Mechanisms and Algorithms

Lab: Lego Levers, Shafts and Cranks

Lab Philosophy

	Electronics	Mechanisms
Plans	Schematic Drawings	Assemblies
Items	Resistors, etc	Beams, etc
Acquisition	Radio Shack	McMaster-Carr
Drawing	Orcad	Pro/E
Simulating	Spice	Pro/E
Test/Evaluate	Breadboarding	Quick-connect

Lego
Assemblies
Beams, etc
Lego Store
MLCAD
Pro/E
Quick-connect

80/20
Assemblies
Beams, etc
80/20 Store
CAD Plug-ins
Pro/E
Quick-connect

- Plans: read drawings, understand part roles and part connections
- Items: Learn proper name of parts and what parts exist
- Acquisition: Learn vendors for Bill of Materials (BOM)
- Drawing: Communicating and Archiving your designs
- Simulation: Rapid prototyping
- T&E: Learn to physically construct, identify challenges and learn troubleshooting

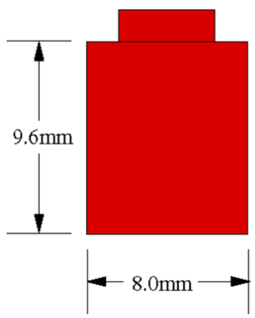
Lab Experiments

1. Introduction to Lego Fundamentals
2. Reciprocating Motion: Simple Crank
3. Reciprocating Motion: 3-Bar Crank (Isogawa Pg. 61)
4. Reciprocating Motion: Crankshaft (Isogawa Pg. 63)

Homework: Reciprocating Motion: Slider-Crank (Isogawa Pg. 62)

Exercise 1: Introduction to Lego Fundamentals

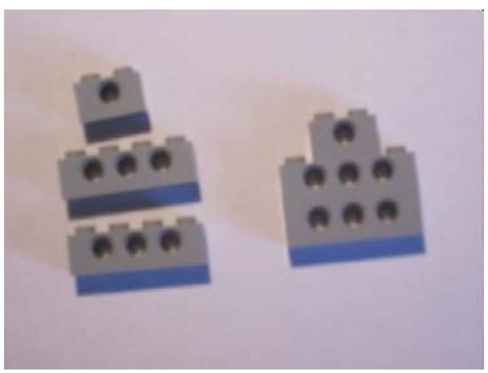
Note 6:5 ratio of unit height to unit length.



In Lego: Vertical > Horizontal. We have a 6:5 ratio

6:5 ratio important: Naïve approaches yield weak and unsound connections:

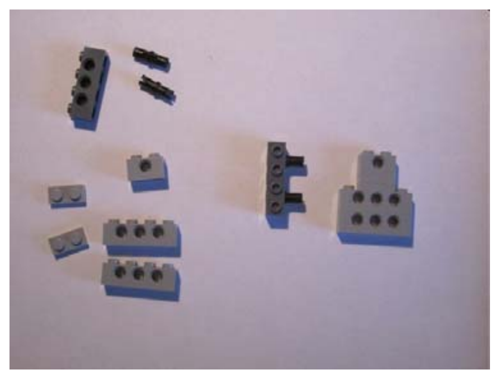
Stacking (naïve approach)

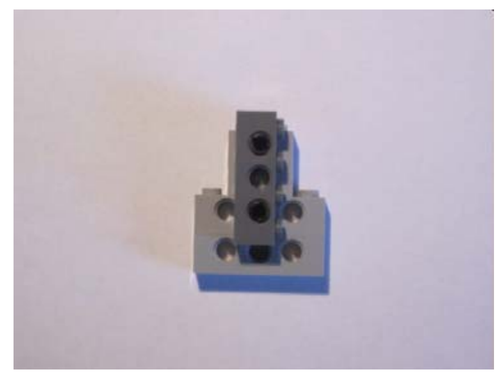


Structural weak (try it)

versus

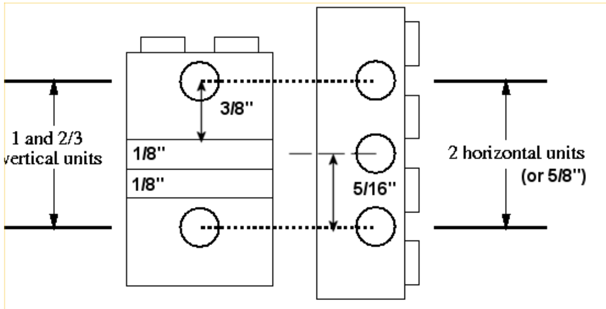
Bracing (best practice)





5:6 ratio demands 2 plates for aligning holes

Motivation for Plates



From example: the 5:6 rule demands 2 plates
- Two stacked bricks = 1 vertical unit
- 1 plate = 1/3 vertical unit

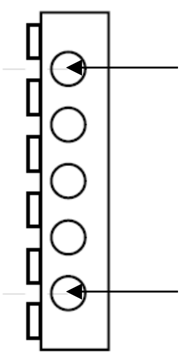
1 vertical unit + 2*1/3 vertical units = 5/3 vertical units

5:6 ratio states 6 vertical units = 5 horizontal units

Hence:

$$\frac{5}{3}\text{vertical units} \bullet \frac{6\text{ horizontal units}}{5\text{ vertical units}} = 2\text{ horizontal units}$$

Exercise 1-1: What do you need to stack to align holes with a 5-hole beam



Aligning holes

Note: space between aligning holes = 4 horizontal units

$$4\text{ horizontal units} \bullet \frac{5\text{ vertical units}}{6\text{ horizontal units}} = \frac{20}{6} = \frac{10}{3} = 3\frac{1}{3}\text{ vertical units}$$

4 vertically stacked bricks = 3 vertical units. Hence need plate

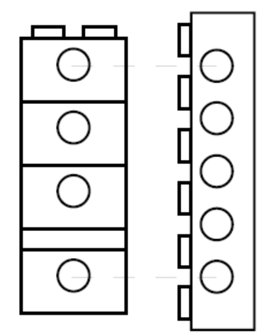


Plate Equation

$$2(3a+b) \equiv 5c$$

a : Number of full-height vertical units (i.e. N bricks - 1)

b : Number of 1/3-height vertical units (i.e. plates)

c : Number horizontal units between holes

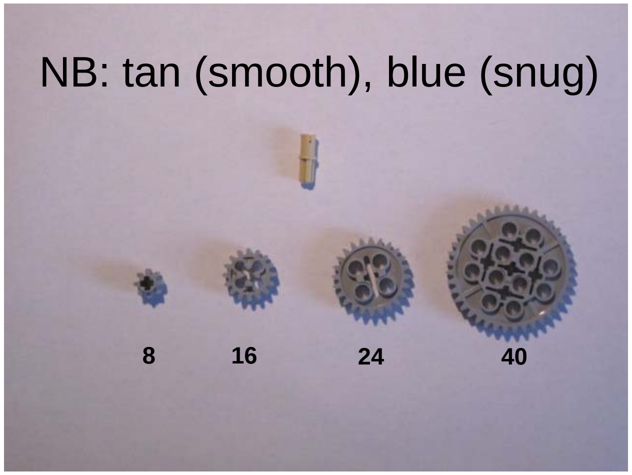
Exercise 1-2: Construct the following and complete the following table

Full height vertical units	1/3-height vertical units	Horizontal Units
1	2	2
3	1	4
		6
6		
8		

Answer:

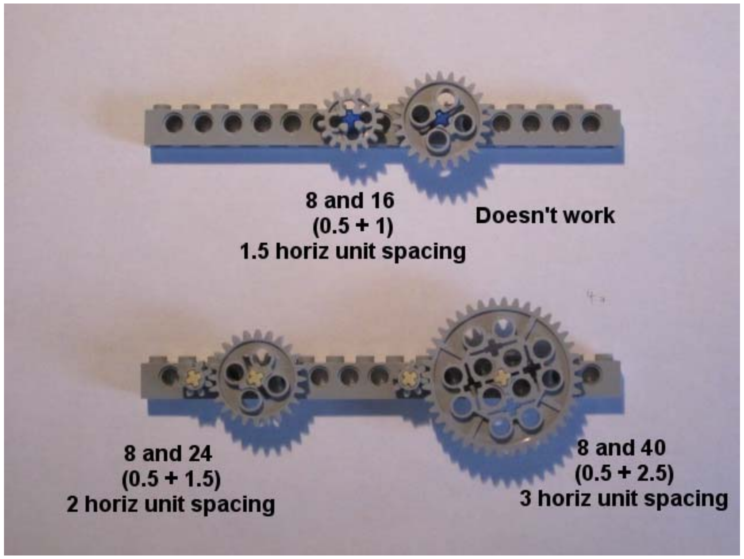
Full height vertical units	1/3-height vertical units	Horizontal Units
1	2	2
3	1	4
5		6
6	2	8
8	1	10

Gears

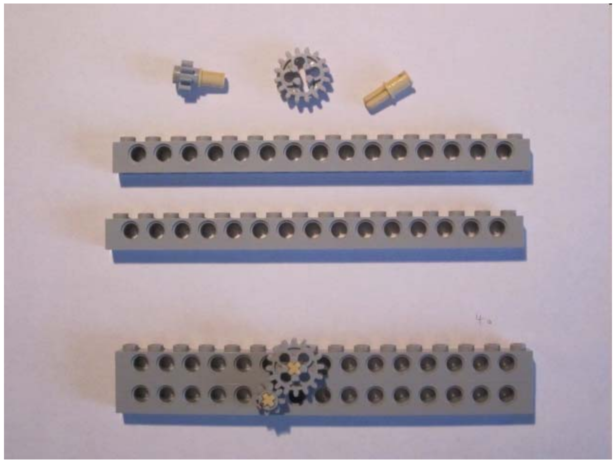


Gear Teeth [number]	Gear Radius [horiz units]
8	0.5
16	1
24	1.5
40	2.5

Gear size in horizontal units demands integer-sized spacing:



Gears: Getting away with non-integer spacing



Recall that 2 stacked bricks = 1 vertical unit

$$1\text{ vertical unit} \bullet \frac{6\text{ horizontal units}}{5\text{ vertical units}} = 1.2\text{ horizontal units}$$

Recall that for a beam, space between holes = 1 horiz unit

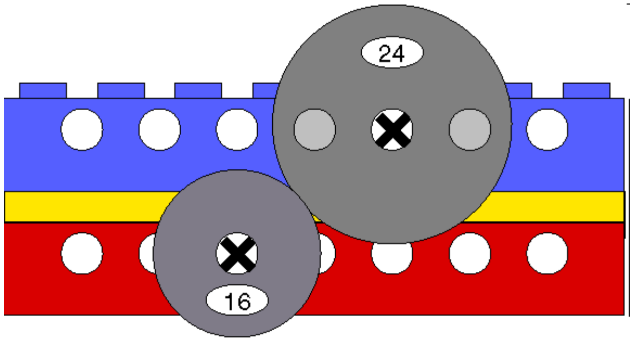
$$(1.2\text{ horiz units})^2 + (1\text{ horiz units})^2 = 1.44 + 1 = 2.44\text{ horiz units}^2$$

Thus diagonal space = $\sqrt{2.44} = 1.56\text{ horizontal units}$

i.e. close enough for a 16:8 or 2:1 gear ratio

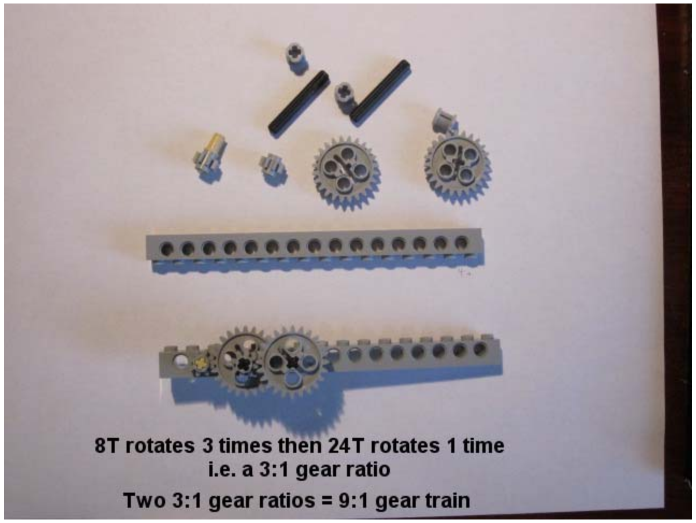
Exercise 1-3: Construct a 3:2 gear train

Answer: Hint: Use a plate to space two beams. Use 24T and 16T gears

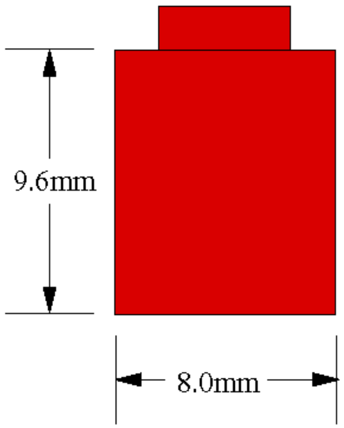


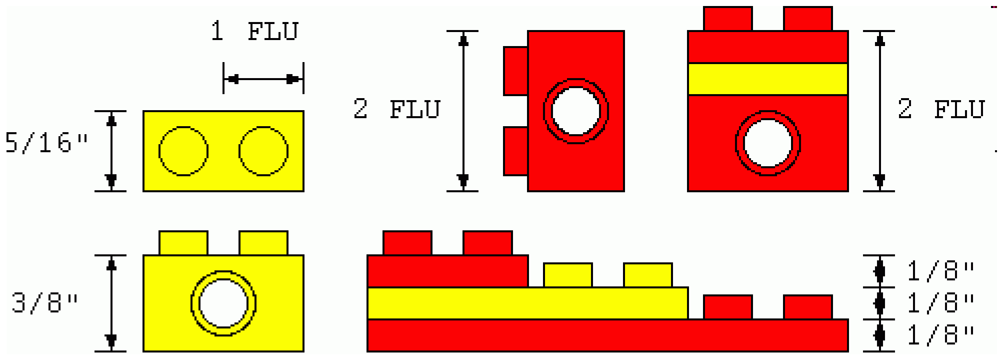
Exercise 1-4: Construct a 9:1 gear train

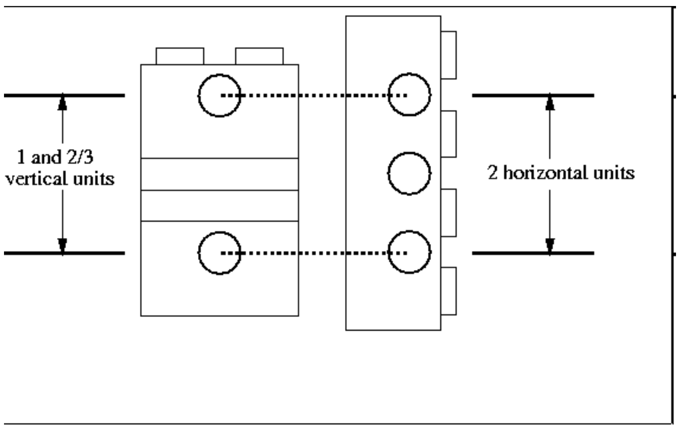
Answer: Hint: Use two 3:1 gear trains



Note 6:5 ratio of unit height to unit length.

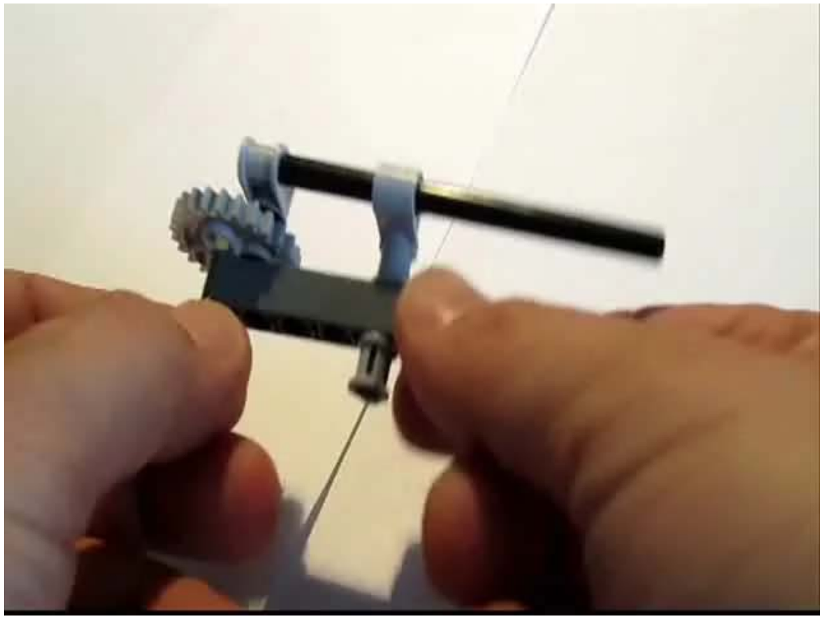




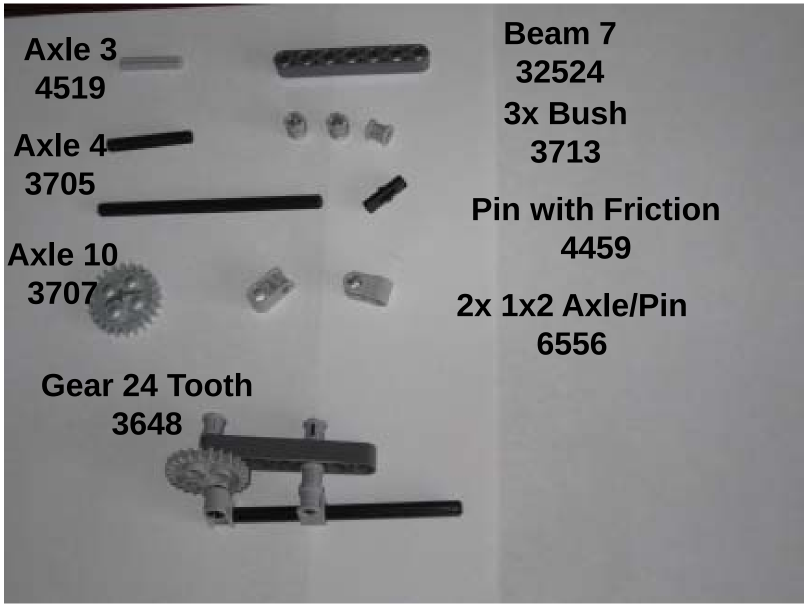


Exercise 2: Simple Crank

Lego Simple Crank



Video



Step 1: Parts for Simple Crank (seen on bottom)

Step 2: Pin the Gear to Beam. Bush Axle 4 to Beam

Step 3: Mount Axle/Pin on Gear with Pin

Step 4: Pass Axle 10 thru Axle/Pin and mount on assembly

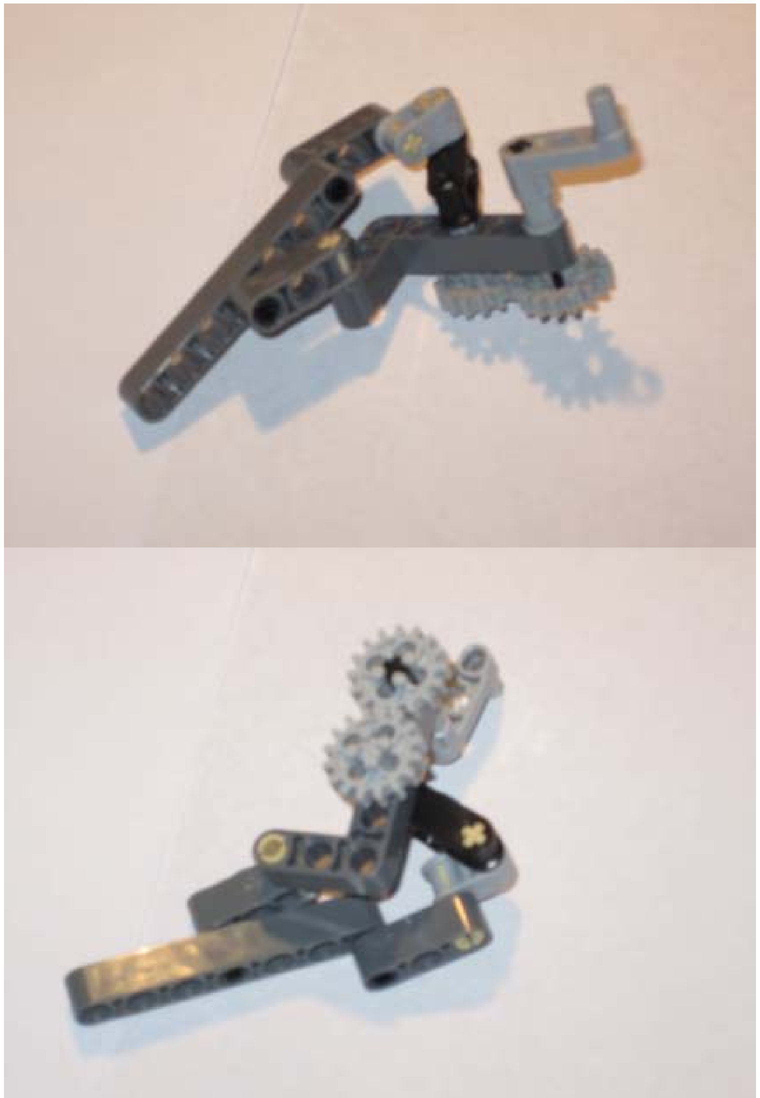
Exercises

2-1 Replace Beam with Brick to re-construct a simple cran

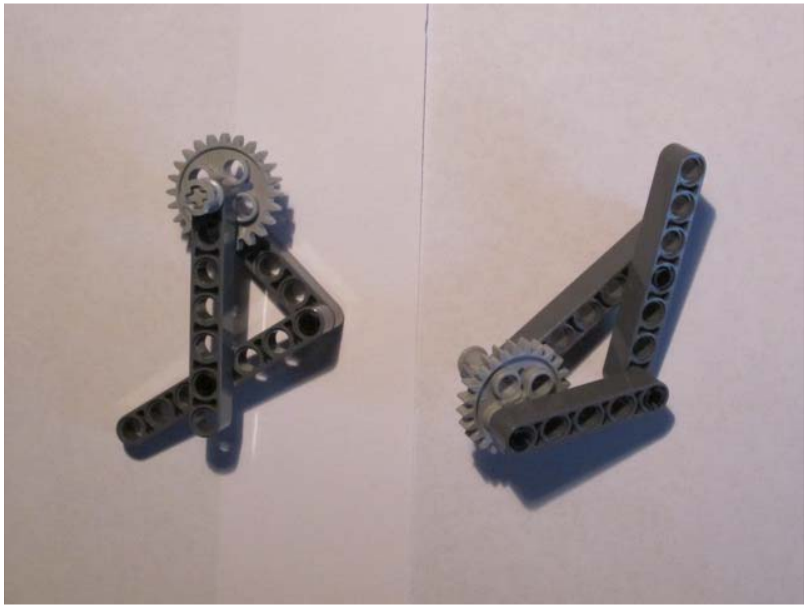
Simple Crank using Brick

Exercises

2-2 Construct the following crank (more complex)

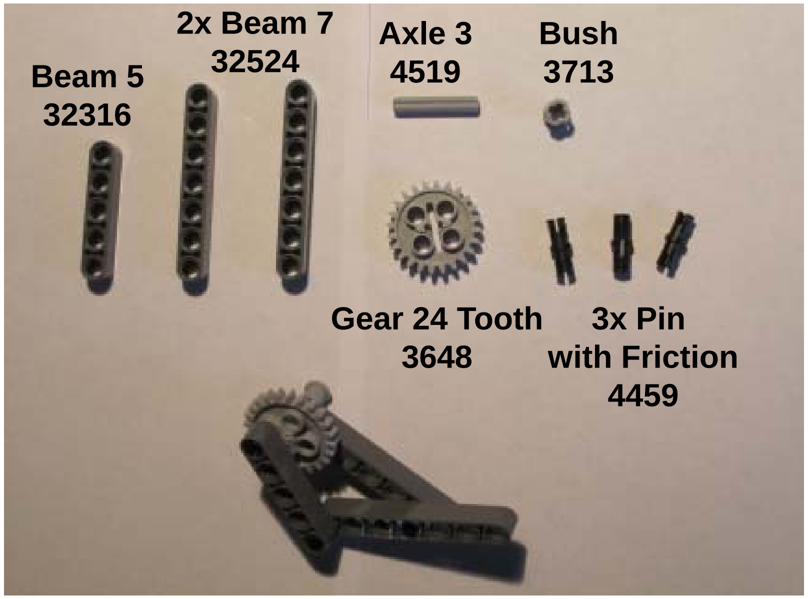


Exercise 3: The Crank and 3-Bar Linkage

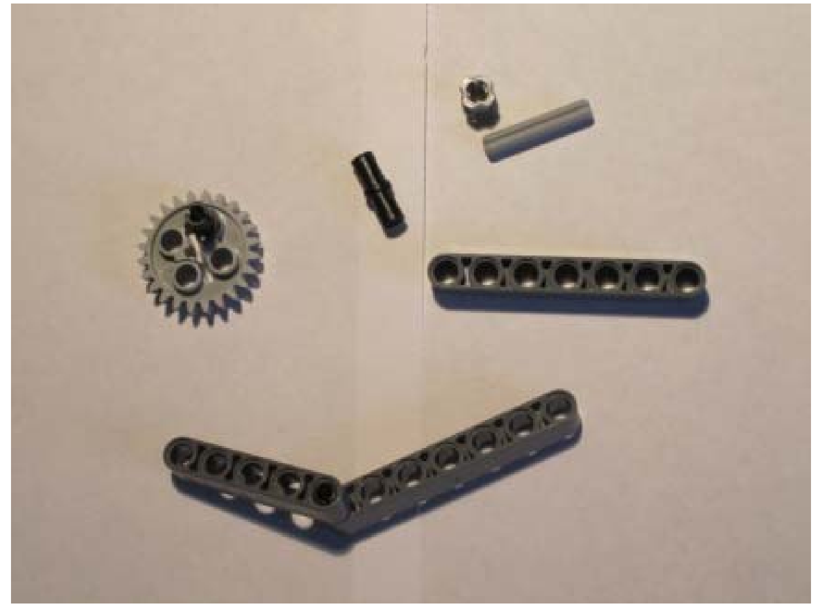


Isogawa’s Lego Crank 3-Bar Linkage

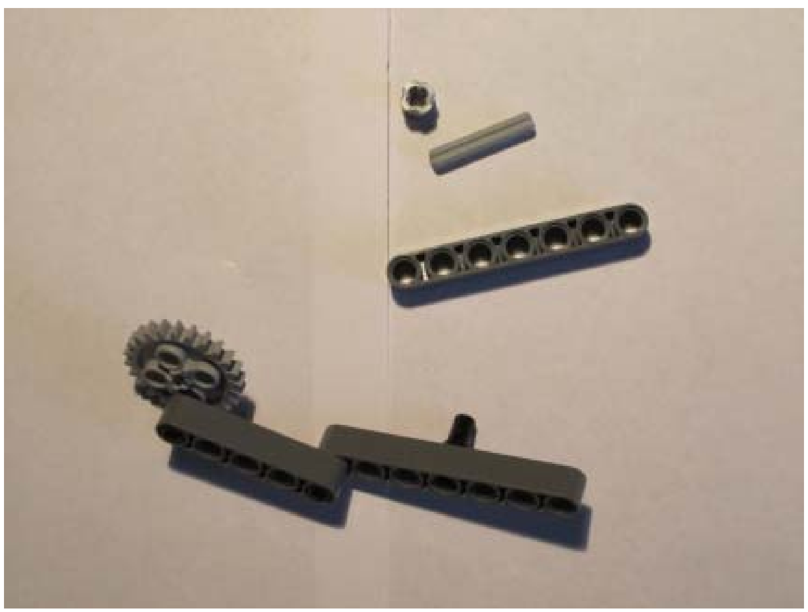
Video



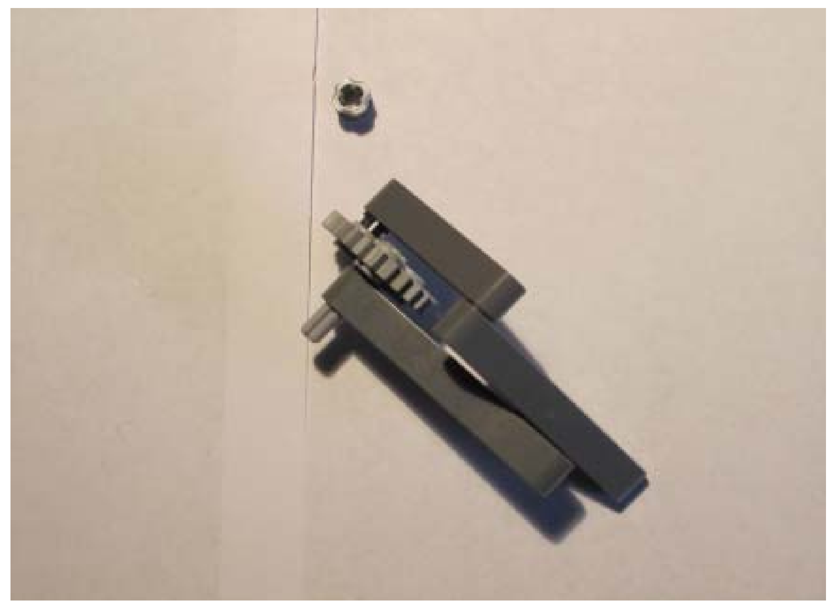
Step 1: Parts. NB: Contrast parts 4459 and 3673



Step 2: Pin the Gear. Join Beam 5 and Beam 7

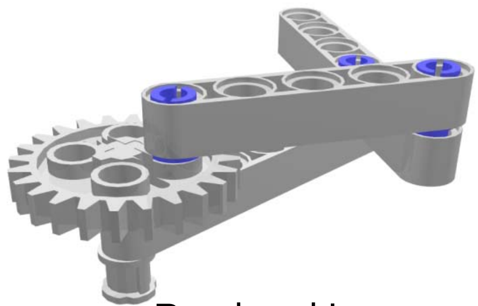


Step 3: Pin Beam 7 and Gear to Beam 5



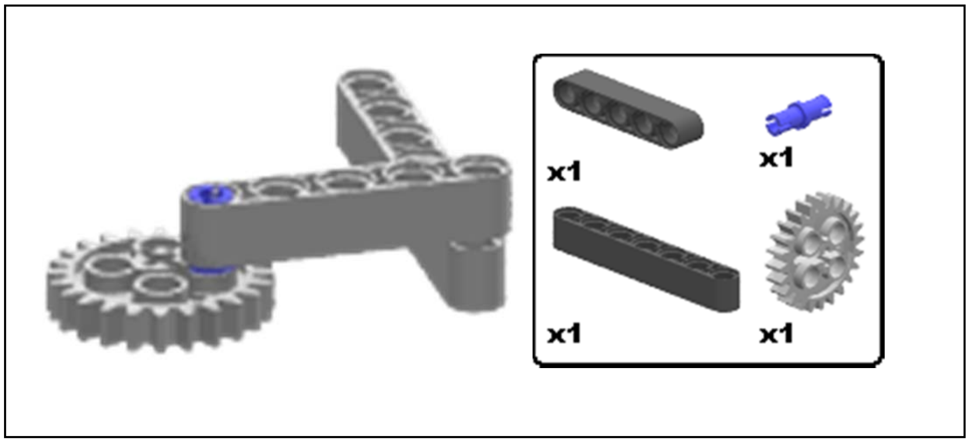
Step 4: Axle and bush the Gear. Join 2 Beam 7s.

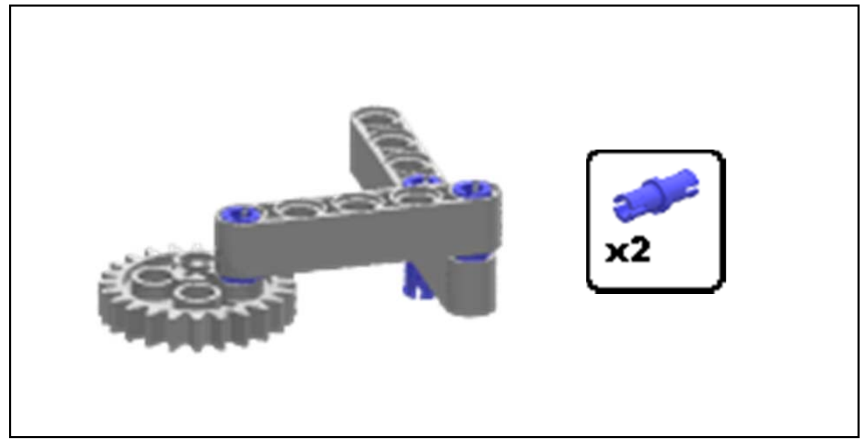
MLCAD Building Instructions and POV Rendering

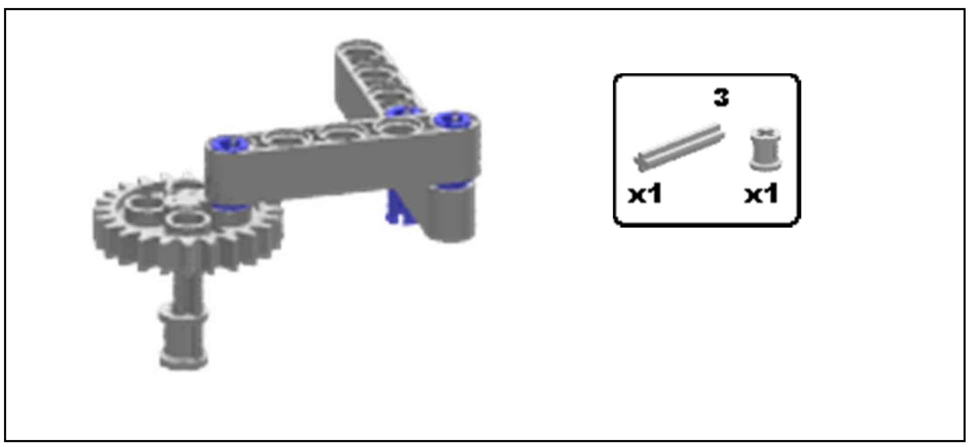


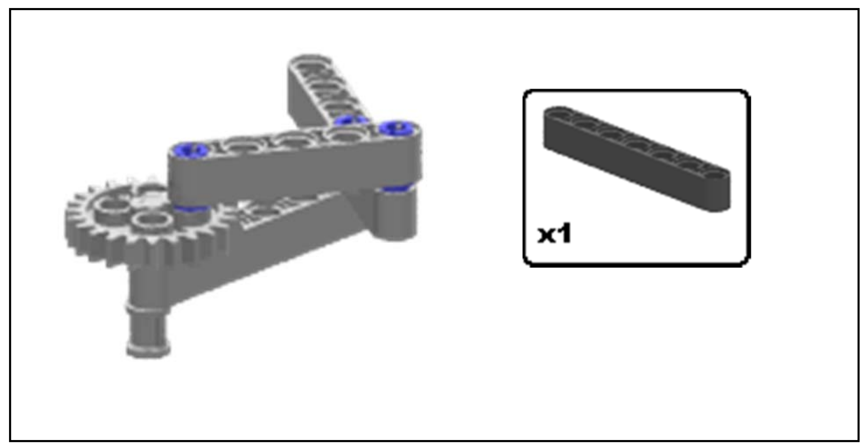
Rendered Image

Bill of Materials (BOM)



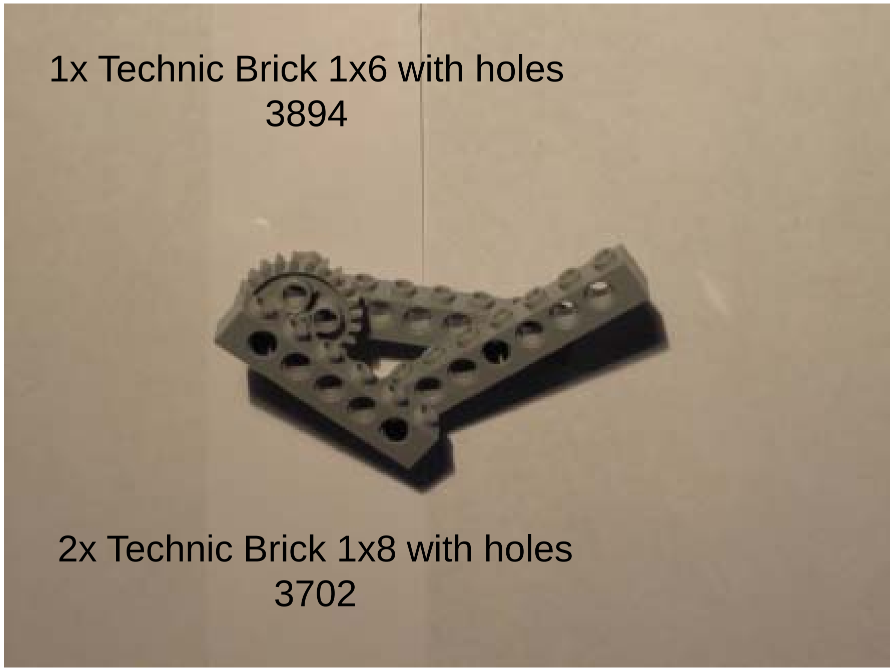






Exercises

3-1 Replace Beams with Bricks to construct the following 3-Bar Crank (left)
3-2 Construct the following 3-Bar Crank (right)



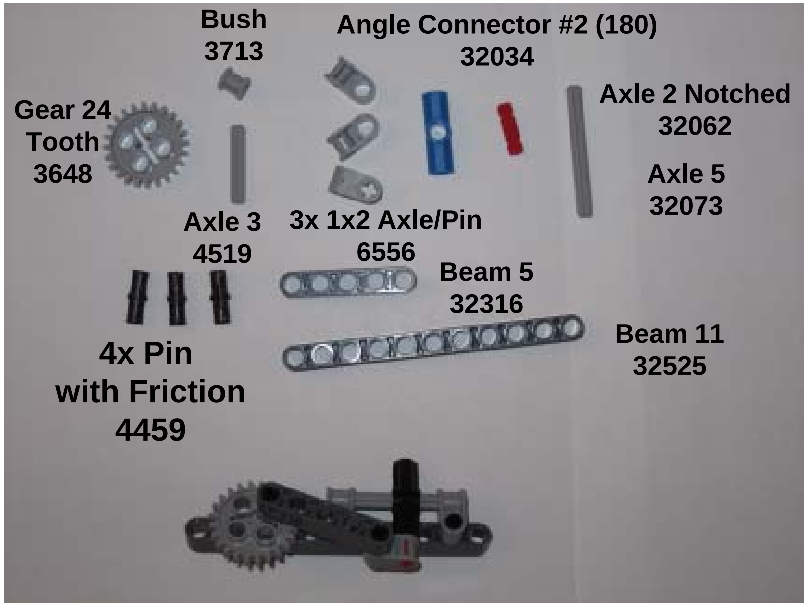
Left: 3-Bar Crank using Bricks

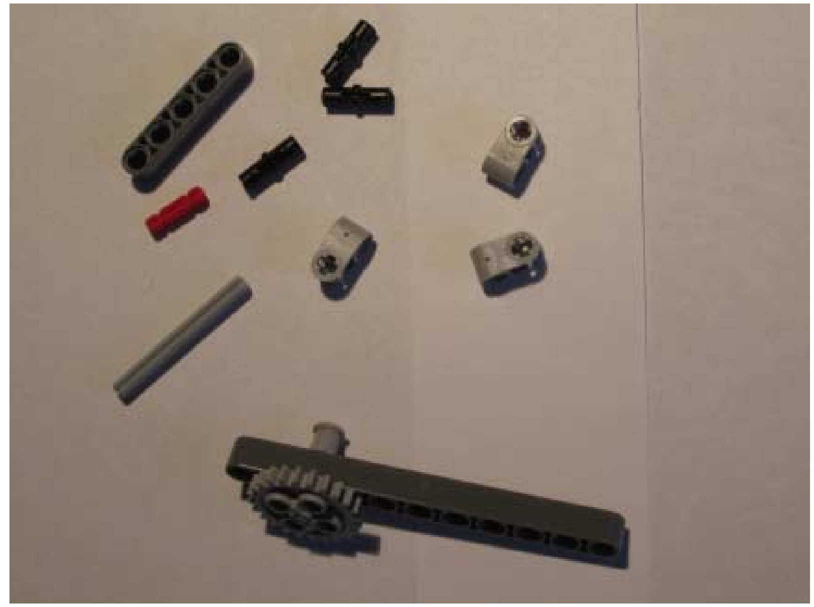
Right: 3-Bar with Crank near Middle

Exercise 4: The Crankshaft

Isogawa’s Lego Crankshaft

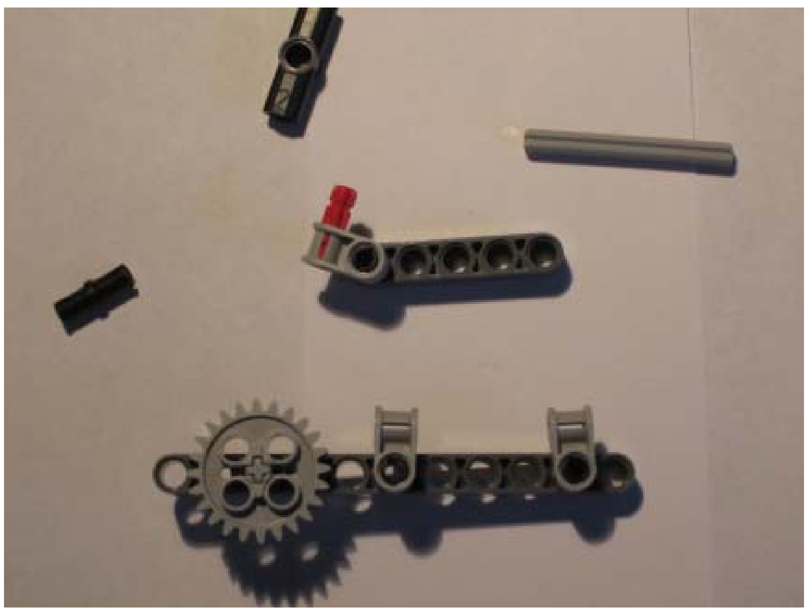
Video

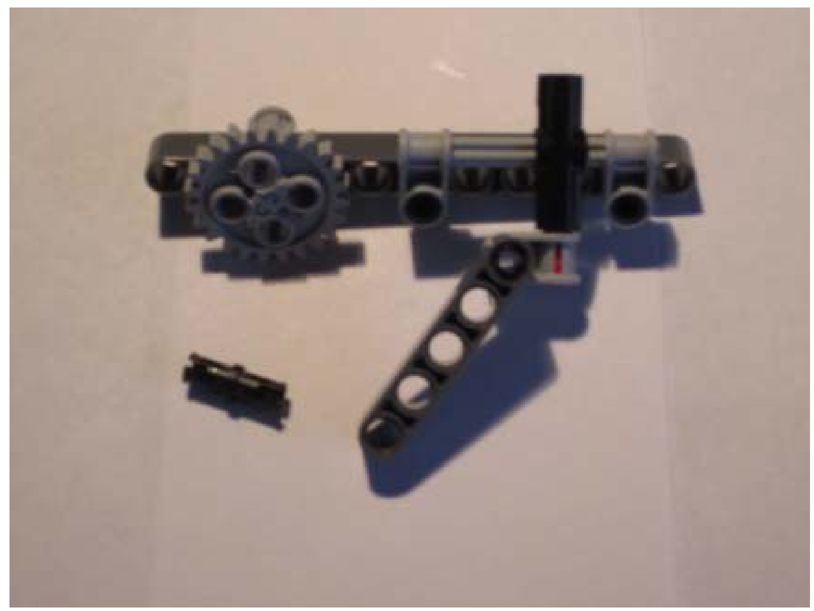




Step 1: Parts.

Step 2: Pin the Gear to Beam 11



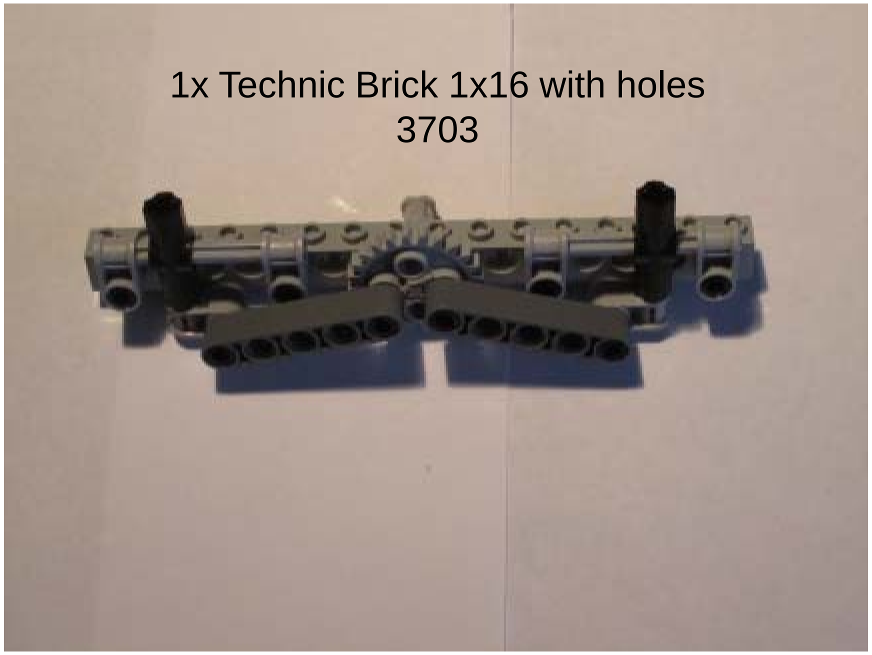


Step 3: Pin Axle/Pins to Beams 5 and 11

Step 4: Thread Axle 5 thru Angle Connector. Pin Beam

Exercises

4-1 Replace Beams with Bricks to construct the following Crankshaft (left)
4-2 Construct the following (right). Rotate Grey Gear. Black Gear output?



Left: Double Crankshaft using Bricks

Right: Crank and Lever (front and rear views)