

sample

Important:

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.

Zybach

a mechanical clock

design by Derek Hugger

The Basics

Contents

These plans include all the information required to build Zybach. 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. Cut and tap all aluminum tubes, brass tubes, and stainless steel. See Plywood Thickness Compensation in Tips + Tactics.
5. Following the assembly instructions, build all subassemblies and then the Top Level Assembly.
6. Cut the Main Weight based on the Weight of the Weight instructions in Tips + Tactics.
7. If desired, disassemble Zybach to finish its components. Note that stain and other finish options can affect the thickness of parts and may also effect friction levels between moving parts.

Notes

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

Zybach 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

Power Tools

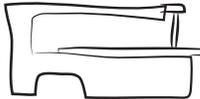
General

Drivers

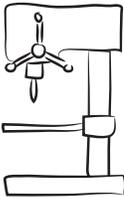
Required



bandsaw



scroll saw



drill press



belt/disc sander



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



drill bits #29*
7/32*
25/64*



taps 8-32*
1/4-20*



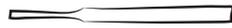
hacksaw



clamps



calipers



precision files



phillips #1



hex 5/64"

Supplies



sandpaper



wood glue



spray adhesive

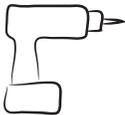


monofilament
(fishing line)

Recommended
(but not required)



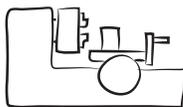
mini chop saw



drill



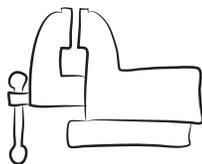
rotary tool



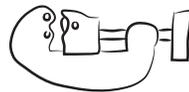
metal lathe



cnc router**



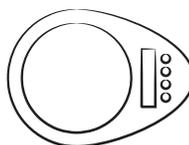
vice



tube cutter



reamers
0.1280", 0.2530"



kitchen scale or balance



awl

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

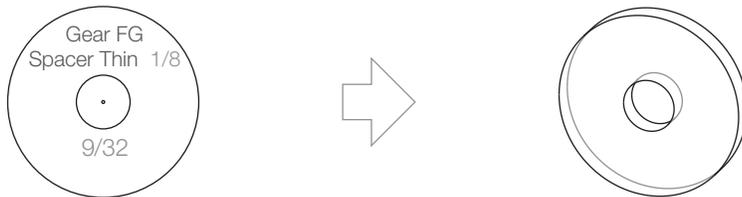
** A CNC router is an optional replacement for the bandsaw and scroll saw for cutting the plywood parts.

Tips + Tactics

Pattern Syntax

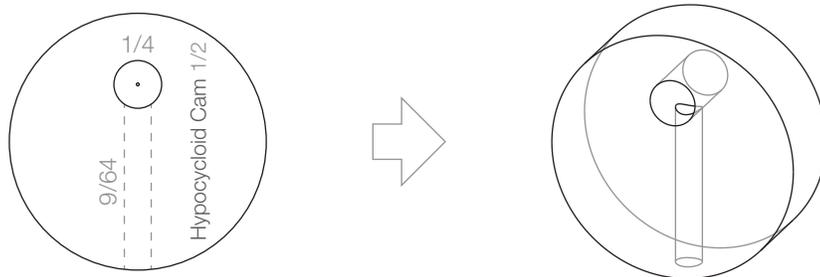
Patterns are labeled with a part name followed by a thickness dimension.

Example: Gear FG Spacer Thin is cut from 1/8" plywood. It also has a hole to be drilled thru with a 9/32" bit.



Dashed lines indicate a hole drilled from the side, centered on the thickness of the part.

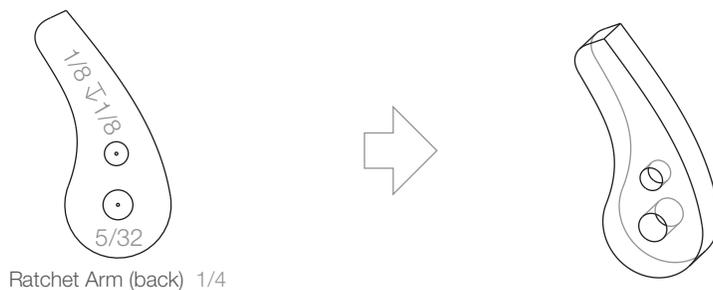
Example: Hypocycloid Cam has a 9/64" hole drilled from the side. It also has a 1/4" thru hole drilled from the front.



A \Downarrow symbol indicates drilling to a certain depth, not thru.

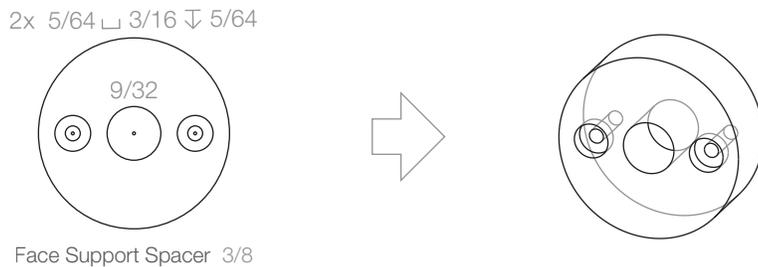
Example: Ratchet Arm has a 1/8" hole drilled 1/8" deep. It also has a 5/32" thru hole.

As indicated by "(back)", this pattern shows the back side of the part.



Two concentric circles indicate a hole with a counterbore.

Example: Face Support Spacer has two 5/64" holes with a 3/16" counterbore drilled 5/64" deep. It also has a 9/32" thru hole.



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 Zybach's metal parts.

Not Quite Clearance Holes

To ensure maximum clamping force when using a screw to fasten two parts together, it is best practice to have a clearance hole in one part and a threaded hole in the other. However, because Zybach uses such small screws in wood, this otherwise good practice can easily lead to stripping out holes in the plywood parts. Even a minimal amount of over tightening can strip out a hole. To help reduce the risk of stripping out holes, Zybach's patterns specify holes that are not quite clearance holes. That is, they are sized to allow for slight thread engagement. As a result, when all the threads of the screw are engaged, and the screw head bottoms out on the wood, more force is required to strip the wood. This also makes it easier for the builder to know when to stop tightening. Though the screw may not clamp as tightly with this "not quite clearance" method, simply squeezing the parts together by hand as they are fastened will more than suffice.

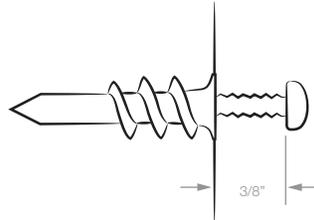
Wall Mounting

Use the Wall Mount Template as a guide for locating Zybach's three mounting points on a wall. Mount into studs or use appropriate anchors to ensure that Zybach will not fall or otherwise separate from the wall. The mounts must support Zybach's weight plus several additional pounds applied while winding.

Zybach should be mounted to a wall prior to completing the top level assembly. Mount the assembly any time between Top Level Assembly Step 1 and Step 6.

As Zybach is weight driven, its height on the wall will directly impact its run time. For a 30 hour run time, drill Zybach's mounting holes such that the indicated line on the Wall Mount Template is 67" from the floor.

Ensure that the mounting screws fully engage the studs or anchors while maintaining a 3/8" gap from the wall to the head of each screw.



Weight of the Weight

To ease the amount of stress applied to Zybach, less weight is best. Zybach should not require more than 7 lbs to run. To determine exactly how much weight is required, assemble the entire system with the exception of the Main Weight. Hang an empty jar or canister from the Wind Cord that the Main Weight will ultimately attach to. Slowly add mass to the jar. Coins or BBs work well. Continue adding mass in small increments until a strong and consistent tick is achieved and the clock runs reliably without stopping.

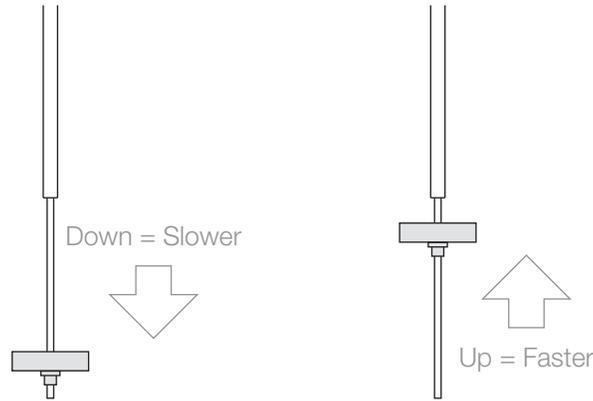
Weigh the jar of coins/BBs, and then weigh and measure the length of the 2" stainless steel cylinder.
The cut length of the cylinder to make the Main Weight = (jar weight / cylinder weight) * cylinder length

Note that when drilling and tapping the Main Weight, the hole must be centered. Any offset will cause the Main Weight to hang at a slant.

Tips + Tactics

Time Tuning

To adjust Zybach's timing, adjust the Pendulum Weight and Thumb Screw. If the clock is running too quickly, slow it down by moving the Pendulum Weight and Thumb Screw down. If the clock is running too slowly, speed it up by moving the Pendulum Weight and Thumb Screw up. Note that very small changes in position can make a difference.



Once proper timing is achieved, tighten the Pendulum Weight and Thumb Screw against each other. This will help keep them from lowering unintentionally over time.

Escapement Tuning

For optimal performance, a steady and even “tick tock” is desired. To adjust the timing of the escapement mechanism, remove the Main Weight, slightly loosen the Set Screw in the Pallet Asm and adjust the angle of the Pallet relative to the Pendulum Link Asm (see Top Level Assembly Step 6). Note that very small angle adjustments can result in large changes in the escapement timing. Adjust the angle such that the timing between each “tick” and “tock” is as equal as possible.

- ✓ Tick.....Tock.....Tick.....Tock.....Tick.....Tock
- ✗ Tick...Tock.....Tick...Tock.....Tick...Tock.....
- ✗ Tick.....Tock..Tick.....Tock..Tick.....Tock..

General Operation

To set the time, turn the Minute Hand clockwise or counterclockwise. Always let the Minute Hand drive the Hour Hand. Never turn the hour hand directly, as doing so will damage the hypocycloid mechanism.

To wind Zybach, stop the Pendulum. Lift the Main Weight and gently pull down on the Wind Weight. Do not pull the Wind Weight without lifting the Main Weight, as this can put undue stress on the components. Once wound, gently release the Main Weight. Never allow the Main Weight to drop suddenly. Doing so will damage Zybach.

To start Zybach, gently push the Pendulum. Note that very little force is needed.

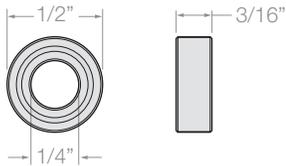
Parts + Assemblies List

Type	Description	Qty	Type	Description	Qty	Type	Description	Qty
Aluminum Tube	A Tube 1/4" x 1/2"	2	Plywood 1/8"	Gear BC Spacer	1	Subassembly	Escapement Wheel Asm	1
Aluminum Tube	A Tube 1/4" x 1-3/4"	1	Plywood 1/8"	Gear FG Spacer Thin	2	Subassembly	Face Asm	1
Aluminum Tube	A Tube 1/4" x 2-1/2"	4	Plywood 1/8"	Hand Spacer	1	Subassembly	Face Spacer Asm	1
Aluminum Tube	A Tube 1/4" x 4-1/8"	1	Plywood 1/8"	Pendulum Pivot Mount Front Spacer	1	Subassembly	Face Support Asm	1
			Plywood 1/8"	Pendulum Pivot Mount Rear Spacer	1	Subassembly	Frame Asm	1
Brass Tube	B Tube 5/32" x 1/4"	3	Plywood 1/8"	Wind Wheel Large	3	Subassembly	Gear A Asm	1
Brass Tube	B Tube 9/32" x 1/2"	1	Plywood 1/8"	Wind Wheel Small	2	Subassembly	Gear BC Asm	1
Brass Tube	B Tube 9/32" x 5/8"	2	Plywood 1/8"	Wind Wheel Spacer	1	Subassembly	Gear DE Asm	1
Brass Tube	B Tube 9/32" x 3/4"	2				Subassembly	Gear FG Asm	1
Brass Tube	B Tube 9/32" x 1"	1	Plywood 1/4"	Face Spacer Thin	1	Subassembly	Hour Hand Asm	1
Brass Tube	B Tube 9/32" x 1-1/2"	1	Plywood 1/4"	Gear C	1	Subassembly	Hypocycloid Gear Asm	1
Brass Tube	B Tube 9/32" x 1-3/4"	1	Plywood 1/4"	Gear E	1	Subassembly	Main Weight Asm	1
			Plywood 1/4"	Gear E Spacer	1	Subassembly	Pallet Asm	1
Stainless Steel Rod	Rod 1/16" x 3/8"	8	Plywood 1/4"	Gear G	1	Subassembly	Pendulum Asm	1
Stainless Steel Rod	Rod 1/16" x 5/8"	12	Plywood 1/4"	Hypocycloid Gear B	1	Subassembly	Pendulum Link Asm	1
Stainless Steel Rod	Rod 1/8" x 3/4"	3	Plywood 1/4"	Pendulum Pivot Front	1	Subassembly	Pendulum Pivot Front Asm	1
			Plywood 1/4"	Pendulum Pivot Rear	1	Subassembly	Pendulum Pivot Rear Asm	1
Stainless Steel	Main Weight	1	Plywood 1/4"	Pin Plate	1	Subassembly	Ratchet Arm Asm	3
Stainless Steel	Pendulum Weight	1	Plywood 1/4"	Ratchet Arm	3	Subassembly	Wind Wheel Asm	1
Stainless Steel	Wind Weight	1	Plywood 1/4"	Ratchet Wheel	1			
						Top Level Asm	Zybach	1
Hardware	Bearing	2	Plywood 3/8"	Escapement Wheel	1			
Hardware	Eyebolt	1	Plywood 3/8"	Face	1			
Hardware	Leather Plug	1	Plywood 3/8"	Face Spacer Thick	1			
Hardware	LSHCS 8-32 x 1/4"	12	Plywood 3/8"	Face Support Spacer	1			
Hardware	LSHCS 8-32 x 1/2"	2	Plywood 3/8"	Hour Hand	1			
Hardware	LSHCS 8-32 x 3/4"	5	Plywood 3/8"	Hypocycloid Gear A	1			
Hardware	LSHCS 8-32 x 1"	3	Plywood 3/8"	Minute Hand	1			
Hardware	Magnet	6	Plywood 3/8"	Pallet	1			
Hardware	Screw #2 x 1/2"	13	Plywood 3/8"	Pallet Spacer	1			
Hardware	Screw #2 x 3/4"	12	Plywood 3/8"	Pendulum Link	1			
Hardware	Set Screw	7	Plywood 3/8"	Pendulum Pivot Mount Front	1			
Hardware	Threaded Rod	1						
Hardware	Thumb Nut	1	Plywood 1/2"	Face Support	1			
Hardware	VSHCS 1/4-20 x 3/8"	1	Plywood 1/2"	Frame	1			
Hardware	Washer	2	Plywood 1/2"	Frame Spacer	3			
Hardware	Wind Cord	1	Plywood 1/2"	Frame Support	1			
			Plywood 1/2"	Gear A	1			
			Plywood 1/2"	Gear B	1			
			Plywood 1/2"	Gear D	1			
			Plywood 1/2"	Gear F	1			
			Plywood 1/2"	Gear FG Spacer Thick	1			
			Plywood 1/2"	Gear H	1			
			Plywood 1/2"	Hypocycloid Cam	1			
			Plywood 1/2"	Pendulum Mount	1			
			Plywood 1/2"	Pendulum Pivot Mount Rear	1			
			Dowel 3/8"	Pendulum	1			

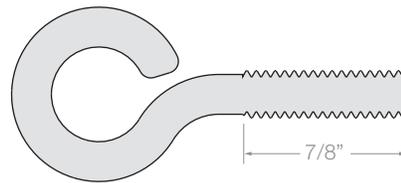
Hardware

Description	Qty	McMaster Carr P/N *
Bearing (see image below)	2	57155K376
Eyebolt (see image below)	1	9489T517
Leather Plug** ~1/8" x 1/8" x 1/8"	1	-
LSHCS 8-32 x 1/4" Low Socket Head Cap Screw	12	93615A317
LSHCS 8-32 x 1/2" Low Socket Head Cap Screw	2	93615A320
LSHCS 8-32 x 3/4" Low Socket Head Cap Screw	5	93615A323
LSHCS 8-32 x 1" Low Socket Head Cap Screw	3	93615A324
Magnet Neodymium, Ø1/8" x 1/8"	6	5862K61
Screw, #2 x 1/2" Pan Head Self Tapping Screw	13	92470A098
Screw, #2 x 3/4" Pan Head Self Tapping Screw	12	92470A103
Set Screw 8-32 x 1/4"	7	92311A190
Threaded Rod 8-32 x 6"	1	95412A821
Thumb Nut 8-32	1	92533A103
VSHCS 1/4-20 x 3/8" Vented Socket Head Cap Screw	1	93235A534
Washer #8 (outer Ø 3/8, inner Ø 0.174")	2	90107A010
Wind Cord Braided Nylon Squidding Line 45 lb Minium length: 12 feet	1	available from amazon.com

Bearing Double Shielded, ABEC-5

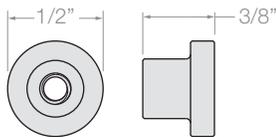


Eyebolt 1/4-20 thread



7/8" threaded area may be cut shorter to reduce the required depth of the tapped hole in the Main Weight.

Thumb Nut 8-32



If a Thumb Nut is unavailable, any 8-32 nut may be used.

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

** Exact dimensions are not critical. Leather can be cut from any stock, or from an old belt.

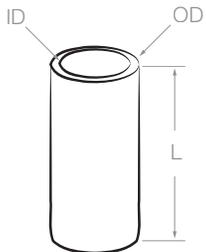
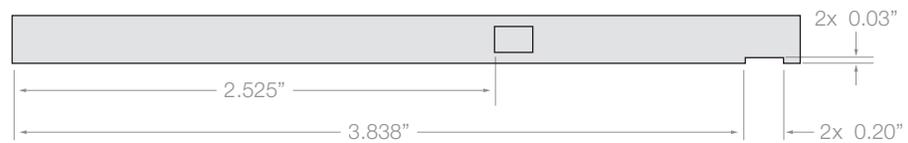
Metal

Rods + Tubes

Description	Material	OD x L *	ID	Qty	Tap**	McMaster Carr P/N ***
B Tube 5/32" x 1/4"	Brass	5/32" x 1/4"	0.128"	3	-	8859K21
B Tube 9/32" x 1/2"	Brass	9/32" x 1/2"	0.253"	1	-	8859K25
B Tube 9/32" x 5/8"	Brass	9/32" x 5/8"	0.253"	2	-	
B Tube 9/32" x 3/4"	Brass	9/32" x 3/4"	0.253"	2	-	
B Tube 9/32" x 1"	Brass	9/32" x 1"	0.253"	1	-	
B Tube 9/32" x 1-1/2"	Brass	9/32" x 1-1/2"	0.253"	1	-	
B Tube 9/32" x 1-3/4"	Brass	9/32" x 1-3/4"	0.253"	1	-	
Rod 1/16" x 3/8"	Stainless Steel	1/16" x 3/8"	-	8	-	90145A417
Rod 1/16" x 5/8"	Stainless Steel	1/16" x 5/8"	-	12	-	90145A421
Rod 1/8" x 3/4"	Stainless Steel	1/8" x 3/4"	-	3	-	90145A473
A Tube 1/4" x 1/2"	Aluminum	1/4" x 1/2"	0.120"	2	thru	4568T11
A Tube 1/4" x 1-3/4"	Aluminum	1/4" x 1-3/4"	0.120"	1	one side	
A Tube 1/4" x 2-1/2"	Aluminum	1/4" x 2-1/2"	0.120"	4	one side	
A Tube 1/4" x 4-1/8"	Aluminum	1/4" x 4-1/8"	0.120"	1	both sides	

A Tube 1/4" x 4-1/8"

Cut or file the flats shown below. Flats must be 90° apart.



OD outer diameter
 ID inner diameter
 L length

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

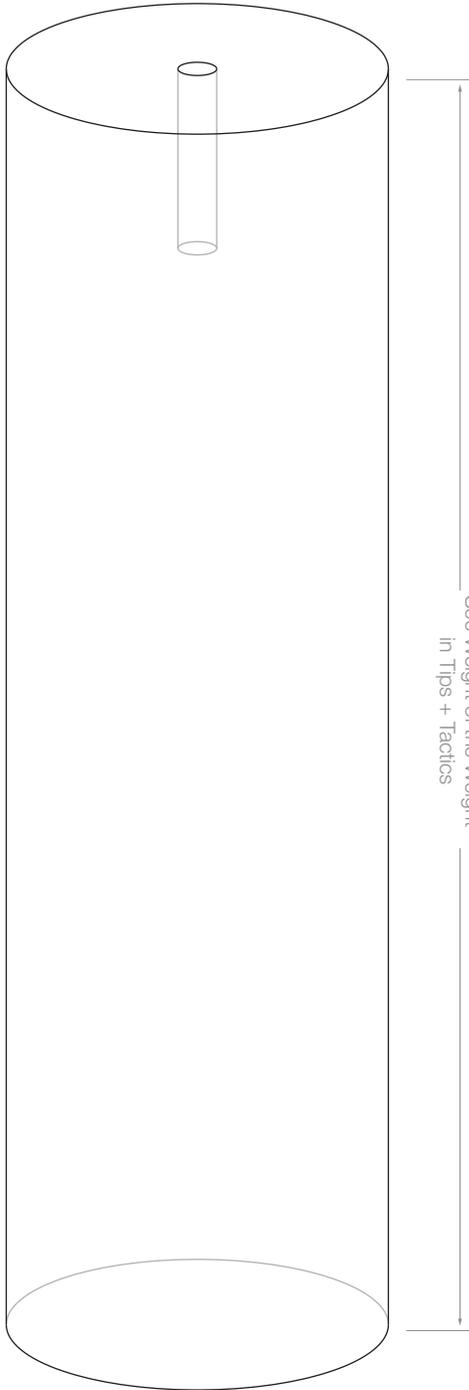
** Expand 0.120" tube ID with a #29 drill bit and then tap for 8-32 thread. Minimum thread depth: 1/2".

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

Metal Weights

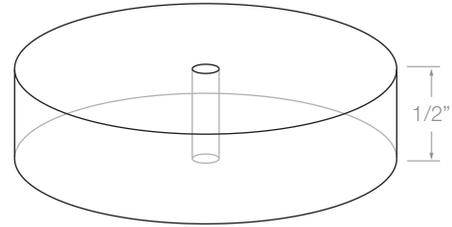
Pilot hole: 13/64"
Tap for 1/4-20 thread.

Minimum thread depth without cutting Eyebolt: 7/8"
Eyebolt may be cut short if a 7/8" depth cannot be achieved.



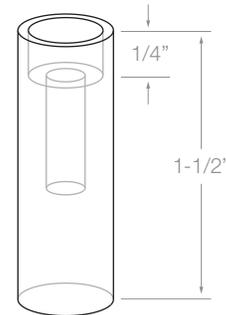
Main Weight
Ø2" Stainless Steel
McMaster P/N: 8984K57

Pilot hole: #29 drill
Tap thru for 8-32 thread.



Pendulum Weight
Ø2" Stainless Steel
Cut from cylinder used for Main Weight.

Pilot hole: 13/64"
Tap for 1/4-20 thread.
Minimum thread depth: 3/8"
Counterbore: 25/64"



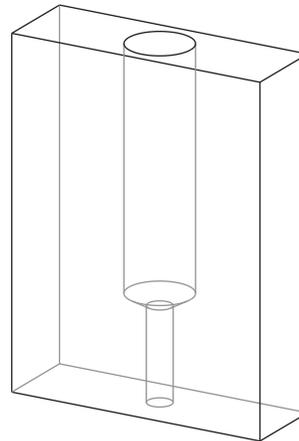
Wind Weight
Ø1/2" Stainless Steel
McMaster P/N: 8984K83

- Cobalt steel drill bits and taps are required for cutting stainless steel. Standard bits and taps will not work well if at all.
- Weights may be made from steel or brass if desired.
- All holes must be perfectly centered. If holes are not drilled on center, the weights will hang at a slant.

Pendulum



Pendulum $\text{Ø}3/8"$
Pilot holes $9/64$
Tap both sides for 8-32 thread.

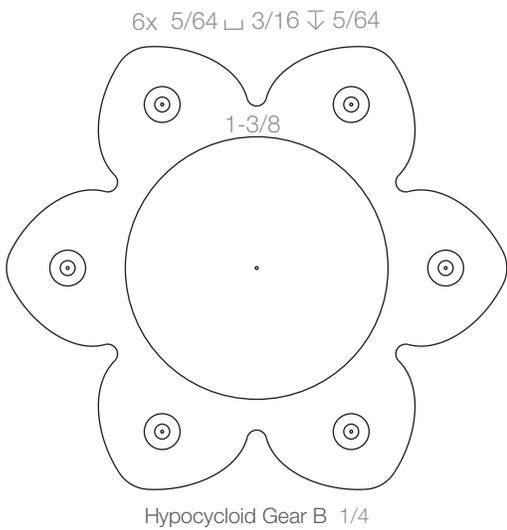
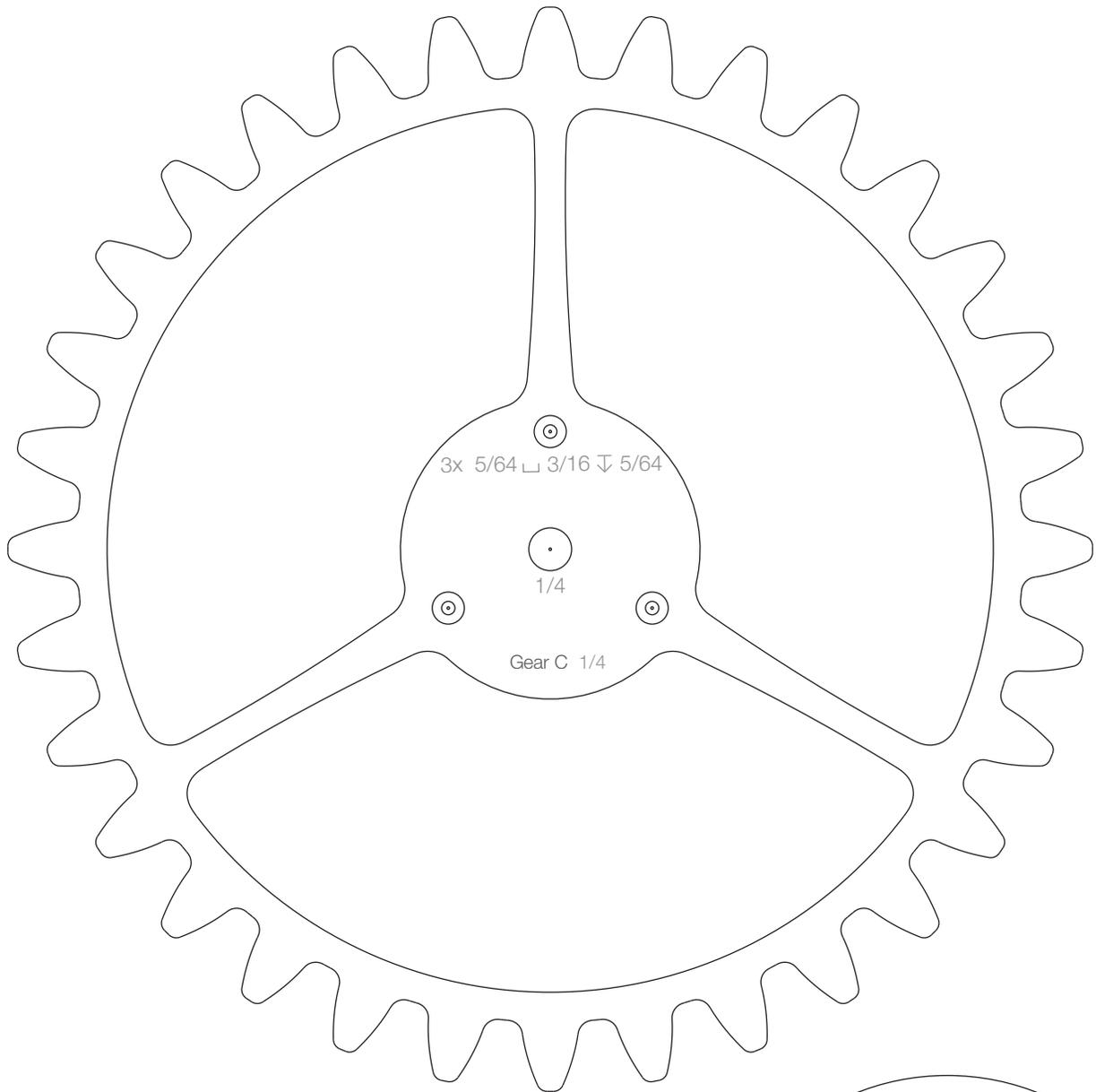


Pendulum Jig
Drill a $3/8"$ hole, 1.5" deep into $1/2"$ plywood.
Then, drill a $9/64"$ hole the rest of the way through. Insert the Pendulum into the $3/8"$ end, and use the $9/64"$ end to drill into the Pendulum using a hand drill.

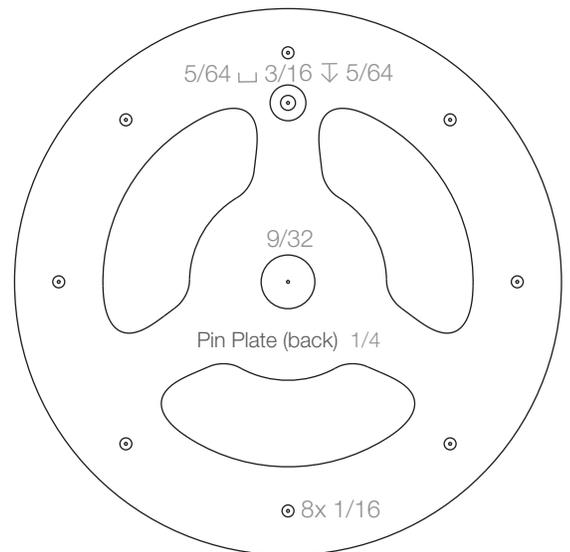
As dowels can split easily, it is not recommended to use untapped $9/64"$ holes like those used for set screws in the plywood parts. Instead, drill the $9/64"$ holes and then tap both ends of the pendulum for an 8-32 thread. As tapping wood will leave minimal diametric thread engagement, it is important to not overtighten the Pendulum's mating parts.

The holes must be drilled centered and straight. If a lathe is not available for doing this, the above jig can be made to help drill straight and centered holes in the pendulum.

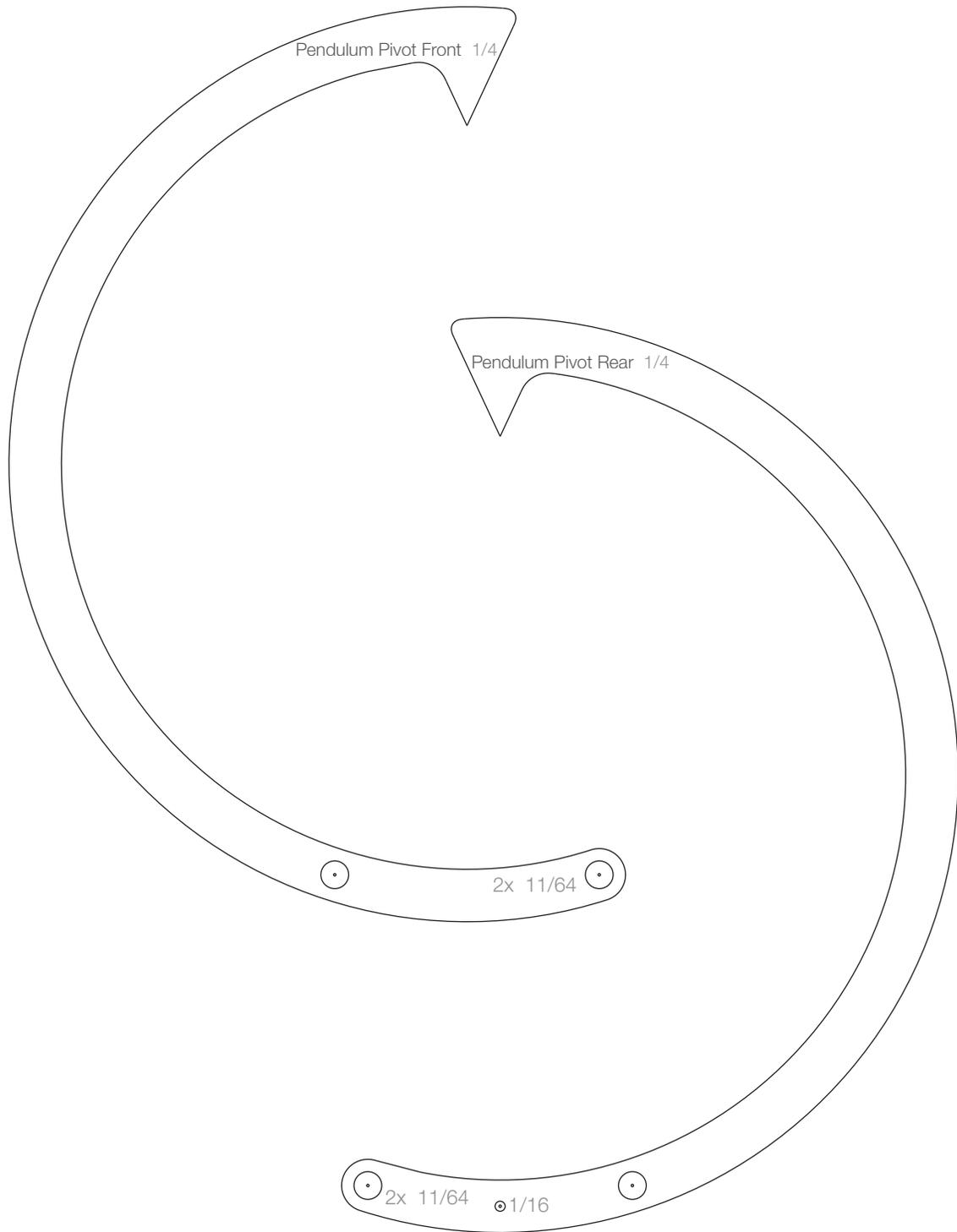
Scale reference. To measure exactly six inches when printed.



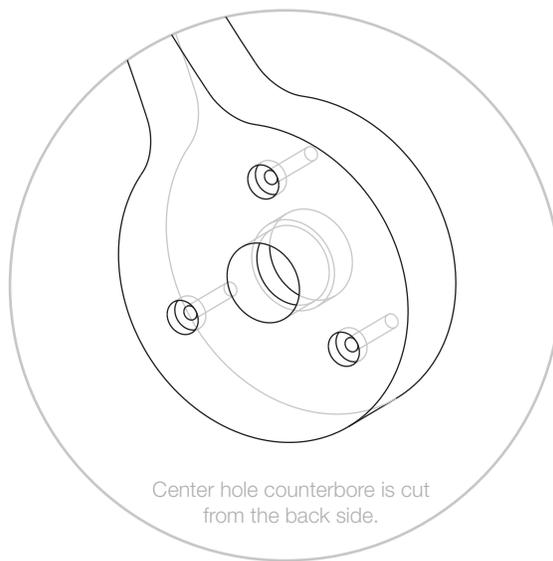
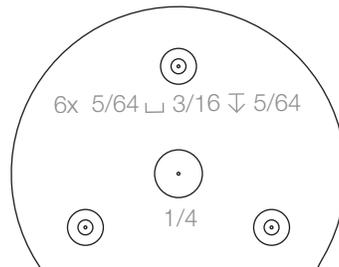
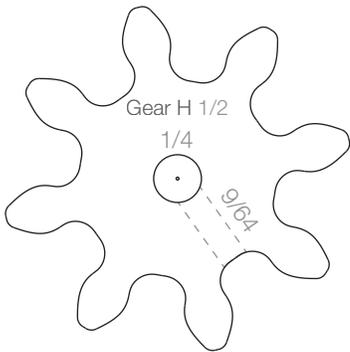
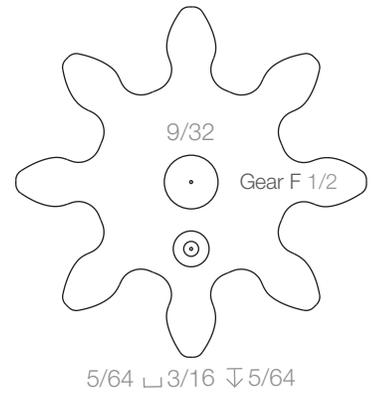
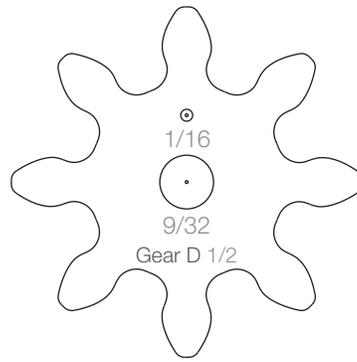
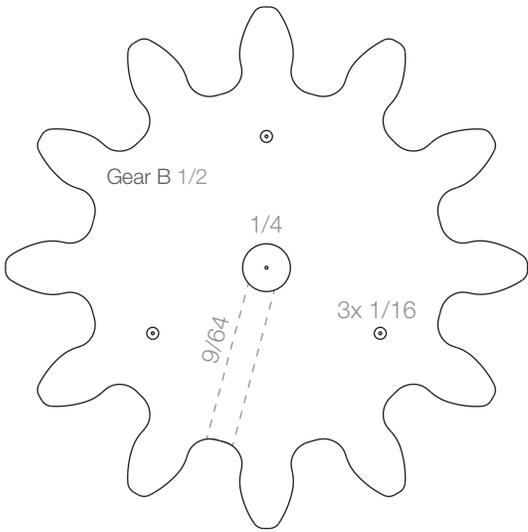
Hypocycloid Gear B 1/4



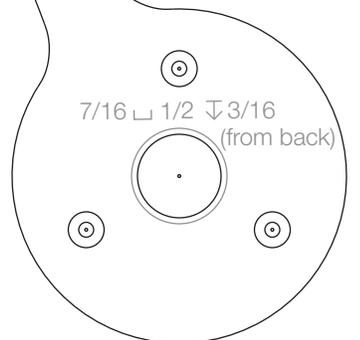
Scale reference. To measure exactly six inches when printed.



Scale reference. To measure exactly six inches when printed.



Frame Support 1/2



Wall Mount Template

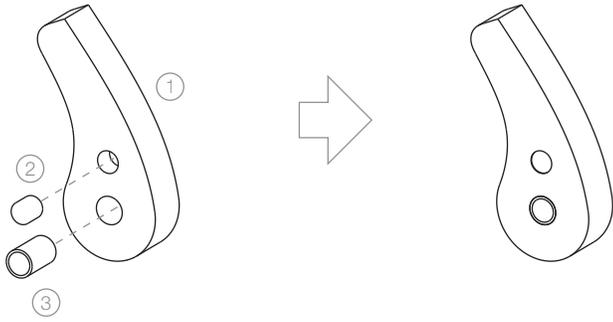


Level this line. This line to be 67" from the floor.



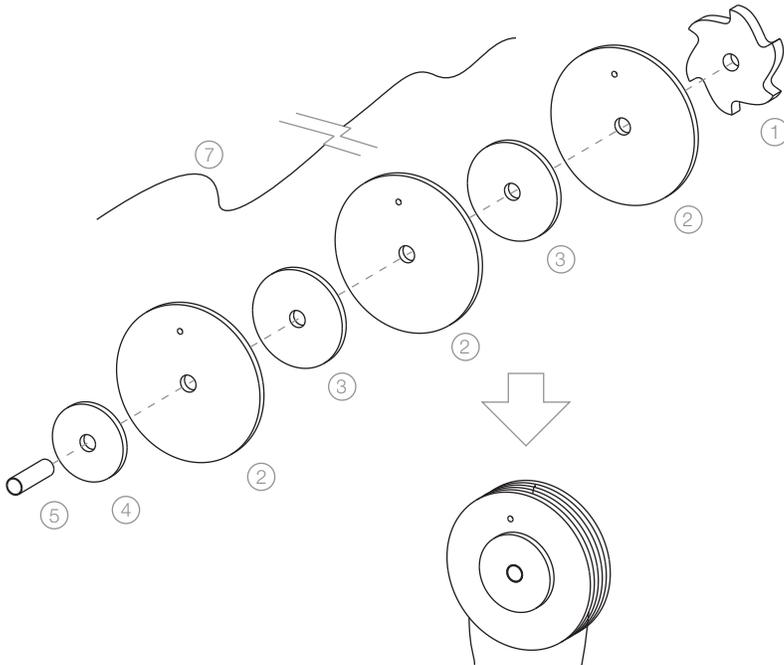
Subassemblies

Steps 1, 2, 3, 4



Ratchet Arm Asm (3x)

1	Ratchet Arm	1x
2	Magnet	1x
3	B Tube 9/32" x 1/4"	1x

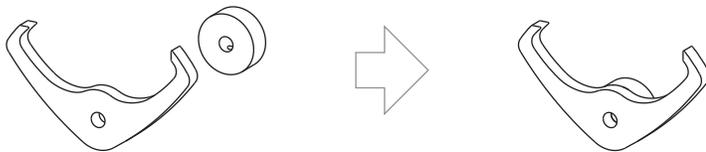


Wind Wheel Asm

1	Ratchet Wheel	1x
2	Wind Wheel Large	3x
3	Wind Wheel Small	2x
4	Wind Wheel Spacer	1x
5	B Tube 9/32" x 1"	1x
6	Wind Cord	1x

Glue the Ratchet Wheel and all six Wind Wheel parts together. Ensure the three holes in each Wind Wheel Large are aligned.

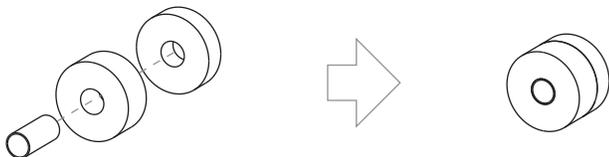
See Wind Cord Installation in Tips + Tactics.



Pallet Asm

1	Pallet	1x
2	Pallet Spacer	1x

Glue the Pallet and Pallet Spacer together. Ensure their holes align and the side hole in the Pallet Spacer faces downward.

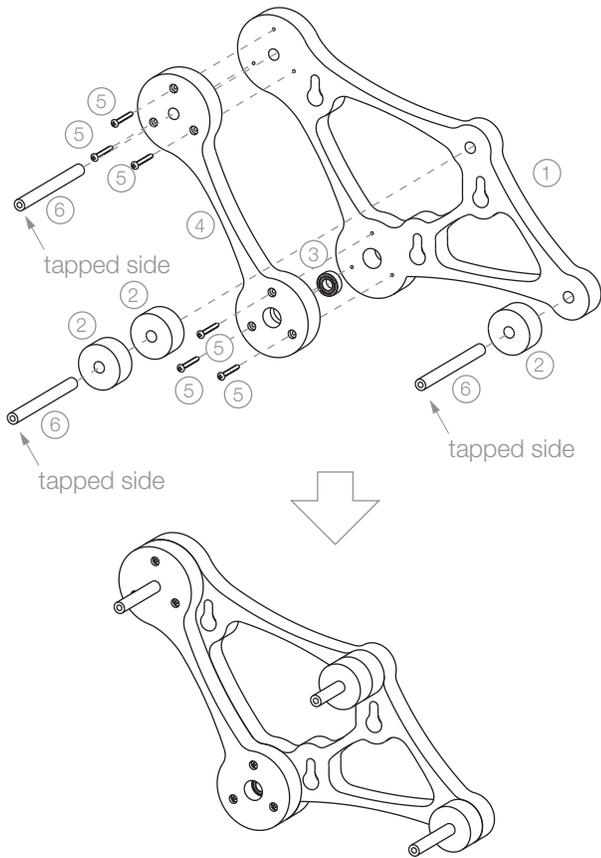


Face Spacer Asm

1	Face Spacer Thin	1x
2	Face Spacer Thick	1x
3	B Tube 9/32" x 5/8"	1x

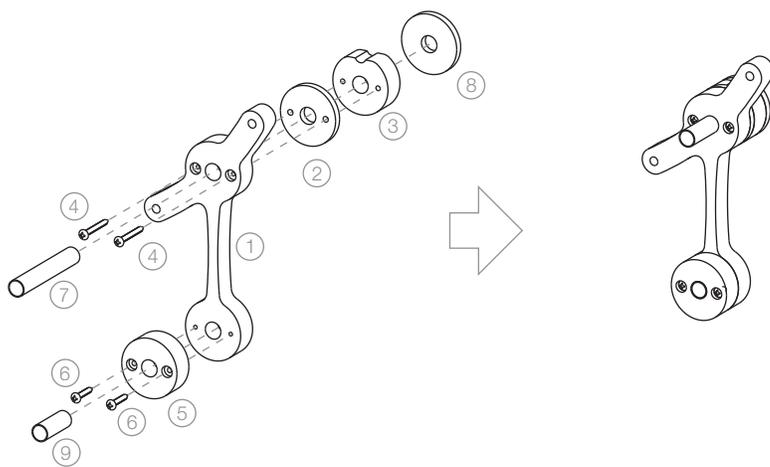
Subassemblies

Steps 9, 10



Frame Asm

1	Frame	1x
2	Frame Spacer	3x
3	Bearing	1x
4	Frame Support	1x
5	Screw #2 x 3/4"	6x
6	A Tube 1/4" x 2-1/2"	3x

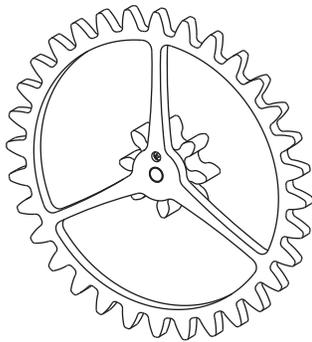
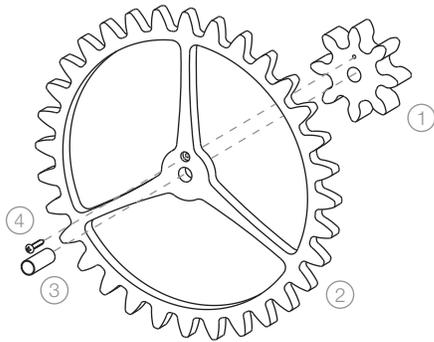


Face Support Asm

1	Face Support	1x
2	Pendulum Pivot Mount Front Spacer	1x
3	Pendulum Pivot Mount Rear	1x
4	Screw #2 x 3/4"	2x
5	Face Support Spacer	1x
6	Screw #2 x 1/2"	2x
7	B Tube 9/32" x 1-3/4"	1x
8	Pendulum Pivot Mount Rear Spacer	1x
9	B Tube 9/32" x 3/4"	1x

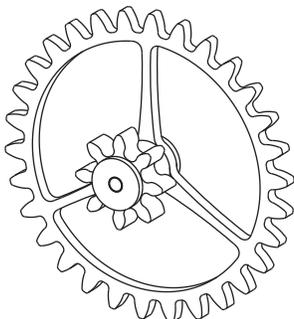
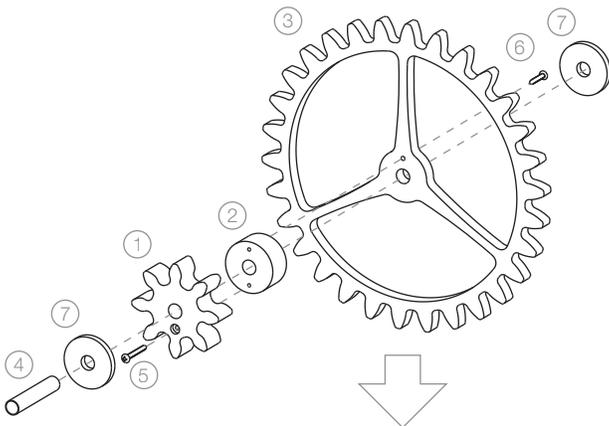
Subassemblies

Steps 16, 17



Gear DE Asm

1	Gear D	1x
2	Gear E	1x
3	B Tube 9/32" x 3/4"	1x
4	Screw #2 x 1/2"	1x

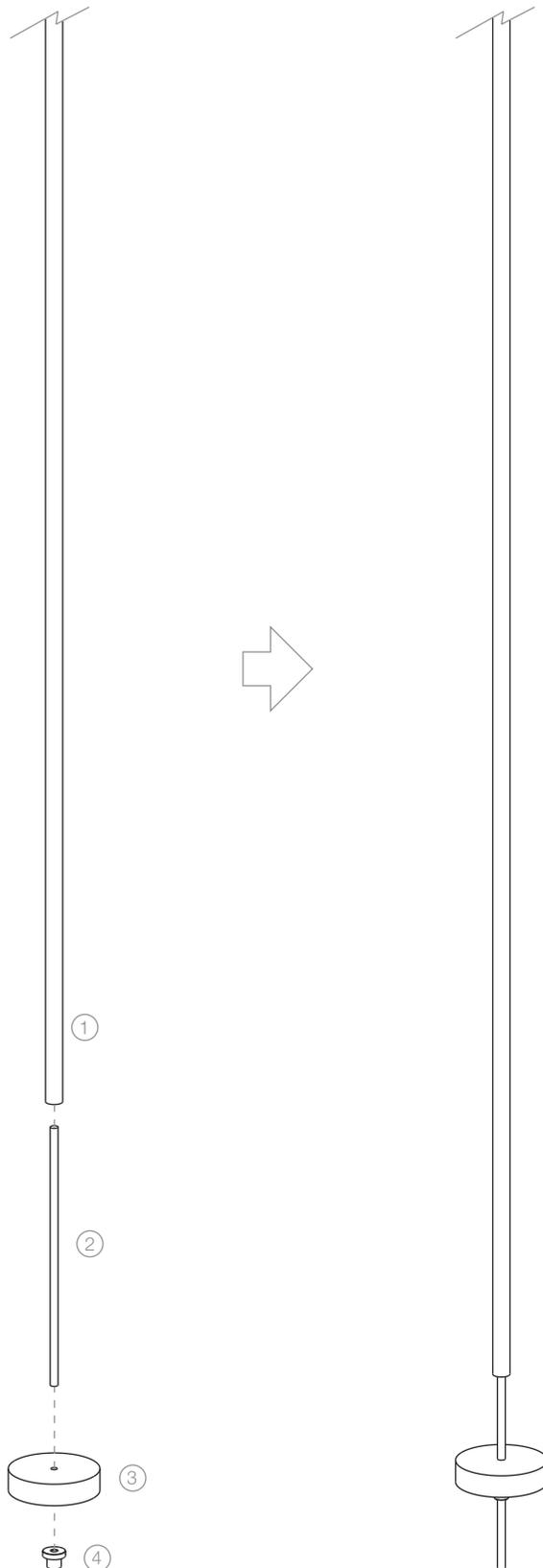


Gear FG Asm

1	Gear F	1x
2	Gear FG Spacer Thick	1x
3	Gear G	1x
4	B Tube 9/32" x 1-1/2"	1x
5	Screw #2 x 3/4"	1x
6	Screw #2 x 1/2"	1x
7	Gear FG Spacer Thin	2x

Subassemblies

Step 19



Pendulum Asm

1	Pendulum	1x
2	Threaded Rod	1x
3	Pendulum Weight	1x
4	Thumb Nut	1x

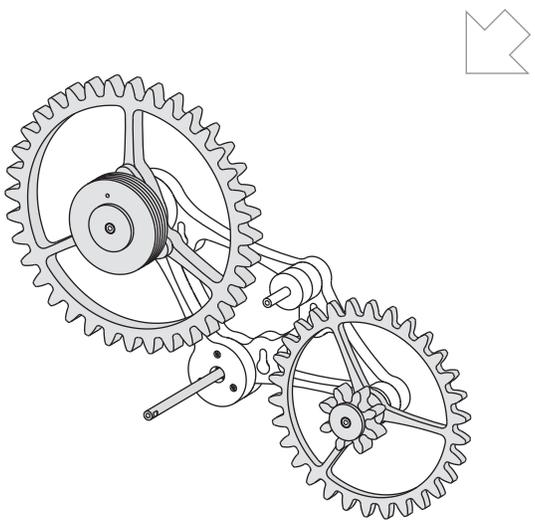
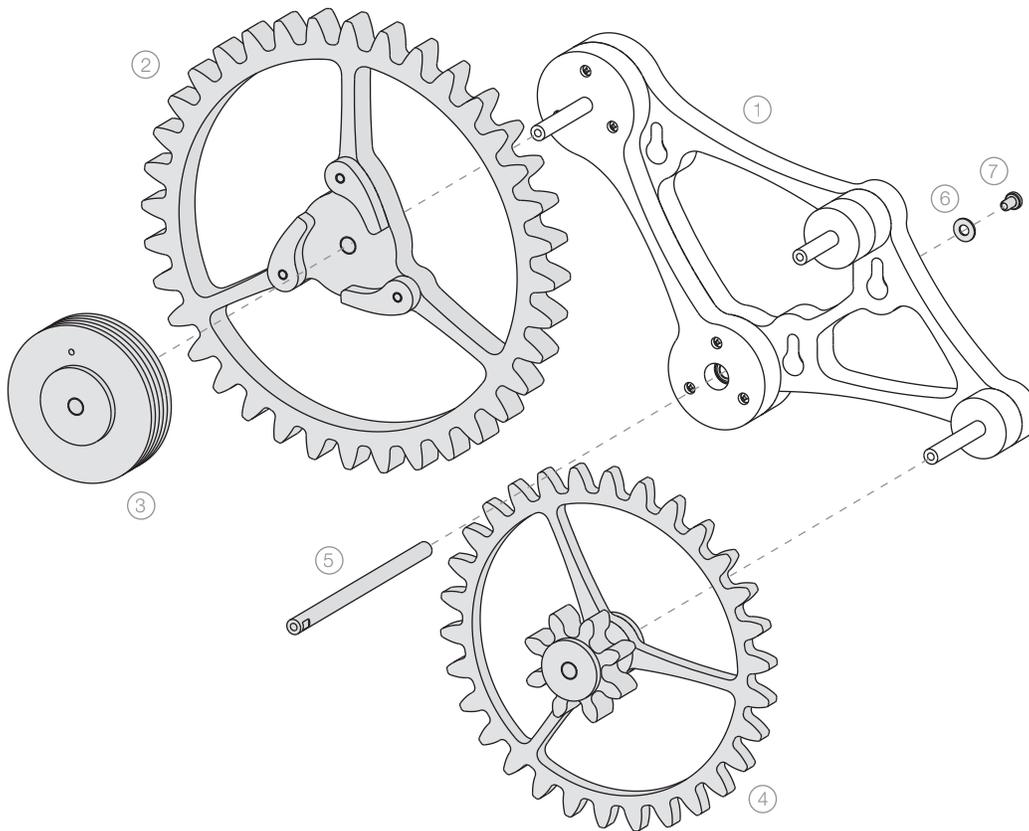
Do not over tighten the Threaded Rod in the Pendulum, as doing so could strip out the threads or split the Pendulum.

If desired, the Threaded Rod may be glued into the Pendulum.

For positioning the Pendulum Weight and Thumb Nut, see Time Tuning in Tips + Tactics.

Top Level Assembly

Step 1



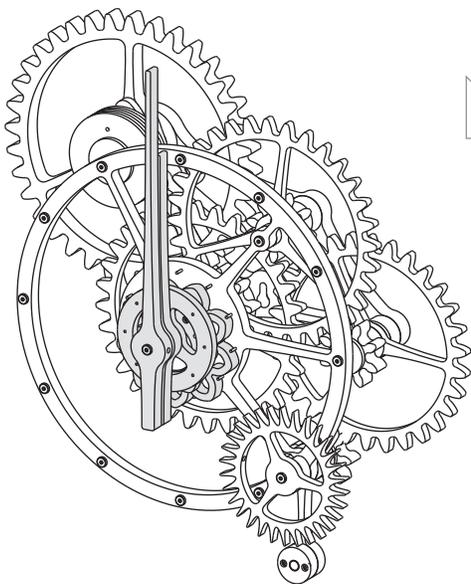
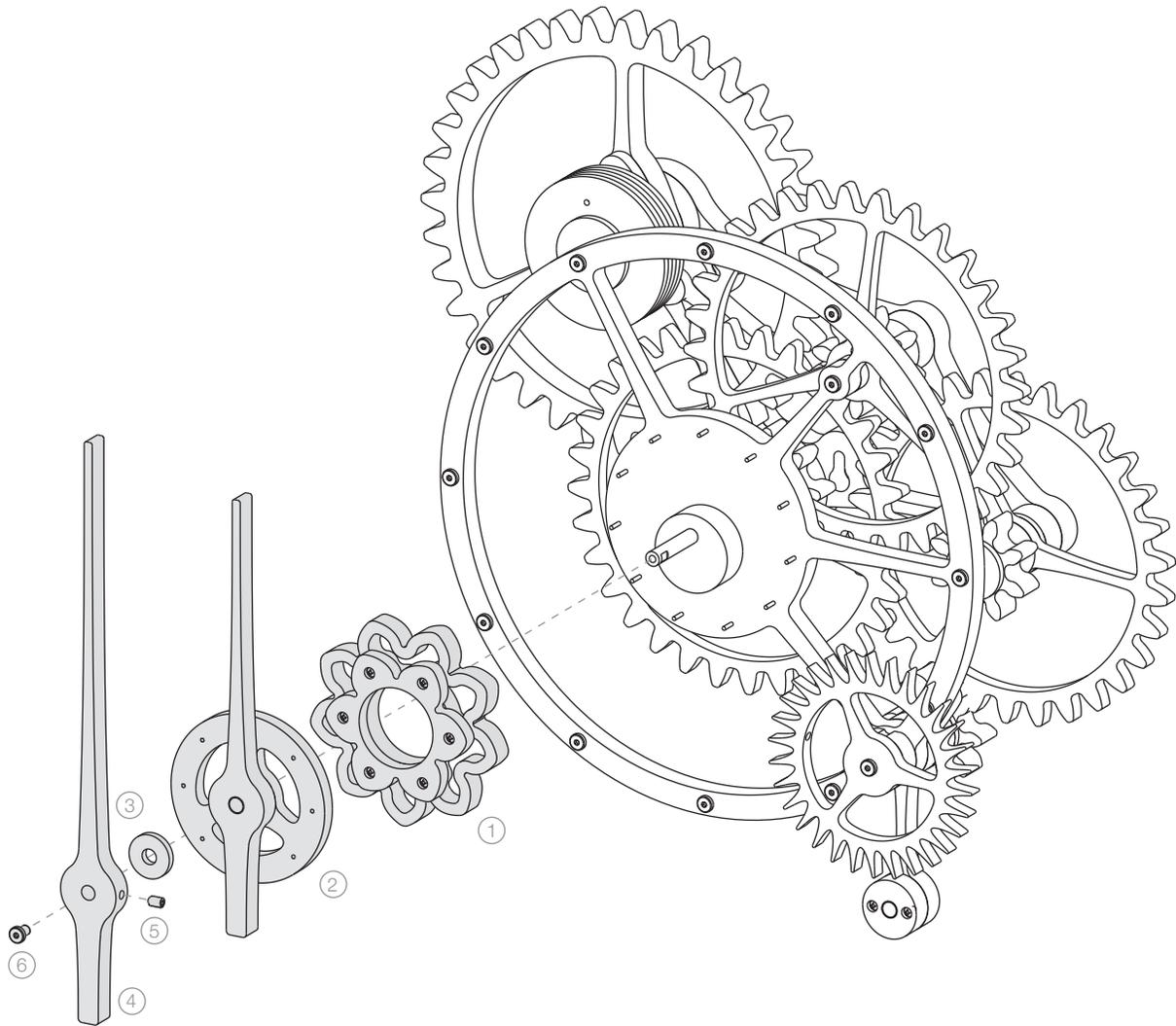
1	Frame Asm	1x
2	Gear A Asm	1x
3	Wind Wheel Asm	1x
4	Gear FG Asm	1x
5	A Tube 1/4" x 4-1/8"	1x
6	Washer	1x
7	LSHCS 8-32 x 1/4"	1x

The outer diameter of the Washer must not contact the wood. The A Tube, Washer, and LSHCS must be able to spin freely.

After completing this step, Zybach may be mounted to the wall.

Top Level Assembly

Step 5

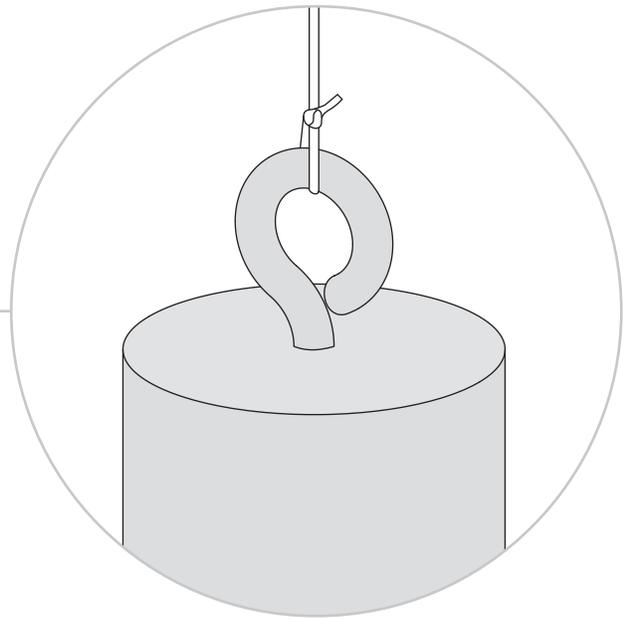
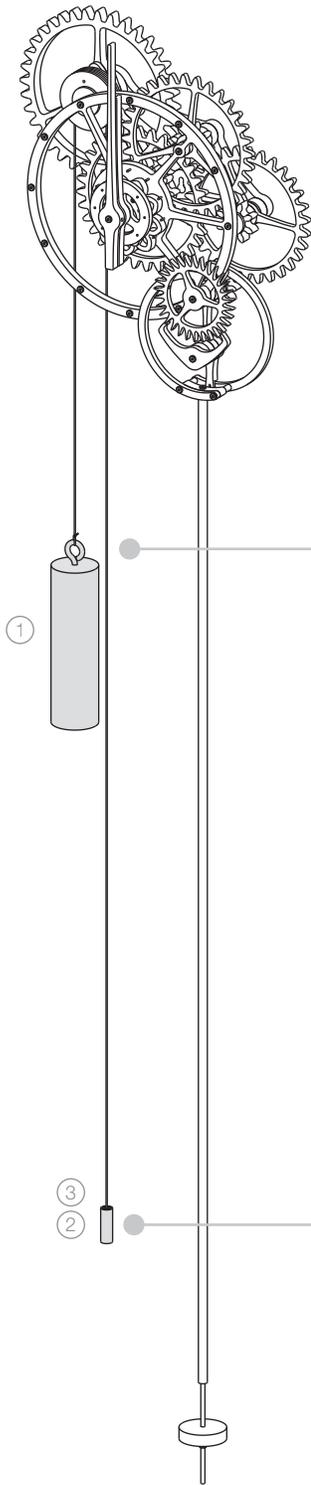


1	Hypocycloid Gear Asm	1x
2	Hour Hand Asm	1x
3	Hand Spacer	1x
4	Minute Hand	1x
5	Set Screw	1x
6	LSHCS 8-32 x 1/4"	1x

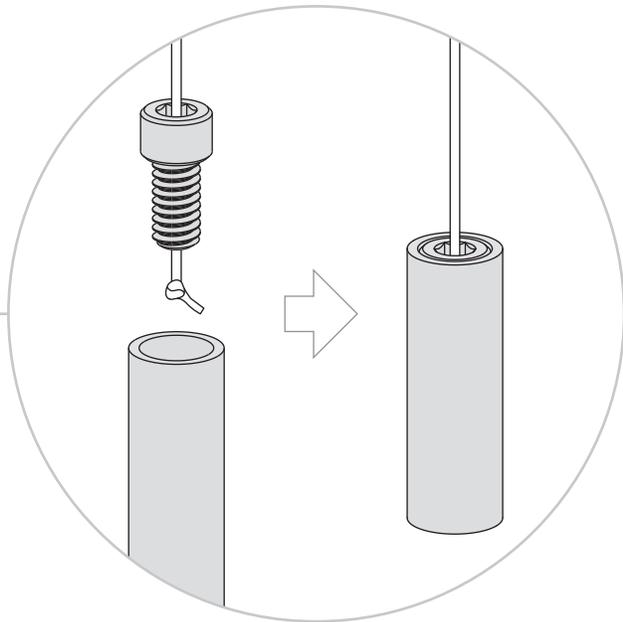
Note the Hypocycloid Gear Asm's orientation. Ensure the Set Screw in the Minute Hand contacts the flat cut into the A Tube.

Top Level Assembly

Step 9



Tie a knot in the Wind Cord to form a loop. Hang the Main Weight Asm from that loop.



Feed the Wind Cord through the VSHCS and tie a knot. Thread the VSHCS into the Wind Weight.

- | | | |
|---|---------------------|----|
| 1 | Main Weight Asm | 1x |
| 2 | Wind Weight | 1x |
| 3 | VSHCS 1/4-20 x 3/8" | 1x |