the rotation sensor**
  - **Programming: forgetting to reset the sensor before use**
  - **Design: inadequate sensor resolution (trying to measure something very accurately without using gear reduction)**
  - **Control: accelerating and turning too fast**
  - **Variations in the initial conditions: not putting everything in the right place,or at least the same place, before pushing the run button.**

Sensor Tricks and Tips

- **Use a touch sensor to get more program slots**
  - **If touch sensor is in, execute one program stack**
  - **If touch sensor is out, execute another program stack**
  - **Do this for every program slot, and you end up with 10 program slots instead of 5.**
  - **Add a brick to robot between missions to push the touch sensor in, to achieve this.**
- **Use a light sensor to achieve rotation counting**
  - **Aim light sensor at a piece of your robot that rotates and measure color differences (for example, have two colors on a piece that rotates), and count these.**

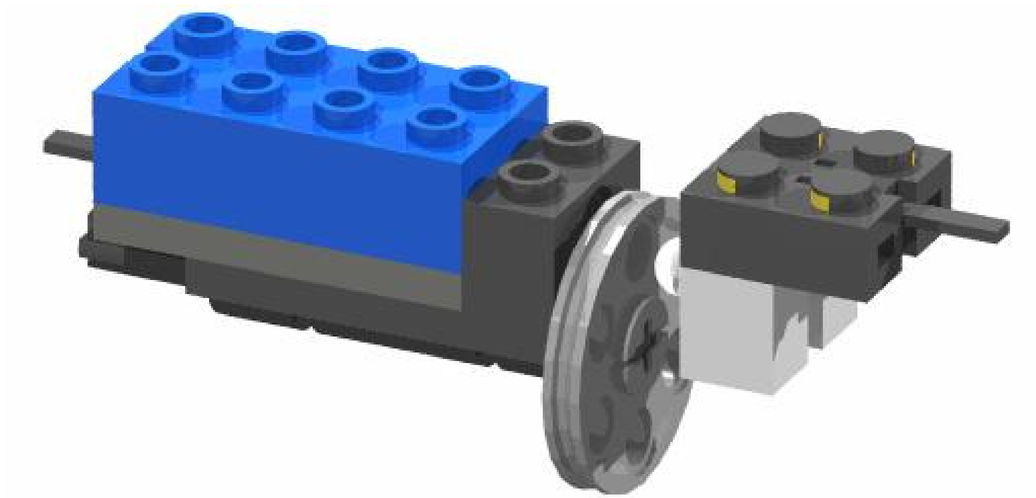
Stacking Sensor Ports

- Attaching multiple sensors to the same port
- Allows you to use more than 3 sensors
- Touch sensors work best for this, rotation sensors cannot be stacked.

	Touch Open	Touch Closed	Light Sensor
Touch Open	0	1	light level
Touch Closed	1	1	100
Light Sensor	light level	100	???

Sensor readings for 2 stacked sensors

Homemade Rotation Sensor



Uses the lamp, light sensor, and a pulley

Drive Mechanisms

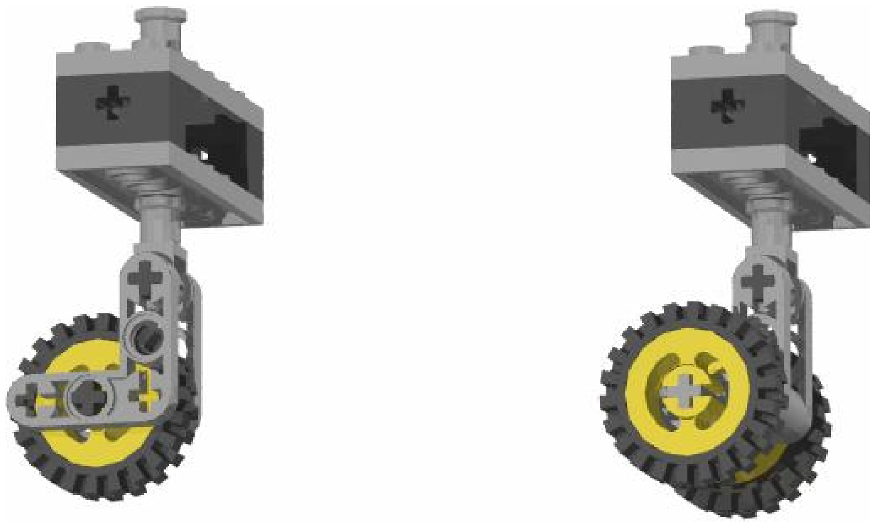
Robot Drives

- **FLL robots need to move. They have places to go and scientists to save, and all without any outside intervention or control. This kind of robot is commonly referred to an Autonomous Robotic Vehicle or ARV, and is among the most difficult kinds of robot to build and program**.
- **Questions to think about:**
  - **What's more important, speed or accuracy? Is traveling in a perfectly straight line really required? Do your plans require lots of turns and maneuvering in tight quarters? Is pulling capacity or load carrying capacity important?**

Differential Drive

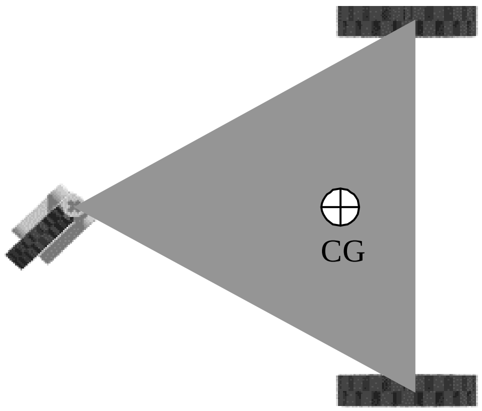
- Differential are very popular and a good choice for FLL.
- Two wheels mounted on a single axis are independently powered and controlled, providing both drive and steering. Steering is performed by changing the relative velocities of the two drive wheels. Spinning the left wheel faster causes the robot to turn right. Spinning the right wheel faster causes the robot to turn left. By spinning the wheels in opposite directions it is possible to turn in place
- Perhaps the most common example of a differential drive platform in everyday life is the wheelchair.

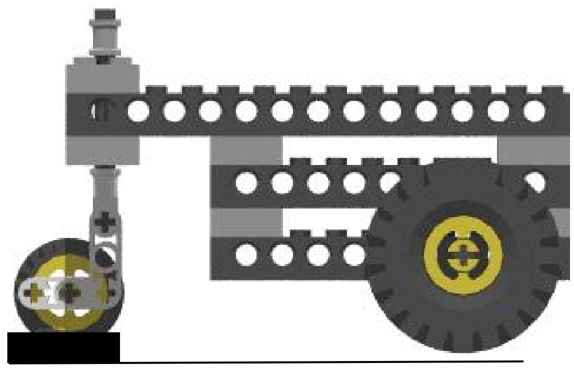
The Third Wheel



- **Making a two-wheeled robot is difficult. Swivel Casters are an example of a good third wheel. (Also called idlers or bogey wheels)**
- **Caster steer effect is discussed at length in text. Think of how shopping carts work (or don't work).**

Triangle Shaped Wheel Layout





- **Guaranteed to have all three wheels in contact with the ground. But the center of gravity (CG) cannot be centered over the drive wheel axis and some of the robot's weight will be supported by the caster.**

- **Position the CG as close to the drive wheel axis and as far away from the caster as possible. Moving the caster farther away from the drive wheels also helps.**

Straight Line Travel

- **A problem that many teams have with their differential drive robots is getting them to travel in a straight line.**
- **Can be minimized through good building practices, even weight distribution and choosing well matched motors. But to travel in a perfectly straight line requires some sort of correction mechanism, either mechanical or software.**

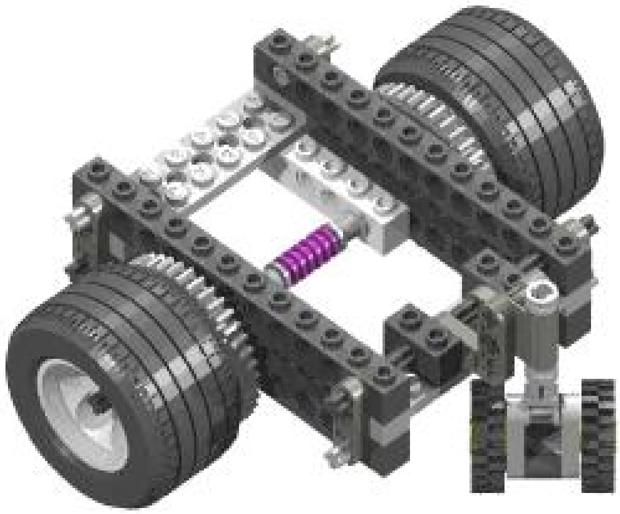
Straight Line Travel

- **First you need to decide if traveling in a straight line is important or not. If your competition strategy is based on making perfect turns and traveling along laser straight paths your team may be in for some disappointment.**
- **The most successful teams build a robot that "goes straight enough" and rely on other strategies to compensate for any navigation errors. These self correcting robots are better able to handle the inevitable variations in starting position or unexpected bumps and slips that occur during the competition.**

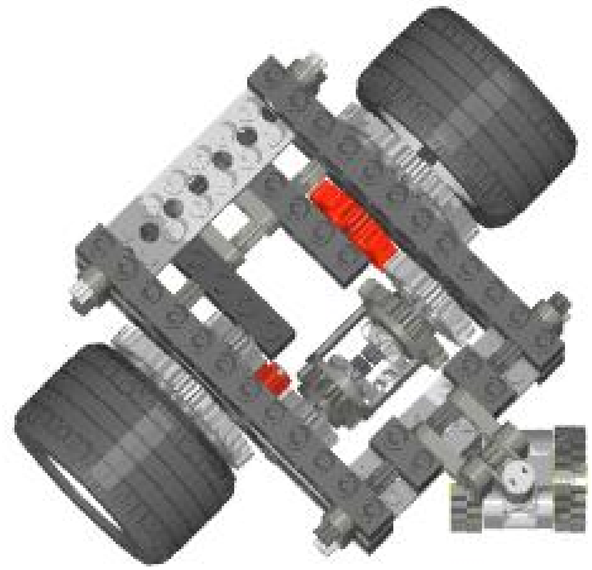
Software Solution

- **Most differential drive robots use encoders (rotation sensors) to measure the position of each drive wheel. To travel in a straight line, the robot's control software continuously monitors the encoder feedbacks and adjusts the power to the left and right motors to keep the values even.**
- **This method is difficult to implement with only one rotation sensor available in the FLL challenge kit. It requires that a second encoder be constructed using the light sensor or a touch sensor.**

Mechanical Solutions



Simple LEGO Slip Limiter



A Locking Differential

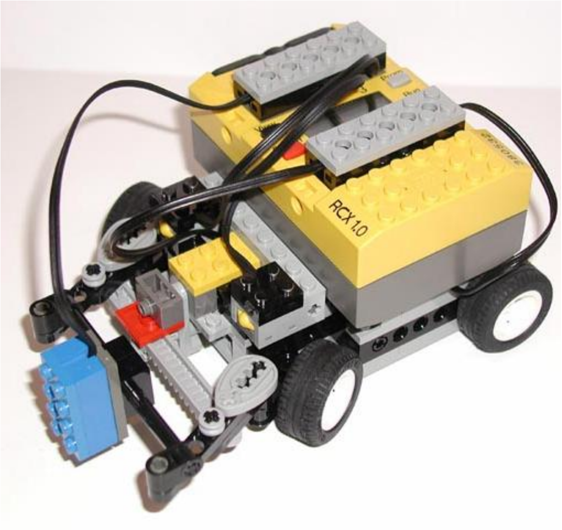
Differential Skid

- **Sometimes called skid steer and common in FLL.**
- **It's normally used with tracked vehicles, but sometimes with 4 or 6 wheel platforms as well. Casters are not used in a differential skid drive; all the wheels are driven. Wheels on the left side are driven by one motor, wheels on the right by another.**
- **Skid steer configurations rely on track or wheel slippage for steering.**
- **Skid steer robots are good climbers and can handle rougher terrain than most other robot designs. They are as maneuverable as a differential drive robot, but less prone to unwanted differential steer. Can't used odometry well though.**

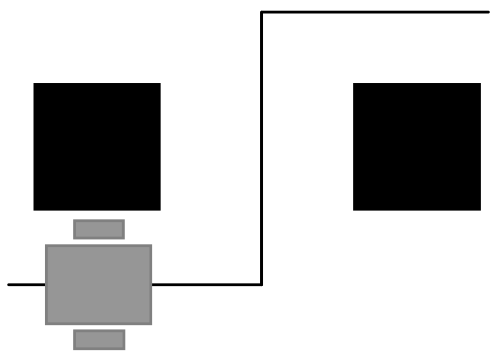
Steering Drive

- A steering drive is the familiar configuration used in automobiles. In a steering drive, one motor is used for locomotion, and a second motor for steering. Decoupling steering from forward motion makes a steering drive easier to control than a differential drive where the velocity of each drive wheel must always be carefully measured and controlled.
- However it is more difficult to build.
- Has a non-zero turning radius.

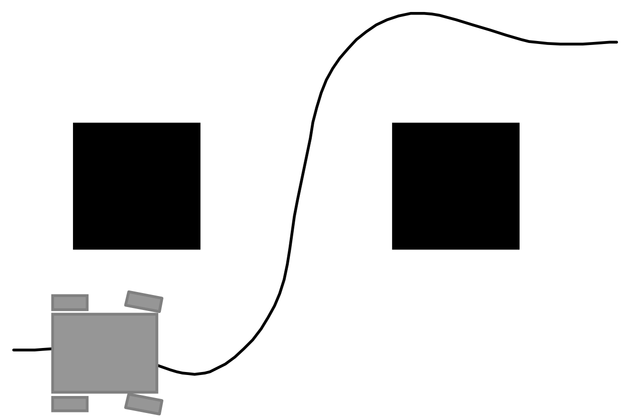
Examples of Steering Drive



Turning Comparison



Differential Drive



Steering Drive

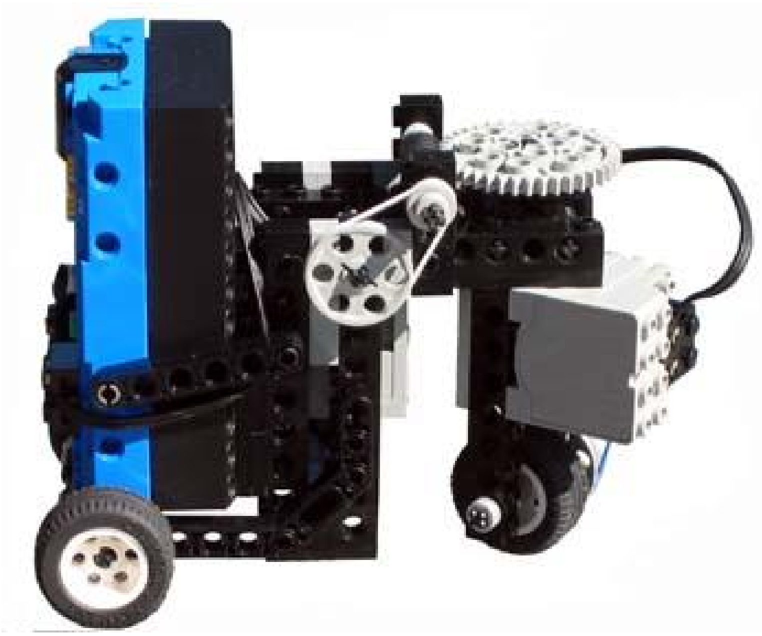
Think parallel parking!!

Tricycle Drive

- **A tricycle drive is a steered drive platform with a single driven front wheel and two passive rear wheels (or vice versa).**
- **Though it may look very similar to a three wheeled steering drive platform, a tricycle drive has some unique characteristics that make it preferable for most robotic applications.**
- **The most important of these is its ability to turn in place.**

Tricycle Drive vs. Steering Drive

Tricycle Drive



Steering Drive

- **A tricycle drive robot has the drive motor attached to the steered wheel, allowing it to operate at any steer angle.**
- **This gives it maneuverability that rivals that of differential drive and skid steering robots.**

Summary

- 1 Beam - 2 Plates - 1 Beam for vertical bracing
- Gear down to get more torque (power), less speed
- Gear up to get more speed, less torque
- Be careful with sensor usage, they are critical but follow the guidelines here.
- You have a number of options for driving your robot, think through what you want it to do.
- Have fun!!!!!!!!