FLL Coaches Clinic
Chassis and Attachments

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Presentation Outline

LEGO basics

Chassis design

Attachments

LEGO basics

Coaching tip

Have all team members identify and use pieces by name

Correct: "beam", "L-beam", "axle", "axle peg"

Incorrect: "stick", "thingy", "that"

EV3 brick

“Brains” of the robot

Mindstorms EV3 programming environment

Four motor ports (A-D)

Four sensor ports (1-4)

Highly recommended:
Rechargeable battery
+ charger

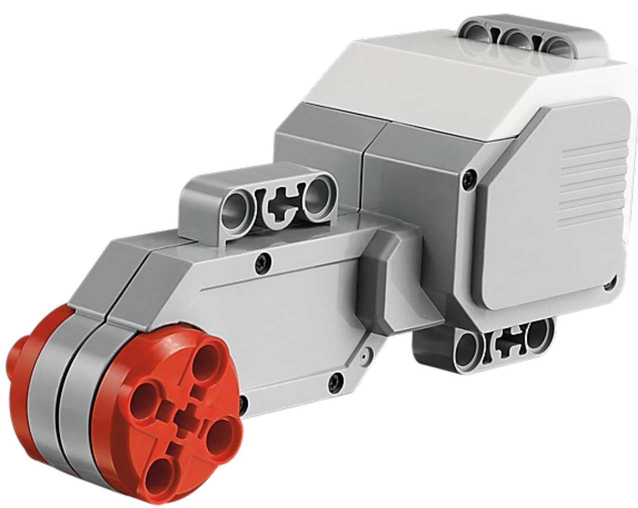
EV3 motors

Large motor

- Good for driving wheels
- Higher torque / power

Medium motor

- Good for arms & attachments
- Smaller size
- Lower torque / power



EV3 sensors

Gyro sensor

detects robot turns

Touch sensor

detects button press

Color sensor

senses color and light

Ultrasonic sensor

distance to surface

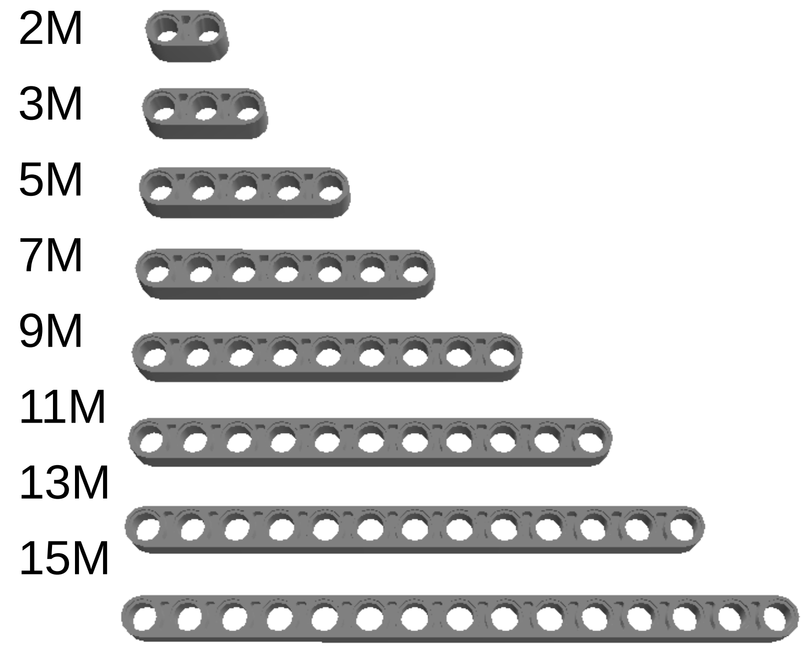
Beams

Beams are the basic building pieces for most LEGO robots

Length of beam determined by number of holes

- Often called “M” or “L” units
- Center-to-center distance is 8mm

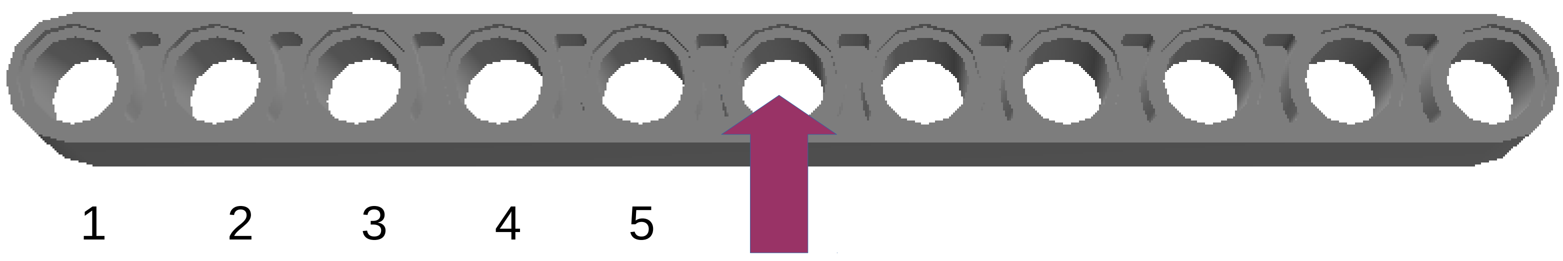
Can be “thin” or “thick”



Quickly determining beam size

To quickly determine the size of a beam

- Place a finger over the center hole
- Count the holes on one side
- Double that and add one



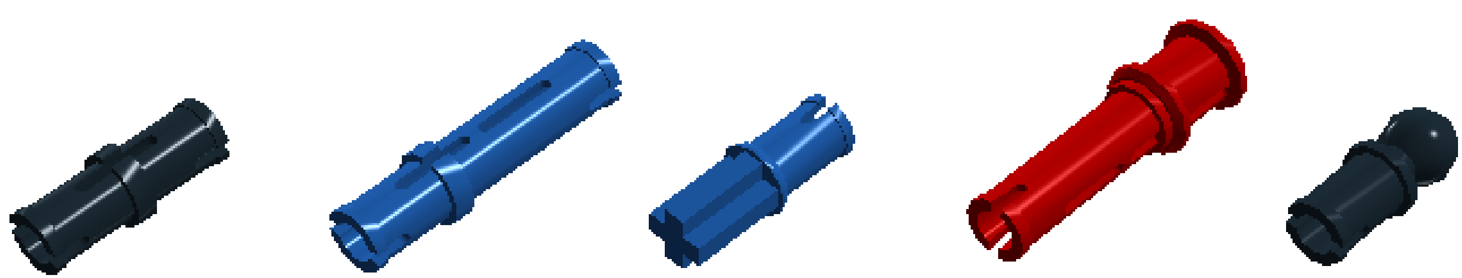
Pegs

Used to connect beams and other components

Fit inside beam holes

Friction pegs do not turn freely in holes

- Connector peg with friction (“peg”)
- 3M connector peg with friction (“long peg”)
- Connector peg with cross-axle (“axle peg”)
- Connector peg with cross-hole (“bushing peg”)
- Ball with friction snap



Pegs

Non-friction pegs will turn in beam holes

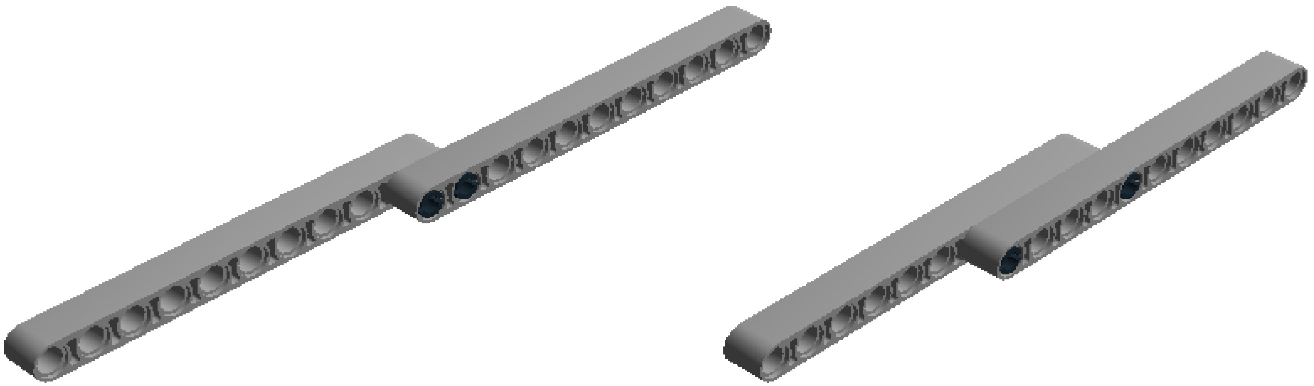
- Connector peg
- 3M connector peg
- Connector peg cross axle

Connecting beams

Use pegs to connect beams

At least two pegs are needed to make a rigid structure

Greater distance between pegs reduces flex



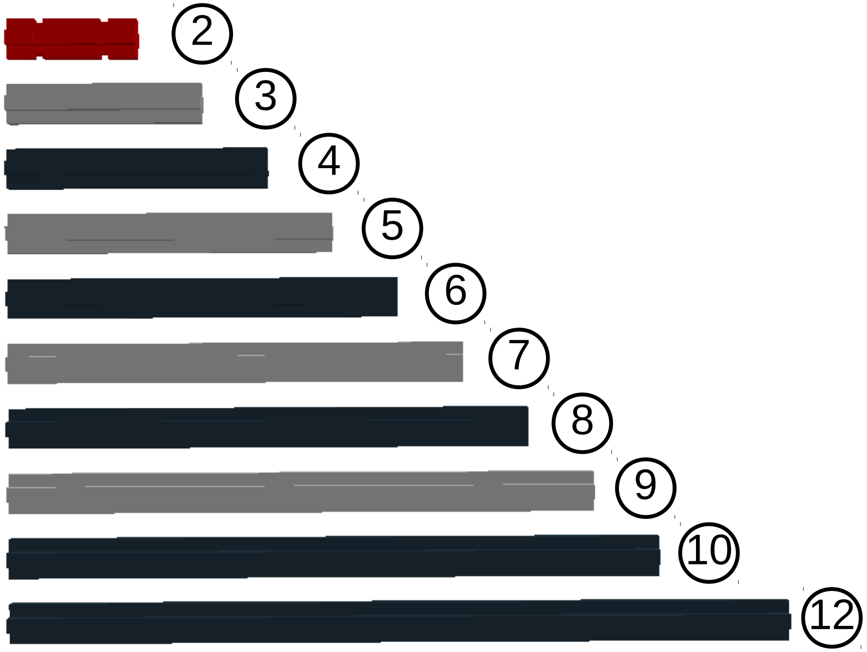
More pegs increases hold between beams

Axles

Used for wheels, gears, and attachments

Length also measured in “M” units

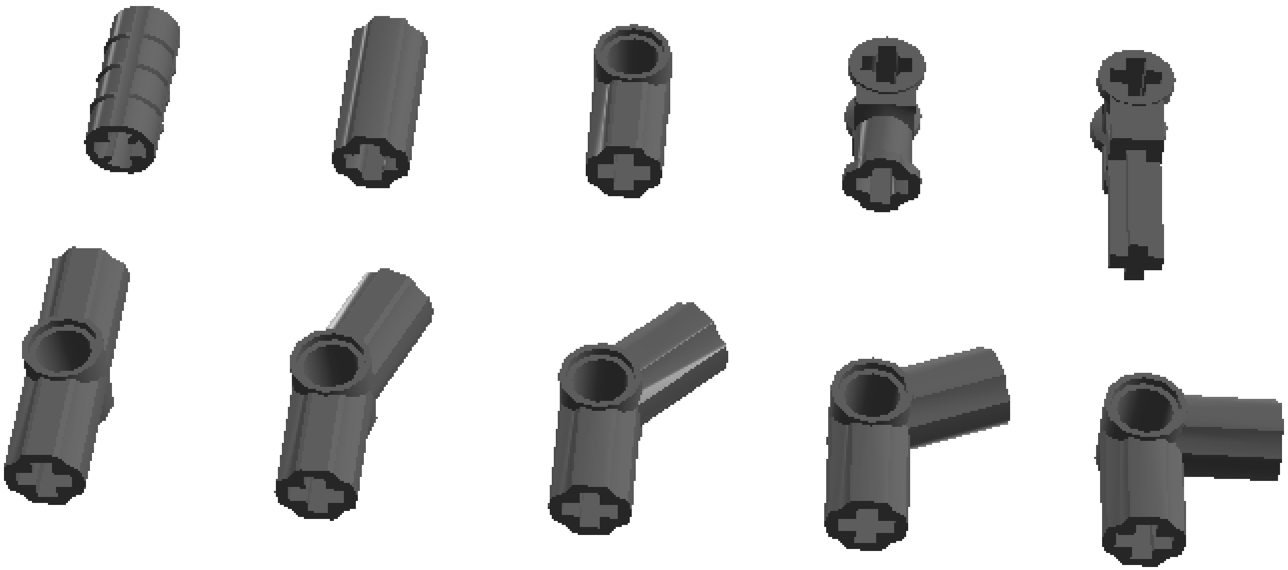
Grey axles are typically odd lengths, black axles are typically even lengths



Axles will rotate and slide in beam holes unless constrained

Axle connectors

Axles can be joined using a wide variety of connectors



Wheels

Many types of wheels and tires available

Wheel consists of “rim” and “tire”

Tire measurements printed on sidewall

Cross hole attaches to axles

- 56908 Rim wide 43.2 x 26
- 41897 Tyre Low Wide 56 x 28
- 32020c01 Wheel 62.4 x 20, with Black Tire 62.4 x 20

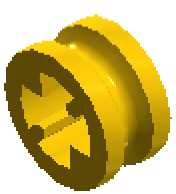


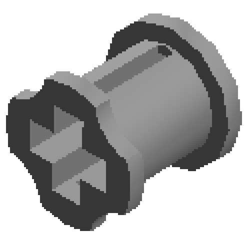
Bushings

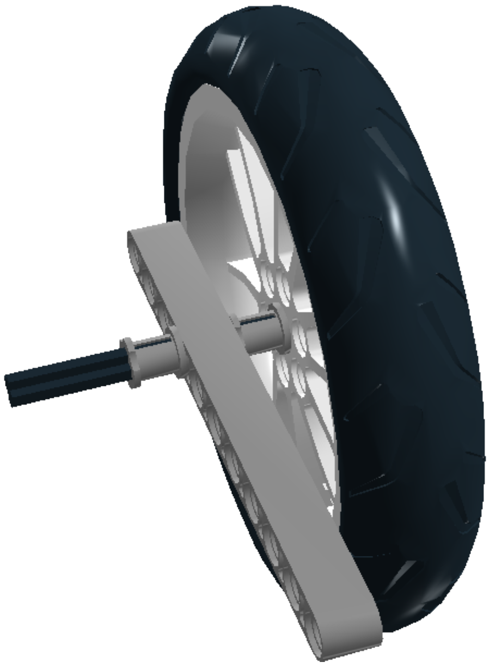
Used to hold axles on beams

Also used as spacers to prevent tires from hitting beams or other elements

- 32123 Half-bushing
- 6590 Bushing

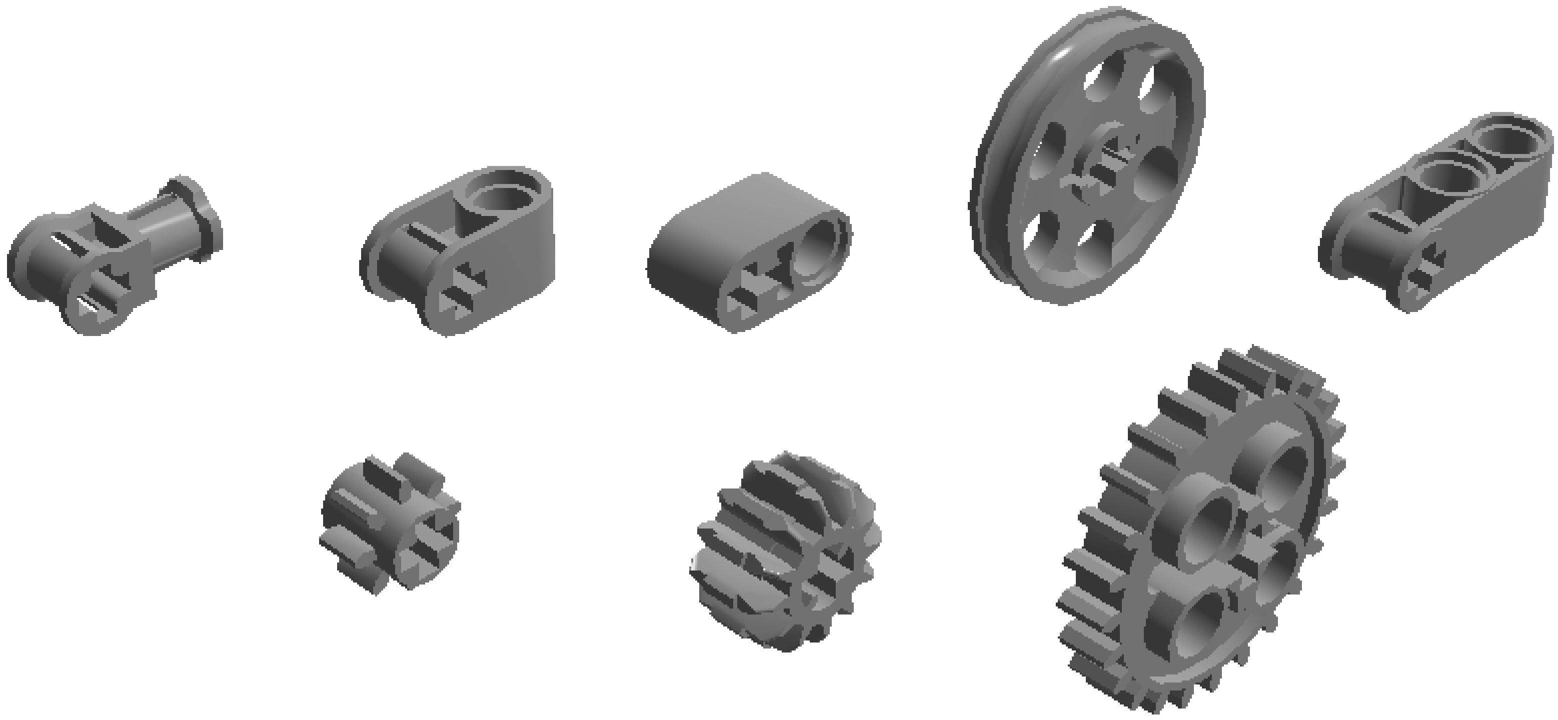






Bushings

Other elements can also be used as bushings or spacers



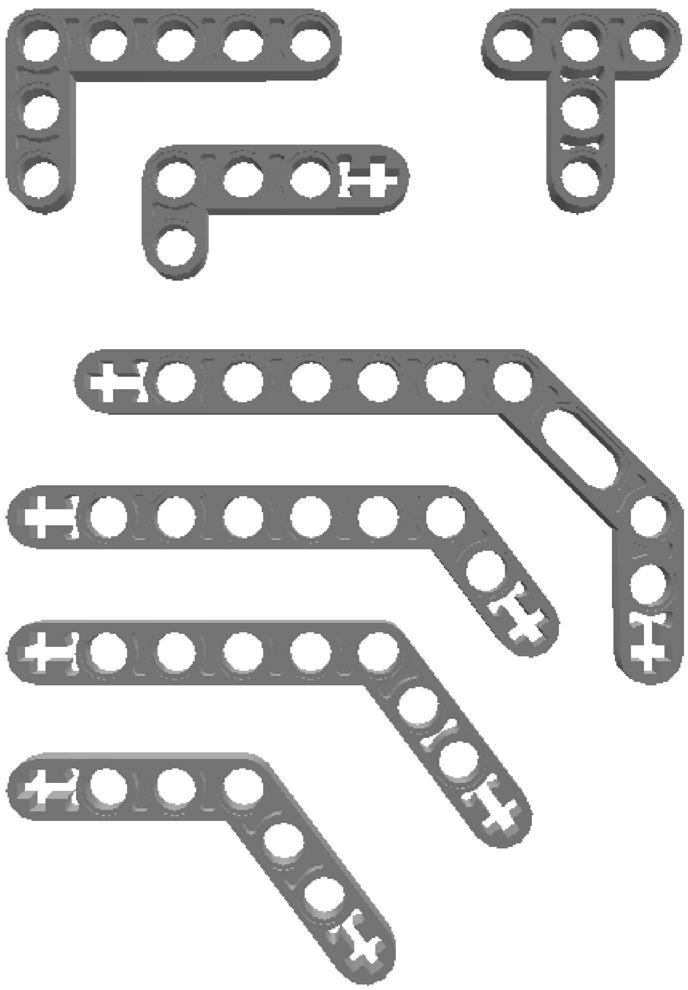
Angle beams

Allow beams to be connected at rigid angles

Excellent for structure

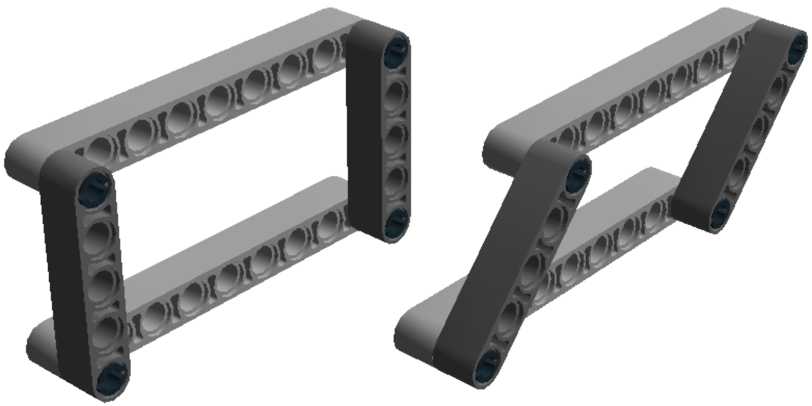
Some beams have cross holes

- 32526: 3x5 L beam
- 32140: 2x4 L beam
- 60484: 3x3 T beam
- 32009: 3x7 double-angle beam
- 32271: 3x7 angle beam
- 6629: 4x6 angle beam
- 32348: 4x4 angle beam

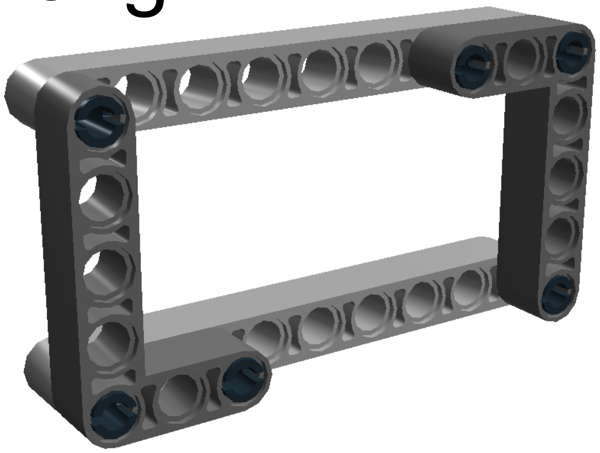


Structural strength

Weak



Strong



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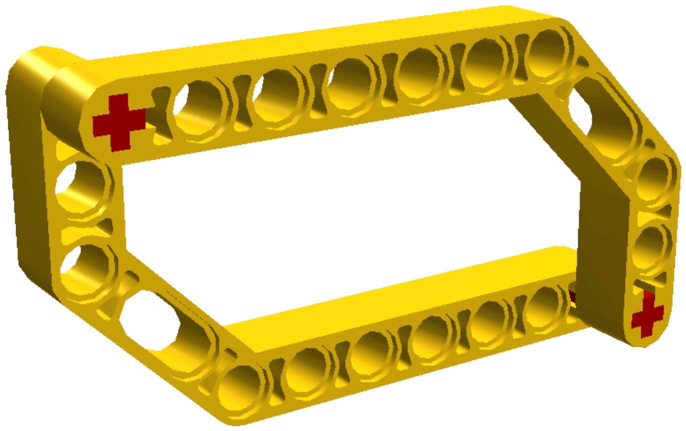

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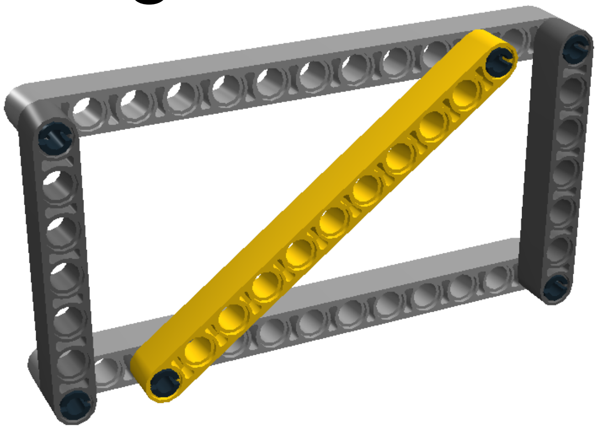
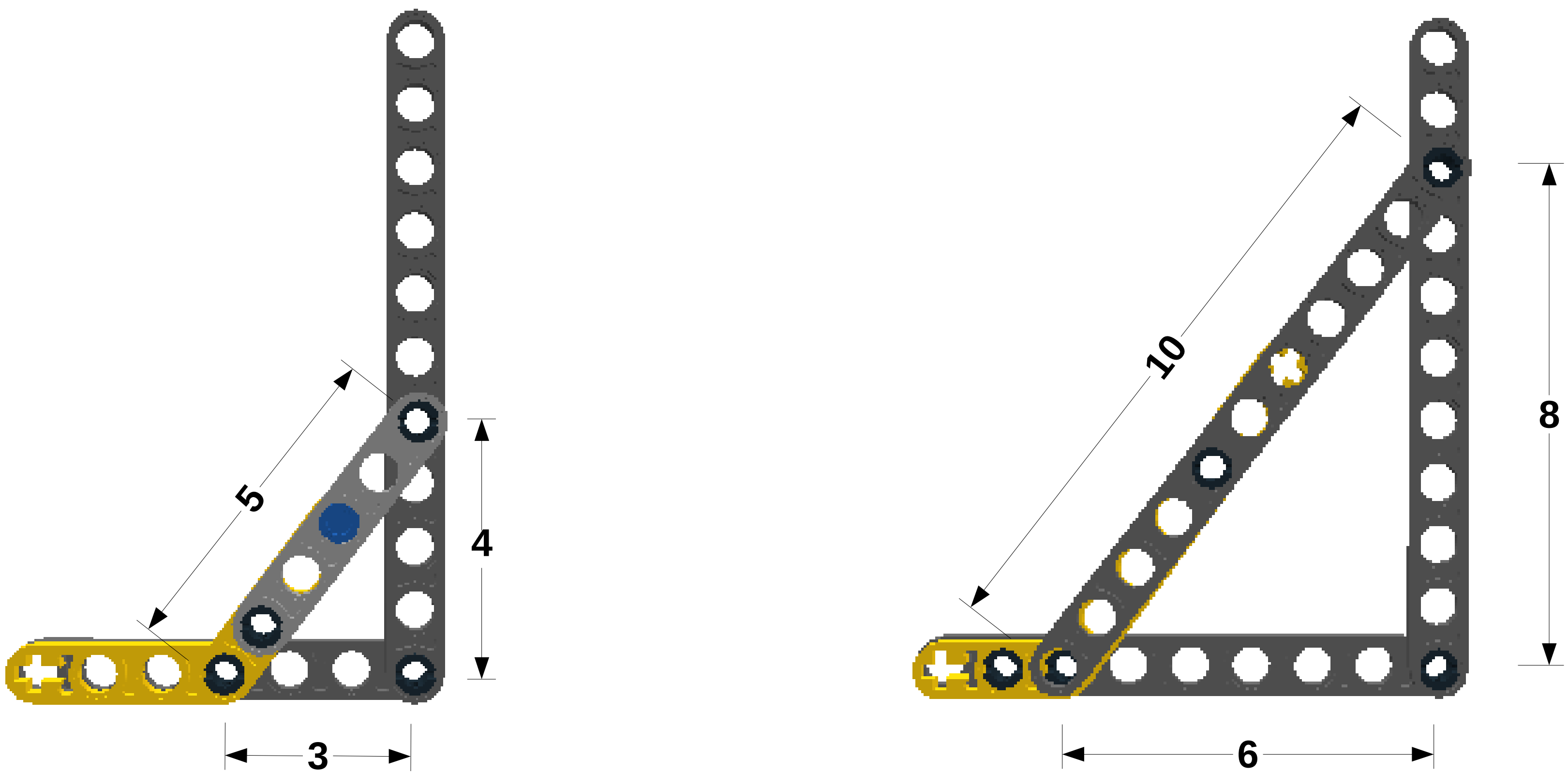


3:4:5 triangles

Angled bracing is very strong

Use 3:4:5 spacing to ensure right angles and proper alignment



Frames and panels

These pieces are excellent for building large structures and boxes

Holes in all three axes for multiple mounting options

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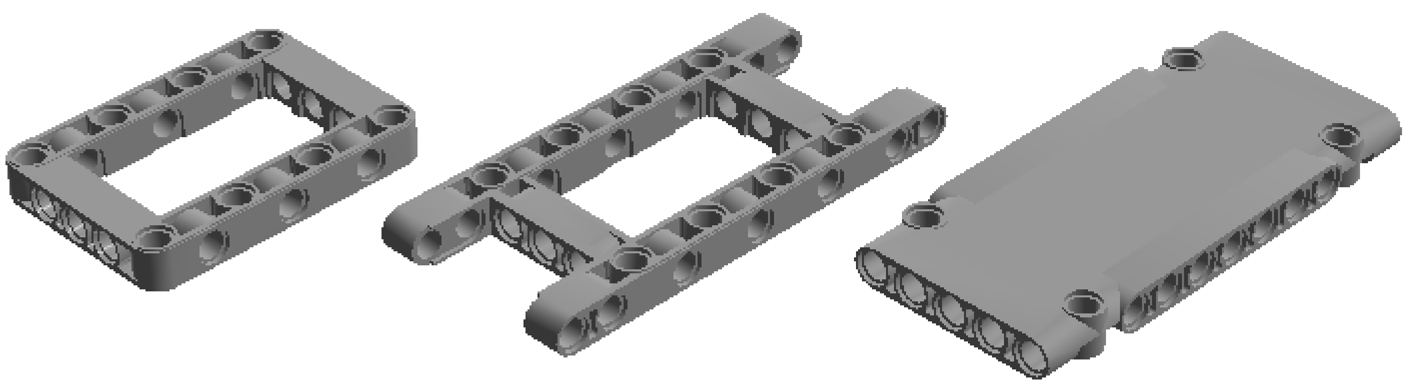
- 64170: Beam H frame 5x11 (“H frame”)
- 64782: Flat Panel



Robot design and game strategy

Chassis and attachments

The *chassis* is the part of the robot that is responsible for navigating the field and providing a base for attachments

Attachments are the things added to the chassis to solve missions and manipulate models

Design is about creating a chassis and attachments that will perform well in the Robot Game

Consistency wins

Good programming and strategy are essential to consistently good performance

Programming overcomes the limitations of the hardware

Great robot + poor strategy → inconsistent scores

Fair robot + good strategy → consistent scores

Robot Game Strategy - Base

The robot must always start from Base

Base is the only place where changes can be made

Robot Game Strategy - Time

Matches are 2:30

When the Robot is in Base, it's not scoring

→ minimize time spent in Base

Travel on the field takes time

→ minimize time spent moving from place to place

→ solve multiple missions in the same region

Robot Game Strategy - reliability

Distance:

- Error increases with distance
  - 1 degree is 1.7cm error after 100cm
- Missions that are close become easier
- Missions that are far become harder
- → Use field elements (lines, walls, models) to guide the robot to make things seem “close”

Size:

- Large targets are easy to hit
- Small targets are hard to hit
- → Use large attachments to make small targets “bigger”

Robot game strategy - humans

The Robot does exactly what physics and programming say to do

Humans (drivers) make mistakes and are inconsistent

Design the robot and strategy to prevent human mistakes

→ *Always* start robot from same location
→ Don't require humans to aim
→ Build safeties into robot
→ Robot must adapt to humans, not vice-versa

Republic of Pi's design mantra

Whenever the robot or humans
make a mistake in scoring,

redesign the *robot* so that mistake
cannot happen again.

Tip: Start every mission from same spot

Put solid edges on robot

- Align robot with solid edges, not by sight-aiming
- Robot can always start with known location and heading
- Faster setup in Base between mission runs

Place flat edge against wall

Pick a marking to align robot

To save match time, always start from same spot

Navigation

A key to scoring is to move robot consistently

Things a program(mer) needs to know to navigate:

- Where the robot currently is
- How precisely you know where it is
- Where the robot is going
- What's in the way, or what can guide you there

Robot needs to be able to move in a straight line

Common FLL robot characteristics

Two motors for drive wheels - one for each side

Multiple attachments for different missions

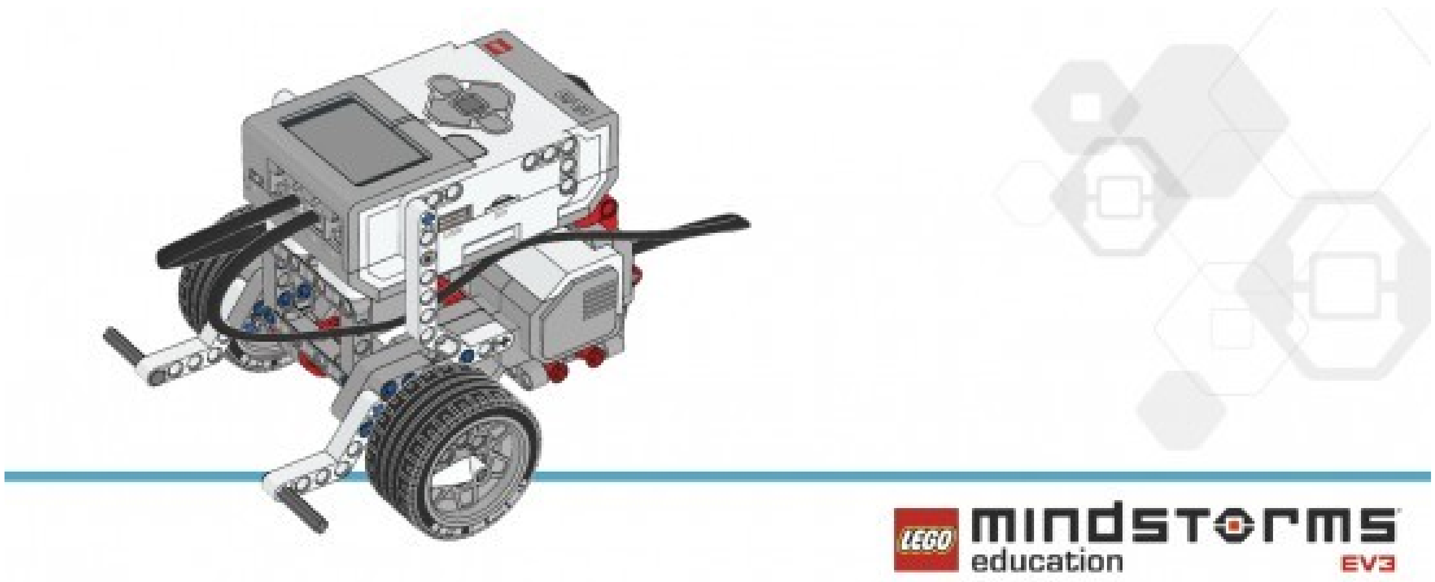
Attachments may be passive or powered

- Third and fourth motors can be used for power
- Maximum of four motors allowed during match

Recommended first build

EV3 Education Kits come with instructions for building a simple “educator vehicle” robot

This robot is a good start for learning about LEGO parts, sensors, and programming



Robot design characteristics

From the Robot Design judging rubrics:

		Beginning	Developing	Accomplished	Exemplary
Mechanical Design	**Durability**	Evidence of structural integrity; ability to withstand rigors of competition			
	N D	quite fragile; breaks a lot	frequent or significant faults/repairs	rare faults/repairs	sound construction; no repairs
	Mechanical Efficiency	Economic use of parts and time; easy to repair and modify			
	N D	excessive parts or time to repair/modify	inefficient parts or time to repair/modify	appropriate use of parts and time to repair/modify	streamlined use of parts and time to repair/modify
	Mechanization	Ability of robot mechanisms to move or act with appropriate speed, strength and accuracy for intended tasks (propulsion and execution)			
	N D	imbalance of speed, strength and accuracy on most tasks	imbalance of speed, strength and accuracy on some tasks	appropriate balance of speed, strength and accuracy on most tasks	appropriate balance of speed, strength and accuracy on every task

Evaluate the robot:

- Does the robot break often?
- Does it seem solid? Does it have a lot of “flex”?
- Do the wheels make good contact with the surface?
- Does it perform well in the game?

Chassis design

Chassis design considerations

The *chassis* gets the robot from place to place

Size

- Smaller robots are easier to navigate
- Robot must fit completely in Base when starting

Consistency and reliability

- Robot needs to act consistently when moving

Speed

- Faster robot → time to solve more missions
- Slower robot → more consistent and accurate

Chassis basics

Good motor and wheel design are key to consistency

Motor and wheel frame needs to be solid with very little “flex”

- “flex” produces inconsistent runs

Use cross bracing, frames, and angle beams to increase structural stability

Wheels

Wheel selection is important

Larger wheels are faster, but may be less accurate

Tire shape, pattern, and field mat surface affect traction and consistency

- Wheels that "slip" on the mat produce inconsistency

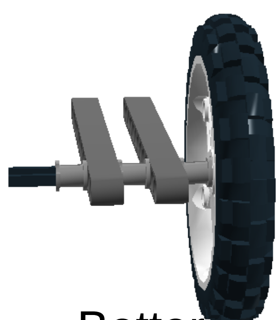
Wheels

Wheels should be mounted close to supporting beam (but not rubbing against it):

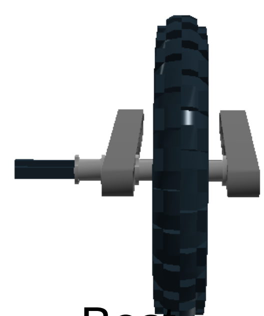
Good

Poor

Axles do better when supported by at least two beams. Beams on both sides of wheel are best.



Better

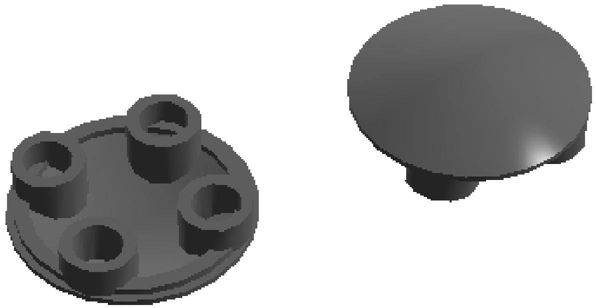


Best

Wheel styles

2 wheels and skid(s)

Works great, may have difficulty with ramps/obstacles



2 wheels and caster

Caster wheel will make driving inconsistent

2 wheels and ball pivot (3-point design)

Works fine, may be a little unstable

2 wheels and 2 balls (4-point design)

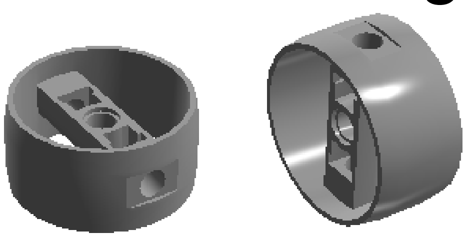
Very nice

Wheel styles continued

4 wheels (4-point design)

Make sure non-driving wheels can slide while turning

#41531 Turbine has worked well for my teams



6 wheels

Stable, but generally quite large and turning may be imprecise

Treads

Good for obstacles, hard to predict turns

Exotics

Balance and center of gravity

Balance and center of gravity affects stability and consistency of robot

Center of gravity is the average location of weight of the robot

If the center of gravity is outside the wheelbase, the robot will tip over

High center of gravity will make robot more likely to tip

Weight

Heavier robots are more accurate, but slower and use more battery

Try to keep weight over driving wheels (but watch the center of gravity!)

Other chassis considerations

Put solid edges on robot

- Align robot with solid edges, not by sight
- Robot can always start with known location and heading
- Provides attachment mounting points
- Can be used for wall navigation and aligning with mission models

Place flat edge against wall

Pick a marking to align robot

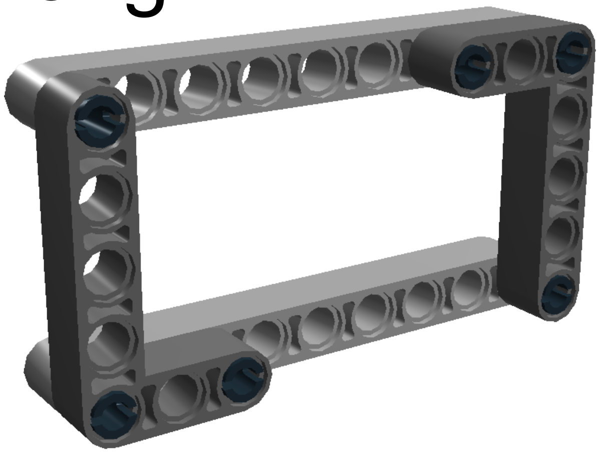
To save match time, always start from same spot

LEGO structures and pieces

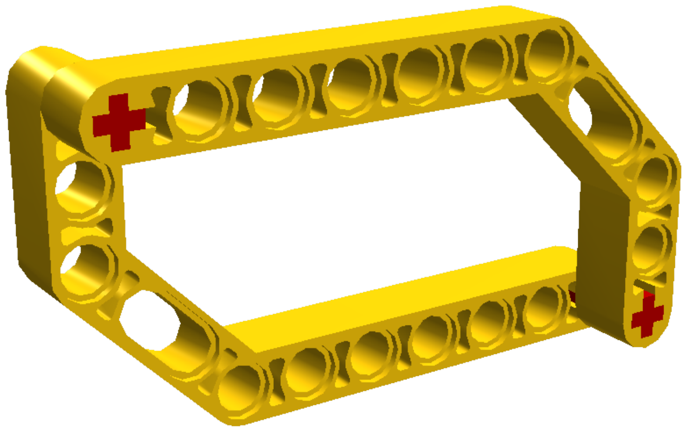
Structural strength

Weak

Strong



Strong



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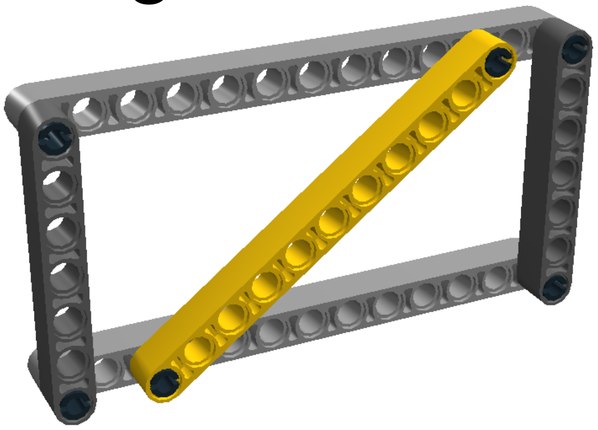

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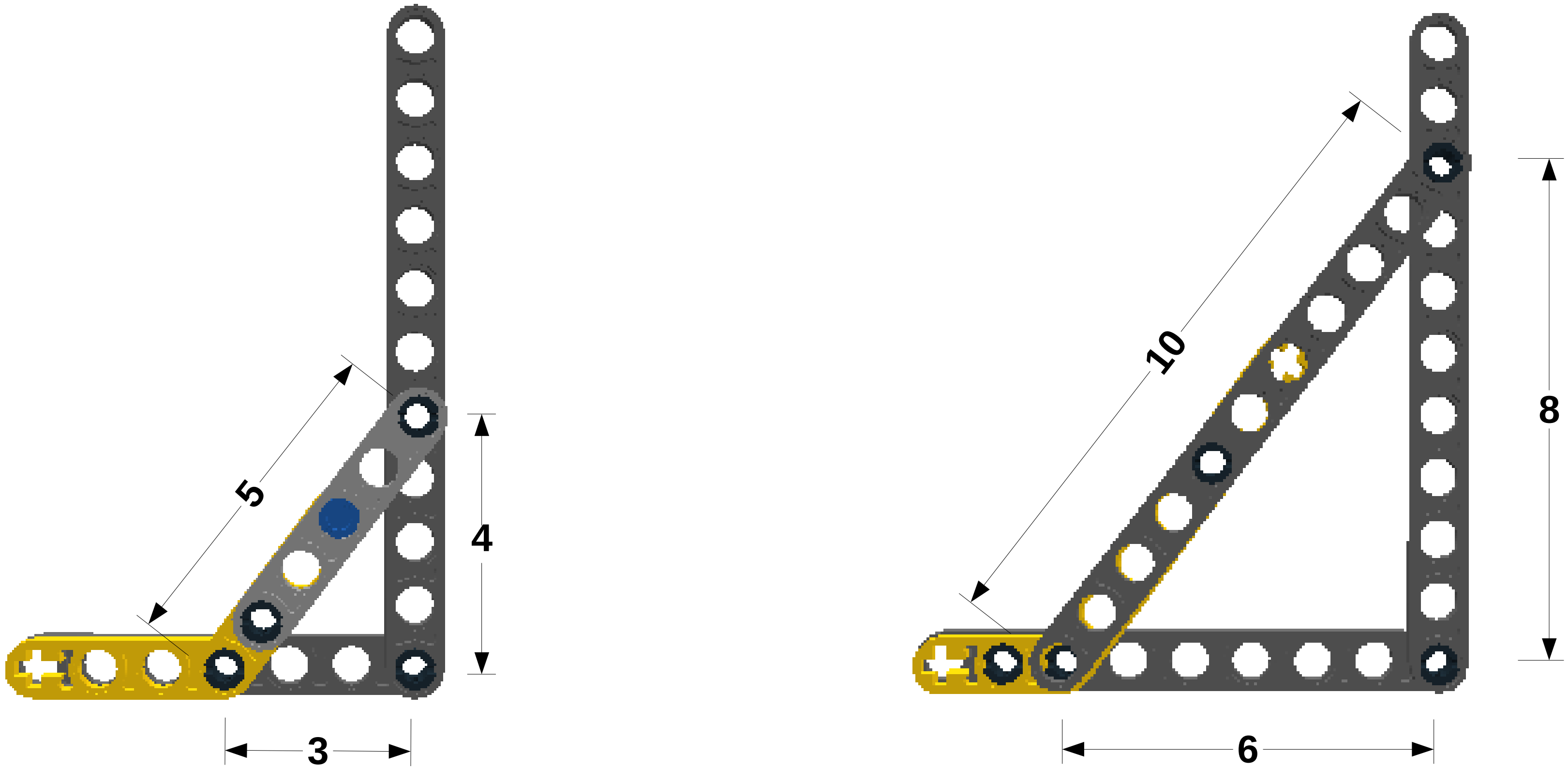

Useful LEGO pieces - frames and panels

These pieces are excellent for building large structures and boxes

Holes in all three axes for multiple mounting options

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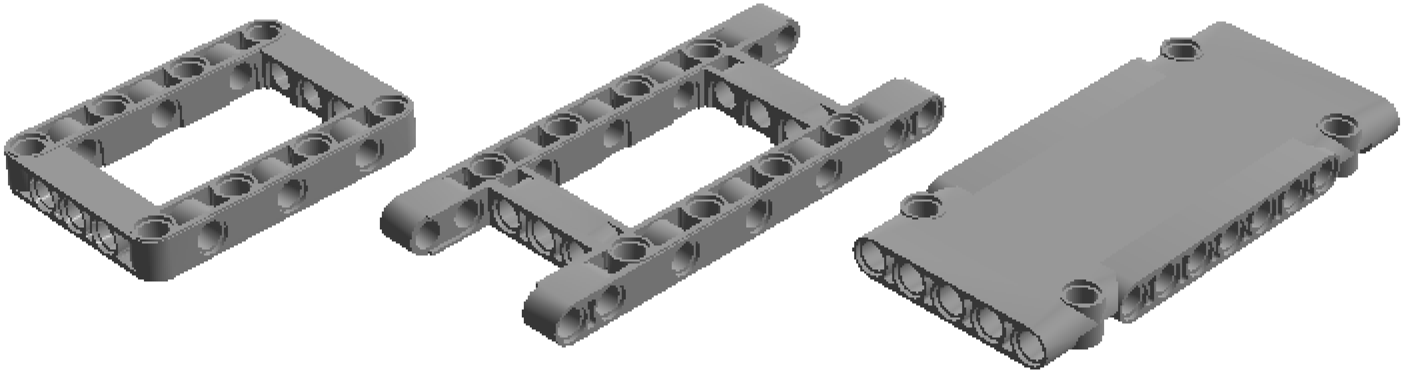
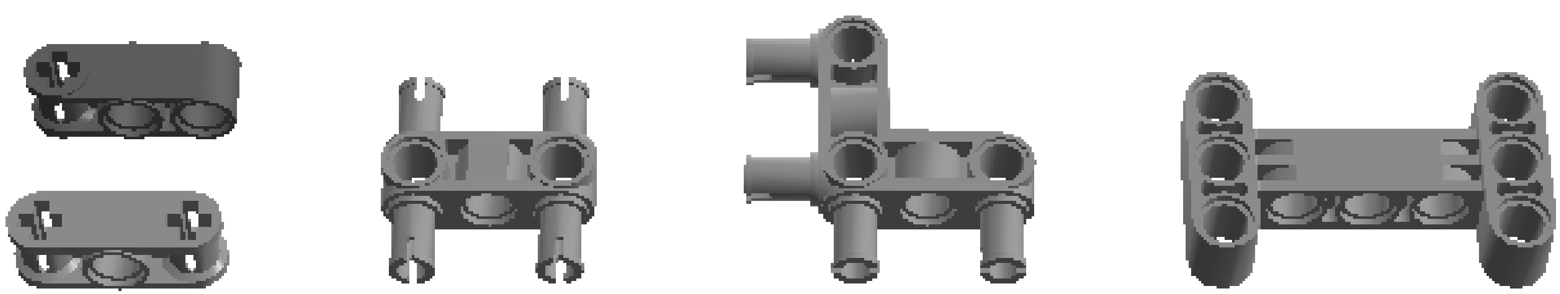


Useful LEGO pieces - cross blocks and beams

These allow connections in multiple directions

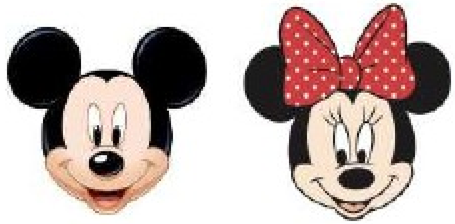
- 42003: Cross block 3M
- 32184: Double cross block
- 48989: Beam 3M with 4 snaps
- 55615: Angular beam 90 degrees with 4 snaps
- 14720: Beam I-Frame 3x5 90 degrees

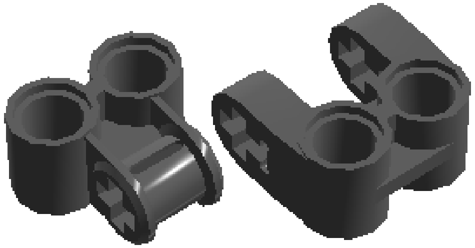


Useful LEGO pieces - cross blocks

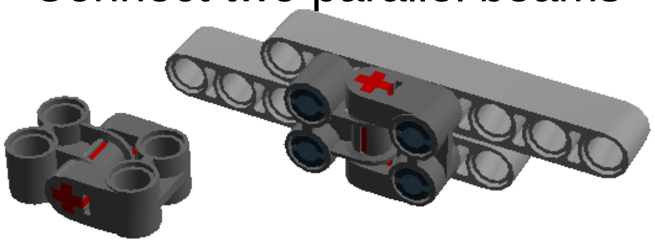
These cross blocks have a wide variety of uses

- 32291: Cross block 2x1 ("Mickey")
- 41678: Cross block fork 2x2 ("Minnie")

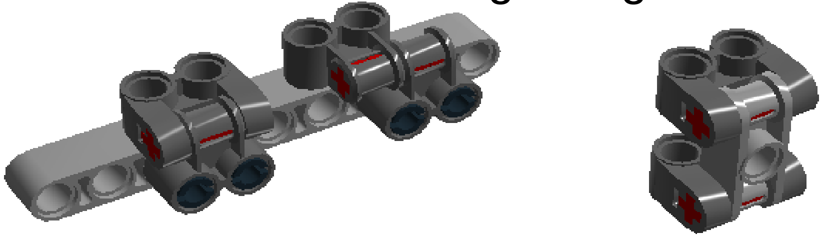




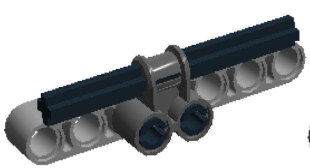
Connect two parallel beams

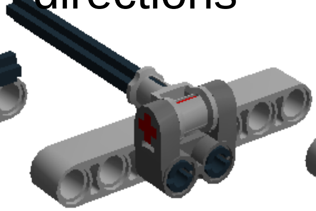


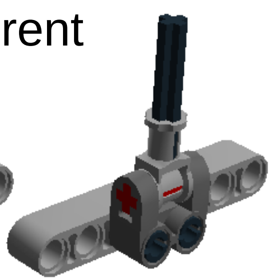
Create holes at right angles



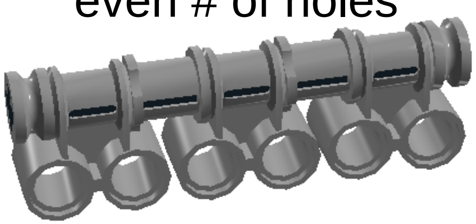
Mount axles in different directions







Create "beams" with even # of holes



Places to find and buy LEGOs

http://bricklink.com/

Website to connect buyers and sellers of LEGOs

Attachments

Attachments

Attachments are the things added to the chassis to solve missions and manipulate models

Good attachment design makes solving missions easy

Attachment design principles

Robot precision often limited to 1.5cm

If a target is small, try to make the attachment big

Use mission models and walls for precise alignment

Things that seem easy for humans can be hard for a robot

- Manually test attachments with eyes closed

Mounting attachments

The best attachments are those that never need to be added or removed from the robot

→ saves time during matches

If an attachment must be added or removed, make sure it can be done quickly

- Avoid using pegs for removable attachments
- Use axles and axle pegs
- Use gravity

Removing is usually faster than adding

Rubber bands can be used to snap attachments into place

Attachment types

FLL missions usually involve

- Pushing
- Pulling
- Lifting
- Dropping / dumping
- Placing / delivering
- Releasing
- Capturing / collecting
- Shooting
- Turning

Attachment building tips

Tend to use axles and plates when possible

- Axles are easy to adjust, resize, and relocate
- Plates and frames are better than walls of beams

Sources of energy for attachments

(Republic of Pi's preferences)

1. Gravity
2. Leverage
3. Elastics
4. Motors

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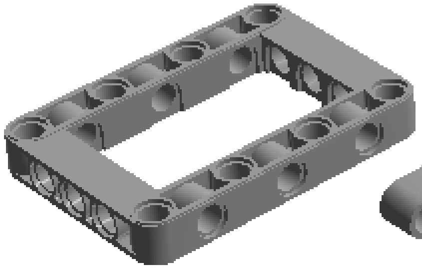
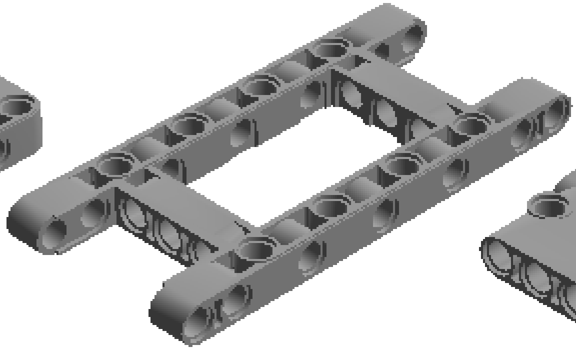
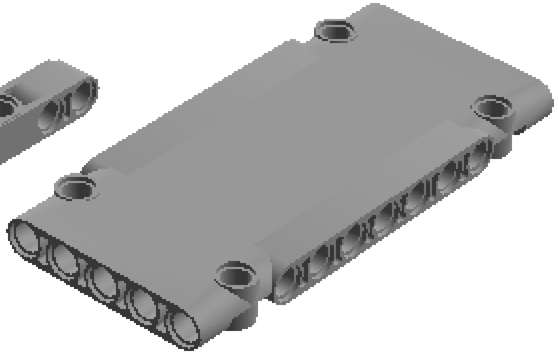

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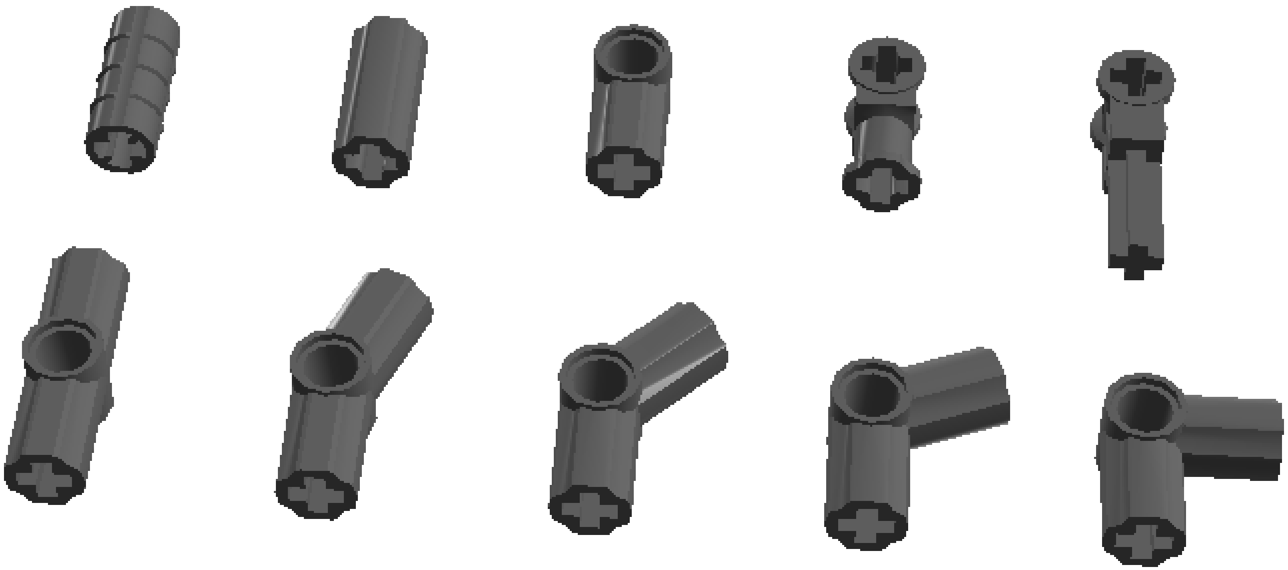

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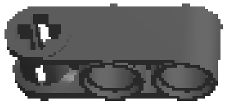
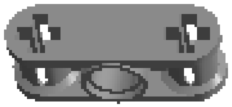
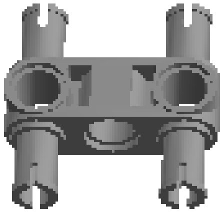
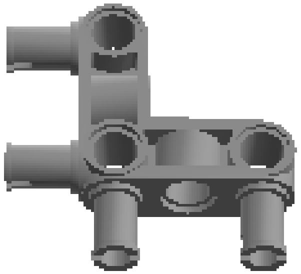
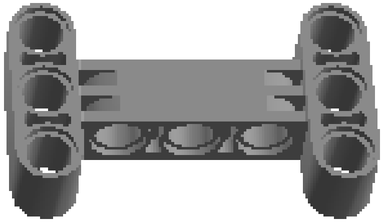
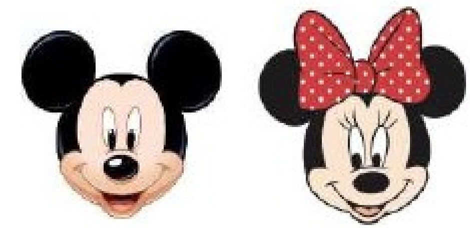
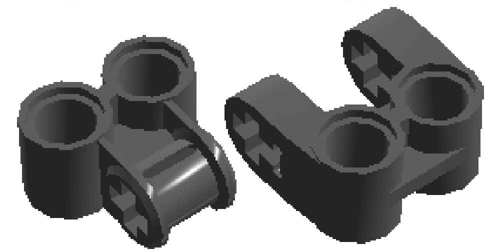






Useful LEGO pieces - cross blocks

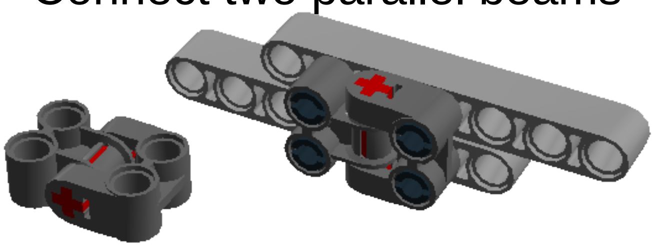
These cross blocks have a wide variety of uses



- 32291: Cross block 2x1 (“Mickey”)
- 41678: Cross block fork 2x2 (“Minnie”)

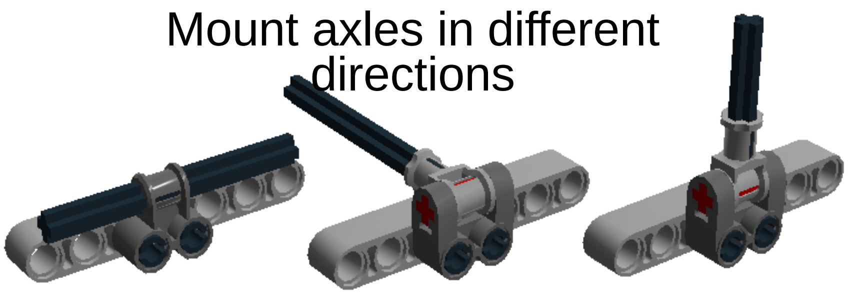


Connect two parallel beams

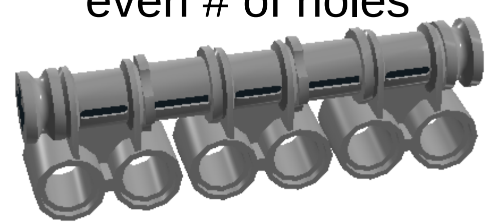


Create holes at right angles

Mount axles in different directions



Create “beams” with even # of holes

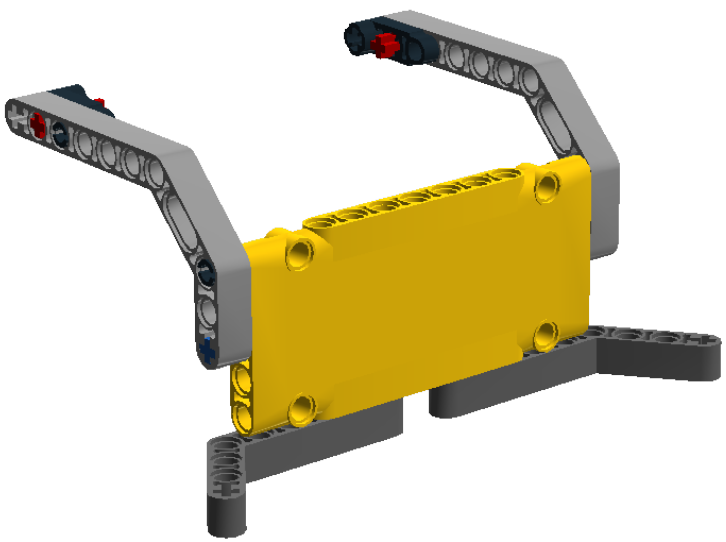


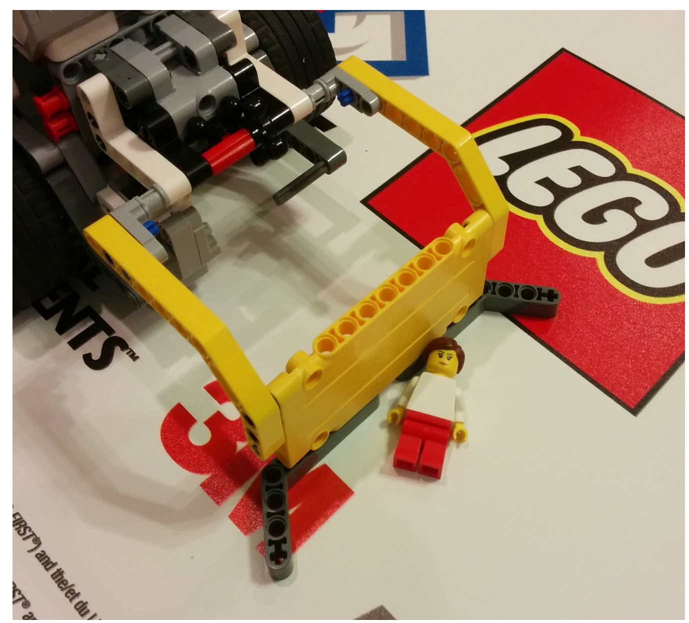
Passive attachment: Pusher

One of the simplest (and useful) attachments is a bumper.

A bumper can easily push/deliver objects

It can also provide places for other attachments

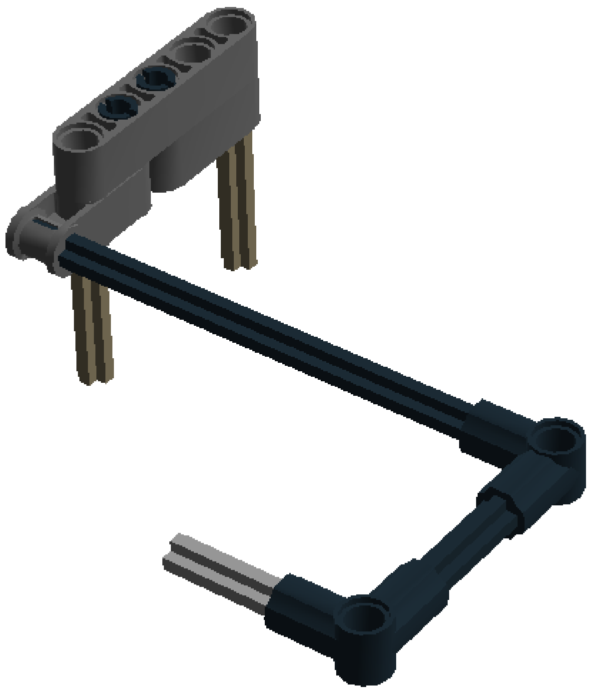


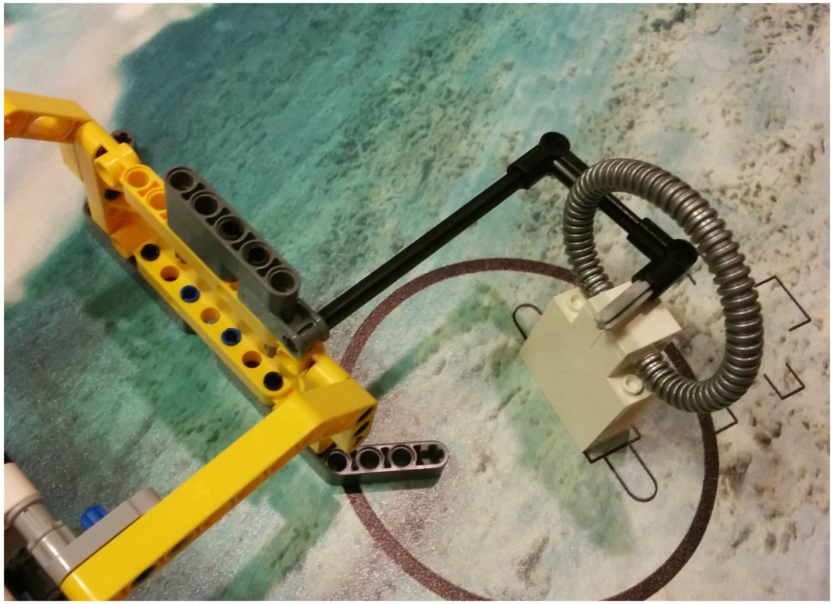


Passive attachment: Hook

A hook can be used to capture objects

Axles allow quick attach / removal

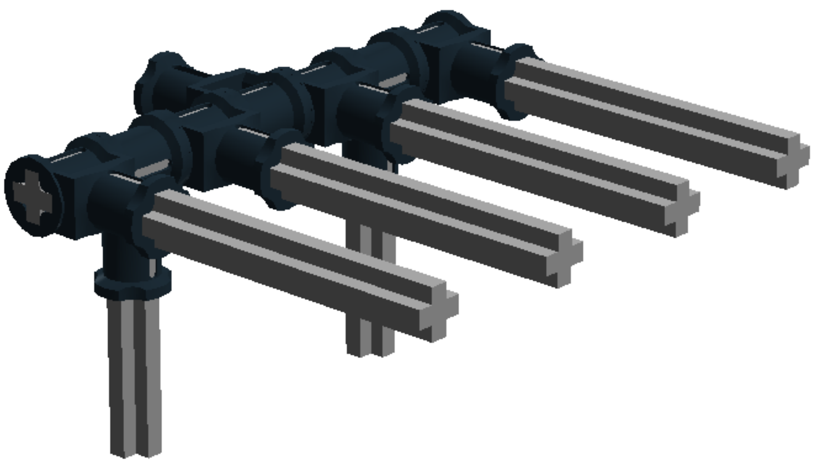


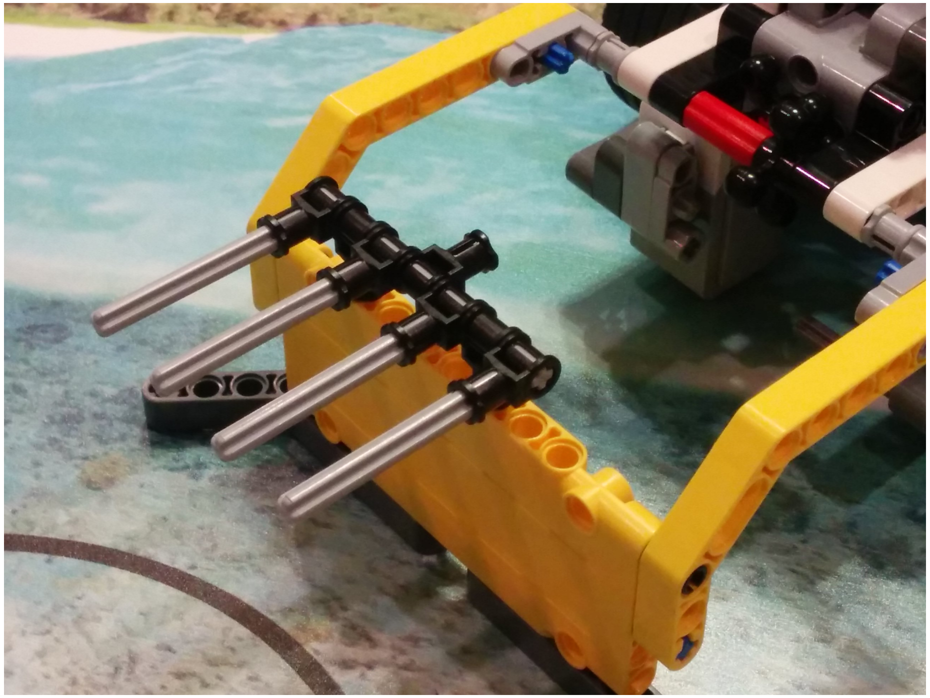


Passive attachment: Fork

A fork has multiple prongs for capturing objects

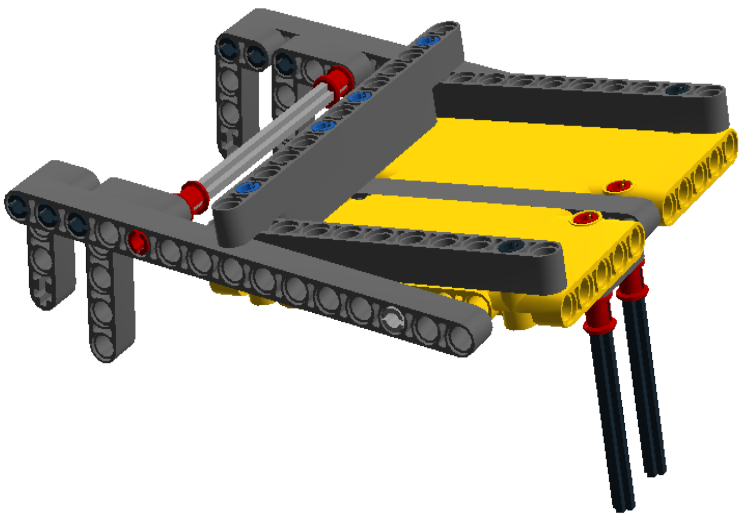
This helps make a wider target

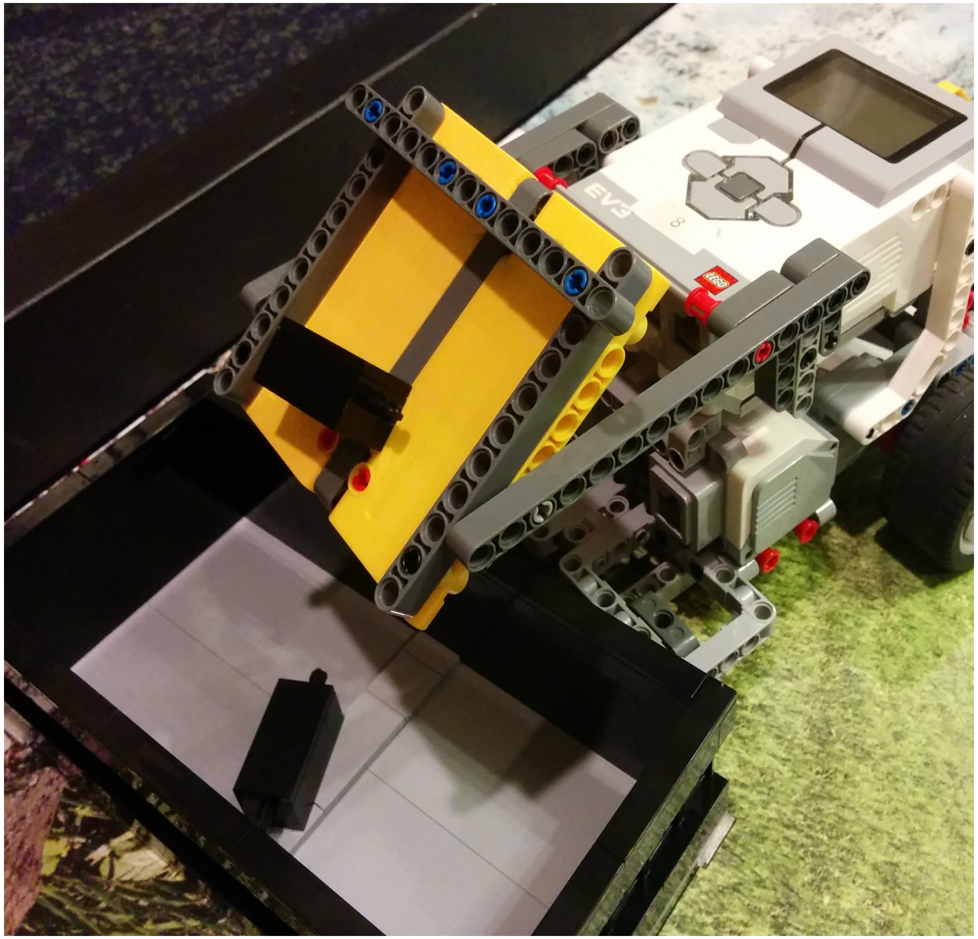




Passive attachment: Dumper

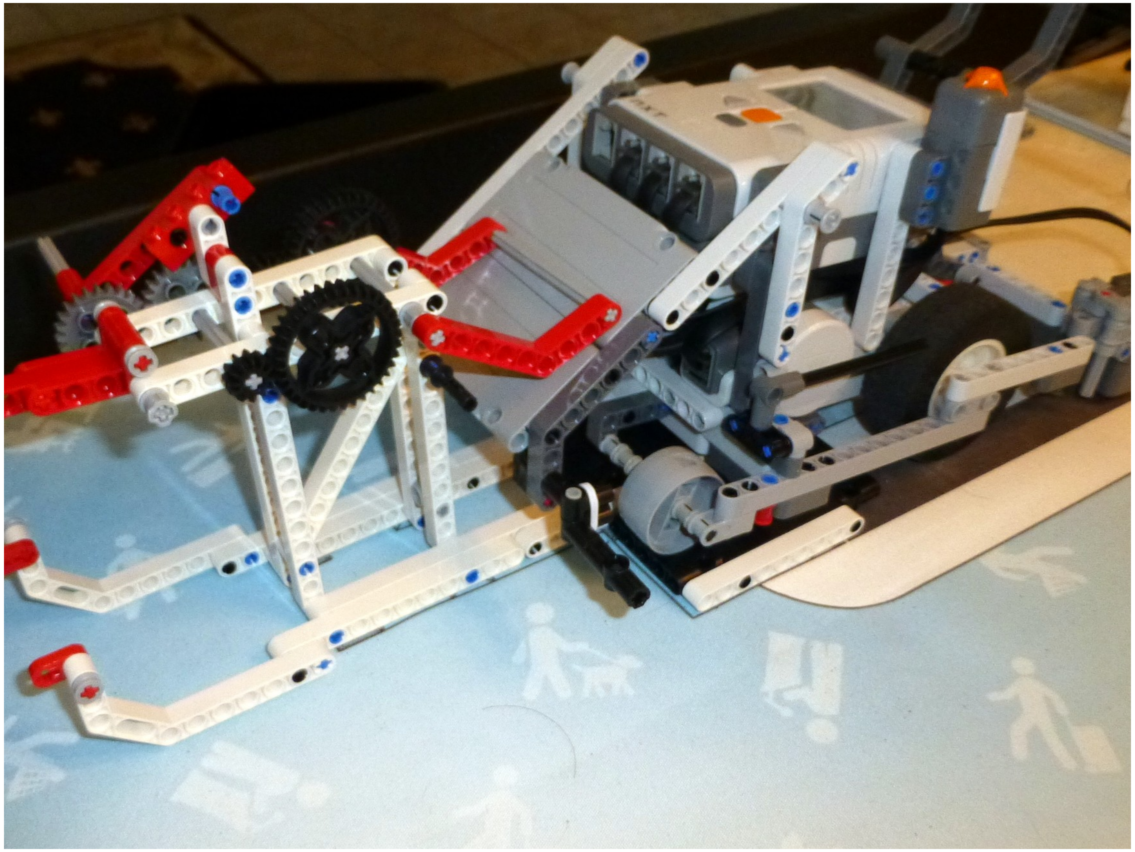
Dumpers use gravity and simple pegs to release contents





Passive attachment: Wedge

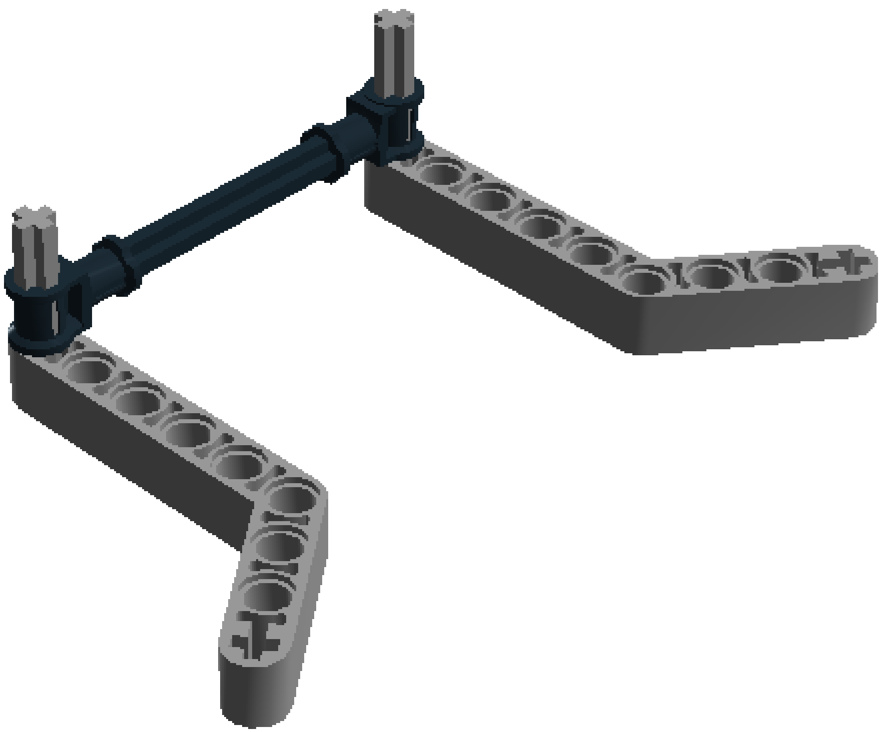
A “wedge” can be used to push things up or down



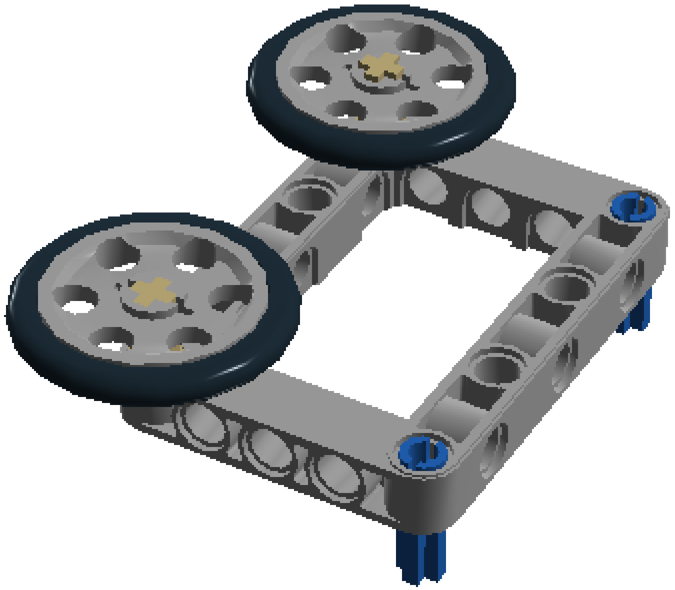
Passive attachment: guides

Guides can be used to align things with mission models

Around a model

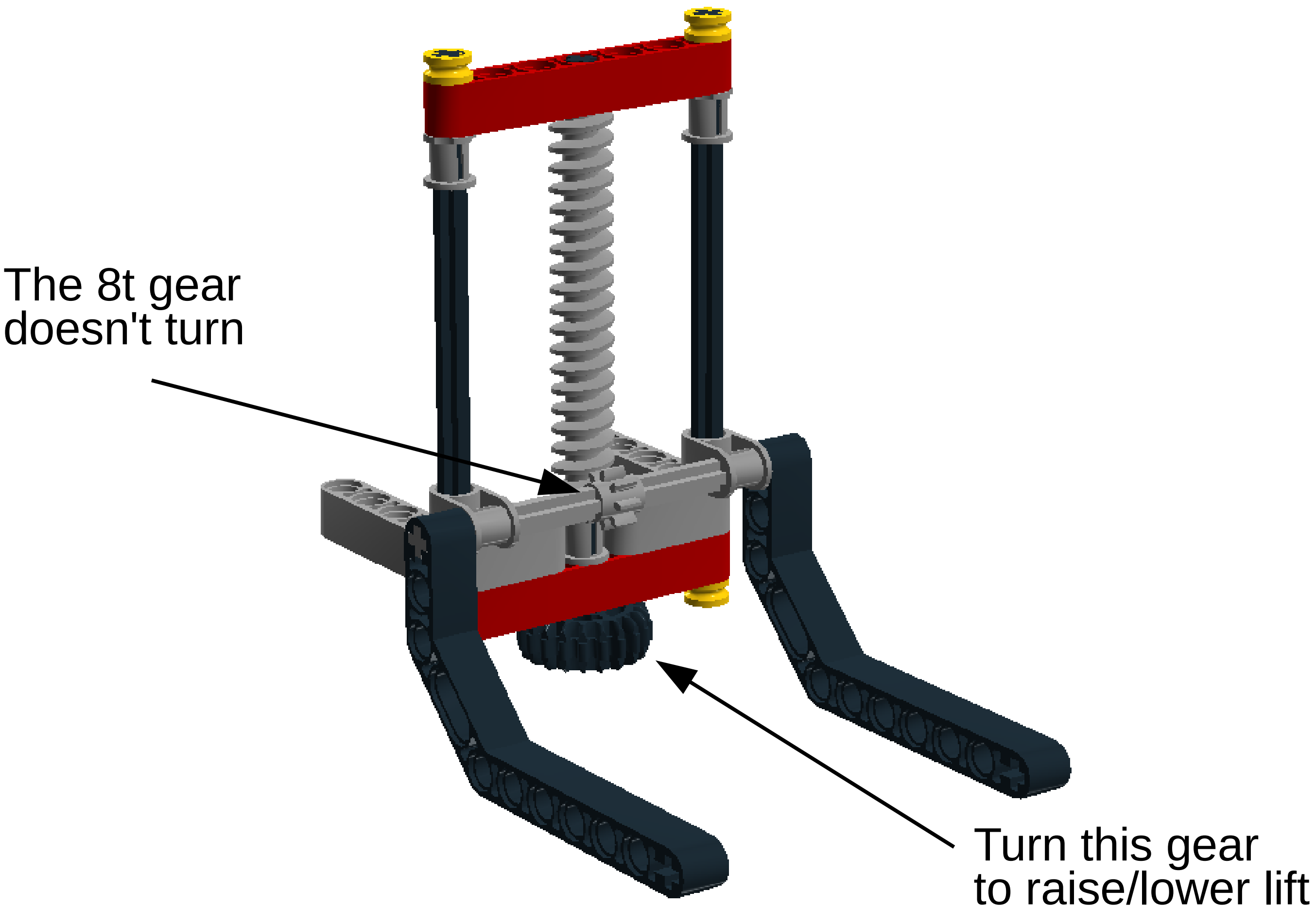


Along a wall



Powered attachment: Vertical lifts

Forklift will raise or lower as worm gear turns



Powered attachment: Four-bar linkage

Raise/lower bar without rotating it