Carapace

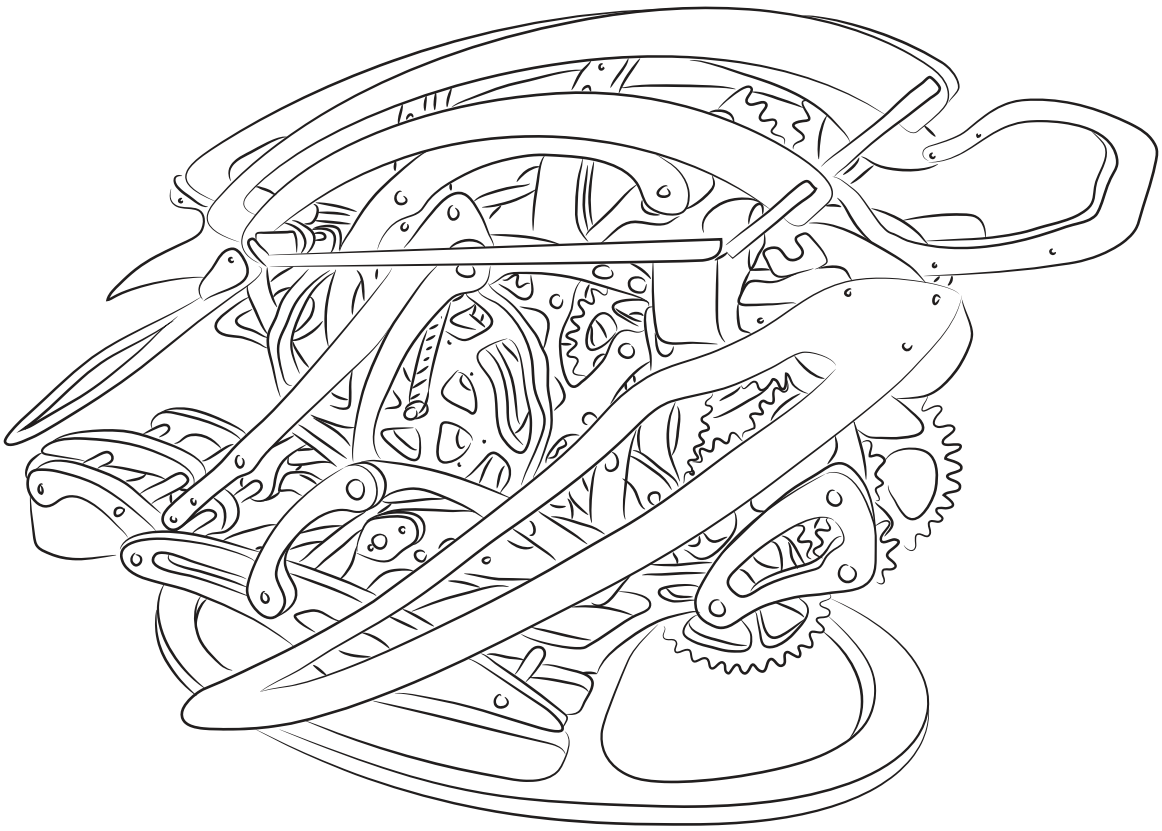
an organic motion sculpture

sample

Important information:

McMaster Carr, a supplier whose part numbers are referenced throughout this document, can only ship within the United States. Builders outside of the U.S. must find an alternate supplier for the required hardware.

Hardware part numbers and availability are subject to change.
Verify that all hardware or equivalents are obtainable prior to purchasing these plans.



design by Derek Hugger

The Basics

Contents

These plans include all the information required to build Carapace. They provide an outline of the build process, tips for an accurate and successful build, lists of required tools and off-the-shelf components, a complete parts list, full scale patterns for all plywood parts, and step-by-step assembly instructions.

Before Building

Read and understand all instructions before building. Failure to do so will lead to increased frustration levels, lengthened build times, wasted material, and other vexing occurrences.

Build Process

Always wear eye protection and any other necessary personal protective gear. Read, understand, and abide by all manufacturer instructions and warnings for all tools used.

1. Use a light duty/general purpose spray adhesive to temporarily bond the patterns to plywood. Apply the adhesive evenly and sparingly.
2. Drill the holes first, and then cut out the parts. Hole alignment between parts is critical to proper function, so care must be taken to drill the holes accurately. Take time to cut out the parts accurately. An accurately cut part will require less sanding and less modification later.
3. Remove the patterns from the cut plywood parts, and then sand the parts to remove rough edges and any residual adhesive.
4. Following the assembly instructions, build all subassemblies and then the Top Level Assembly. While assembling, cut and tap all aluminum tubes, brass tubes, and stainless steel as required. See Plywood Thickness Compensation in Tips + Tactics.
6. If desired, disassemble Carapace to finish its components. Note that stain and other finish options can affect the thickness of parts and may also affect friction levels between moving parts.

Notes

When printing the patterns, always print at 100% scale. Do not use the “scale to fit page” option.

Carapace contains many moving wood parts as well as wood parts that stack onto one another. As such, using a quality, flat Baltic birch plywood is very important. Cheaper, lower quality plywood, such as types often found at home improvement stores like Home Depot, can be warped and knotted.

Changing humidity levels can cause wood parts to swell and move. Some binding or changes in performance may occur with changes in humidity. As humidity levels return to normal, so too should the system’s performance.

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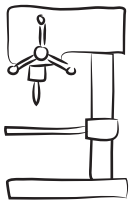
Tools

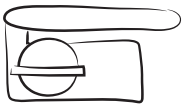
Required

Power Tools


bandsaw


scroll saw


drill press


belt/disc sander

General

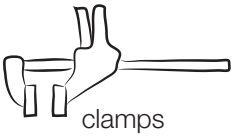

brad point drill index
1/16" to 1/2"
in 1/64" increments

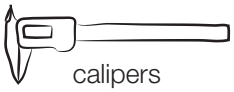

drill bit #29*


tap 8-32*


spade or forstner bits
7/8", 1-1/4"


hacksaw


clamps


calipers


precision files

Drivers


phillips #1


hex 0.035"
5/64"

Supplies

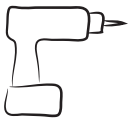

sandpaper

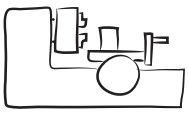

spray adhesive

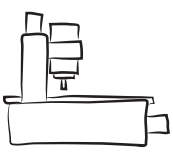

wood glue

Recommended (but not required)

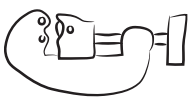

mini chop saw


drill

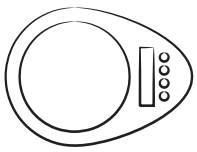

metal lathe


cnc router**


vice


tube cutter


reamers
0.0650", 0.1280", 0.2530"


kitchen scale or balance

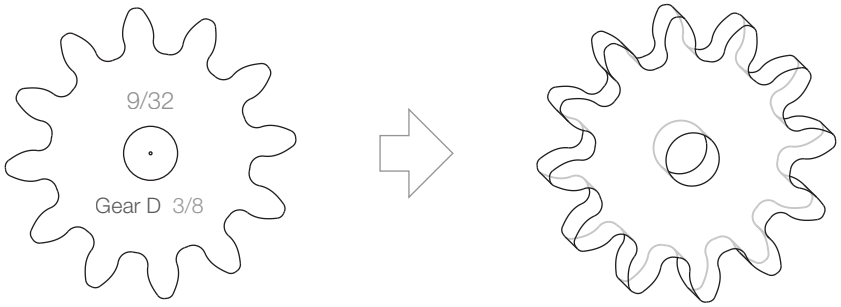
* For drilling and tapping into stainless steel, cobalt steel drill bits and taps are required.

** A CNC router is an optional replacement for the bandsaw and scroll saw for cutting the plywood parts.

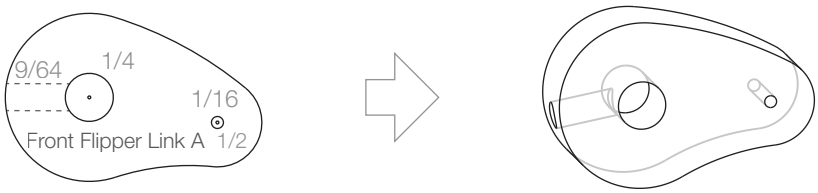
Tips + Tactics

Pattern Syntax

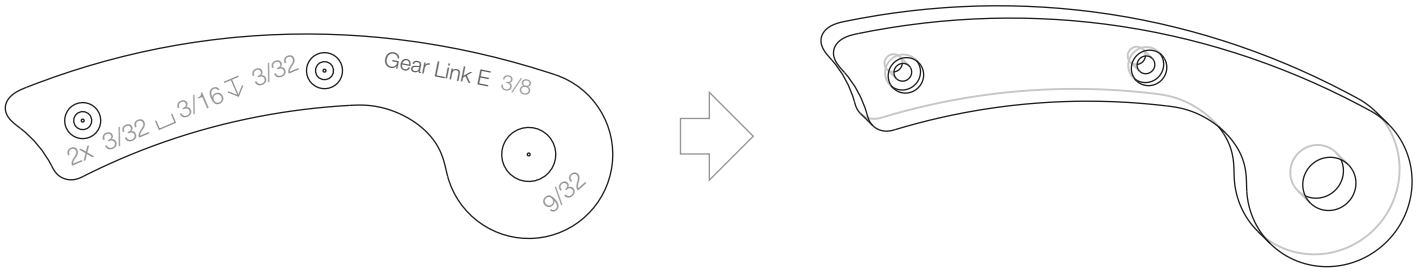
Patterns are labeled with a part name followed by a thickness dimension.
Example: Gear D is cut from 3/8” plywood. It also has a hole to be drilled thru with a 9/32” bit.



Straight dashed lines indicate a hole drilled from the side, centered on the thickness of the part.
Example: Front Flipper Link A has a 9/64” hole drilled from the side. It also has a 1/16” thru hole and a 1/4” thru hole drilled from the front.



Two concentric circles indicate a hole with a counterbore.
Example: Gear Link E has two 3/32” holes, each with a 3/16” counterbore drilled 3/32” deep. It also has a 9/32” thru hole.



Two concentric circles with a dotted outer circle indicate a hole with a counterbore drilled from the back side of the part. The hole callout will also say “(back)” next to it.
Example: See Moving Frame B (too large to show on this page).

When a part name is followed by “(back)”, this indicates the part is shown from its back side.
Example: See Moving Frame A (too large to show on this page).

Tips + Tactics

Plywood Thickness Compensation

The exact thickness of plywood is typically thinner than the plywood's specification. For example, 1/4” plywood may actually measure 0.23” thick. Because of this, it may be necessary to adjust the lengths of many of Carapace’s metal components. To save time and reduce the reworking of metal parts, cut the metal parts after cutting and measuring the thickness of their mating wood parts.

Tapping

Many of Carapace’s metal tubes must be tapped for an 8-32 thread. Expand the 0.12” inner diameter holes with a #29 drill bit before tapping the threads. When tapping the stainless steel tubes, **cobalt steel** drill bits and taps must be used. Standard HSS drill bits and taps that are found at most hardware stores are not hard enough to cut stainless steel, and they will likely dull and break when used on stainless steel.

When tapping the metal tubes, use plenty of lubricant. Never force the tap; if it feels like it’s going to break, it probably will. For every 1/2 to 3/4 turn the tap advances into the metal tube, back it out about 1/4 turn. Repeat this process until the tube is threaded to the desired depth - advance a bit, then back out a bit, advance a bit, then back out a bit.

Hypocycloid Tuning

Carapace has two sets of hypocycloid reducers, and each component of those two sets must be cut accurately in order to function properly. Virtually no force is required to drive the Hypocycloid Gears or their mating Cam Wheel assemblies when they are built properly. If any part of a hypocycloid reduction system is binding or if unnecessary friction is occurring, do the following:

- Ensure the holes for the Rods were drilled accurately. Position and perpendicularity are both important for minimizing friction and binding.
- Ensure the outer profile of the Hypocycloid Gear is smooth and accurately cut, with no bumps or divots.
- If a hypocycloid cam does not rotate freely within its hypocycloid gear, evenly sand the perimeter surface of the hypocycloid cam until it can rotate freely. Do not over sand, as doing so can lead to a significant amount of play in the system, which can affect the timing of the moving components.
- If the Cam Stack Asm’s rods are binding or causing unnecessary friction with its mating hypocycloid gear, evenly sand the four outer holes of the hypocycloid gear until the binding stops. Do not over sand, as doing so can lead to a significant amount of play in the system, which can affect the timing of the moving components.

Assembly Tuning + Friction

Through most of Carapace’s motion cycle, roughly 1 - 2 in-lbs of torque is required to turn the Crank Wheel and drive the system. At certain times, particularly when it is moving upward, a torque of 3 - 3.5 in-lbs may be required. However, turning the Crank Wheel must never require more than 4 in-lbs of torque. If it does, there may be some binding or excessive friction in the system. Reduce the torque needed to drive the system by ensuring that:

- all bearings are free to rotate without binding.
- all wooden surfaces that contact bearings are smooth and free of bumps and divots.
- all gears mesh smoothly.
- all hypocycloid components rotate freely. See Hypocycloid Tuning in Tips + Tactics.
- stainless steel rods and tubes and aluminum tubes rotate freely inside their mating brass tubes.
- the Extension Spring is properly installed.
- an appropriate mass is used for the counterweight. See Weight of the Counterweight in Tips + Tactics.
- all linkages can move freely without binding.

Parts + Assemblies List

Type	Description	Qty
Aluminum Tube	A Tube 11/32" Cored	1
Aluminum Tube	A Tube 1/2"	8
Aluminum Tube	A Tube 5/8"	1
Aluminum Tube	A Tube 3/4"	4
Aluminum Tube	A Tube 7/8"	8
Aluminum Tube	A Tube 1-3/16"	1
Aluminum Tube	A Tube 1-1/4"	2
Aluminum Tube	A Tube 1-1/4" Pivot	2
Aluminum Tube	A Tube 1-5/16"	1
Aluminum Tube	A Tube 1-1/2"	3
Aluminum Tube	A Tube 2-3/8"	1
Aluminum Tube	A Tube 2-1/2"	1
Aluminum Tube	A Tube 2-7/8"	1
Aluminum Tube	A Tube 3"	1
Aluminum Tube	A Tube 3-3/8"	6
Aluminum Tube	A Tube 3-1/2"	1
Aluminum Tube	A Tube 3-5/8"	1
Aluminum Tube	A Tube 5-1/2"	1
Aluminum Tube	A Tube 6-7/8"	2
Brass Tube	B Tube 3/32" x 1/4"	6
Brass Tube	B Tube 3/32" x 3/4"	1
Brass Tube	B Tube 5/32" x 11/16	1
Brass Tube	B Tube 5/32" x 33/40"	2
Brass Tube	B Tube 5/32" x 1"	1
Brass Tube	B Tube 5/32" x 1-1/16"	1
Brass Tube	B Tube 9/32" x 1/8"	2
Brass Tube	B Tube 9/32" x 1/4"	24
Brass Tube	B Tube 9/32" x 5/16"	1
Brass Tube	B Tube 9/32" x 3/8"	13
Brass Tube	B Tube 9/32" x 1/2"	7
Brass Tube	B Tube 9/32" x 5/8"	3
Brass Tube	B Tube 9/32" x 3/4"	2
Brass Tube	B Tube 9/32" x 7/8"	1
Brass Tube	B Tube 9/32" x 1"	1
Brass Tube	B Tube 9/32" x 1-7/16"	4
Brass Tube	B Tube 9/32" x 1-7/8"	1
Brass Tube	B Tube 9/32" x 3-5/8"	1
Stainless Steel Tube	S Tube 1-1/16"	1
Stainless Steel Tube	S Tube 1-3/8"	1
Stainless Steel Tube	S Tube 2-1/8"	2
Stainless Steel Rod	Rod 1/16" x 7/16"	10
Stainless Steel Rod	Rod 1/16" x 5/8"	44
Stainless Steel Rod	Rod 1/16" x 3/4"	2
Stainless Steel Rod	Rod 1/16" x 13/16"	2
Stainless Steel Rod	Rod 1/16" x 7/8"	4
Stainless Steel Rod	Rod 1/16" x 15/16"	2
Stainless Steel Rod	Rod 1/16" x 1-1/4"	1
Stainless Steel Rod	Rod 1/8" x 2-3/8"	2
Stainless Steel Rod	Rod 1/8" x 4-1/8"	1
Steel/Stainless Steel/Brass	Counterweight	1
Hardware	Bearing	10
Hardware	Extension Spring	1
Hardware	LSHCS 8-32 x 1/4"	34
Hardware	LSHCS 8-32 x 3/8"	14
Hardware	LSHCS 8-32 x 1/2"	20
Hardware	LSHCS 8-32 x 5/8"	13
Hardware	LSHCS 8-32 x 3/4"	5
Hardware	Magnet	4
Hardware	Needle Bearing	7
Hardware	Rod End	2
Hardware	Screw #2 x 3/8"	10
Hardware	Screw #2 x 1/2"	50
Hardware	Screw #2 x 5/8"	52
Hardware	Screw #2 x 3/4"	14
Hardware	Set Screw 8-32 x 1/4"	19
Hardware	Shaft Collar	4
Hardware	Washer 1/4"	5
Hardware	Washer #8	50

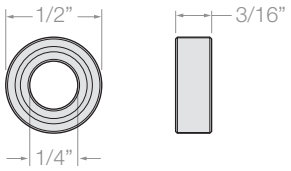
Type	Description	Qty
Plywood 1/8"	Front Flipper	2
Plywood 1/8"	Gear Link D	1
Plywood 1/8"	Head Cam Spacer	1
Plywood 1/8"	Head Gear Spacer	1
Plywood 1/8"	Peau Spacer Thin	1
Plywood 1/8"	Rear Flipper	2
Plywood 1/8"	Rear Flipper Cam Follower Spacer	1
Plywood 1/8"	Shell Spacer A	2
Plywood 1/8"	Shell Spacer B	2
Plywood 1/4"	Front Flipper Link B	2
Plywood 1/4"	Front Flipper Link B Spacer	2
Plywood 1/4"	Front Flipper Link C	2
Plywood 1/4"	Front Flipper Support Left	1
Plywood 1/4"	Front Flipper Support Right	1
Plywood 1/4"	Gear B Spacer Thin	1
Plywood 1/4"	Gear EF Spacer	1
Plywood 1/4"	Gear F	1
Plywood 1/4"	Gear Link A	1
Plywood 1/4"	Gear Link C	1
Plywood 1/4"	Head A	1
Plywood 1/4"	Head Cam Follower	1
Plywood 1/4"	Head Cam Follower Spacer	1
Plywood 1/4"	Head D	1
Plywood 1/4"	Head Gear	1
Plywood 1/4"	Head Spacer A	1
Plywood 1/4"	Head Spacer B	1
Plywood 1/4"	Hypocycloid Gear A	1
Plywood 1/4"	Hypocycloid Gear C	1
Plywood 1/4"	Moving Frame A	1
Plywood 1/4"	Moving Frame B	1
Plywood 1/4"	Peau Link Left A	1
Plywood 1/4"	Peau Link Left G	1
Plywood 1/4"	Peau Link Right Left C	2
Plywood 1/4"	Peau Link Right Left D	3
Plywood 1/4"	Peau Link Right Left F	2
Plywood 1/4"	Peau Link Right A1	1
Plywood 1/4"	Peau Link Right A2	1
Plywood 1/4"	Peau Link Right A3	1
Plywood 1/4"	Peau Link Right B Support	1
Plywood 1/4"	Peau Link Right E1	1
Plywood 1/4"	Peau Link Right E2	1
Plywood 1/4"	Peau Link Right G1	1
Plywood 1/4"	Peau Link Right G2	1
Plywood 1/4"	Peau Spacer Thick	1
Plywood 1/4"	Rear Flipper Cam Follower	1
Plywood 1/4"	Shell A	1
Plywood 1/4"	Shell B	2
Plywood 1/4"	Shell C	2
Plywood 1/4"	Shell D Left	1
Plywood 1/4"	Shell D Right	1
Plywood 1/4"	Shell Front	1
Plywood 1/4"	Shell Rear	1
Plywood 1/4"	Upper Frame B	1
Plywood 3/8"	Base	1
Plywood 3/8"	Crank Wheel	1
Plywood 3/8"	Front Flipper Link Mount	2
Plywood 3/8"	Gear A	1
Plywood 3/8"	Gear B	1
Plywood 3/8"	Gear C	1
Plywood 3/8"	Gear D	1
Plywood 3/8"	Gear E	1
Plywood 3/8"	Gear H	1
Plywood 3/8"	Gear I	1
Plywood 3/8"	Gear Link B Spacer	1
Plywood 3/8"	Gear Link E	1
Plywood 3/8"	Gear Link F	1
Plywood 3/8"	Head B	1
Plywood 3/8"	Head C	1
Plywood 3/8"	Head Cam	1
Plywood 3/8"	Hypocycloid Gear B	1
Plywood 3/8"	Lower Frame A	1
Plywood 3/8"	Lower Frame B	1
Plywood 3/8"	Lower Frame C	1
Plywood 3/8"	Lower Frame D	1
Plywood 3/8"	Moving Frame B Support	1
Plywood 3/8"	Peau Link Left B	1
Plywood 3/8"	Rear Flipper Cam	1
Plywood 3/8"	Rear Shell Connector Left	1
Plywood 3/8"	Rear Shell Connector RIght	1
Plywood 3/8"	Tail Spacer A	1
Plywood 3/8"	Tail Spacer B	1
Plywood 3/8"	Tilt Hard Stop Support	1
Plywood 3/8"	Upper Frame A	1

Type	Description	Qty
Plywood 1/2"	Counterweight Arm	1
Plywood 1/2"	Front Flipper Beam	1
Plywood 1/2"	Front Flipper Link A	2
Plywood 1/2"	Front Flipper Mount Left	1
Plywood 1/2"	Front Flipper Mount Right	1
Plywood 1/2"	Front Flipper Bearing Block Left	1
Plywood 1/2"	Front Flipper Bearing Block Right	1
Plywood 1/2"	Gear A Spacer	1
Plywood 1/2"	Gear BC Spacer	2
Plywood 1/2"	Gear G	1
Plywood 1/2"	Gear Link A Spacer	1
Plywood 1/2"	Gear Link B	1
Plywood 1/2"	Head Gear Link	1
Plywood 1/2"	Hypocycloid AB Cam	1
Plywood 1/2"	Hypocycloid Gear C Cam	1
Plywood 1/2"	Lift Cam	1
Plywood 1/2"	Peau Link Right B	1
Plywood 1/2"	Pivot Block	2
Plywood 1/2"	Rear Flipper Mount Left	1
Plywood 1/2"	Rear Flipper Mount Right	1
Plywood 1/2"	Shoulder Pivot	2
Plywood 1/2"	Tilt Cam	1
Plywood 1/2"	Weight Support	1
Subassembly	Cam Stack Asm	1
Subassembly	Frame AB Asm	1
Subassembly	Frame CD Asm	1
Subassembly	Front Flipper Beam Asm	1
Subassembly	Front Flipper Left Asm	1
Subassembly	Front Flipper Link A Left Asm	1
Subassembly	Front Flipper Link A Right Asm	1
Subassembly	Front Flipper Link B Left Asm	1
Subassembly	Front Flipper Link B Right Asm	1
Subassembly	Front Flipper Link C Asm	2
Subassembly	Front Flipper Right Asm	1
Subassembly	Gear B Asm	1
Subassembly	Gear C Asm	1
Subassembly	Gear D Asm	1
Subassembly	Gear EF Asm	1
Subassembly	Gear H Asm	1
Subassembly	Gear Link A Asm	1
Subassembly	Gear Link B Asm	1
Subassembly	Gear Link CD Asm	1
Subassembly	Gear Link EF Asm	1
Subassembly	Head Asm	1
Subassembly	Head Cam Follower Asm	1
Subassembly	Head Gear Asm	1
Subassembly	Hypocycloid AB Cam Asm	1
Subassembly	Hypocycloid Gear Asm	1
Subassembly	Lift Cam Asm	1
Subassembly	Lower Frame A Asm	1
Subassembly	Lower Frame B Asm	1
Subassembly	Moving Frame A Asm	1
Subassembly	Moving Frame Asm	1
Subassembly	Moving Frame B Asm	1
Subassembly	Peau Link Left A Asm	1
Subassembly	Peau Link Left B Asm	1
Subassembly	Peau Link Left C Asm	1
Subassembly	Peau Link Left G Asm	1
Subassembly	Peau Link Right Left D Asm	3
Subassembly	Peau Link Right Left F Asm	2
Subassembly	Peau Link Right A Asm	1
Subassembly	Peau Link Right B Asm	1
Subassembly	Peau Link Right C Asm	1
Subassembly	Peau Link Right E Asm	1
Subassembly	Peau Link Right G Asm	1
Subassembly	Peaucellier Linkage Asm	1
Subassembly	Peaucellier Linkage Left Asm	1
Subassembly	Peaucellier Linkage Right Asm	1
Subassembly	Pivot Link Asm	2
Subassembly	Pivoting Flipper Left Asm	1
Subassembly	Pivoting Flipper Right Asm	1
Subassembly	Rear Flipper Left Asm	1
Subassembly	Rear Flipper Right Asm	1
Subassembly	Shell A Asm	1
Subassembly	Shoulder Pivot Asm	2
Subassembly	Upper Frame Asm	1
Subassembly	Upper Frame B Asm	1
Subassembly	Weight Support Asm	1
Top Level Asm	Carapace	1

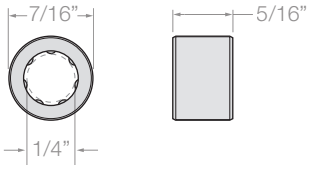
Hardware

Description	Qty	McMaster Carr P/N *
Bearing (see image below)	10	57155K376
Extension Spring (see image below)	1	9654K618
LSHCS 8-32 x 1/4" Low Socket Head Cap Screw	34	93615A317
LSHCS 8-32 x 3/8" Low Socket Head Cap Screw	14	93615A315
LSHCS 8-32 x 1/2" Low Socket Head Cap Screw	20	93615A320
LSHCS 8-32 x 5/8" Low Socket Head Cap Screw	13	93615A321
LSHCS 8-32 x 3/4" Low Socket Head Cap Screw	5	93615A323
Magnet Neodymium, 2.5 lbs max pull, Ø1/4" x 1/4"	4	58605K75
Needle Bearing (see image below)	7	5905K21
Rod End (see image below)	2	60645K98
Screw #2 x 3/8" Pan Head Self Tapping Screw	10	92470A097
Screw #2 x 1/2" Pan Head Self Tapping Screw	50	92470A098
Screw #2 x 5/8" Pan Head Self Tapping Screw	52	92470A101
Screw #2 x 3/4" Pan Head Self Tapping Screw	14	92470A103
Set Screw 8-32 x 1/4"	19	92311A190
Shaft Collar (see image below)	4	6432K71
Washer 1/4"	5	98017A660
Washer #8	50	90107A010

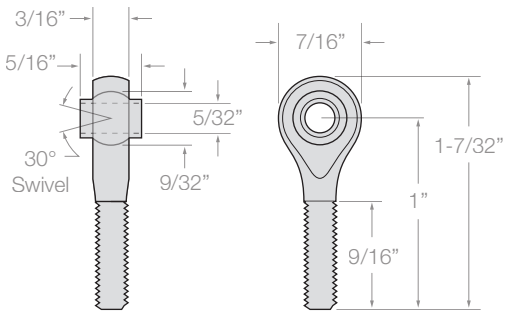
Bearing Double Shielded, ABEC-5



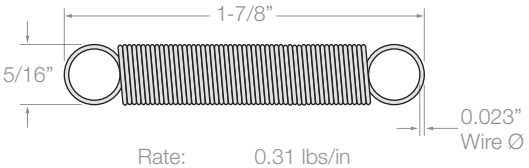
Needle Bearing Steel, Open Bearing Style



Rod End 8-32 Thread



Extension Spring with looped ends



Rate: 0.31 lbs/in
Min Load: 0.16 lbs
Max Load: 1.28 lbs

Shaft Collar with Set Screw

Inner Ø 1/16"
Outer Ø 1/4"
Width 3/16"

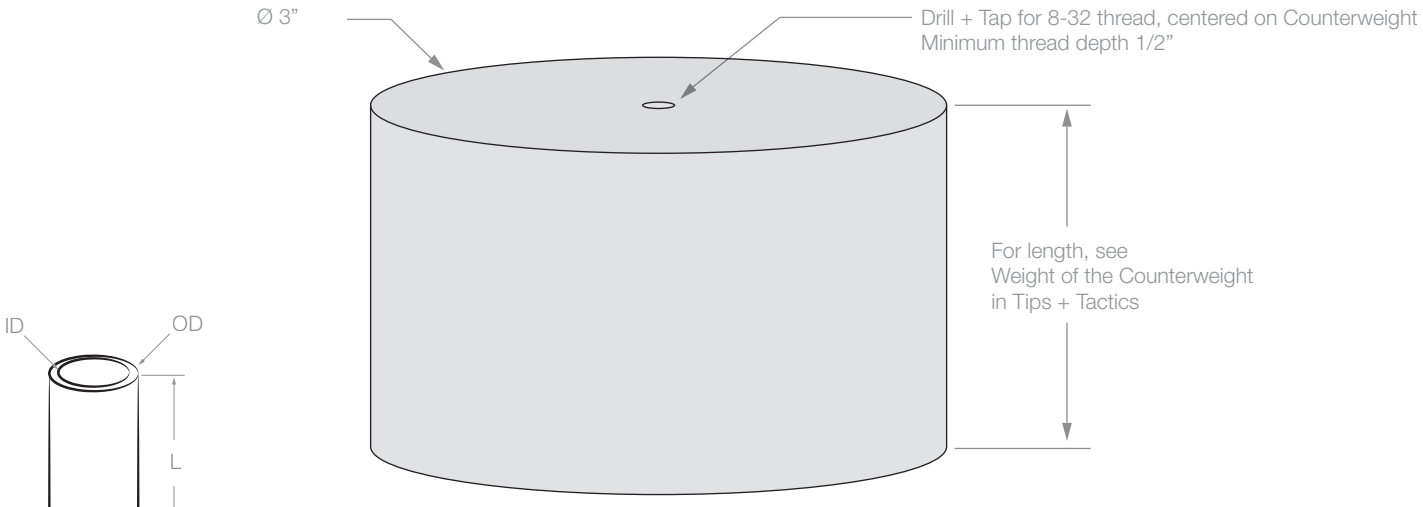
2-56 x 1/8" Set Screw

* Part numbers referenced are from www.mcmaster.com.

Metal

Brass Tubes, Counterweight

Description	OD x L *	ID	Qty	McMaster Carr P/N **
B Tube 3/32” x 1/4”	3/32” x 1/4”	0.066”	6	8859K18
B Tube 3/32” x 3/4”	3/32” x 3/4”	0.066”	1	
B Tube 5/32” x 11/16”	5/32” x 11/16”	0.128”	1	8859K21
B Tube 5/32” x 33/40”	5/32” x 33/40”	0.128”	2	
B Tube 5/32” x 1”	5/32” x 1”	0.128”	1	
B Tube 5/32” x 1-1/16”	5/32” x 1-1/16”	0.128”	1	
B Tube 9/32” x 1/8”	9/32” x 1/8”	0.253”	2	8859K25
B Tube 9/32” x 1/4”	9/32” x 1/4”	0.253”	24	
B Tube 9/32” x 5/16”	9/32” x 5/16”	0.253”	1	
B Tube 9/32” x 3/8”	9/32” x 3/8”	0.253”	13	
B Tube 9/32” x 1/2”	9/32” x 1/2”	0.253”	7	
B Tube 9/32” x 5/8”	9/32” x 5/8”	0.253”	3	
B Tube 9/32” x 3/4”	9/32” x 3/4”	0.253”	2	
B Tube 9/32” x 7/8”	9/32” x 7/8”	0.253”	1	
B Tube 9/32” x 1”	9/32” x 1”	0.253”	1	
B Tube 9/32” x 1-7/16”	9/32” x 1-7/16”	0.253”	4	
B Tube 9/32” x 1-7/8”	9/32” x 1-7/8”	0.253”	1	
B Tube 9/32” x 3-5/8”	9/32” x 3-5/8”	0.253”	1	
Counterweight see image below	3” x X”	-	1	Steel: 7786T36 Brass: 8953K511 Stainless Steel: 8984K71



The Counterweight can be made from either Steel, Stainless Steel, or Brass. Brass is the easiest to cut, but the most expensive. The Steel listed is the lowest cost, but is more difficult to cut.

OD outer diameter
ID inner diameter
L length

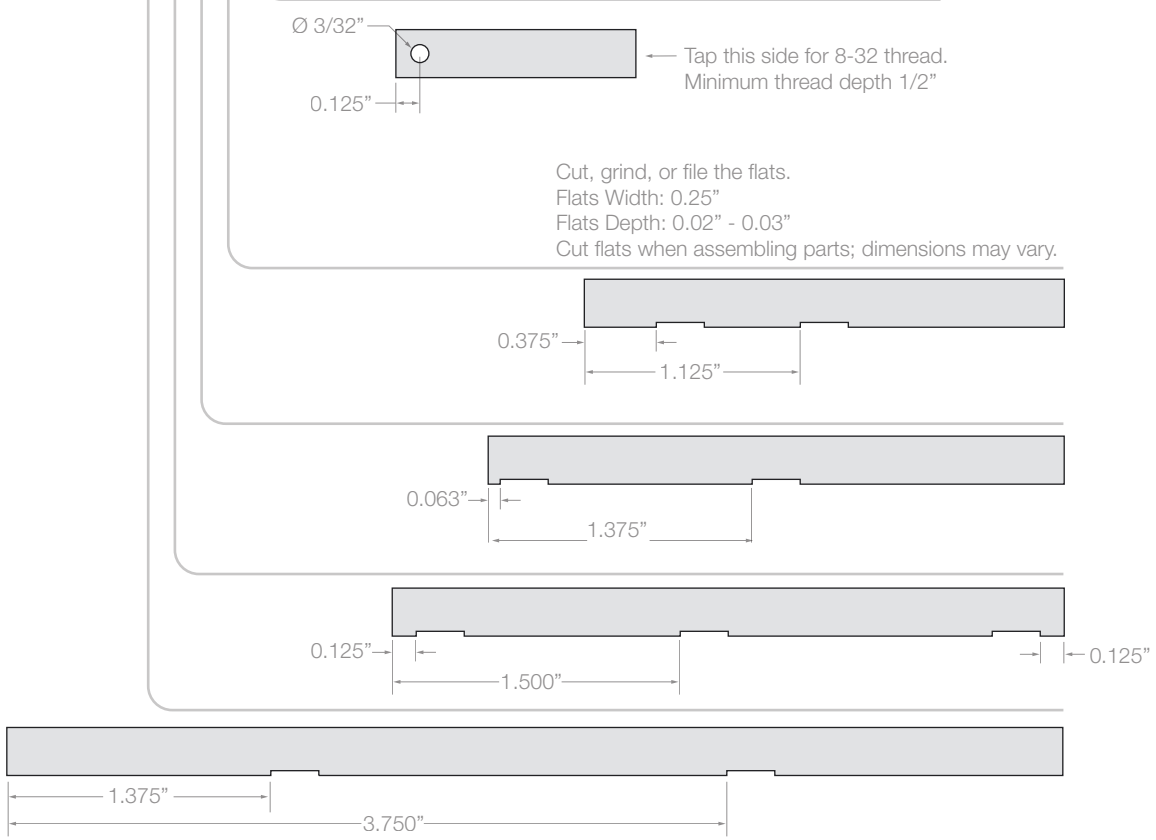
* Due to variations in plywood thicknesses, required tube lengths may vary. See Plywood Thickness Compensation in Tips + Tactics.

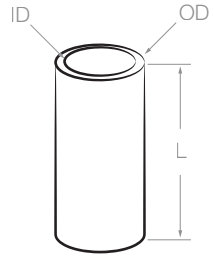
** Part numbers referenced are from www.mcmaster.com.

Metal

Aluminum Tubes

Description	OD x L *	ID	Tap**	Qty	McMaster Carr P/N ***
A Tube 11/32” Cored	1/4” x 11/32”	drill to 11/64”	None	1	89965K23
A Tube 1/2”	1/4” x 1/2”	0.120”	Thru	8	
A Tube 5/8”	1/4” x 5/8”	0.120”	None	1	
A Tube 3/4”	1/4” x 3/4”	0.120”	Thru	4	
A Tube 7/8”	1/4” x 7/8”	0.120”	Both Sides	8	
A Tube 1-3/16”	1/4” x 1-3/16”	0.120”	One Side	1	
A Tube 1-1/4”	1/4” x 1-1/4”	0.120”	Both Sides	2	
A Tube 1-1/4” Pivot	1/4” x 1-1/4”	0.120”	One Side	2	
A Tube 1-5/16”	1/4” x 1-5/16”	0.120”	Both Sides	1	
A Tube 1-1/2”	1/4” x 1-1/2”	0.120”	Both Sides	3	
A Tube 2-3/8”	1/4” x 2-3/8”	0.120”	Both Sides	1	
A Tube 2-1/2”	1/4” x 2-1/2”	0.120”	Both Sides	1	
A Tube 2-7/8”	1/4” x 2-7/8”	0.120”	Both Sides	1	
A Tube 3”	1/4” x 3”	0.120”	Both Sides	1	
A Tube 3-3/8”	1/4” x 3-3/8”	0.120”	Both Sides	6	
A Tube 3-1/2”	1/4” x 3-1/2”	0.120”	None	1	
A Tube 3-5/8”	1/4” x 3-5/8”	0.120”	Both Sides	1	
A Tube 5-1/2”	1/4” x 5-1/2”	0.120”	Both Sides	1	
A Tube 6-7/8”	1/4” x 6-7/8”	0.120”	Both Sides	2	





OD outer diameter
ID inner diameter
L length

* Due to variations in plywood thicknesses, required tube lengths may vary.

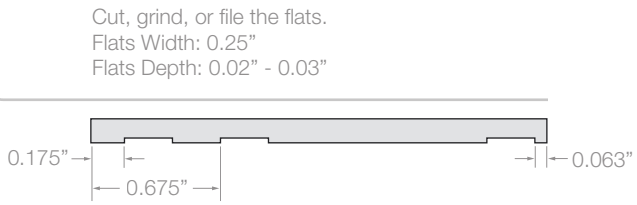
** When tapping, expand 0.120” tube ID with a #29 drill bit and then tap for 8-32 thread. Minimum thread depth: 3/8”.

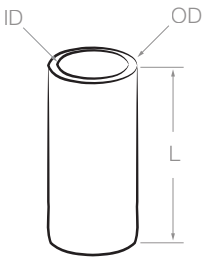
*** Part numbers referenced are from www.mcmaster.com.

Metal

Stainless Steel

Description	OD x L *	ID	Tap**	Qty	McMaster Carr P/N ***
S Tube 1-1/16”	1/4” x 1-1/16”	0.120”	Both Sides	1	89895K726
S Tube 1-3/8”	1/4” x 1-3/8”	0.120”	Both Sides	1	
S Tube 2-1/8”	1/4” x 2-1/8”	0.120”	One Side	2	
					8908K64
Rod 1/16” x 7/16”	1/16” x 7/16”	-	-	10	90145A418****
Rod 1/16” x 5/8”	1/16” x 5/8”	-	-	44	90145A421****
Rod 1/16” x 3/4”	1/16” x 3/4”	-	-	2	90145A422****
Rod 1/16” x 13/16”	1/16” x 13/16”	-	-	2	
Rod 1/16” x 7/8”	1/16” x 7/8”	-	-	4	90145A424****
Rod 1/16” x 15/16”	1/16” x 15/16”	-	-	2	
Rod 1/16” x 1-1/4”	1/16” x 1-1/4”	-	-	1	
Rod 1/8” x 2-3/8”	1/8” x 2-3/8”	-	-	2	8984K2
Rod 1/8” x 4-1/8”	1/8” x 4-1/8”	-	-	1	

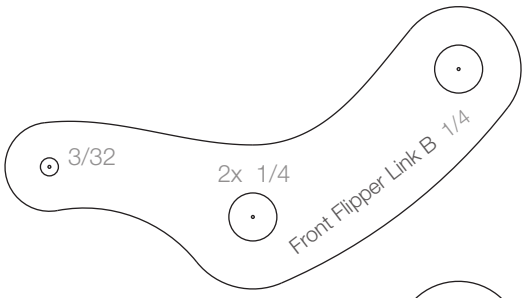


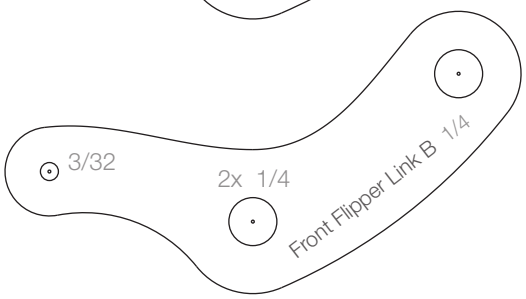


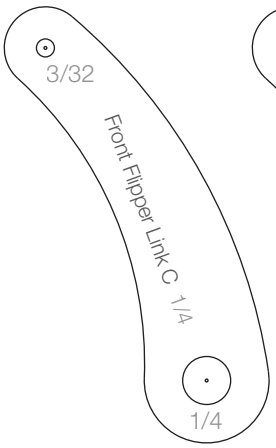
OD outer diameter
ID inner diameter
L length

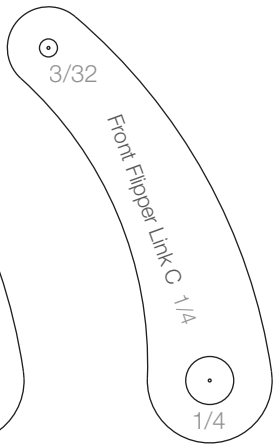
* Due to variations in plywood thicknesses, required tube lengths may vary.
** Expand 0.120” tube ID with a #29 drill bit and then tap for 8-32 thread. Minimum thread depth: 3/8”. Cobalt Steel drill bit and tap required.
*** Part numbers referenced are from www.mcmaster.com.
**** To save the time of cutting these Rods manually, these parst are available as pre-cut dowel pins.

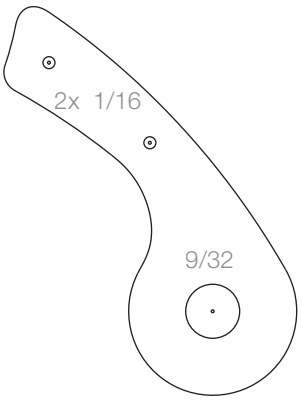
Scale reference. To measure exactly six inches when printed.



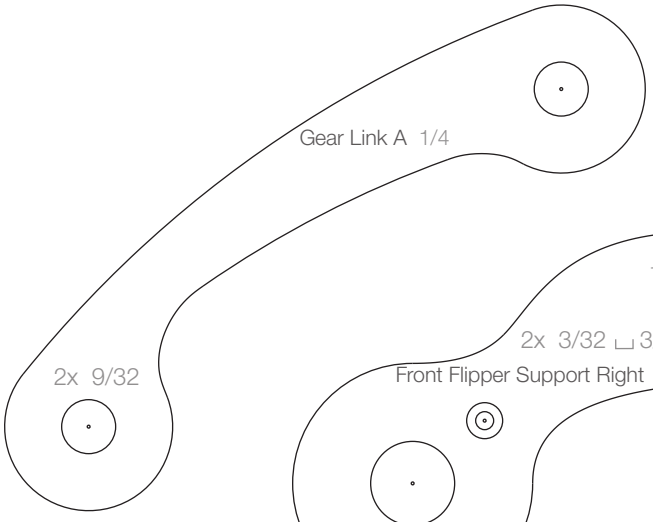


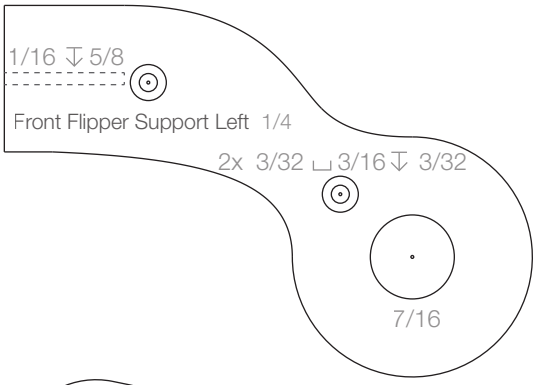


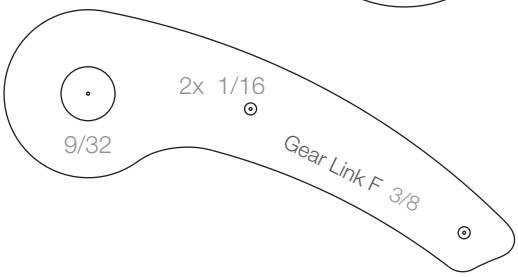


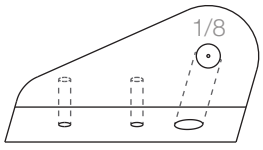


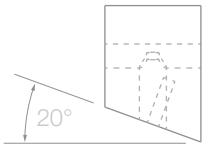
Gear Link C 1/4



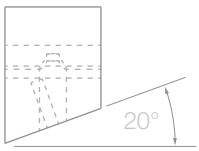


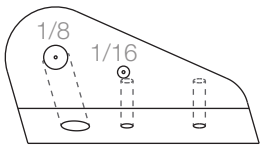




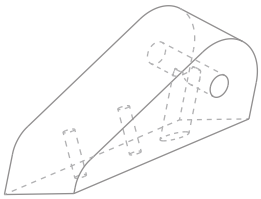


Rear Flipper Mount Left 1/2
1x 9/64 (perpendicular to 1/8" hole)
2x 1/16↧1/4 (perpendicular to 20° cut)

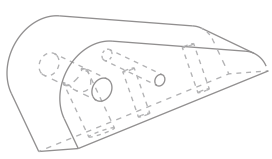




Rear Flipper Mount Right (back) 1/2
1x 9/64 (perpendicular to 1/8" hole)
2x 1/16↧1/4 (perpendicular to 20° cut)

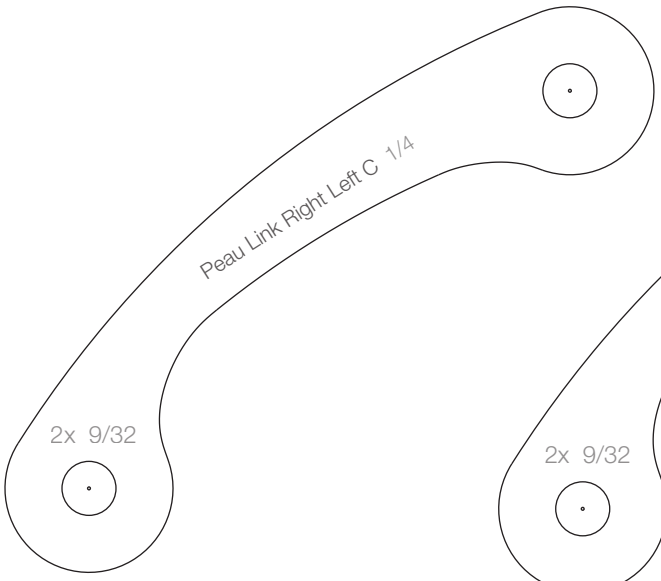


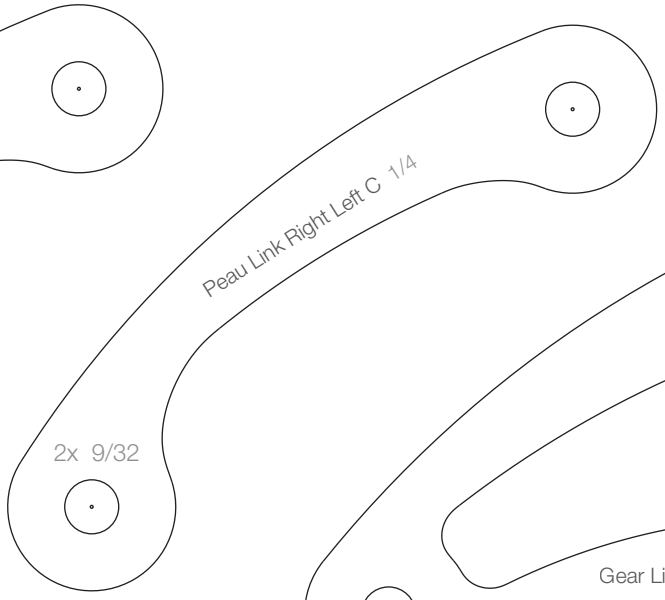
Cut a 20° angle into Rear Flipper Mount Right and Rear Flipper Mount Left as shown. Pay close attention to each hole's orientation.

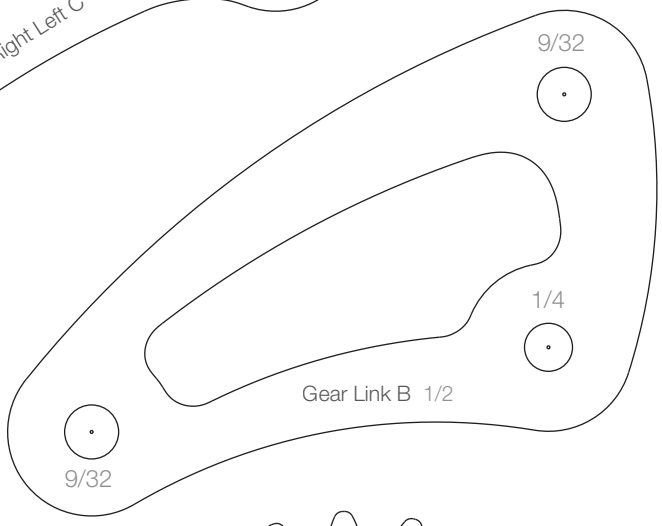


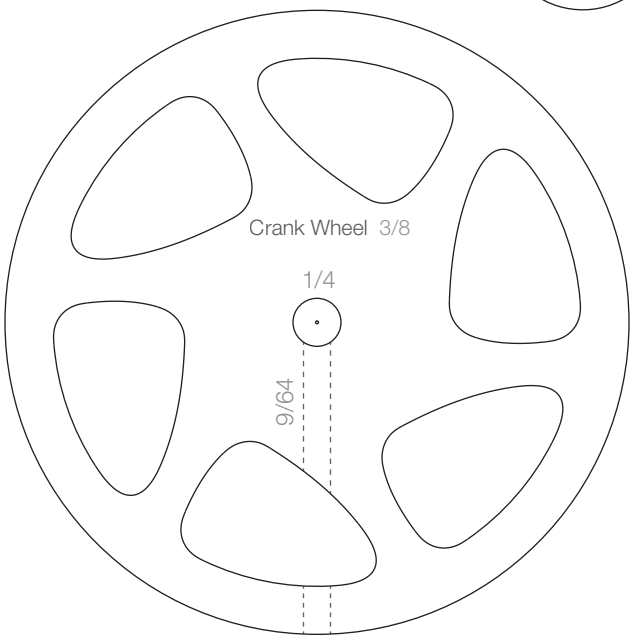
Scale reference. To measure exactly six inches when printed.

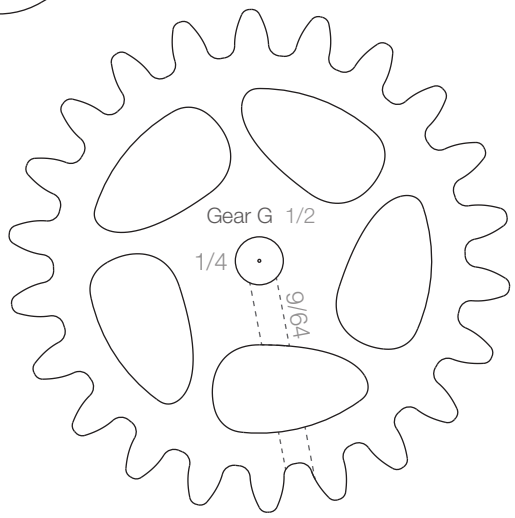
1 2 3 4 5 6 in

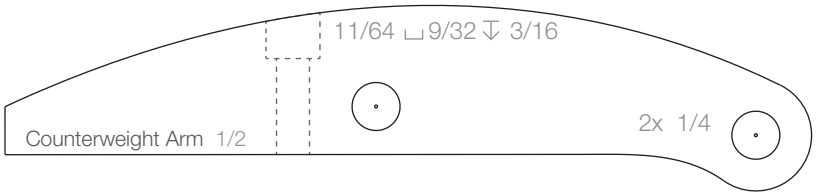


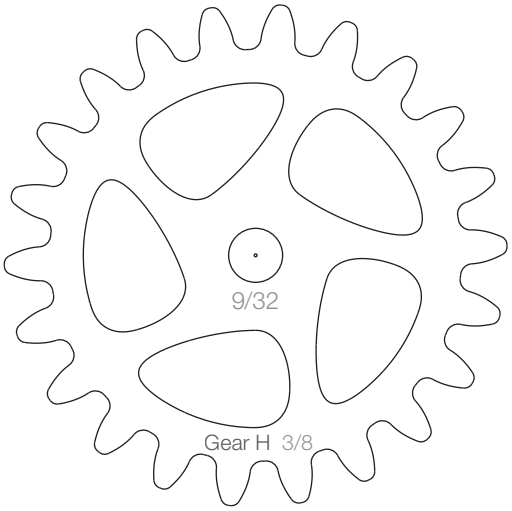


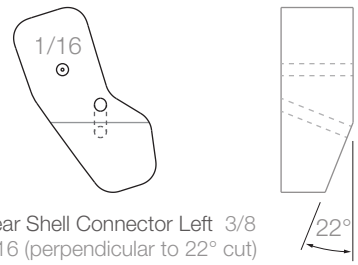




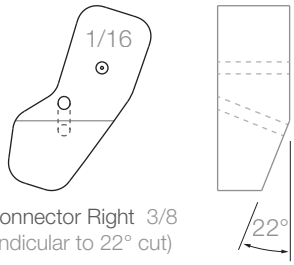








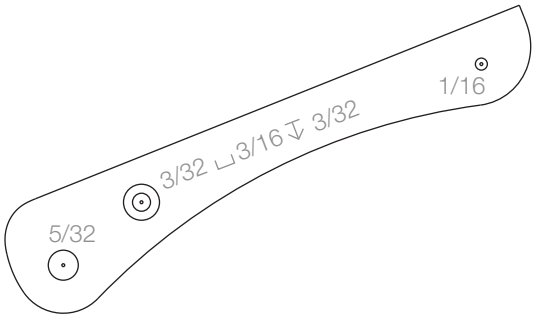
Rear Shell Connector Left 3/8
1/16 (perpendicular to 22° cut)



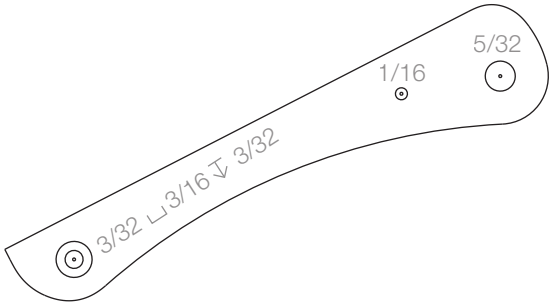
Rear Shell Connector Right 3/8
1/16 (perpendicular to 22° cut)

Scale reference. To measure exactly six inches when printed.

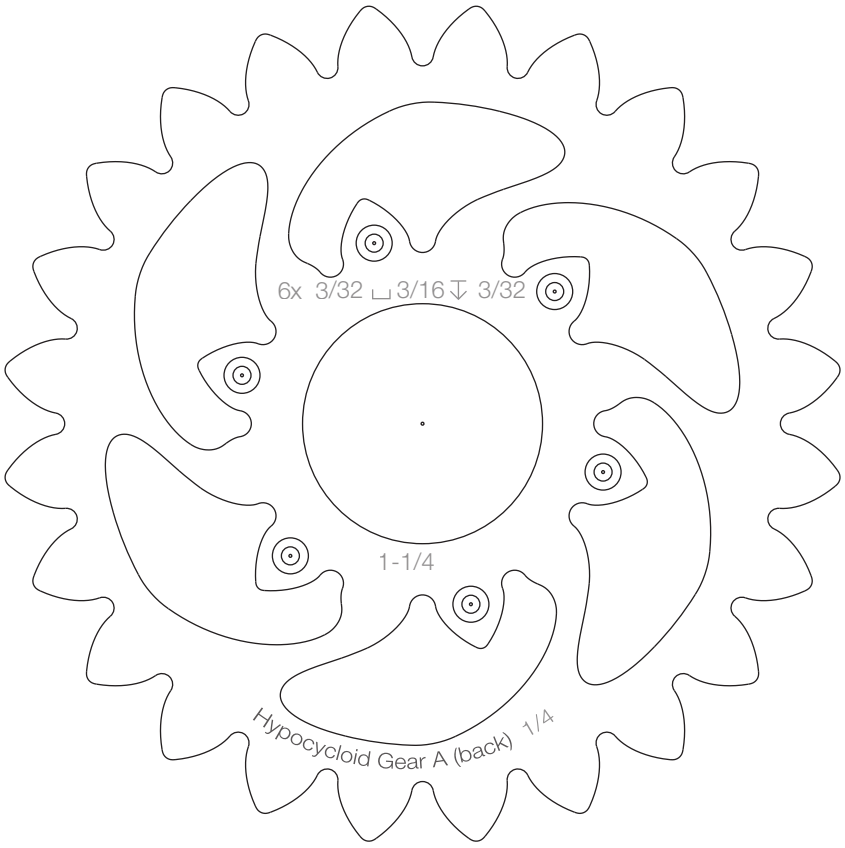
1 2 3 4 5 6 in

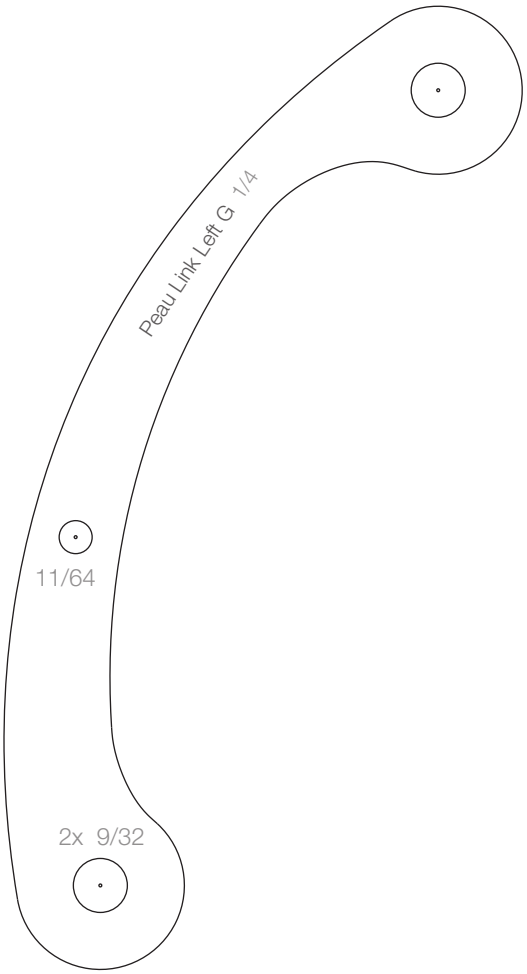


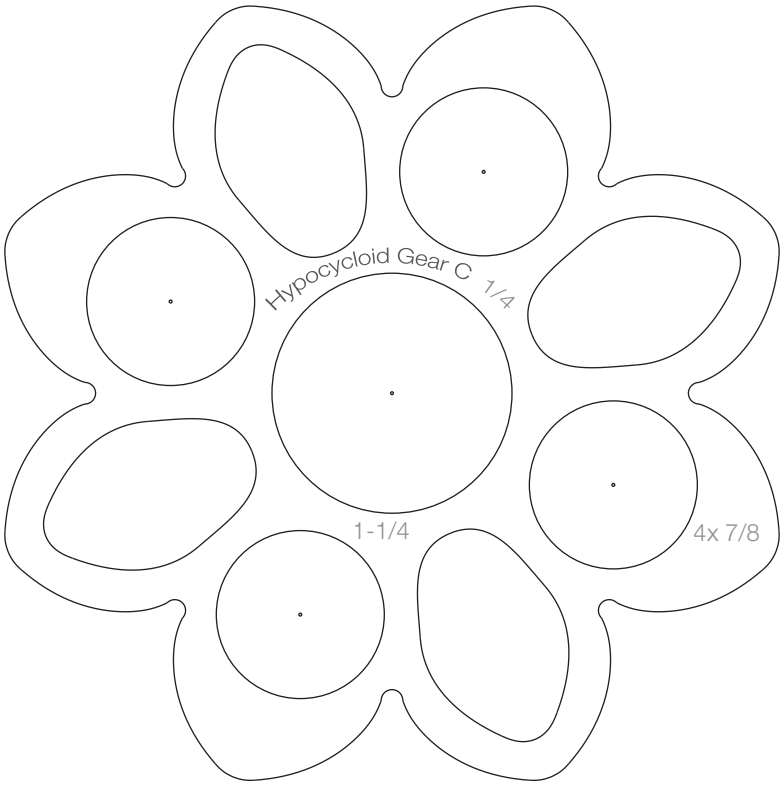
Tail Spacer A (back) 3/8



Tail Spacer B 3/8

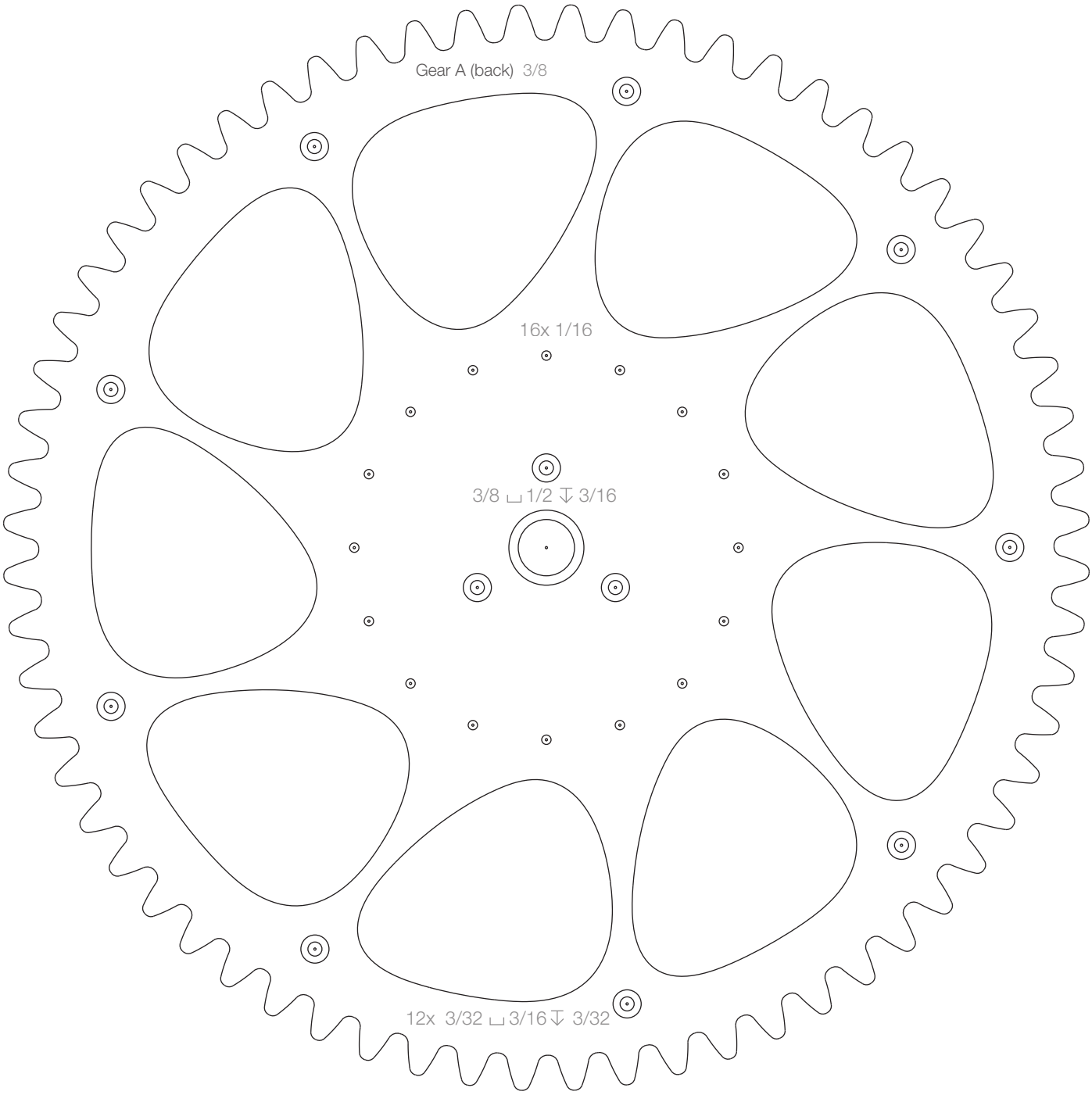






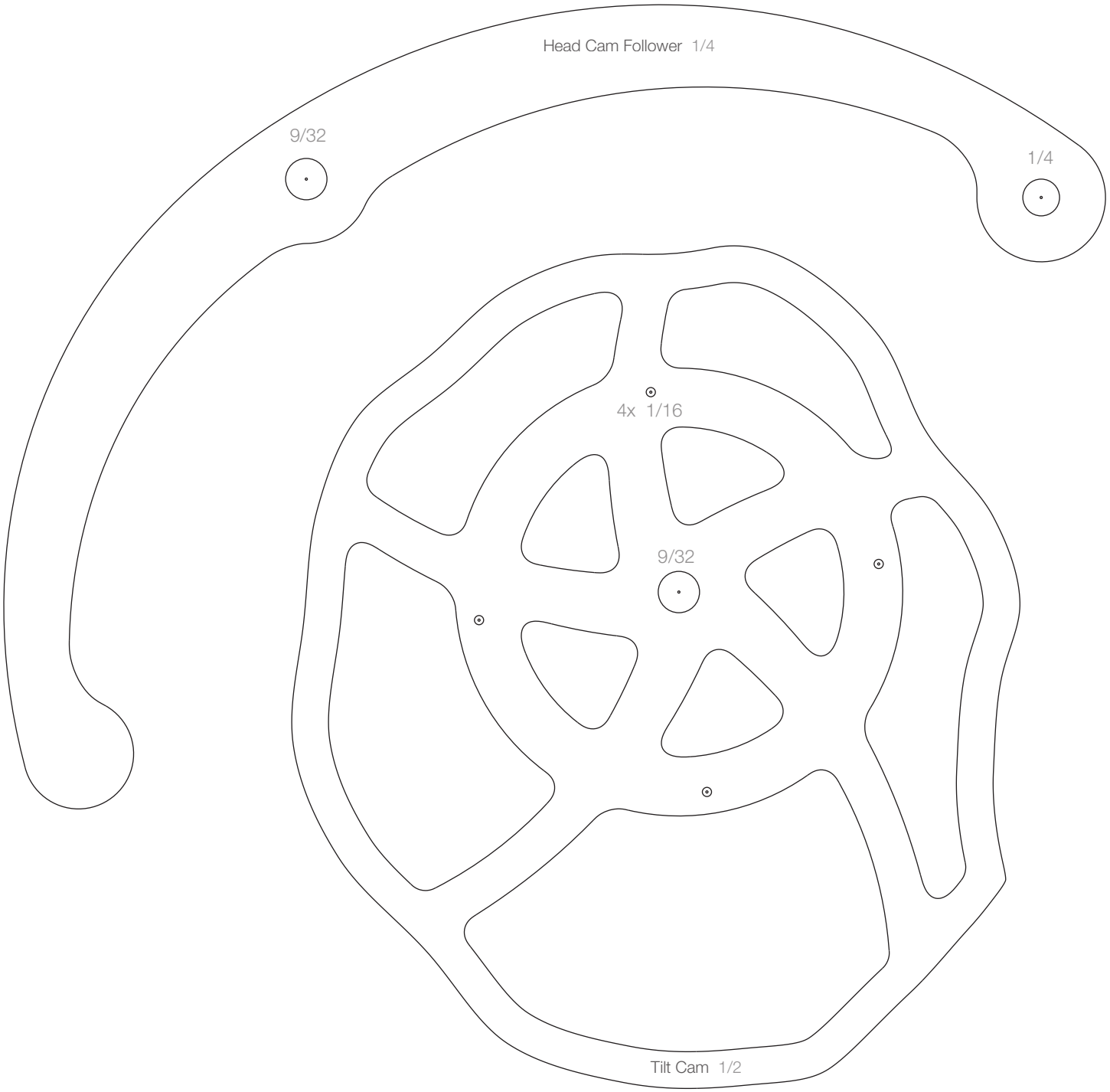
Scale reference. To measure exactly six inches when printed.

1 2 3 4 5 6 in



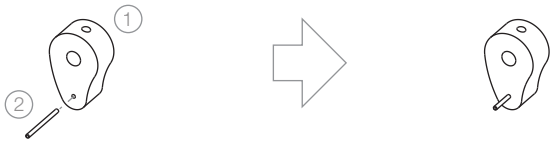
Scale reference. To measure exactly six inches when printed.

1 2 3 4 5 6 in



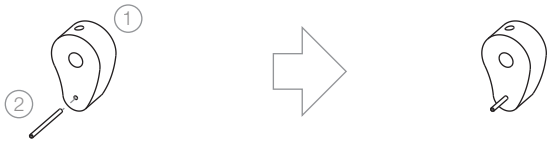
Subassemblies

Steps 1, 2, 3, 4, 5



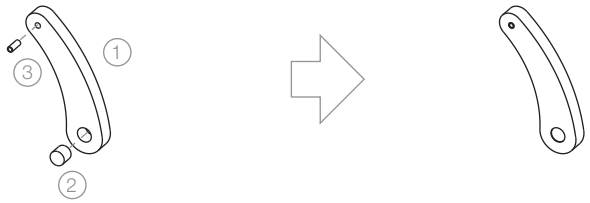
Front Flipper Link A Left Asm

1	Front Flipper Link A	1x
2	Rod 1/16” x 15/16”	1x



Front Flipper Link A Right Asm

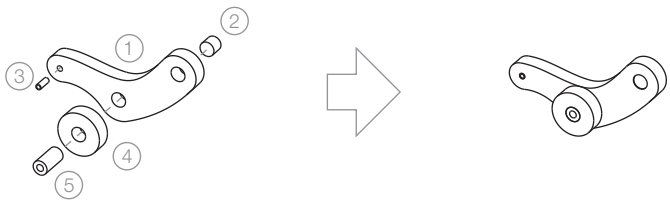
1	Front Flipper Link A	1x
2	Rod 1/16” x 15/16”	1x



Front Flipper Link C Asm (2x)

1	Front Flipper Link C	1x
2	Magnet	1x
3	B Tube 3/32” x 1/4”	1x

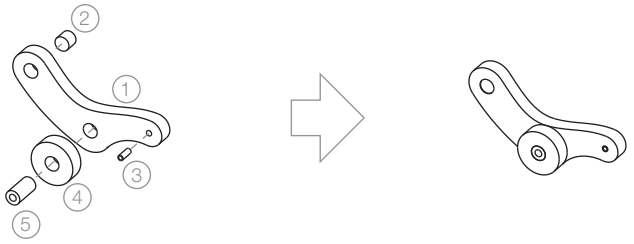
Magnet orientation matters; see Top Level Assembly Step 7.



Front Flipper Link B Right Asm

1	Front Flipper Link B	1x
2	Magnet	1x
3	B Tube 3/32” x 1/4”	1x
4	Front Flipper Link B Spacer	1x
5	A Tube 1/2”	1x

Glue Front Flipper Link B Spacer to Front Flipper Link B. Magnet orientation matters; see Top Level Assembly Step 7.



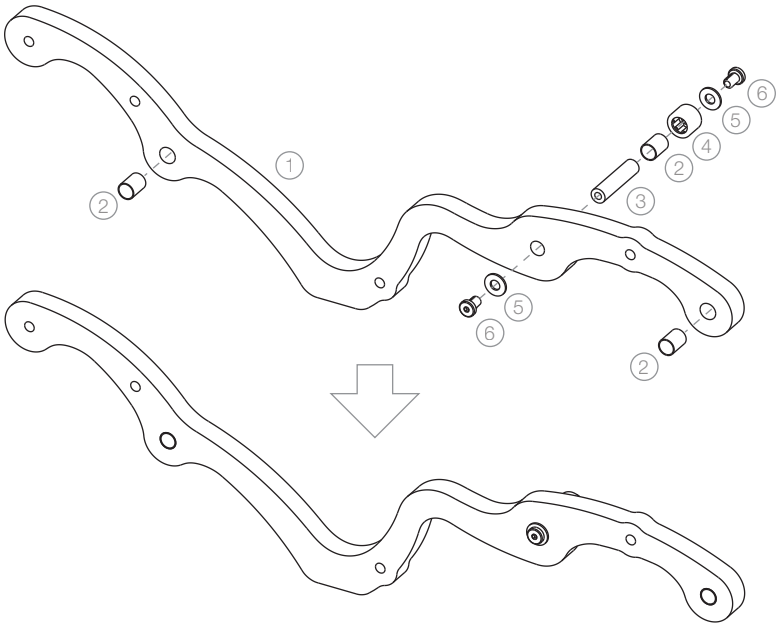
Front Flipper Link B Left Asm

1	Front Flipper Link B	1x
2	Magnet	1x
3	B Tube 3/32” x 1/4”	1x
4	Front Flipper Link B Spacer	1x
5	A Tube 1/2”	1x

Glue Front Flipper Link B Spacer to Front Flipper Link B. Magnet orientation matters; see Top Level Assembly Step 7.

Subassemblies

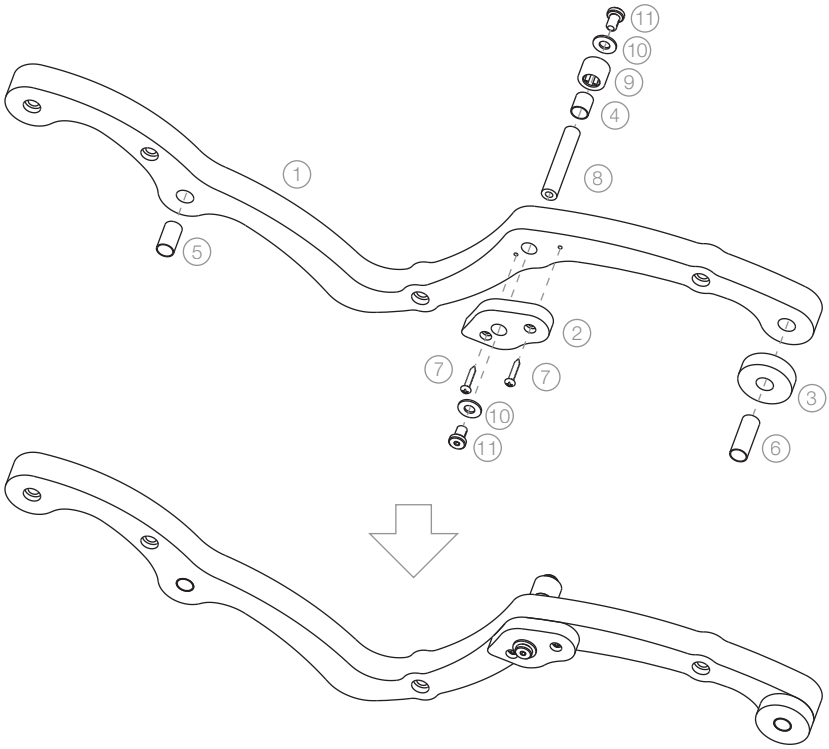
Steps 24, 25



Peau Link Left B Asm

1	Peau Link Left B	1x
2	B Tube 9/32” x 3/8”	3x
3	S Tube 1-1/16”	1x
4	Needle Bearing	1x
5	Washer #8	2x
6	LSHCS 8-32 x 1/4”	2x

Needle bearing must spin freely on the S Tube and must not bind on the B Tube.



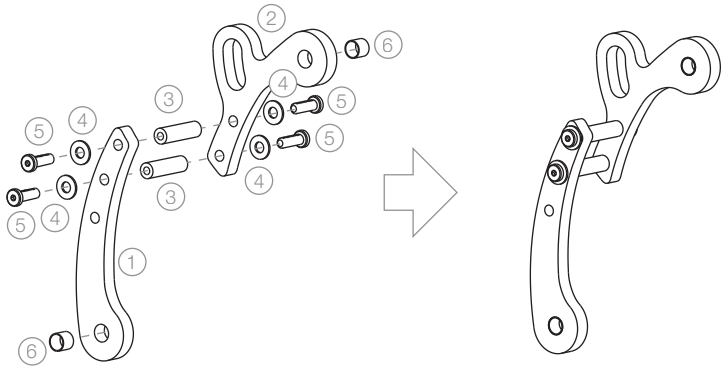
Peau Link Right B Asm

1	Peau Link Right B	1x
2	Peau Link Right B Support	1x
3	Peau Spacer Thick	1x
4	B Tube 9/32” x 5/16”	1x
5	B Tube 9/32” x 1/2”	1x
6	B Tube 9/32” x 3/4”	1x
7	Screw #2 x 1/2”	2x
8	S Tube 1-3/8”	1x
9	Needle Bearing	1x
10	Washer #8	2x
11	LSHCS 8-32 x 1/4”	2x

Needle bearing must spin freely on the S Tube and must not bind on the B Tube.

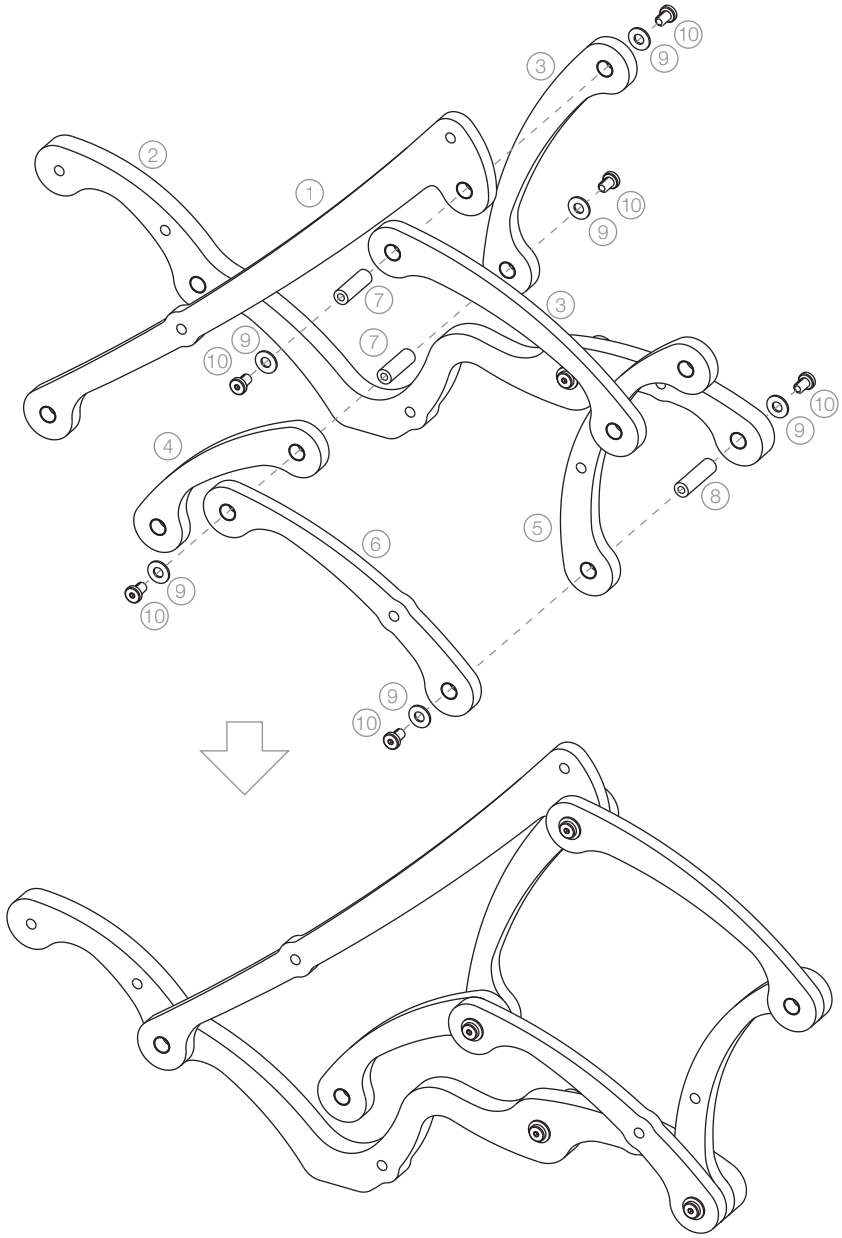
Subassemblies

Steps 26, 27



Peau Link Right G Asm

1	Peau Link Right G1	1x
2	Peau Link Right G2	1x
3	A Tube 7/8”	2x
4	Washer #8	4x
5	LSHCS 8-32 x 1/2”	4x
6	B Tube 9/32” x 1/4”	2x



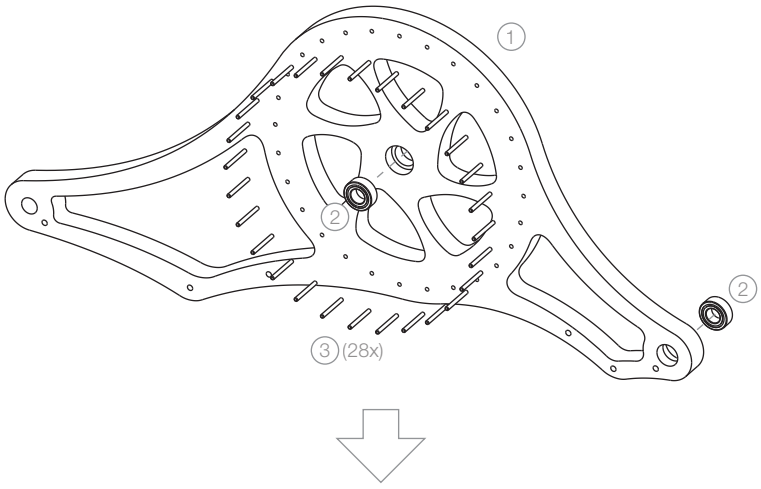
Peaucellier Linkage Left Asm

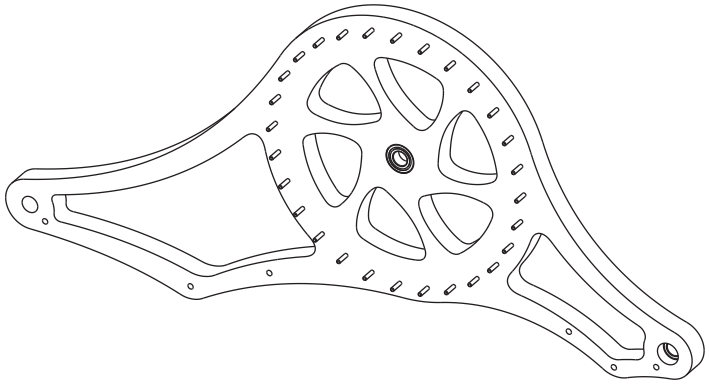
1	Peau Link Left A Asm	1x
2	Peau Link Left B Asm	1x
3	Peau Link Right Left D Asm	2x
4	Peau Link Left C Asm	1x
5	Peau Link Left G Asm	1x
6	Peau Link Right Left F Asm	1x
7	A Tube 3/4”	2x
8	A Tube 7/8”	1x
9	Washer #8	6x
10	LSHCS 8-32 x 1/4”	6x

Links must pivot freely around A Tubes and must not bind. Note that links will not stay in place until they are installed in the Top Level Assembly.

Subassemblies

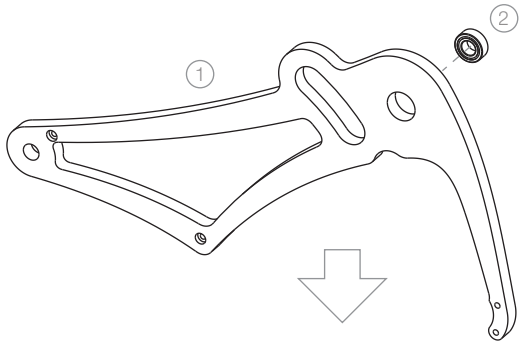
Steps 38, 39

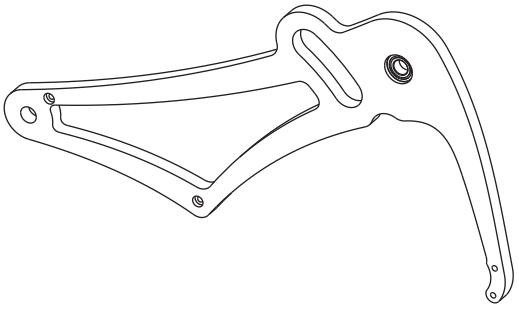




Upper Frame Asm

1	Upper Frame	1x
2	Bearing	1x
3	Rod 1/16” x 5/8”	28x





Upper Frame B Asm

1	Upper Frame B	1x
2	Bearing	1x

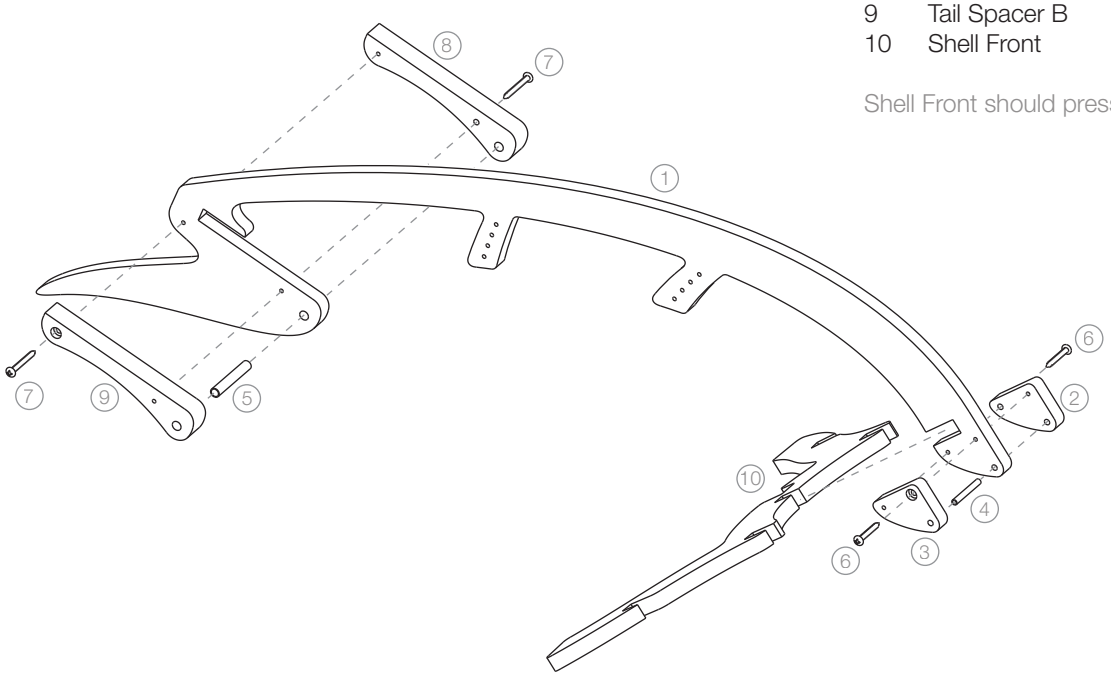
Subassemblies

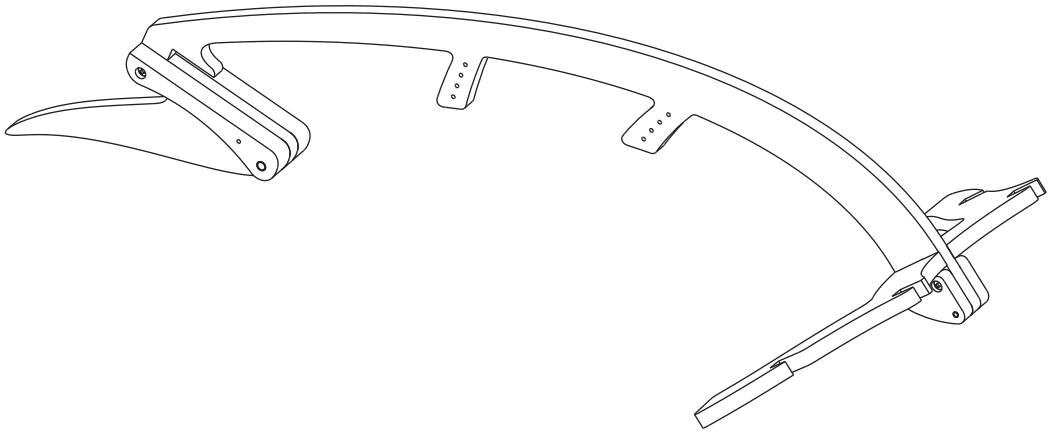
Step 40

Shell A Asm

1	Shell A	1x
2	Head Spacer A	1x
3	Head Spacer B	1x
4	B Tube 3/32” x 3/4”	1x
5	B Tube 5/32” x 1”	1x
6	Screw #2 x 5/8”	2x
7	Screw #2 x 3/4”	2x
8	Tail Spacer A	1x
9	Tail Spacer B	1x
10	Shell Front	1x

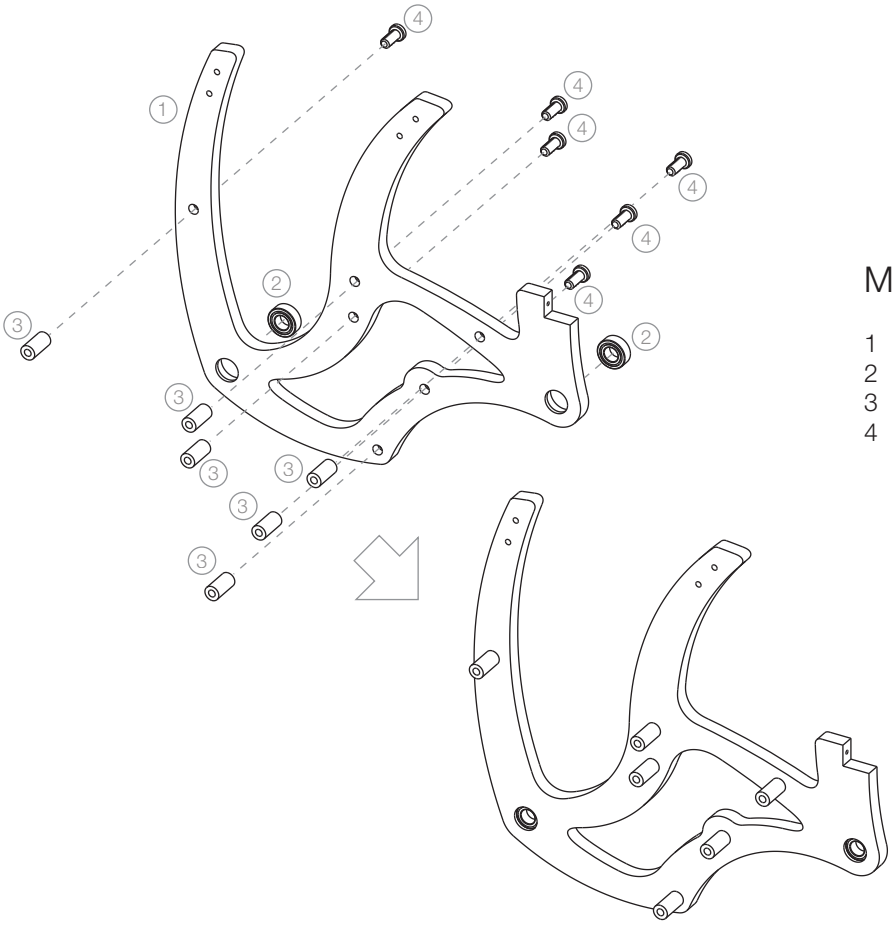
Shell Front should press firmly into place.





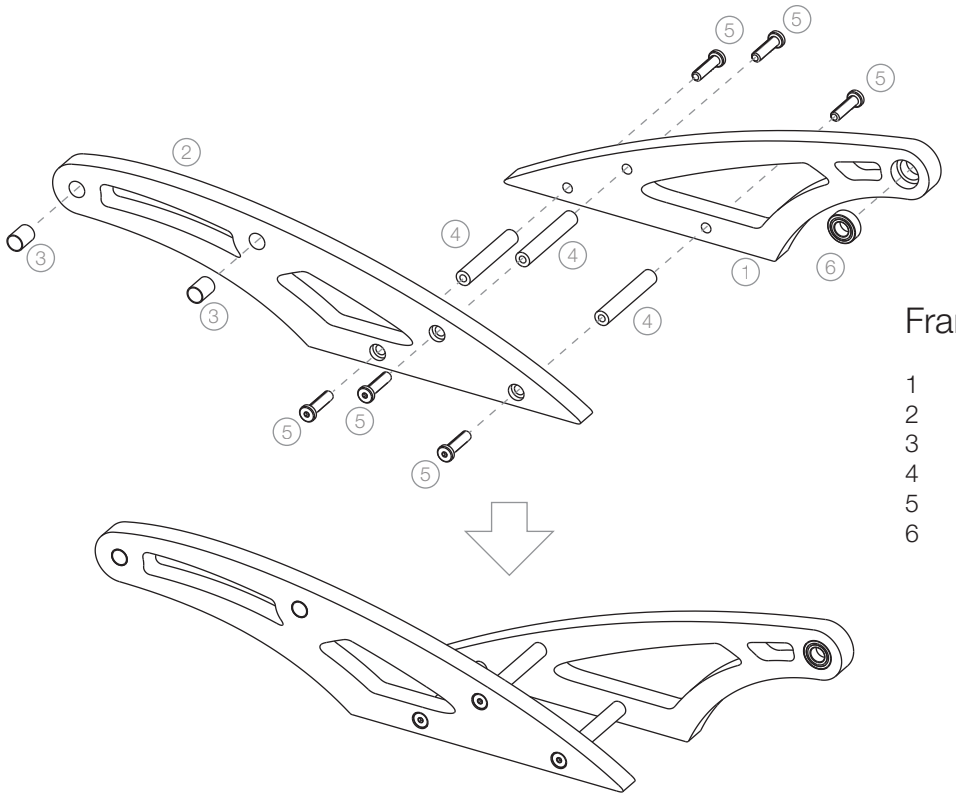
Subassemblies

Steps 49, 50



Moving Frame A Asm

1	Moving Frame A	1x
2	Bearing	2x
3	A Tube 1/2”	6x
4	LSHCS 8-32 x 3/8”	6x

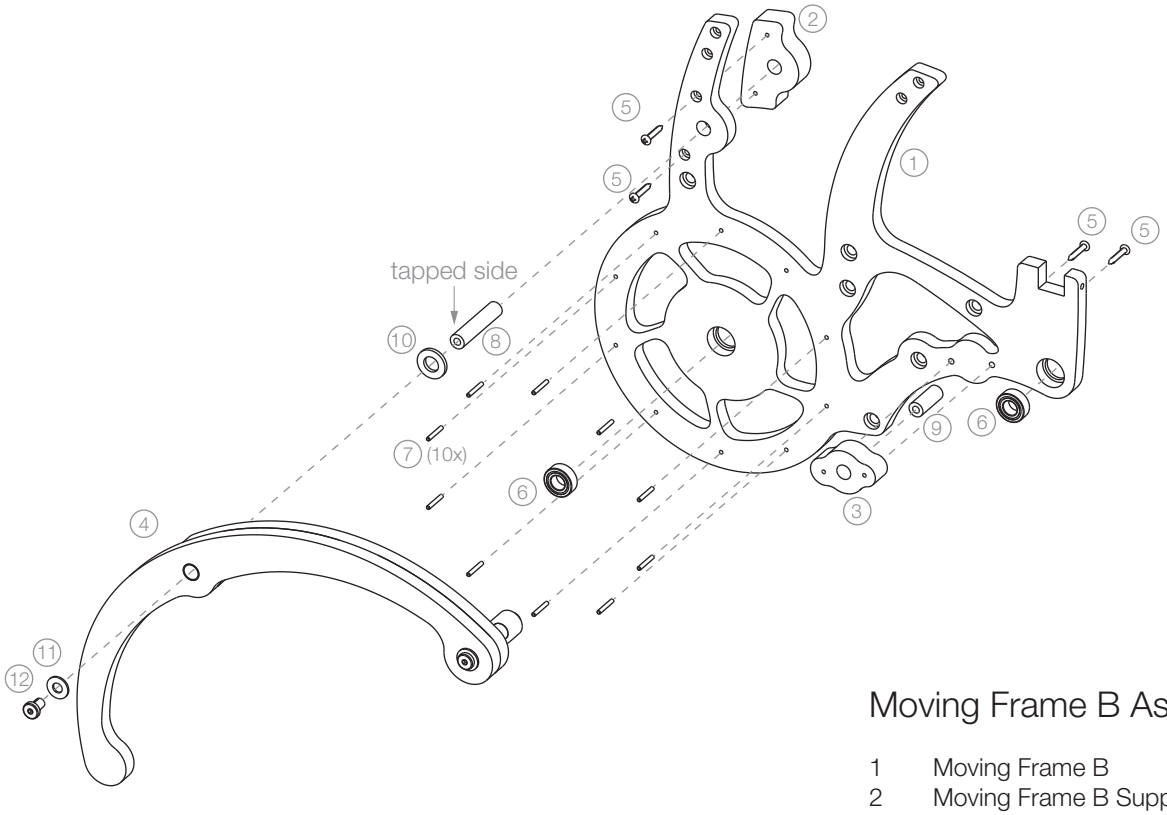


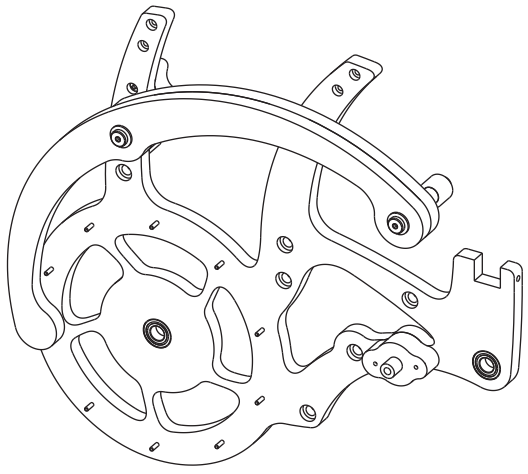
Frame CD Asm

1	Frame C	1x
2	Frame D	1x
3	B Tube 9/32” x 3/8”	2x
4	A Tube 1-1/2”	3x
5	LSHCS 8-32 x 5/8”	6x
6	Bearing	1x

Subassemblies

Step 51





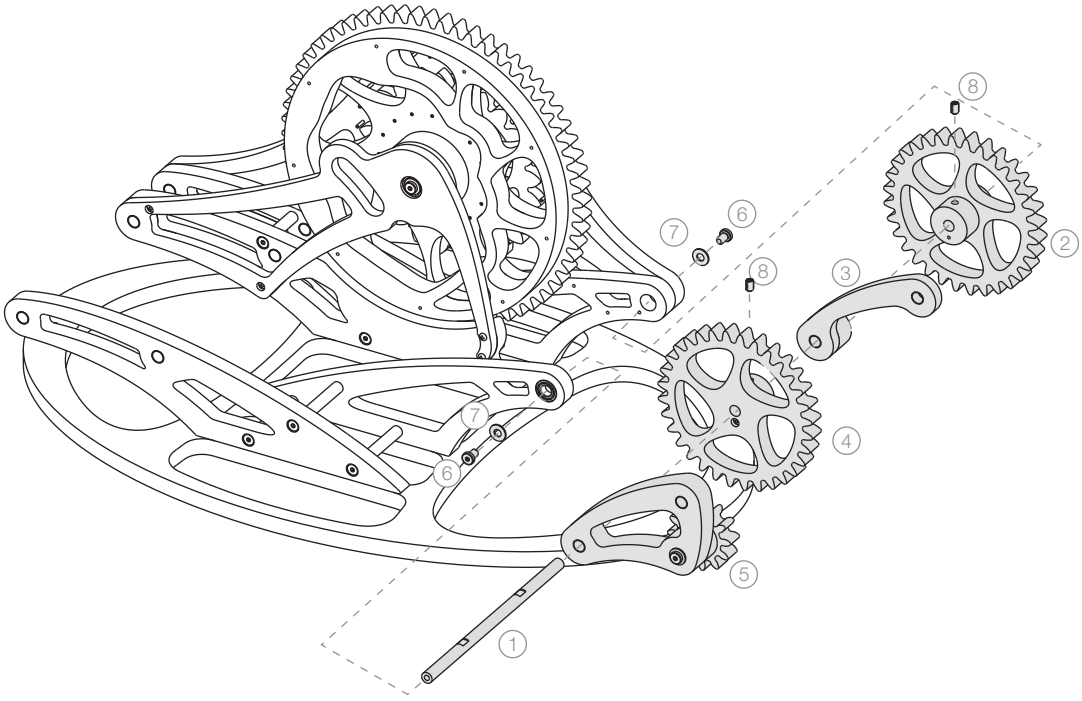
Moving Frame B Asm

1	Moving Frame B	1x
2	Moving Frame B Support	1x
3	Tilt Hard Stop Support	1x
4	Head Cam Follower Asm	1x
5	Screw #2 x 1/2”	4x
6	Bearing	2x
7	Rod 1/16” x 7/16”	10x
8	A Tube 1-3/16”	1x
9	A Tube 5/8”	1x
10	Washer 1/4”	1x
11	Washer #8	1x
12	LSHCS 8-32 x 1/4”	1x

Head Cam Follower Asm must pivot freely and must not bind.

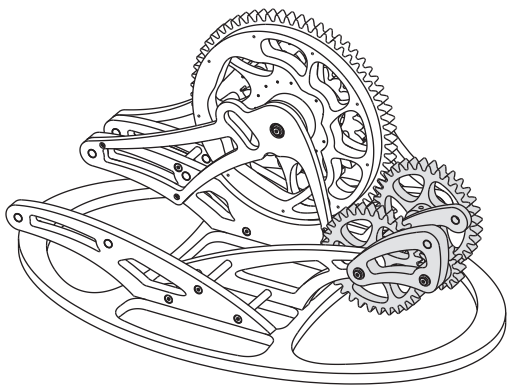
Top Level Assembly

Step 2



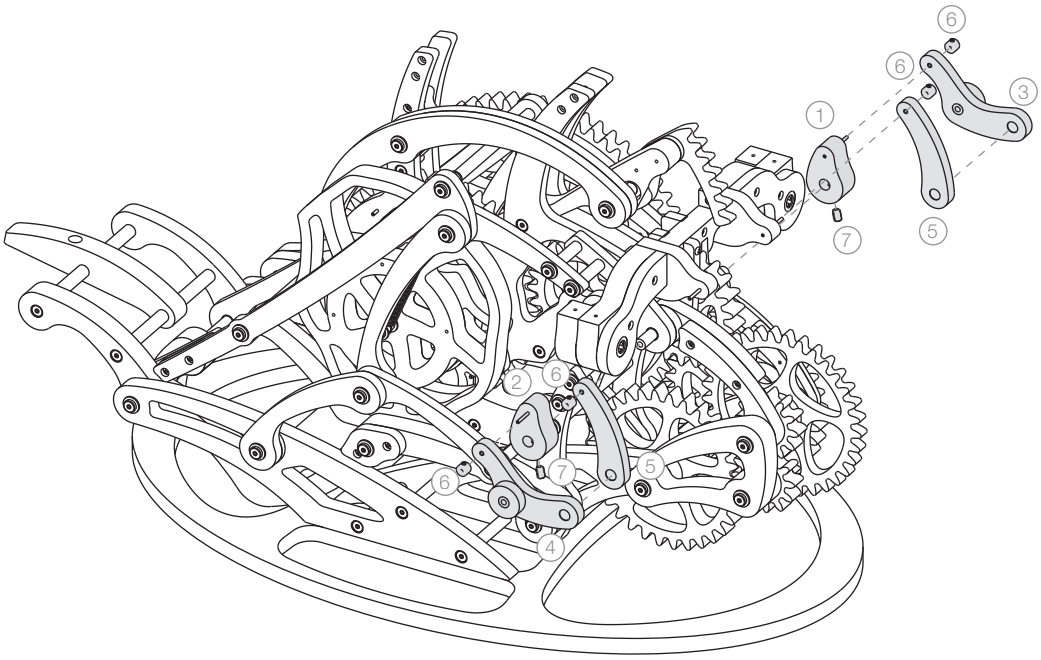
1	A Tube 5-1/2”	1x
2	Gear B Asm	1x
3	Gear Link A Asm	1x
4	Gear C Asm	1x
5	Gear Link B Asm	1x
6	LSHCS 8-32 x 1/4”	2x
7	Washer #8	2x
8	Set Screw 8-32 x 1/4”	2x

Note that links will not stay in place until Top Level Assembly Step 6.



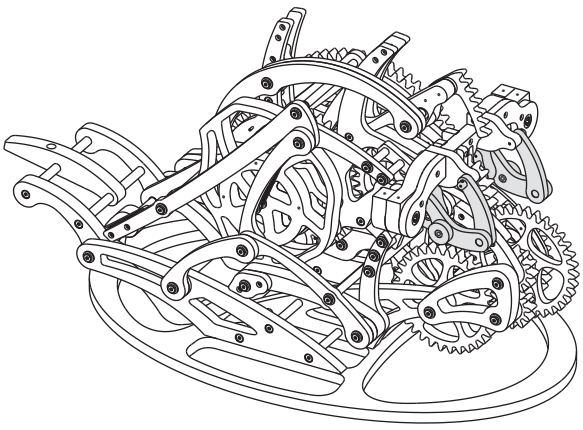
Top Level Assembly

Step 7



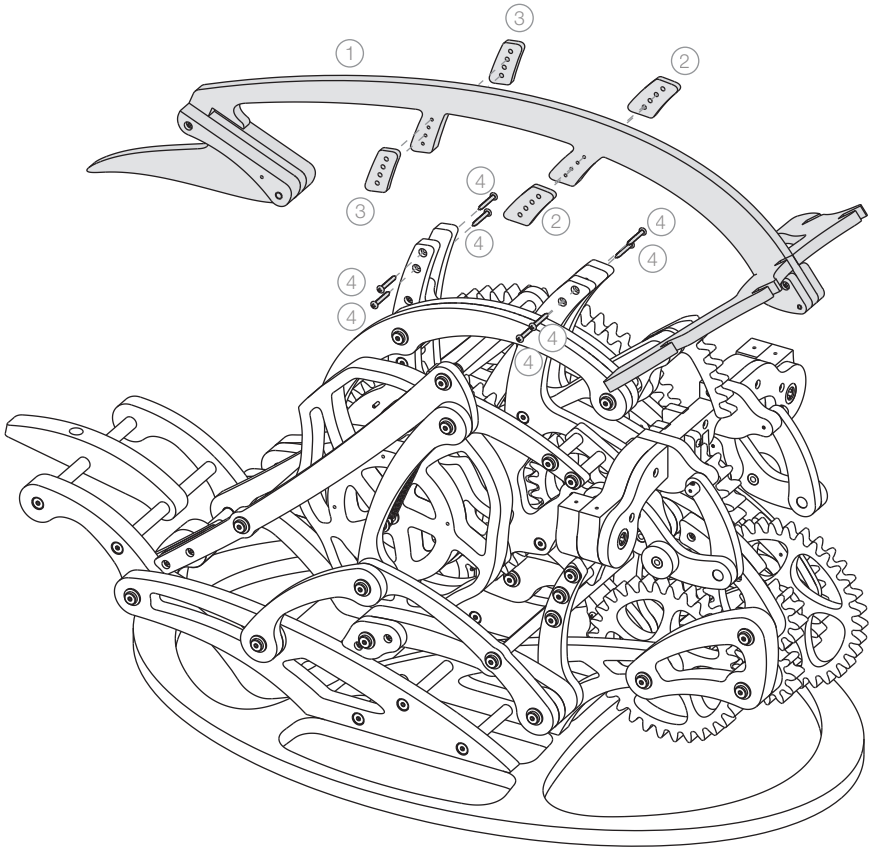
1	Front Flipper Link A Left Asm	1x
2	Front Flipper Link A Right Asm	1x
3	Front Flipper Link B Left Asm	1x
4	Front Flipper Link B Right Asm	1x
5	Front Flipper Link C Asm	2x
6	Shaft Collar	4x
7	Set Screw 8-32 x 1/4”	2x

Ensure Magnets are oriented such that the links attract to each other.

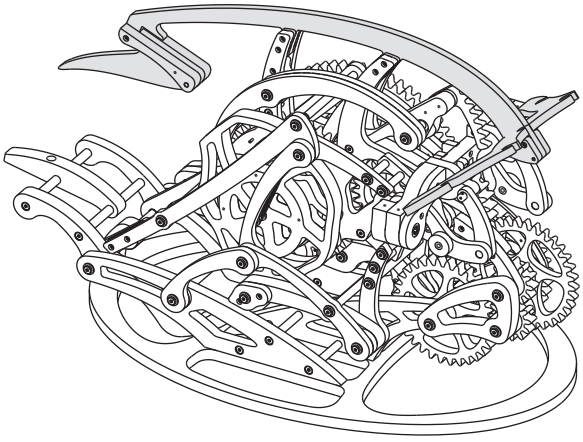


Top Level Assembly

Step 8

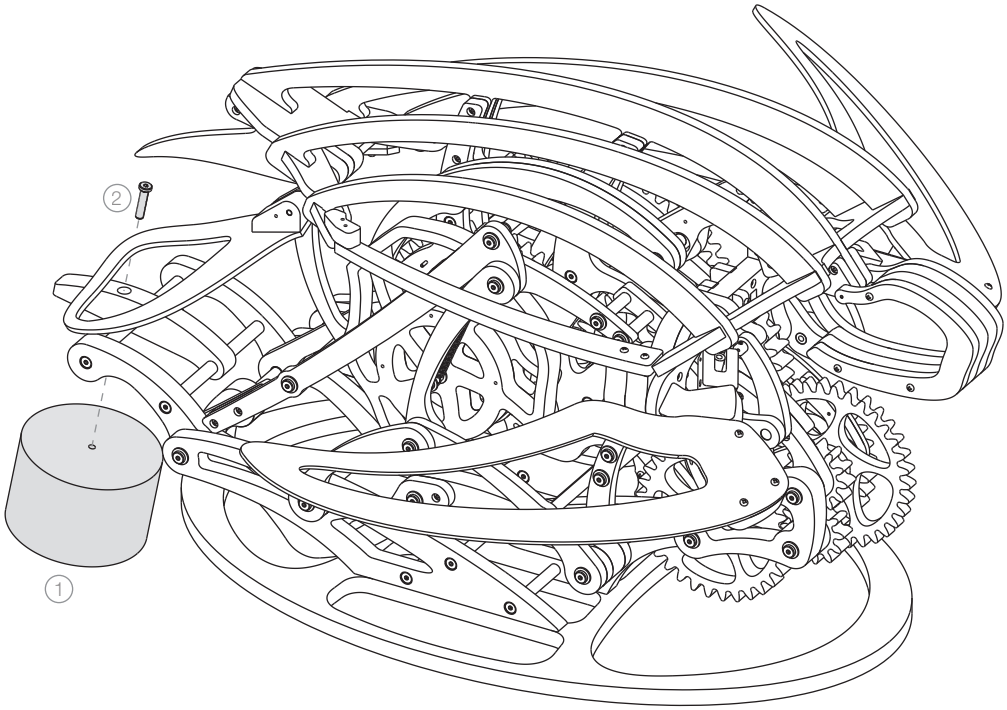


1	Shell A Asm	1x
2	Shell Spacer A	2x
3	Shell Spacer B	2x
4	Screw #2 x 5/8”	8x

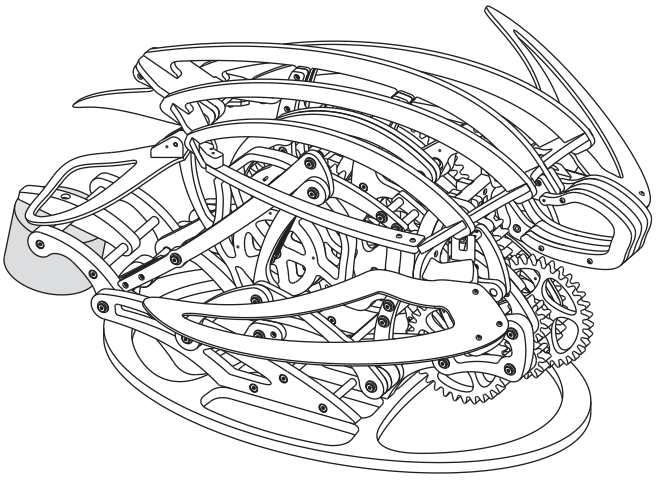


Top Level Assembly

Step 13



1	Counterweight	1x
2	LSHCS 8-32 x 3/4”	1x



After completing the Carapace Top Level Assembly, see Mechanism Timing in Tips + Tactics to ensure that all of Carapace’s motions are accurate to the design intent.