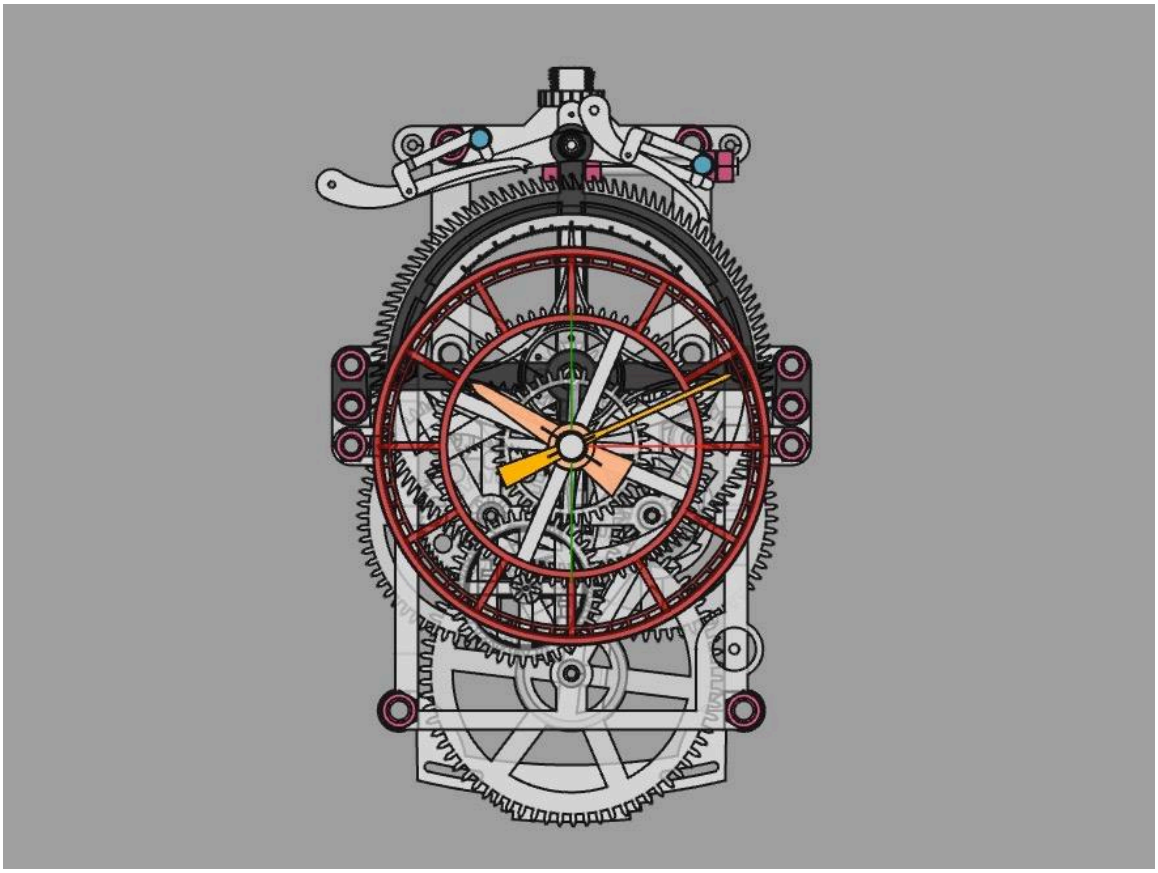
Grasshopper Escapement Clock Instructions



Jacques Favre
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Introduction

This 3D printed escapement clock is inspired by the design and invention of John Harrison
Link to wikipedia:
https://en.wikipedia.org/wiki/John_Harrison

Links of interest:
http://www.hsn161.com/HSN/hsn_harrison_docs.php
https://soptera.wordpress.com/downloads/

Books that I did read:

Harrison Decoded, by Rory McEvoy (Editor), Jonathan Betts (Editor)

John Harrison Contrivance, By Dr Stuart Harrison

About this replica:
The geometry is true to the original, while the size has been adapted for 3D printing
I placed the escapement on the front of the clock, since it is the main feature of this clock
The clock includes a maintain power device, also invented by John Harrison
Printing all the parts will take a week or two, building the clock could take another week or so
You will need 2 spools of filament, between 1 and 2 kg, all the hardware should be between $50 and $100 depending where you shop

Supplies needed

Printed parts:

I use PLA +. It is strong and easy to print
I print at 215C and bed at 60 C on a glass bed
I use 0.4 mm nozzle, 0.2 mm layer, 3 or 4 outer walls, 20% infill
No parts need support, however sometime orientation is critical, the bob for instance is ollow, the roof of the hollow parts is best printed sideways
Many parts will cover the bed, frames are 200 x 200 mm, the escape wheel is 210 mm in diameter, it is critical that the bed is well leveled, and that the first layer is set right for good adhesion. I use the old fashion way of using a sheet of paper to check the leveling and it does work for me
I usually print one gear at the time and that help minimizing stinging that might jam the gears, I also use -0.25 to -0,35 mm layer expansion on the first layer to avoid elephant foot issue

Hardware

6 pieces: Ø 5 x 100 mm steel or brass shafts
10 bearings 605 Ø 14 x Ø 5 x 5 mm
Ø 2 mm piano wire
Ø 1 mm piano wire for maintain power spring
Ø 0.5 piano wire for suspension spring
M6 x 10 bolts
M4 x 10 screws and M4 nuts
M3 screws and nuts, 10 to 20 mm long as needed
10 mm rod wood dowel or carbon fiber tube for pendulum
BB steel balls to fill pendulum bob
3 to 4 kg weight to power the clock, scrap metal and or BB balls
Screws to fix clock to wall
Super glue or epoxy
Emery Cloth

M10 and M12 nuts and bolts can be used as well

Ø5 mm Shaft

- 6x Ø5 x 100 mm, for clock arbors
- Ø5 x 39, for maintain ratchet

Ø2 Shaft Details, piano wire

- Anchor: 5x Ø2 x 30 mm
- Clutch: 1x Ø2 x 73 mm, 2x Ø2 x 58 mm
- Hands: 1x Ø2 x 37 mm

Ø 1 mm piano wire for maintain spring, 160 mm

Ø 0,5 mm piano wire for suspension spring, 180 mm

Assembly Preparation

Some of parts need for the final assembly are composed of several and are best prepared in advance
Also check all holes for potential elephant foot before the assembly, holes holding all the threaded rods, as well as the holes holding the bearing
Check the fitment of nuts and rods
If the nuts are too tight or loose, it is easy enough to scale them up or down 1% or 2 % in the slicer
Commercially available M10 and M12 nuts and bolts can work as well

I found 5 x 100 mm shaft on Amazon, the ends have to be ground /sanded to allow the bearings to fit

Preparation in order

- Side frames
- Drum shaft
- Ratchet shaft
- Maintain shaft
- Escape wheel
- Escapement Anchor
- pickup gear Hands
- Clutch
- Hands
- Wall Frame and Pendulum
- Installation of wall Frame to Wall
- Weight
- Rewind Key

Side Frames

- Left and Right side frames
- Maintain ratchet

- Ø 5 x 100 mm shaft
- Ø 5 x 39 mm shaft

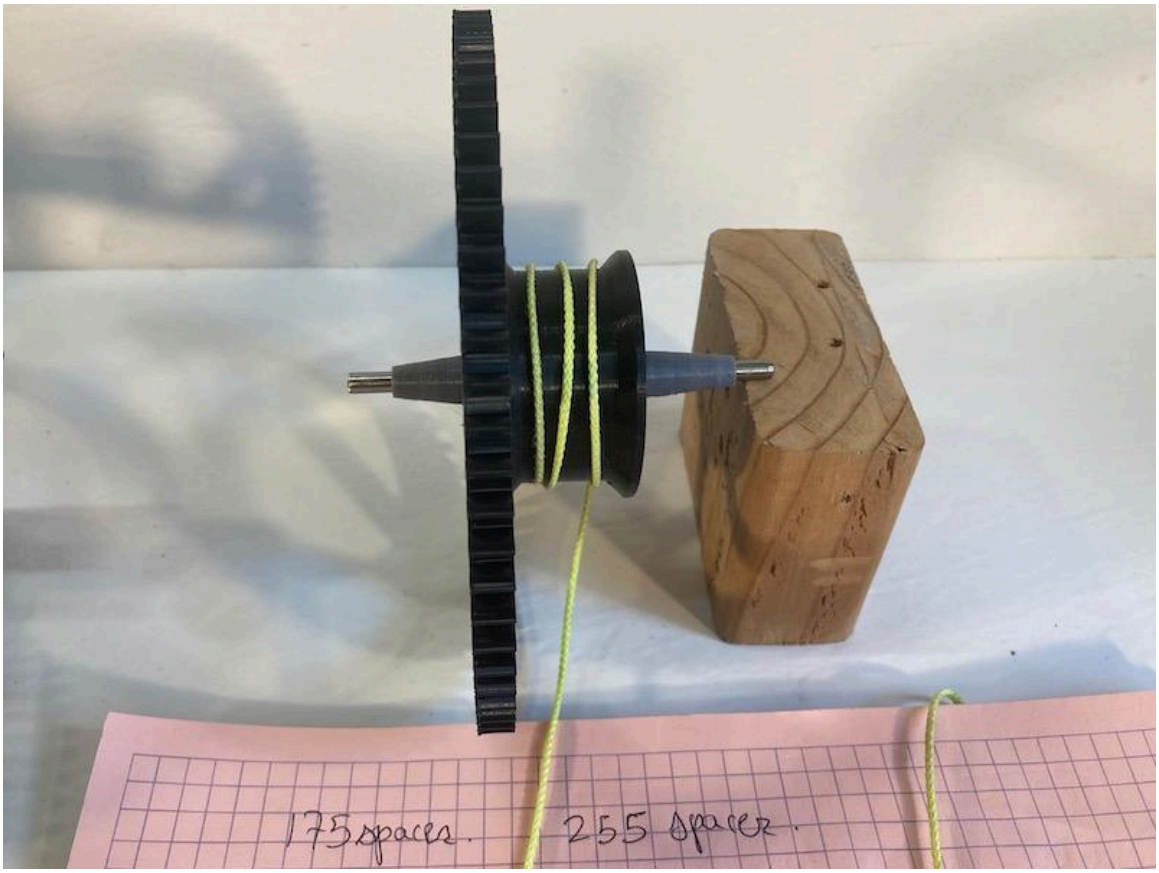
Frames Ready

Drum shaft

- Drum
- Spacer 175 on front
- Spacer 255 on back

- String 1,25 m minimum for a 24 hour run
- Ø 5 x100 shaft

Note: Even up front and rear shaft length

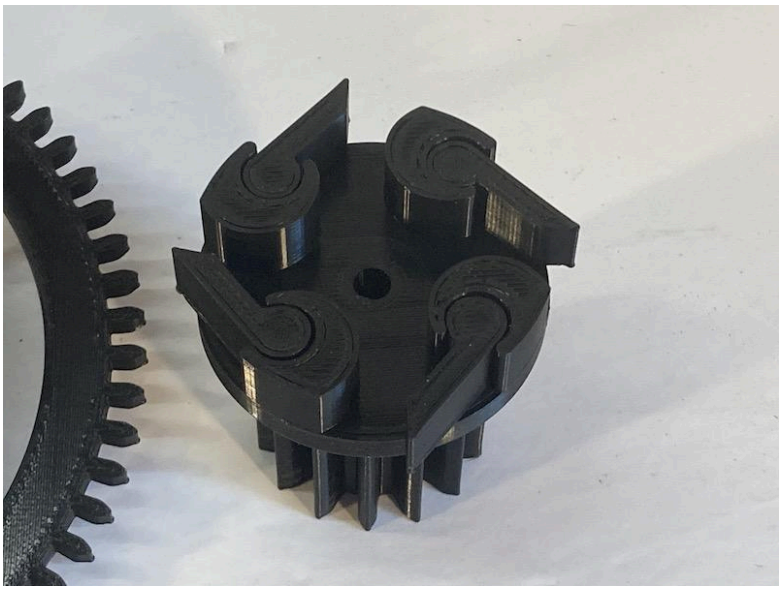


Ratchet shaft

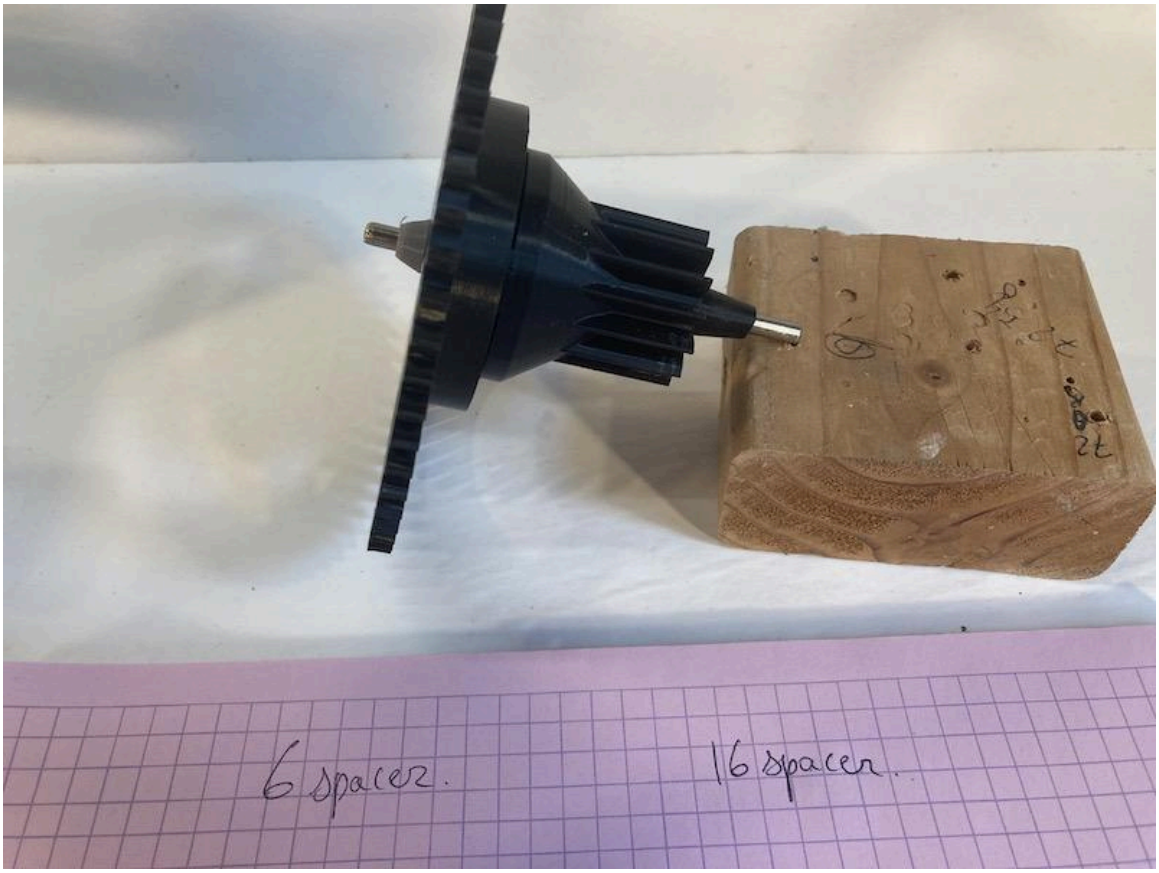
- Gear
- Gear
- 4 ratchets
- Spacer 16
- Spacer 6

- Ø 5 x 100 shaft

Ratchet details



Spacer 6 on back, Spacer 16 on front
Note: Even up front and rear shaft length

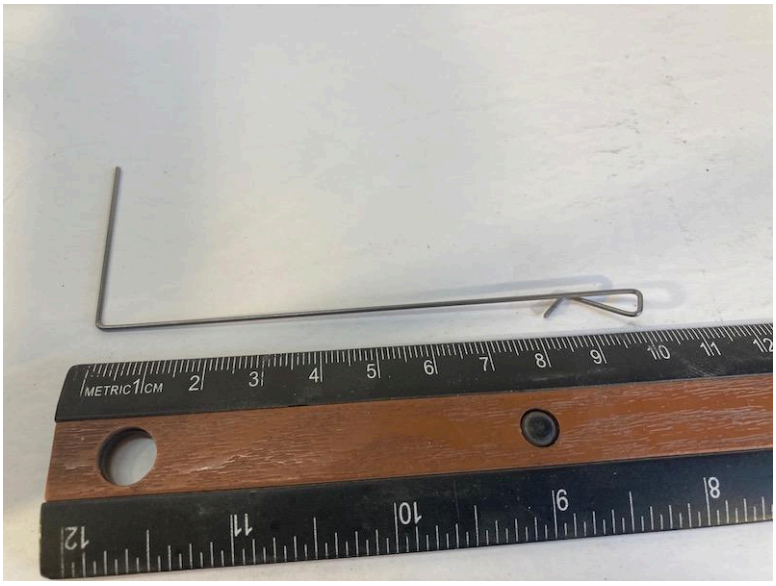


Maintain Power Shaft

- Gear
- Maintain Disk
- Gear 8 to hands

- Ø 5 x 100 mm shaft
- 155 mm of Ø 1 mm piano wire
- M3 x 20 bolt
- 2x M3 nuts
- 5 mm washer

Shape maintain spring to specs

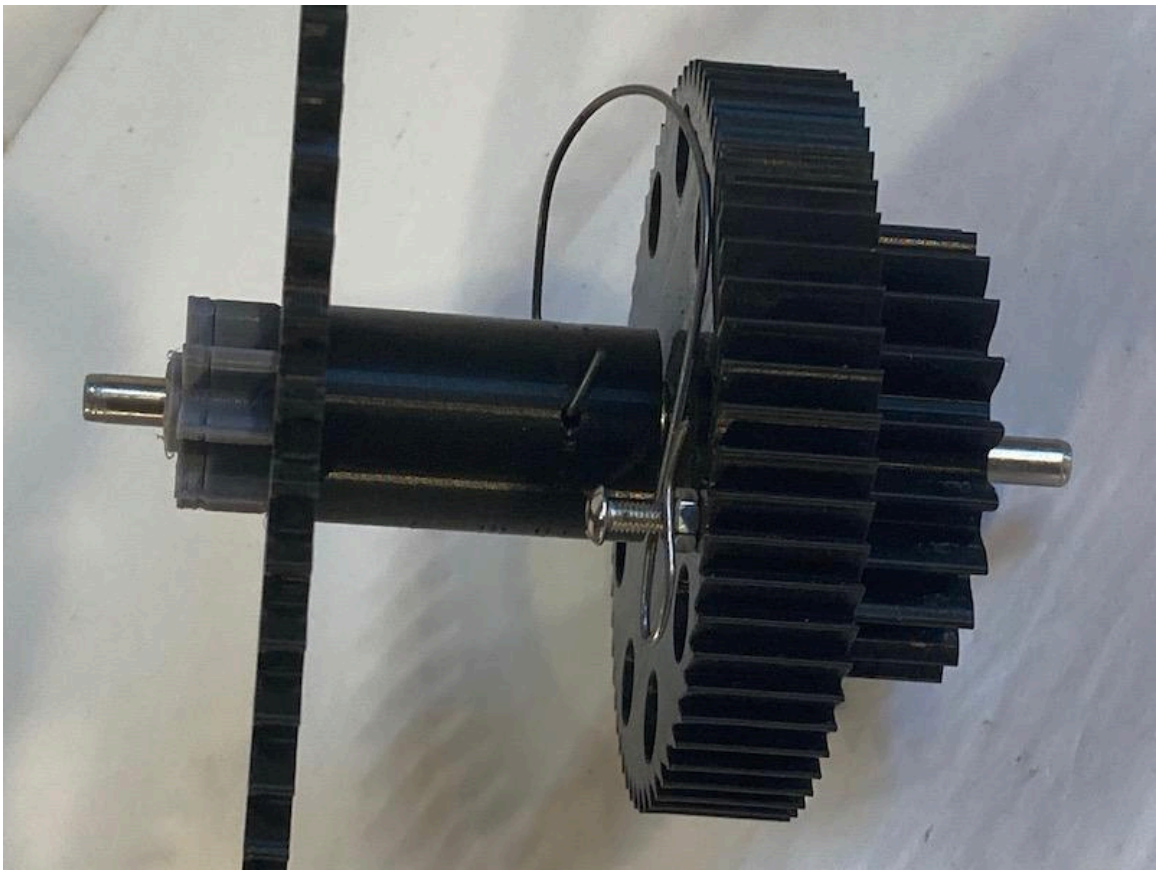


Insert in gear and bend the ends as shown. Note the orientation!

Insert nut in the hole, then screw in the M3 x 20 bolt with the second nut, Tighten.
Install the shaft in gear, it should be a tight fit, allow about 20 mm to stick out
Install the gear 8 (next picture will show) it should be tight fit, glue to gear if needed
Install a washer between gear and maintain disk

Install the maintain disk on shaft and connect the spring to the bolt
Check for a loose fit of disk on shaft

Note: Even up front and rear shaft length

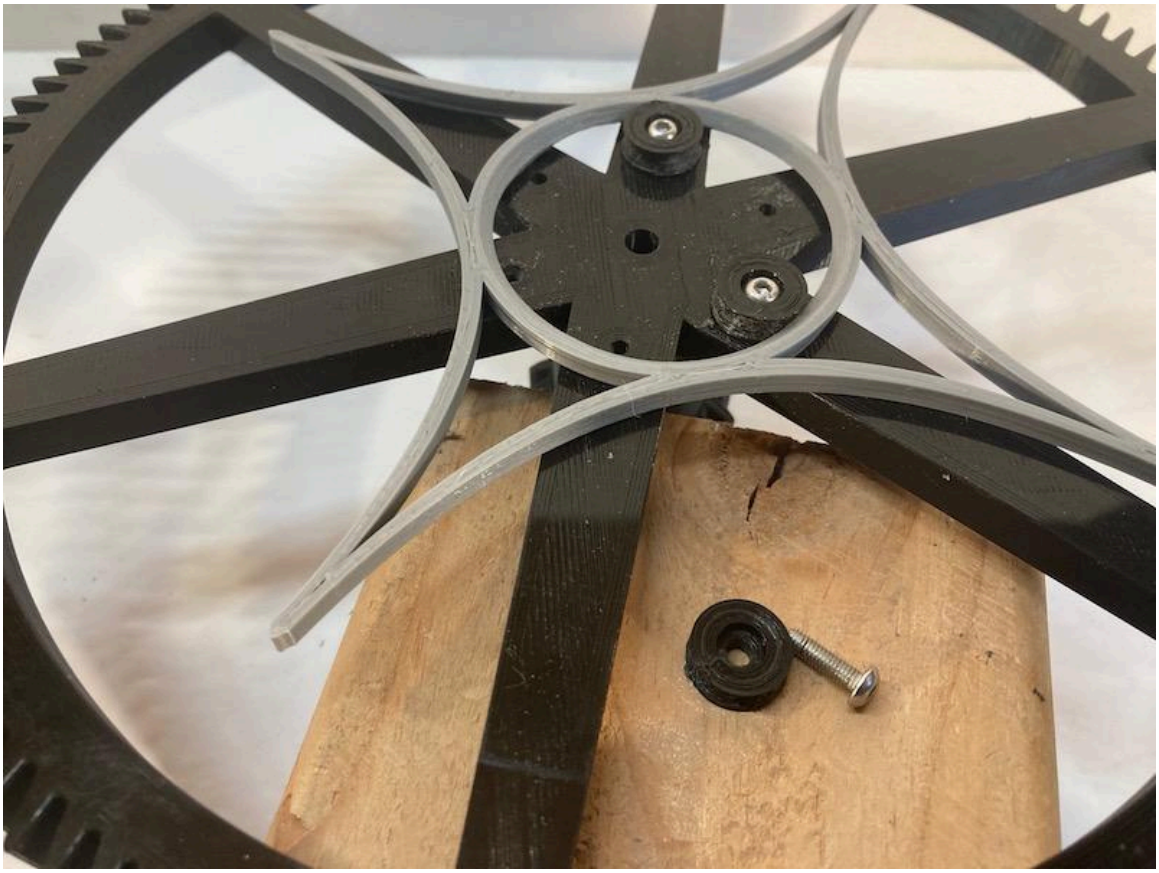


Escape Wheel

- Spacer 6
- Spacer 215
- Second indicator
- Second bushing

- O 5 x 100 mm shaft
- 3 X M3x 12 mm screws

Install 2 bushings and screw
Position second indicator and install third bushing and screw
Once done check for motion of indicator
It should be movable with a little friction



Position the spacers, 6 mm on front, 21.5 mm on back
Even up front and back shaft spacing

Escape wheel installed in place

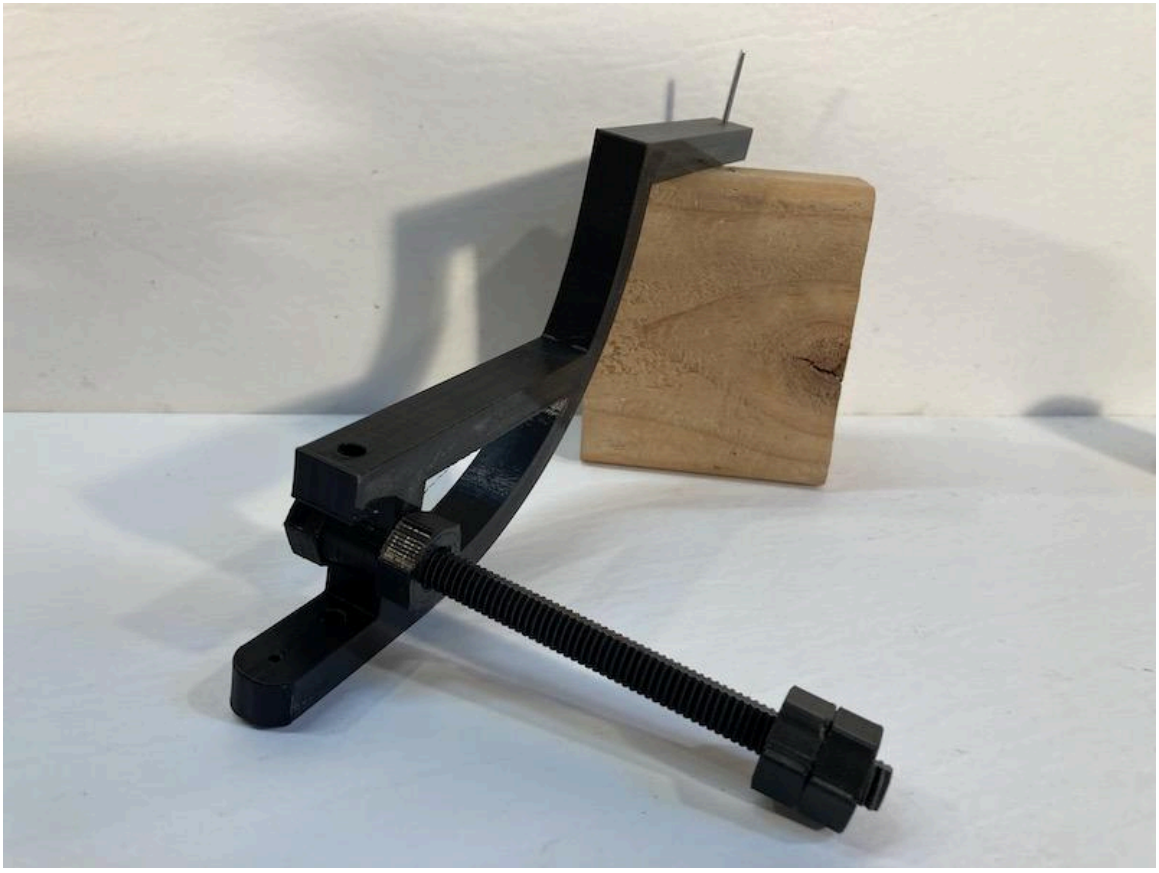
Escapement Anchor

- Anchor
- Crutch
- Entry Pallet
- Entry Composer
- Exit Pallet
- Exit Composer
- 2x RoundNut Composer
- 1x Ø5 x 2 washer
- 4x Ø2 x 2 stop rings
- 1x M10 x 120 stud
- 4x M10 nuts

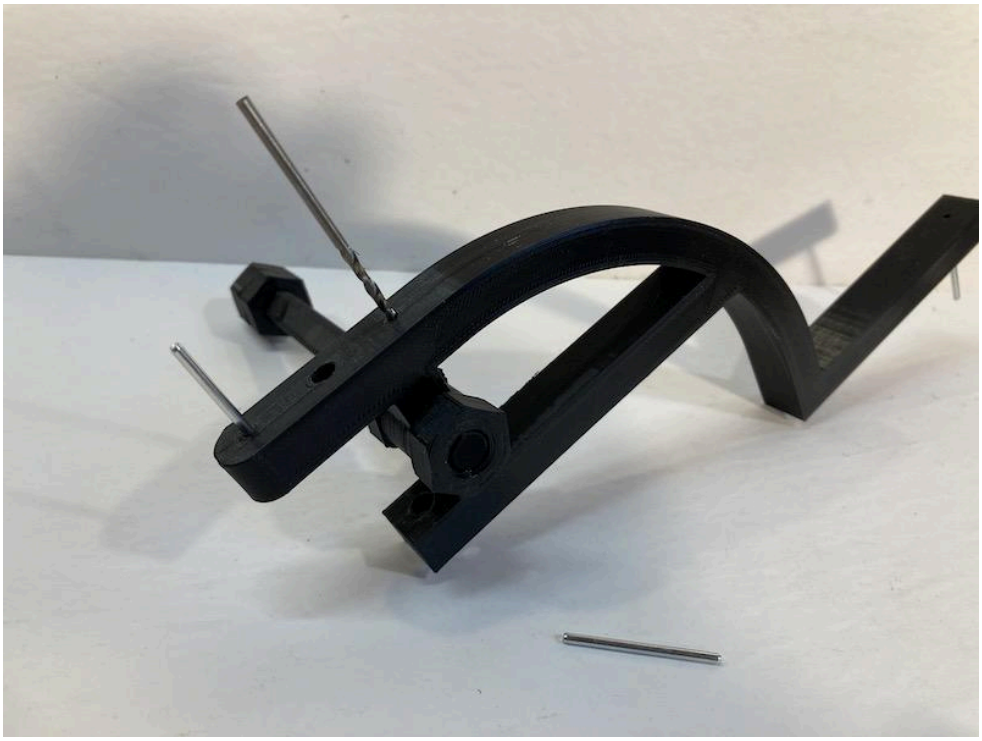
- 5x Ø2 x 30 mm pins/piano wire
- 2x M6 x 10 bolts
- M4 x 10 screw and bolt
- M3 x 10 screw and bolt

Check free rotation of pallets and composer on rod
Install all 4 pins as shown, glue if needed
Install Ø5 mm rod as show, leaving 10 mm out at front
Check fittement of nuts and M6 bolts

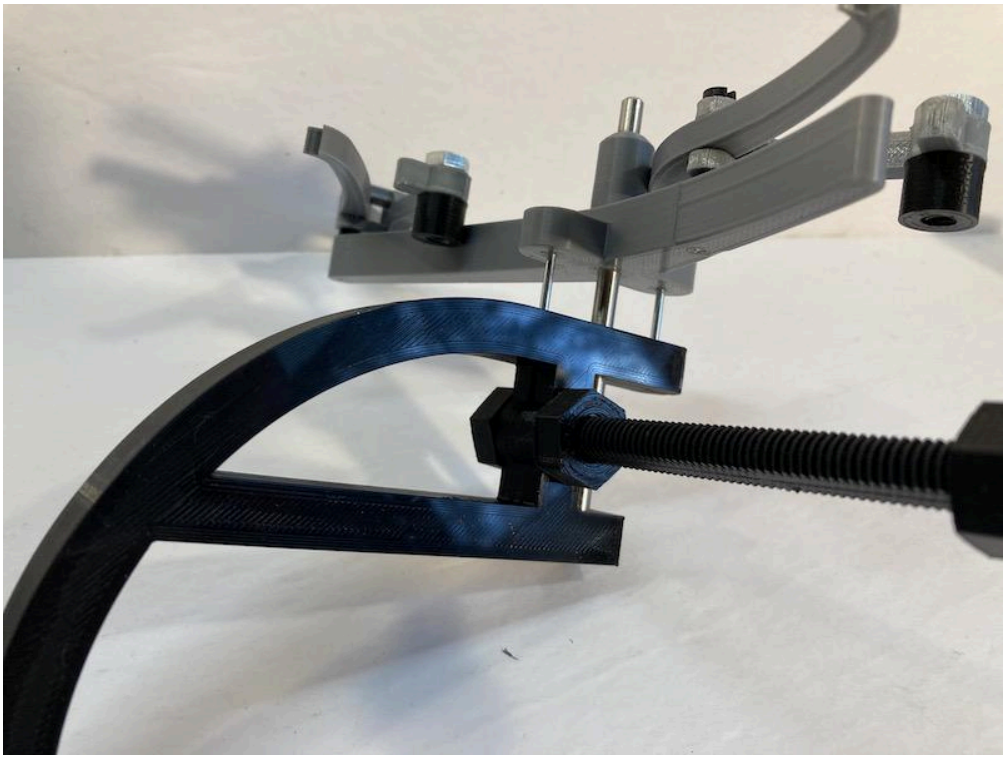
Press pin at end of crutch in place
Install M10 stud and nuts to balance the anchor



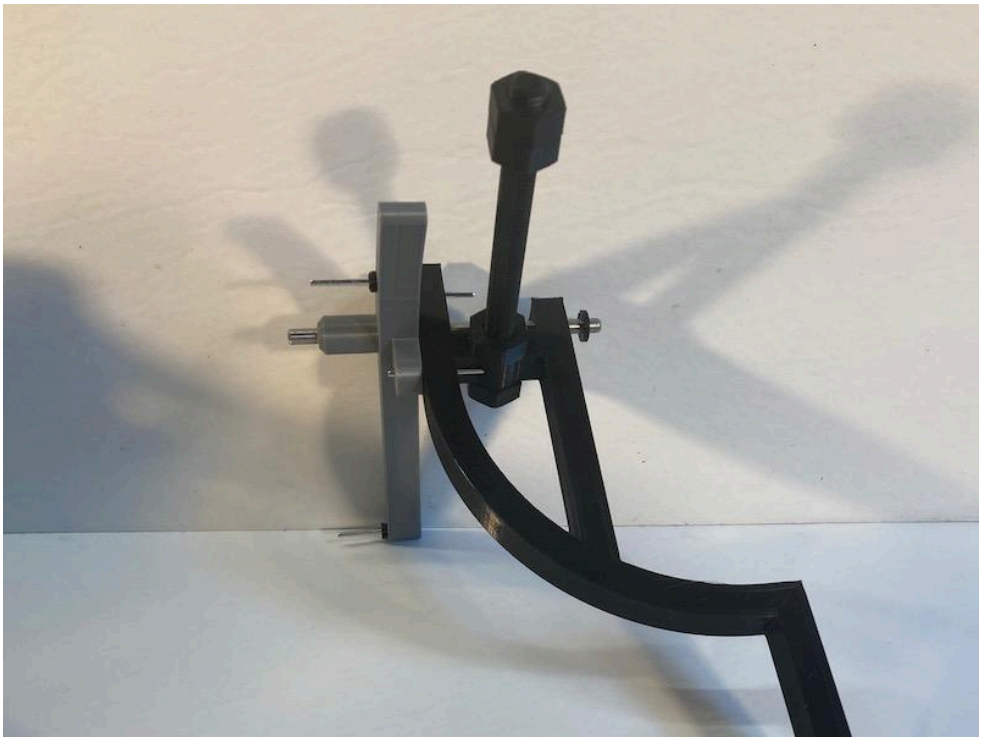
Use 2 mm drill to claen hole



Assemble the anchor frame with the crutch on the shaft

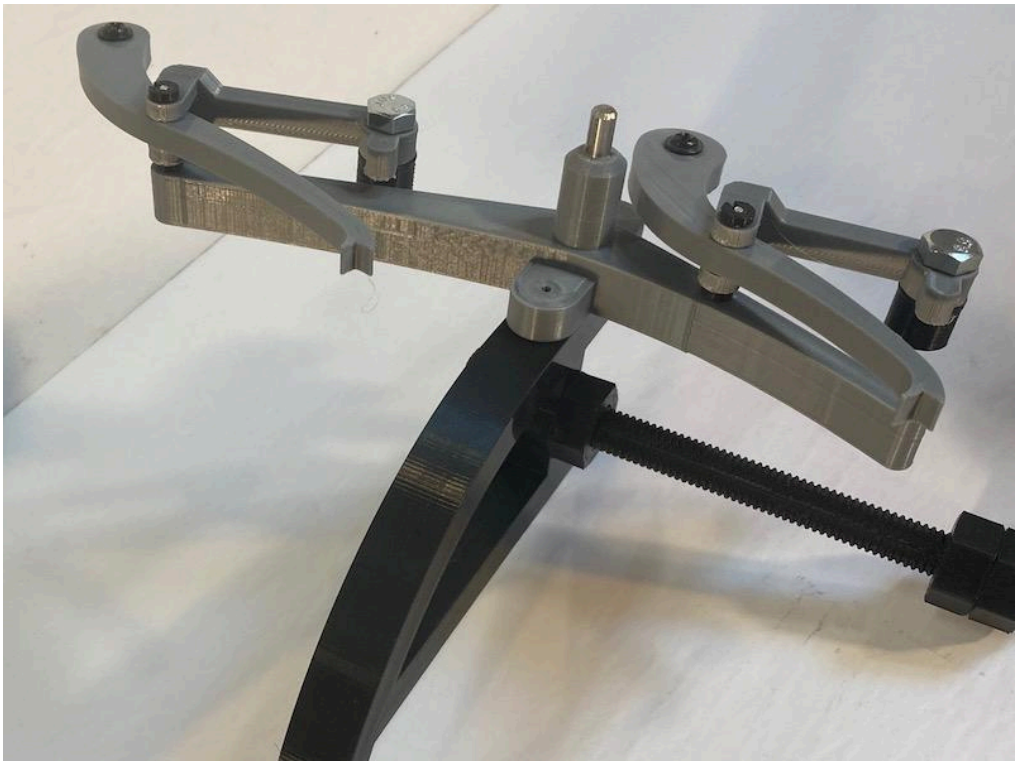


Install Ø5 x 2 washer on back end of shaft

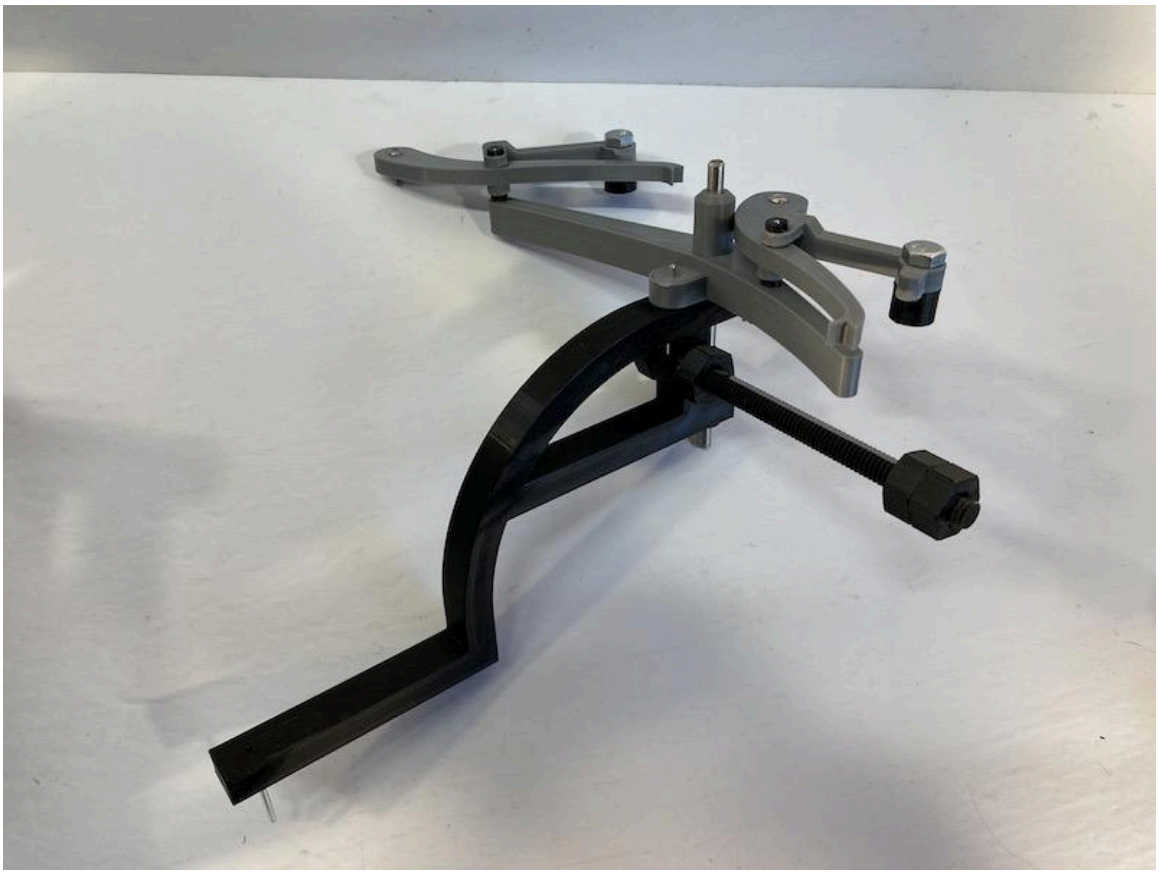


Install M6 bolts and nuts on Composers

Install pallets and composer in place, secure with Ø2 stop rings



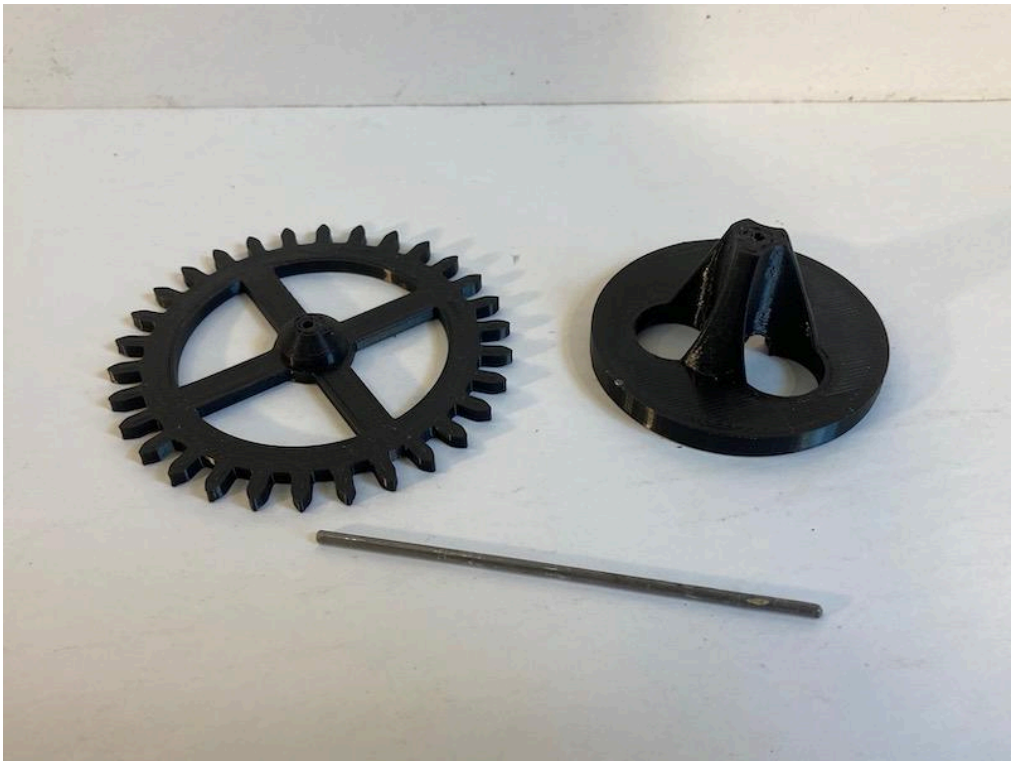
Completed anchor



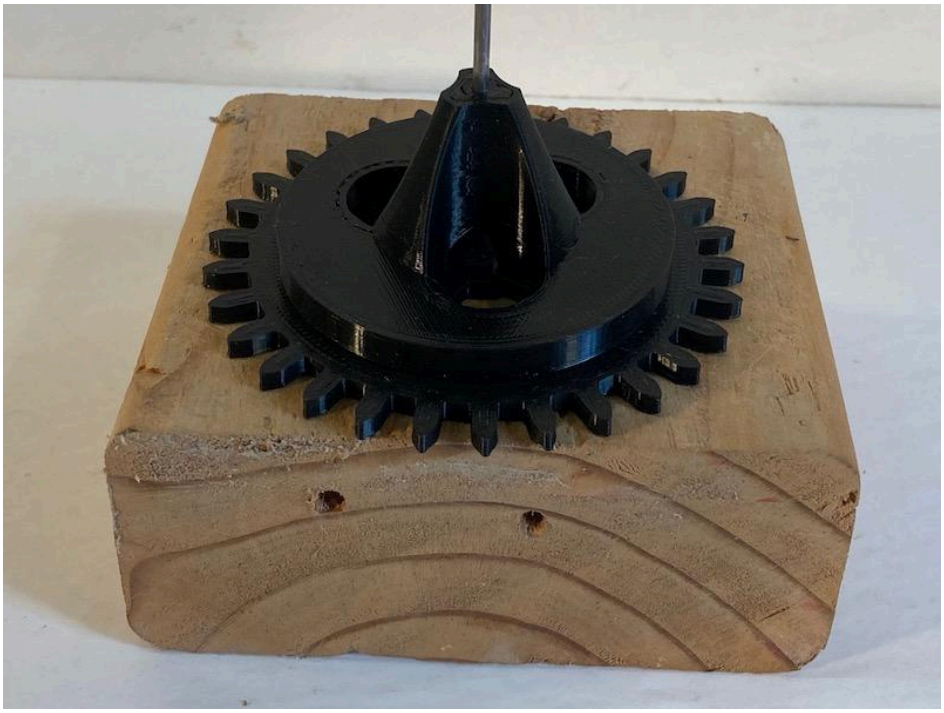
Pickup gear hands

- Gear 30
- toolGear30Shaft
- Ø2 x 73 mm shaft

Do a small chamfer at end of shaft

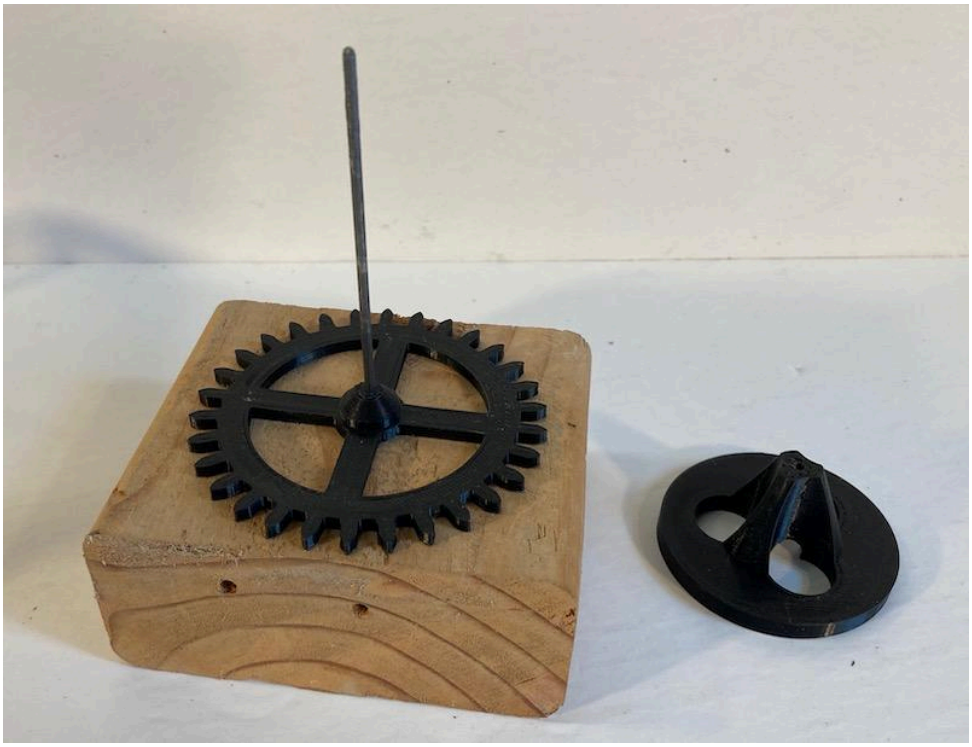


Install tool on top of gear and use as a guide to insert shaft in gear



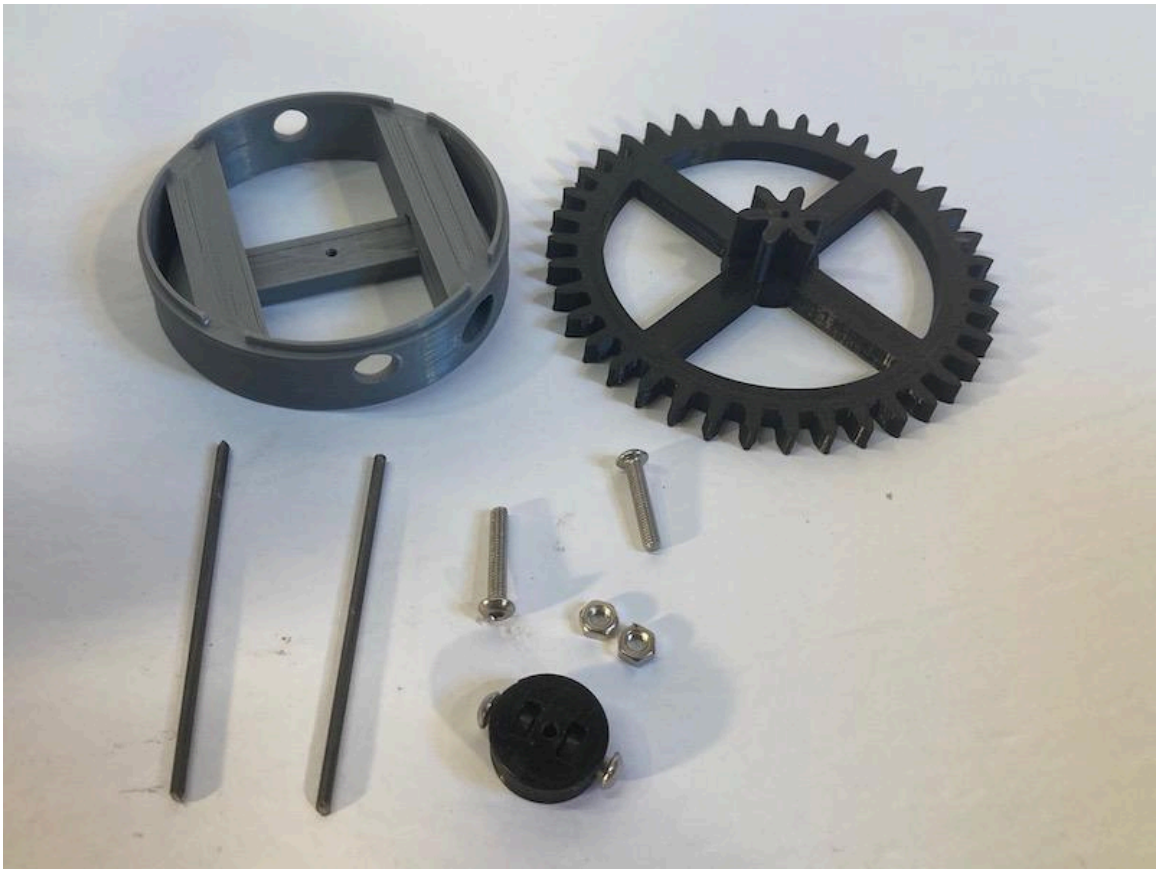
Hammer in till flush with back side, check for tight fit, glue if not

Gear and shaft ready for install



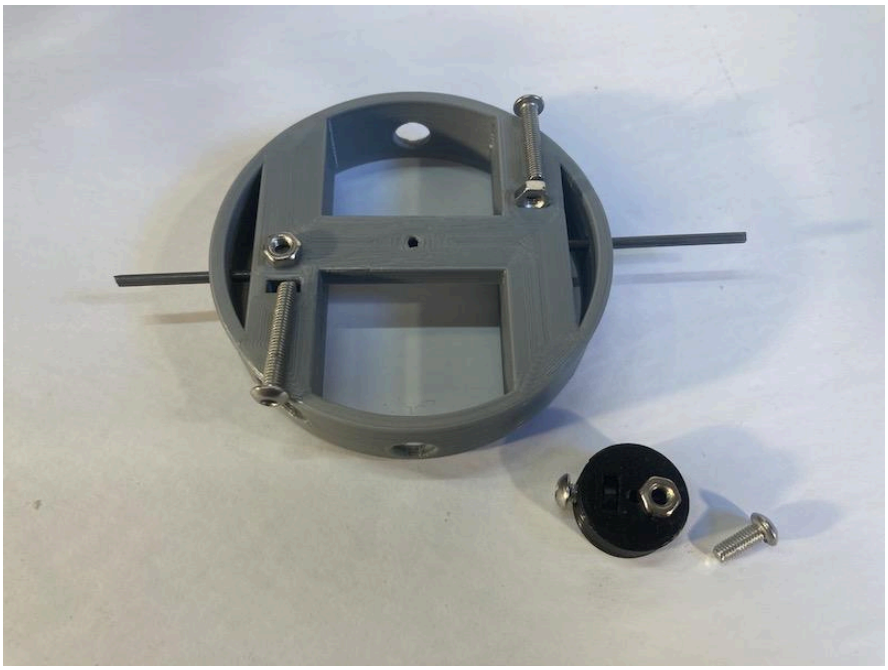
Clutch

- Gear 6-39
- Clutch
- Stop Ring Clutch
- 2x Ø2 x 58 mm piano wire
- 2x M3 x 16
- 2x M3 x 12
- 4x M3 nuts
- Glue



Glue together the gear and the clutch

Inserts nuts and screws in place
Inserts piano wires, one on each side
Do not tighten screws yet



All screws and piano wire in place, gear and clutch glued together

Install a temporary piano wire in place to hold the piano wire in place

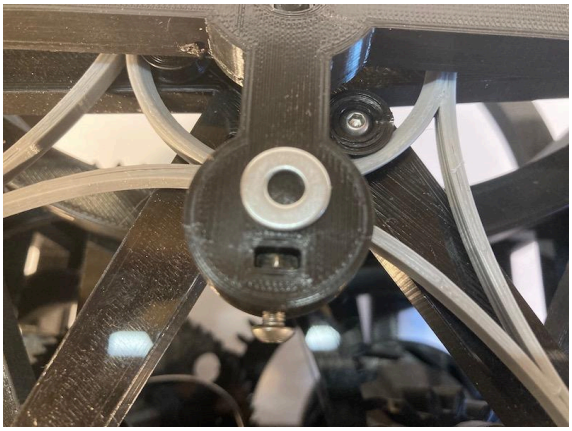
Install stop ring as shown, leave temporary piano wire in place to hold all parts in place

Hands

- Hour gear
- Hour hand
- Minute gear
- Minute hand
- Hand lock
- Ø 2 x 37 mm
- M3 x 12 screw
- M3 nut

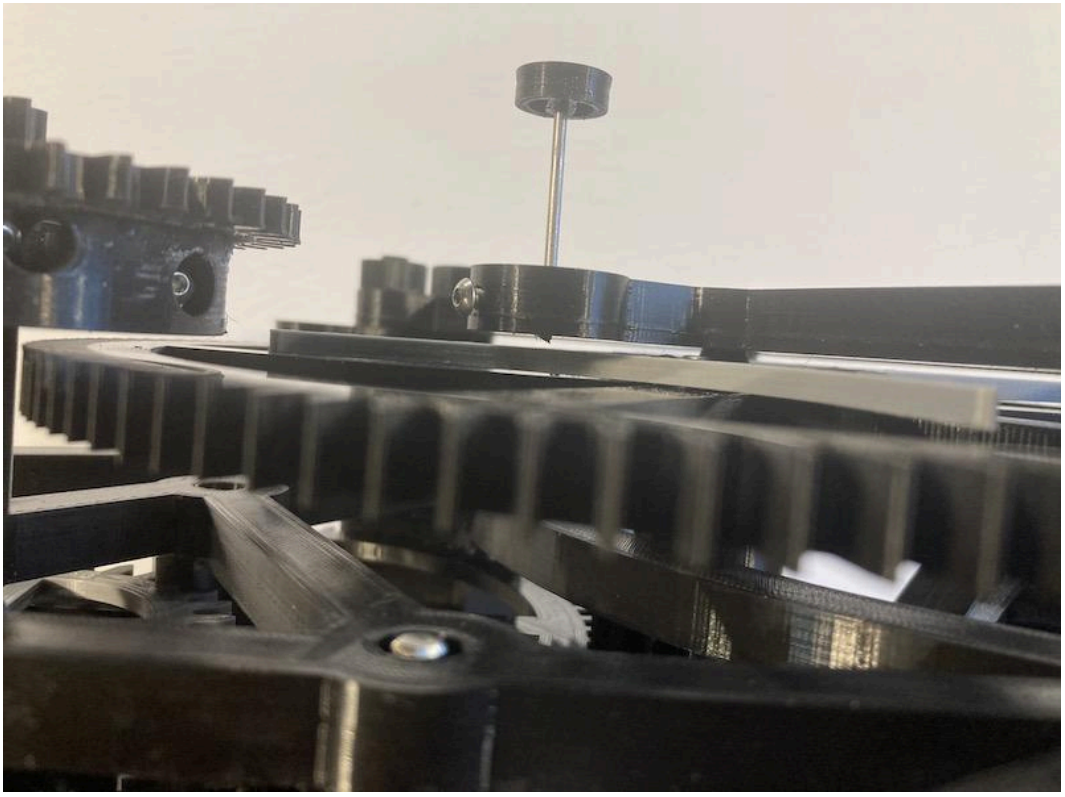
Check that the hour gear spin freely on the minute gear
Engage hour hand on hour gear
Engage min gear in hour gear
Engage min hand on min gear
Check free spinning ot both gears
Prep the hand lock with the shaft, glue if needed

Install a washer on the font escapement frame
Install M3 nut and screw



Check fitment

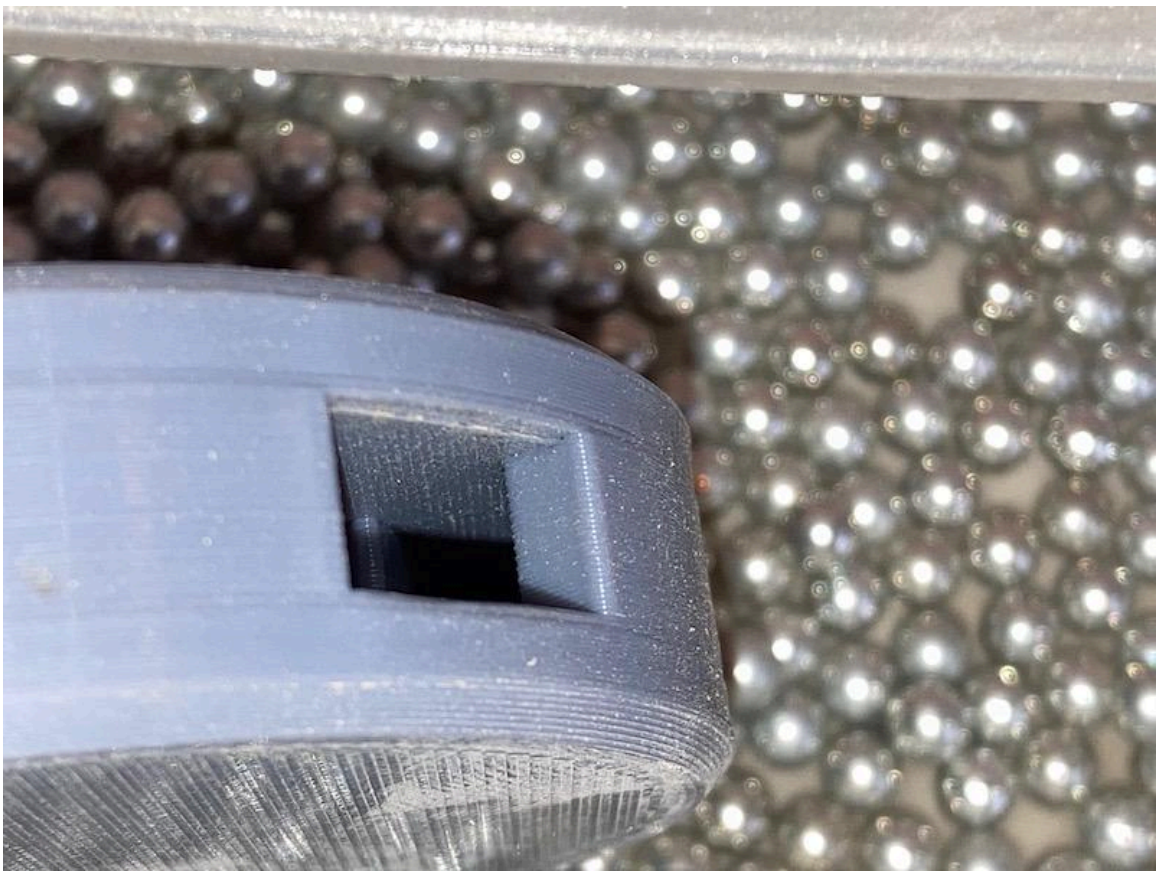
Double check that end of shaft is flush with frame
Adjust length if needed, best to do before final assembly
If shaft is to long, it will jam the escape wheel



Wall Frame and Pendulum

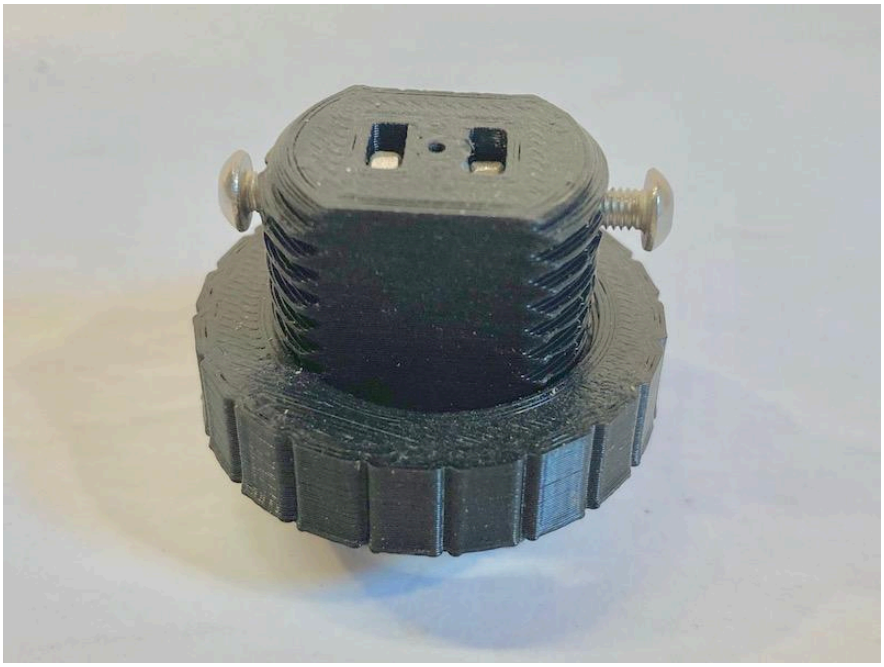
- Wall Frame
- Top Wall Frame
- 2x Studs M12 x 65
- 4x M12 nuts
- Top Pendulum
- Top Pendulum screw
- Top Pendulum nut
- Pendulum Screw
- Bob
- Ø 0.5 x 180 mm piano wire
- Dowel Ø10 mm x 720 (Mine is 720 mm, start longer, adjust as needed)
- M3 screws and nuts

Fill Bob with BB Balls



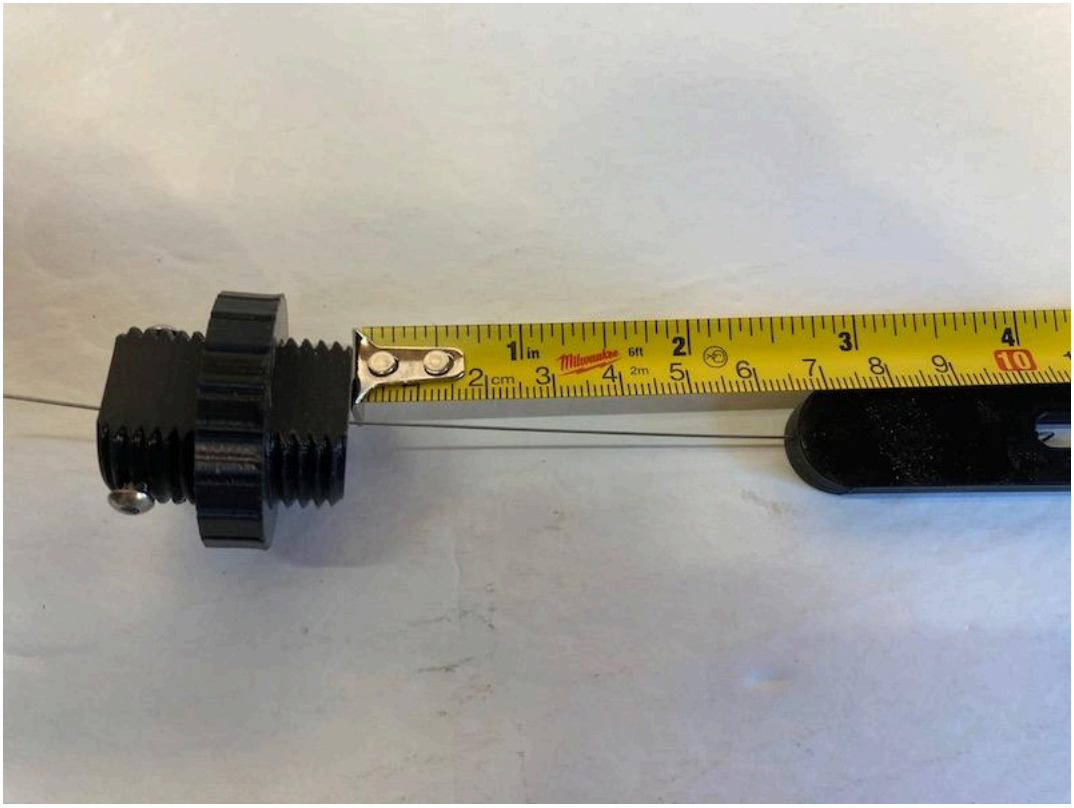
Pendulum and Bob
Make a small loop at end of suspension spring
Install Bob on adjusting screw to prevent loosing the BB balls

Install M3 nuts and screws at top of adjusting screw
Install nut on screw, and check for light play of nut on screw



Install suspension spring in top pendulum part

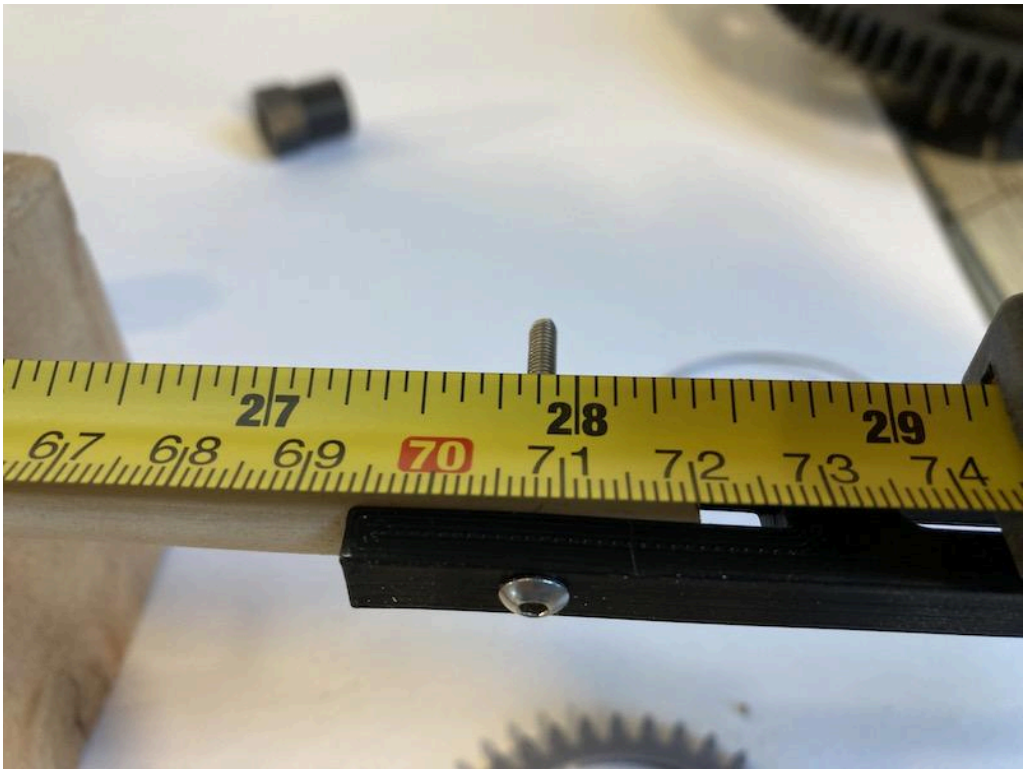
This the setting that works for the length of spring
Note: That length is needed so the crutch pin matches the slot in top pendulum part
Tighten both screws litely



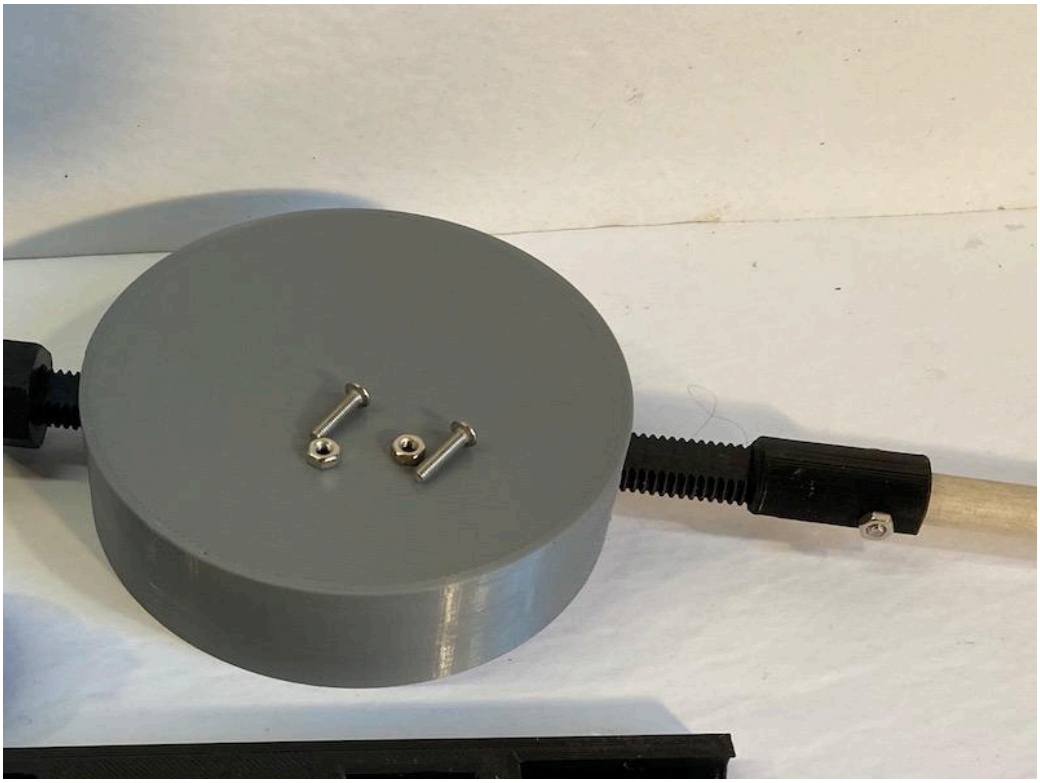
Pendulum rod length

- Mine is 720 mm, start longer, adjust as needed

Top end

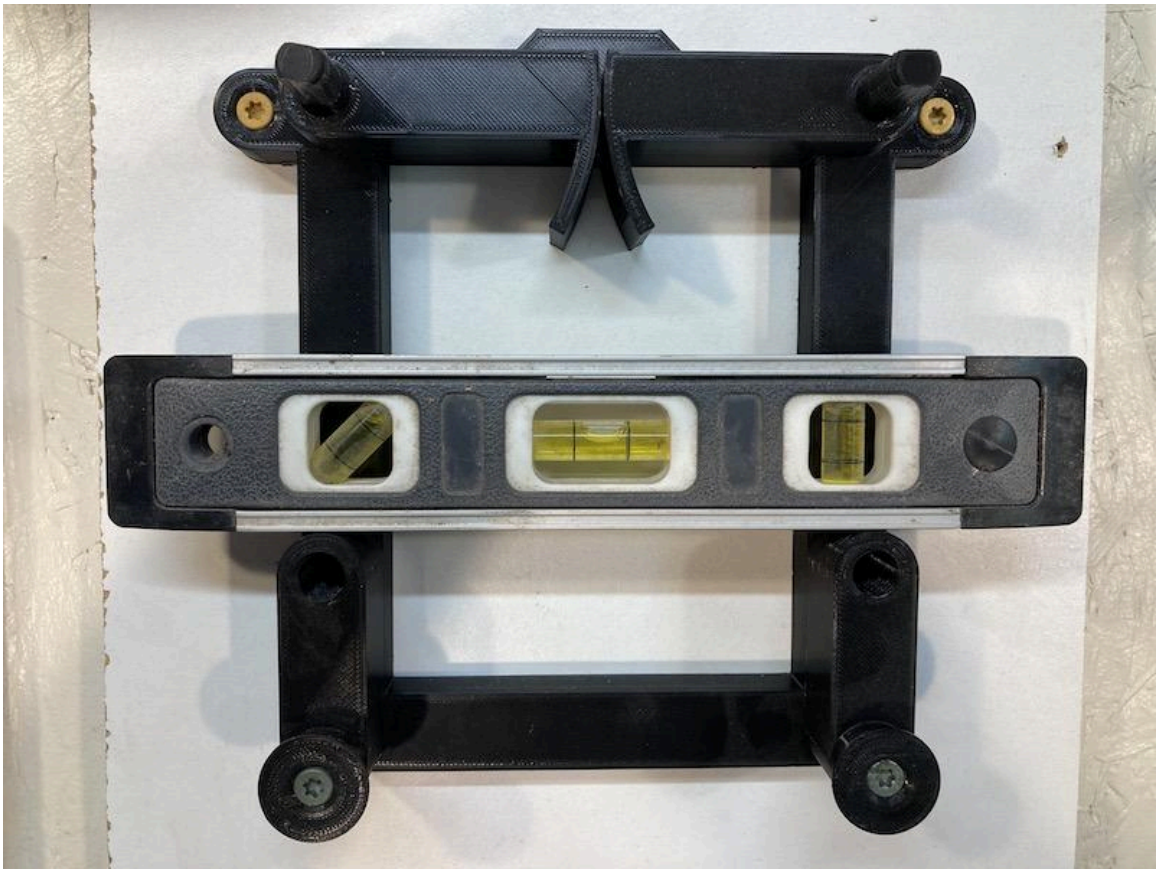


Bottom end



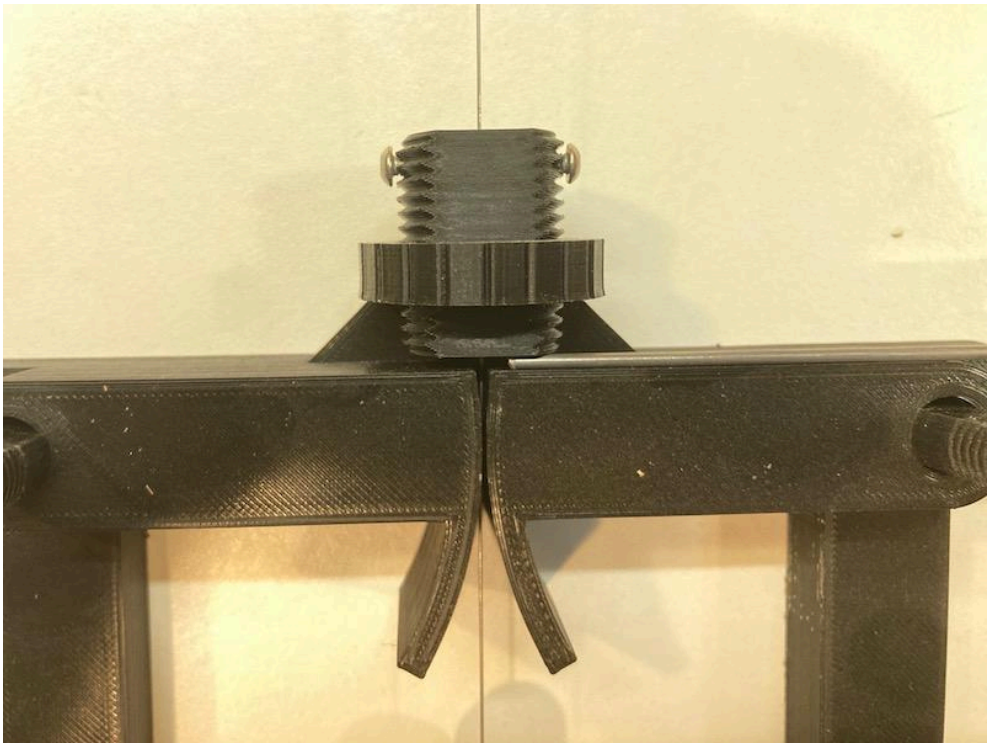
Installation of Wall Frame to Wall

Install frame to wall taking care to level it

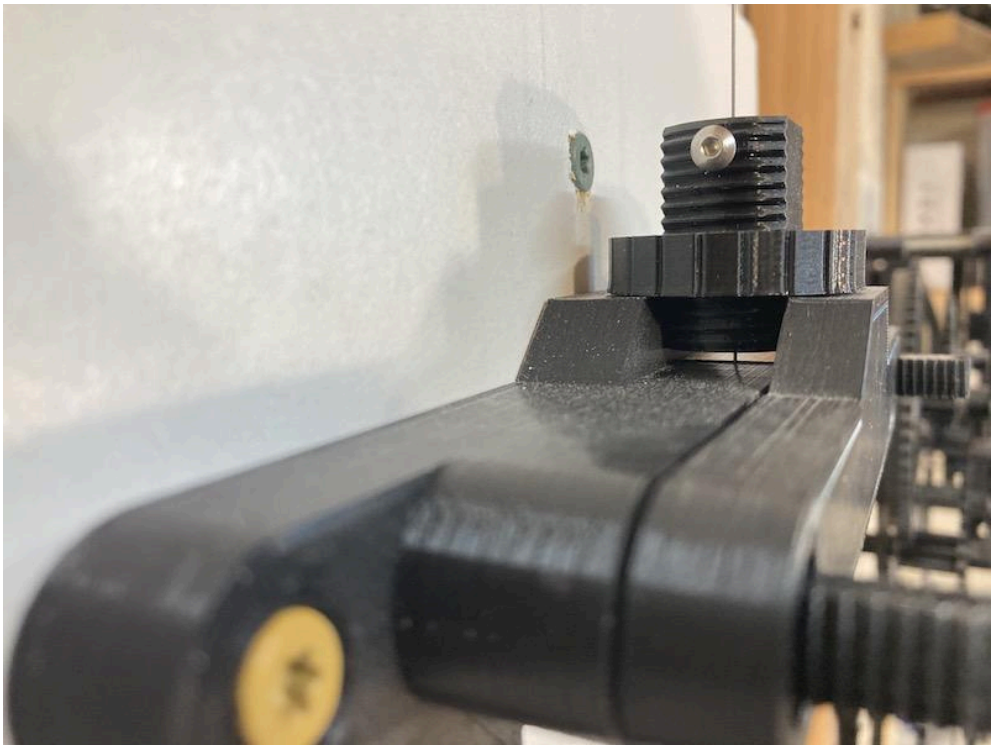


Install studs

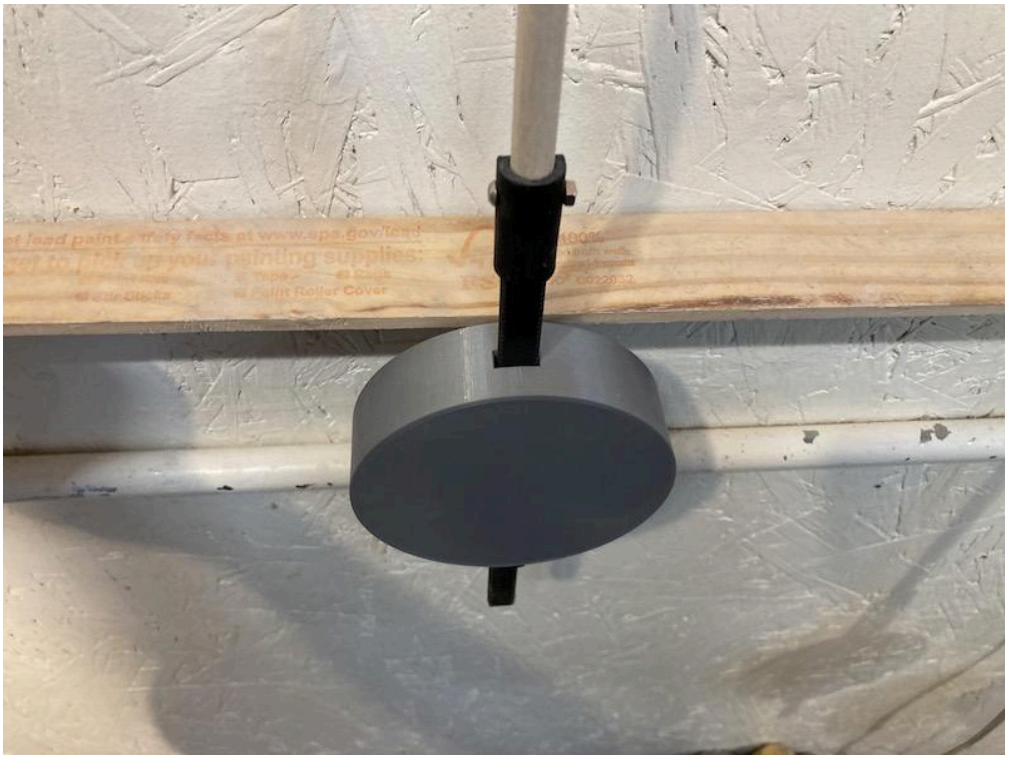
Install pendulum in place
Leave a small gap between screw and frame, here it is 2 mm
That is for final pendulum length adjustment with the clock running



Install front frame and install 2 and install 2 M12 nuts

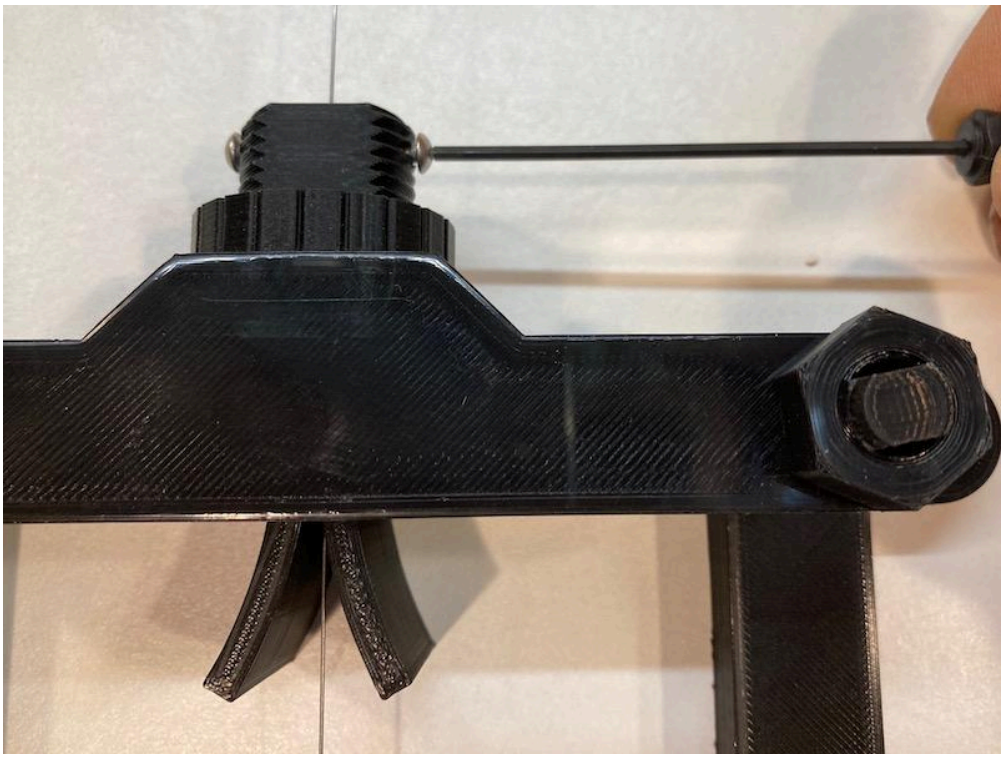


Check that the bob is parallel to the wall



Release and tighten screws as needded

Maintain suspension spring lengh

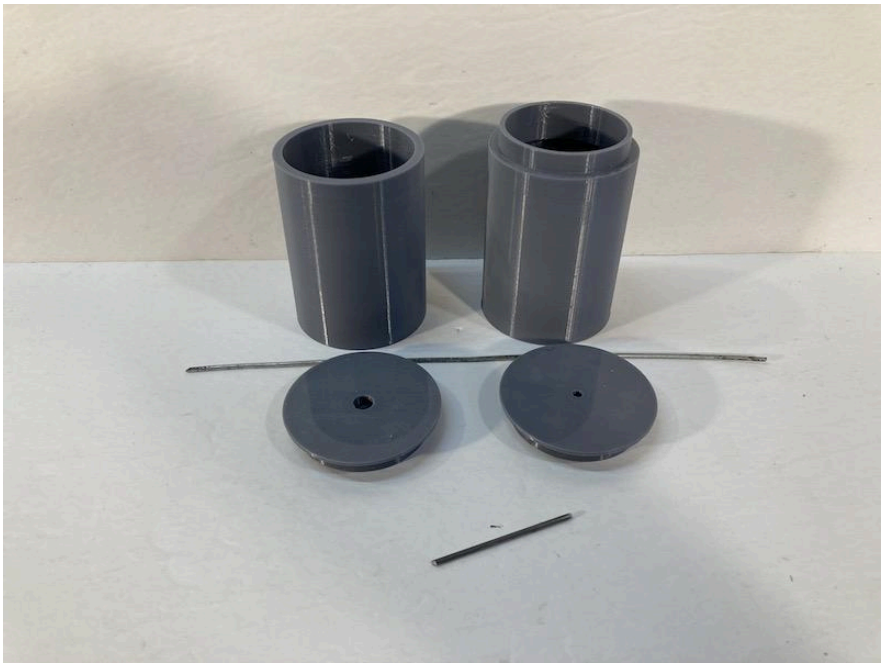


View on position of slot in between wall frame and rear clock frame
Notice how the rear frame has a range of rotation on wall frame for final leveling

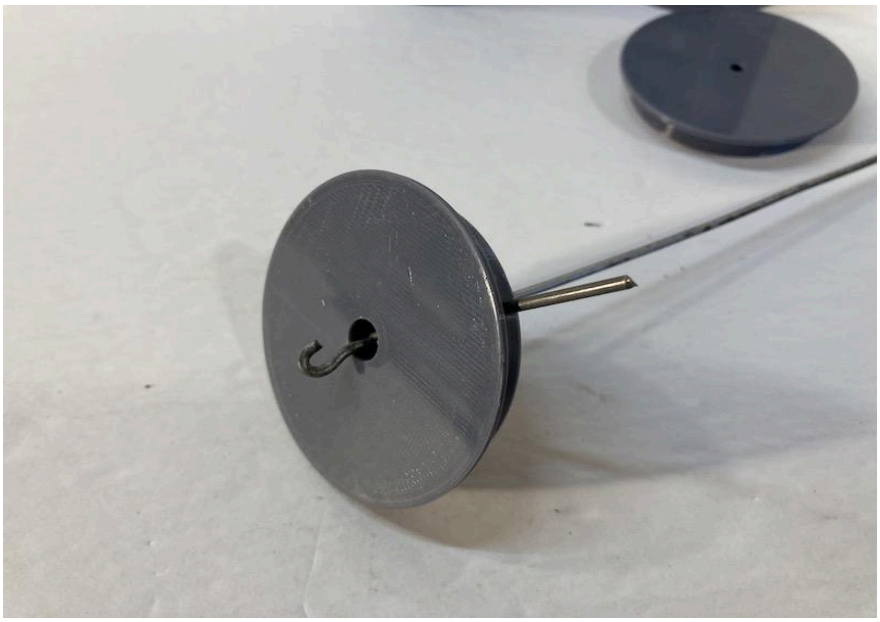
Lower wall mount and swing indicator

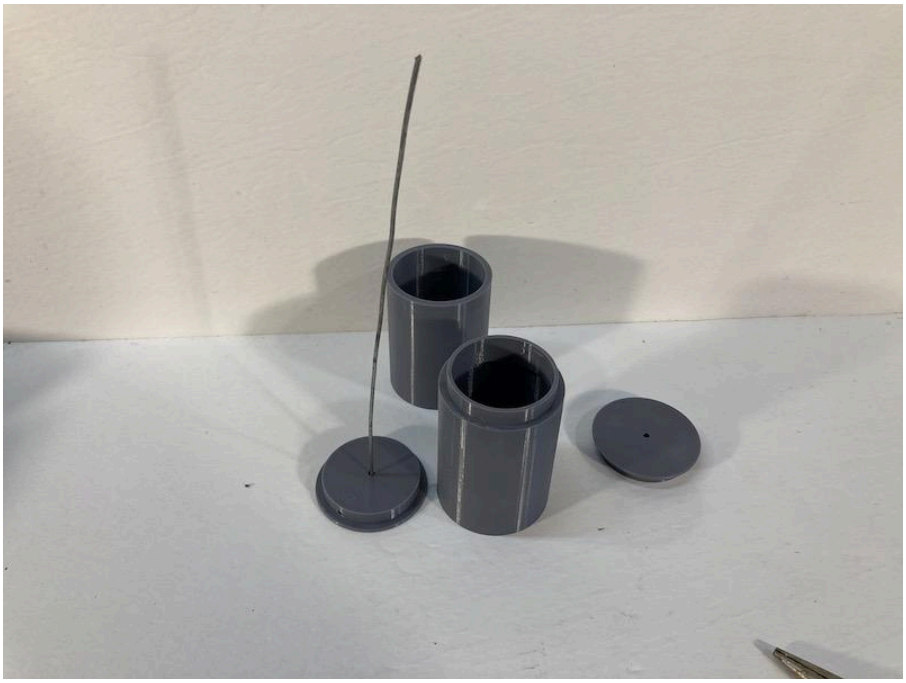
Weight

- Weight Shell Bottom
- Weight Shell Top
- Weight Shell Cylinder
- Weight Shell Cylinder
- Ø 2mm X 50 wire Lock
- Ø 1.5 TO 2 mm steel wire, or picture hanging wire
- Scrap steel, bb Balls to fill up the weight

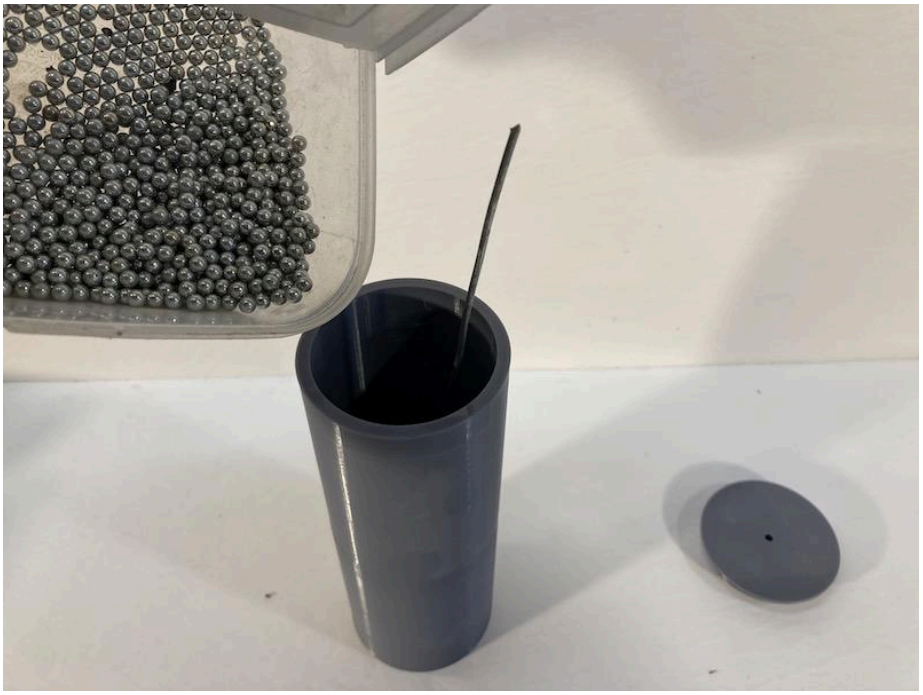


Make a small loop at end of wire and lock in place with Ø 2 pin



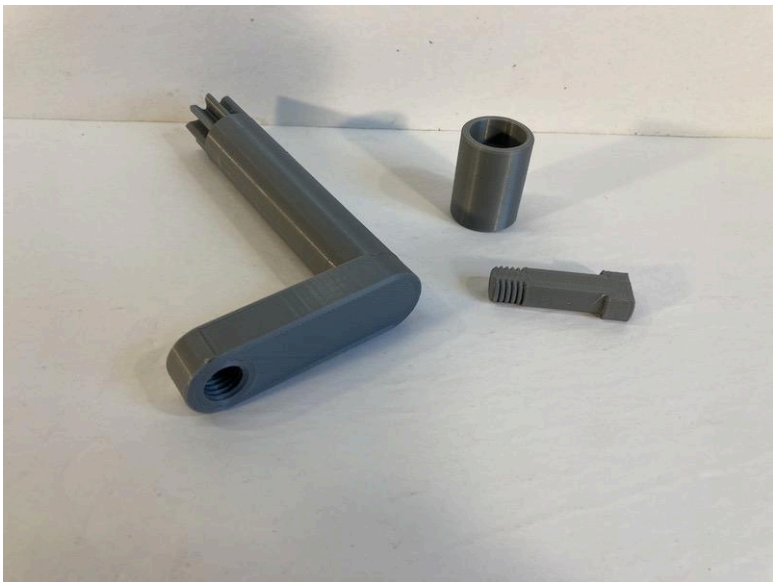


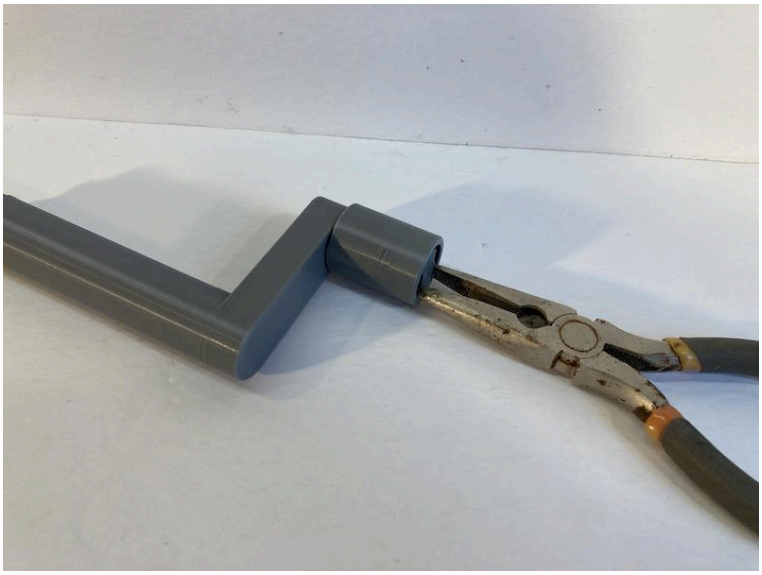
Stack shells as needed and fill with scrap metal and BB Balls



Rewind Key

- Gear 8 Rewind
- Screw Rewind
- Rewind Handle



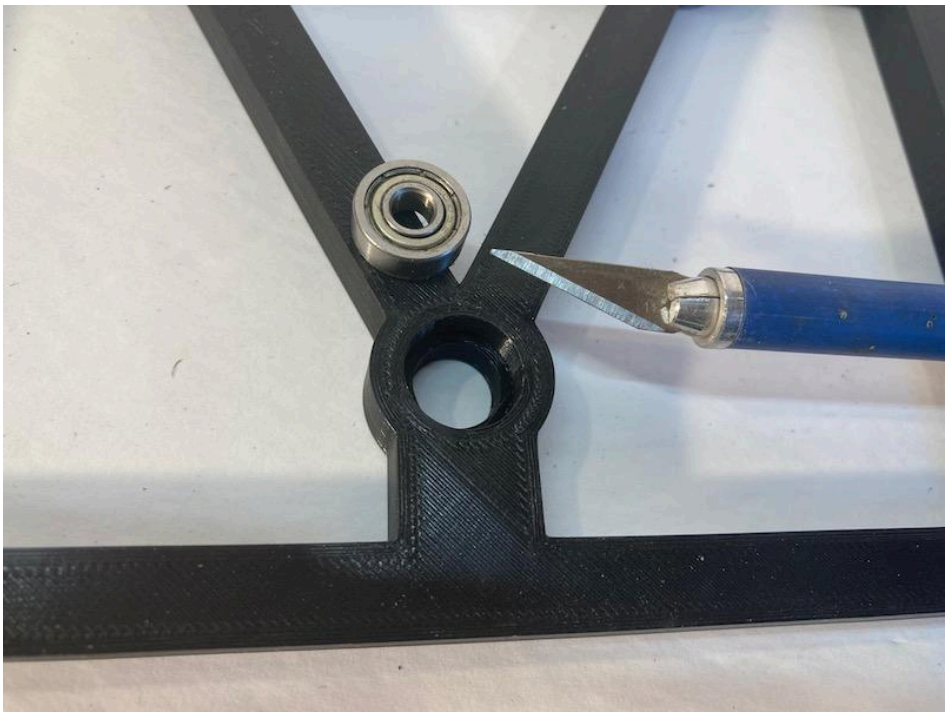


Assembly

Part 1 rear frame/going train

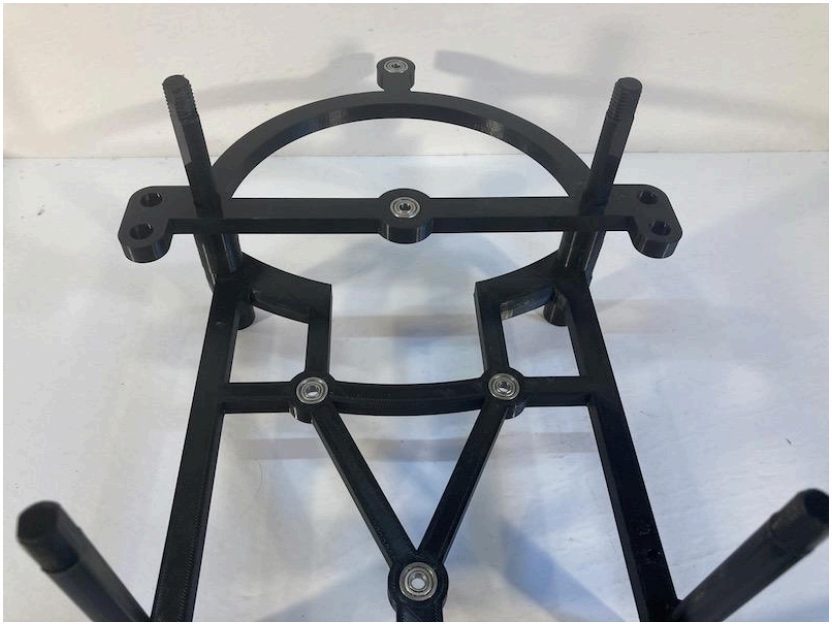
- Back frame
- Rear escape frame
- Side Frames right
- Side Frame Left
- 4 x Rods
- 4x Nuts
- 5 X bearings
- Maintain Power Shaft Assembly
- Ratchet Shaft Assembly
- Drum Shaft Assembly

Deburr holes for bearing



Install bearing
Check fitment of M12 Studs and back nuts
Install M12 rods in back frame

Install Rear Escape Frame on rods

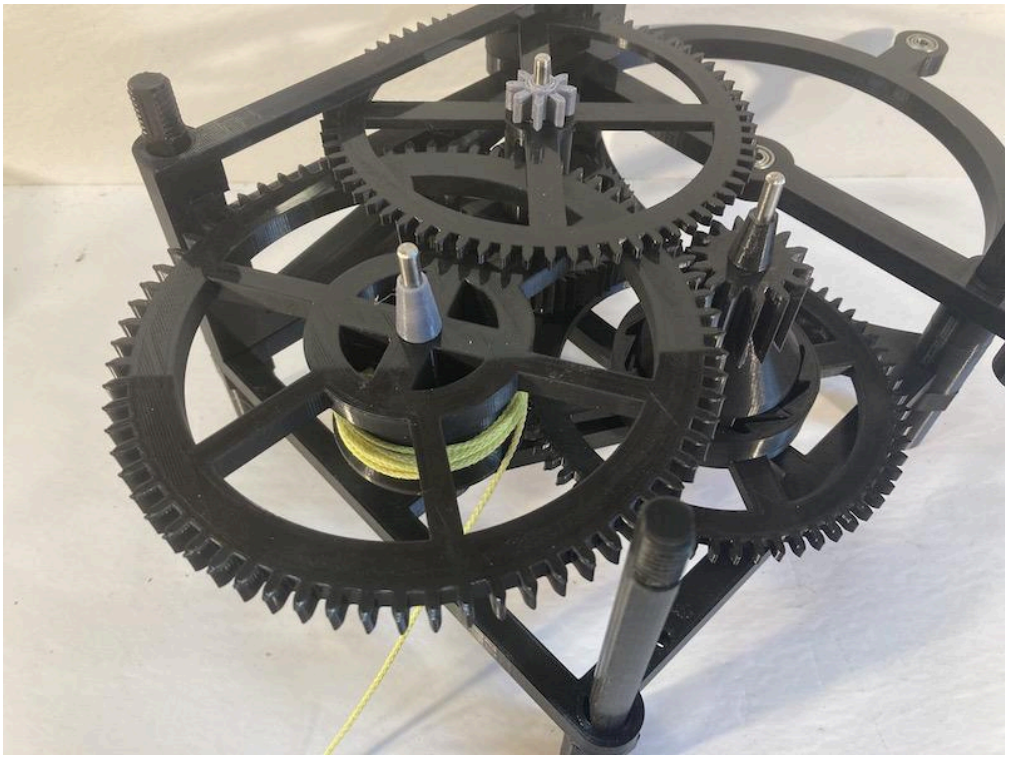


Install Frame Side Left

Install Maintain Power Shaft on the left side
Raise slightly the Side Frame if needed

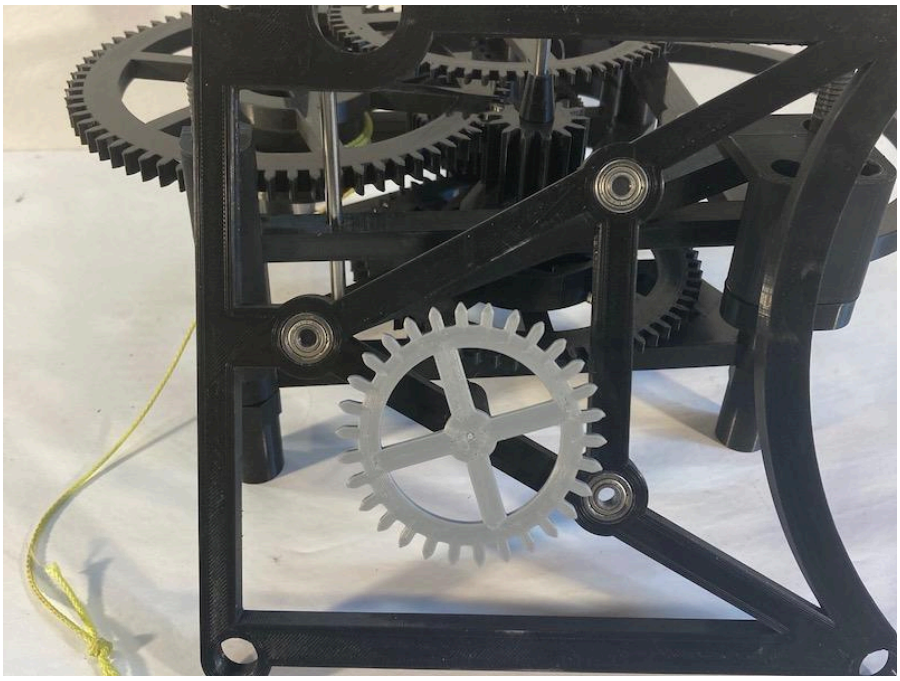
Install Ratchet Shaft on the right side

Install drum Shaft in the middle

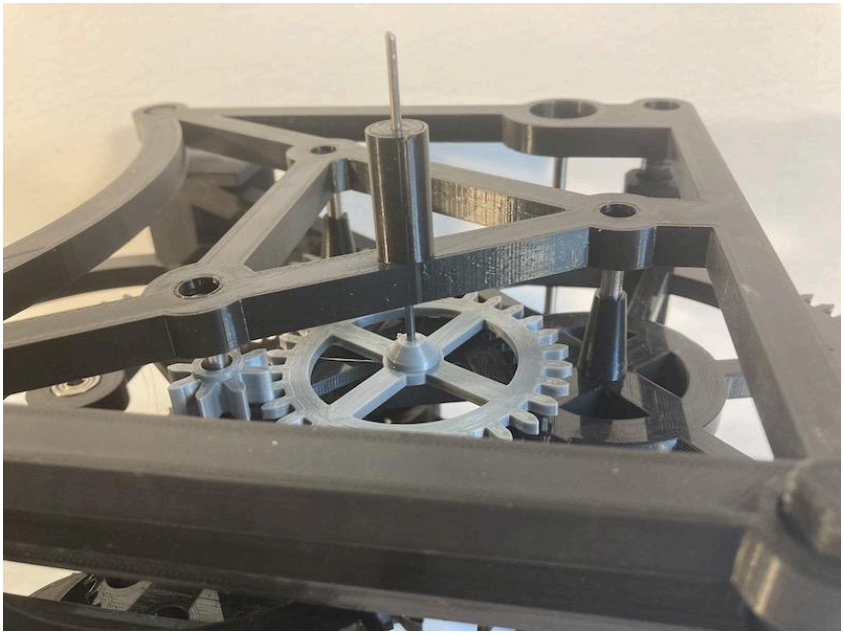


Install middle frame

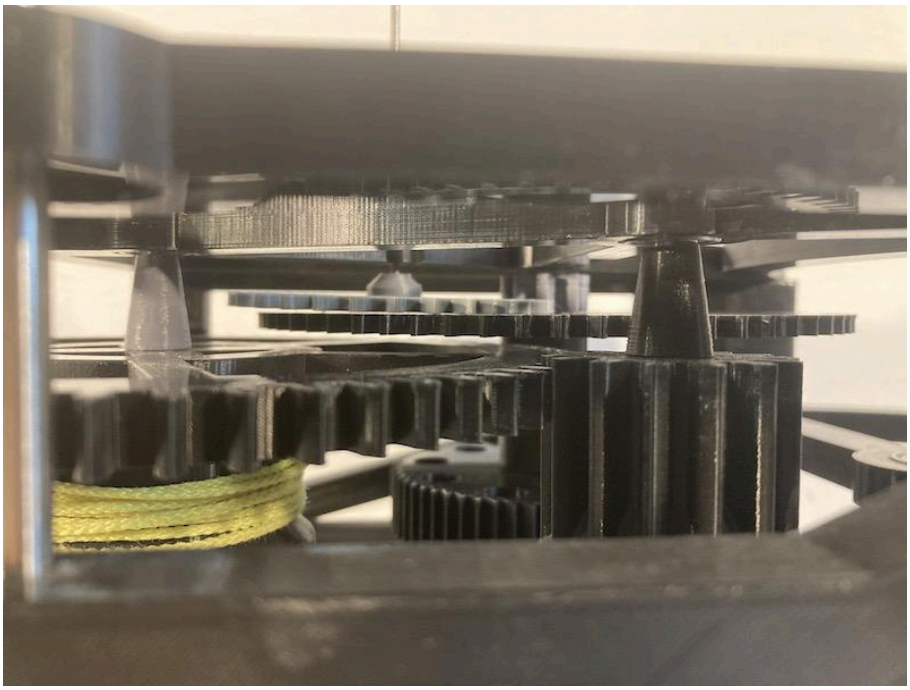
- Middle Frame Assembly with gear pick up and 3 bearings
- 4 x M12 nuts



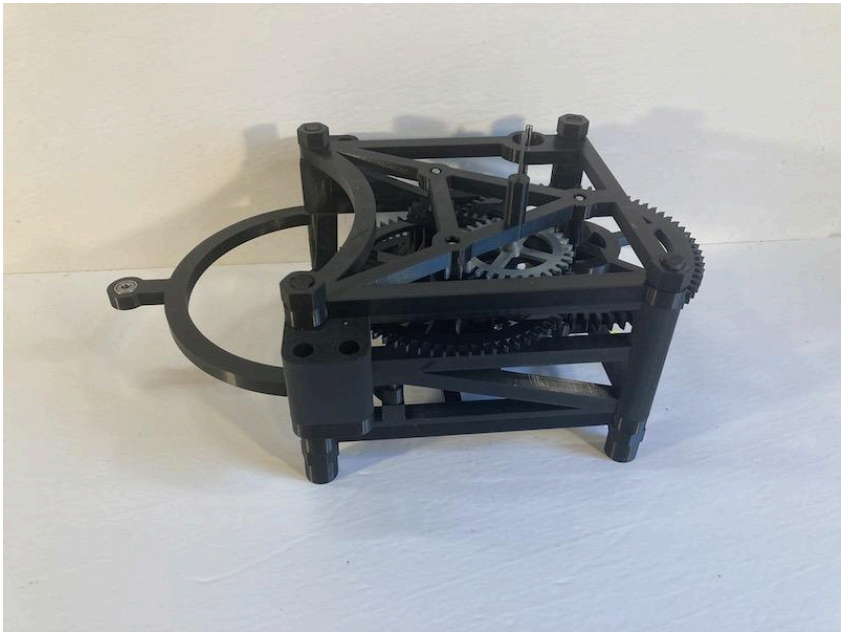
Install frame, check alignment of shafts with bearing
Engage pick up gear with the pinion
Press frame in place



Check clearance and slight axial play of shafts
Install and tighten nuts, make sure nuts are flush with rods
Re-check clearance
Pull the string to check good meshing of gears
Check for absence of hard spot
Check that all gears have some backlash play at multiple position



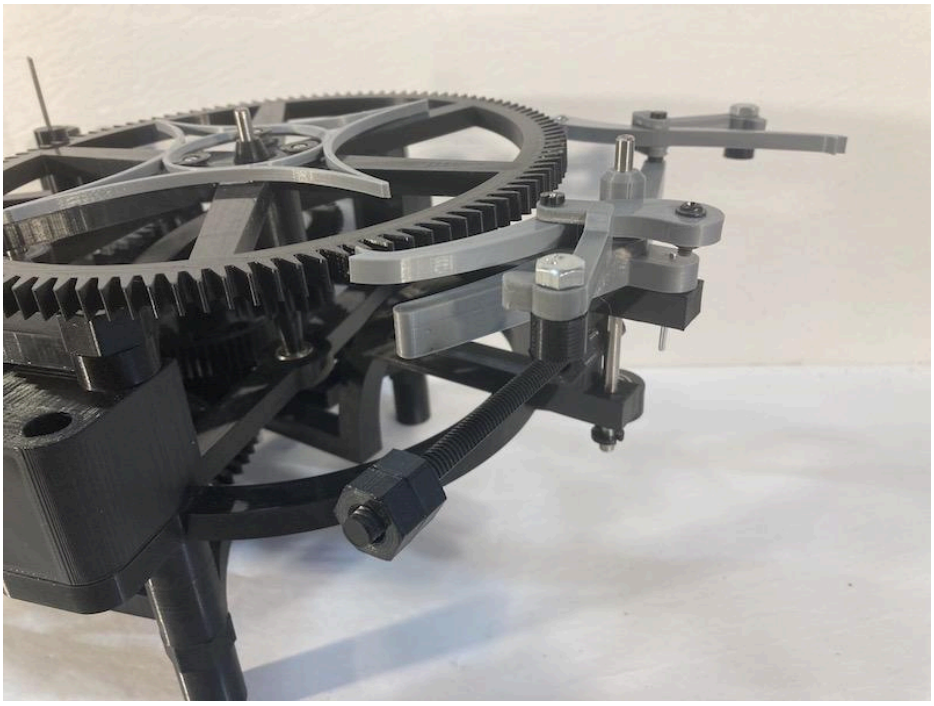
Frame ready for next step



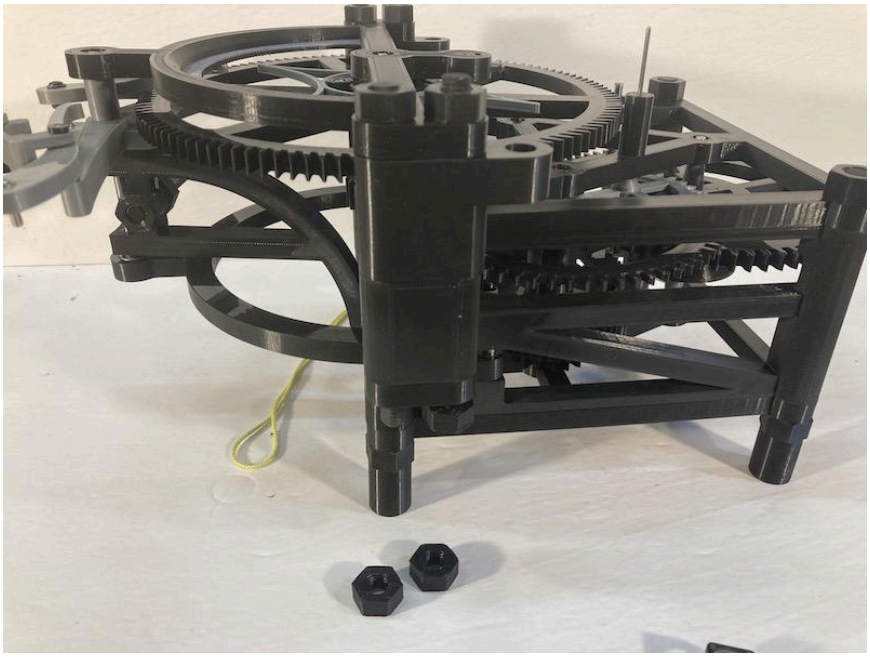
Front Frame, Escape Wheel and Escapement

- Front Escapement frame
- Second Dial
- 2 x Side Spacers
- 4 x M10 rods
- 8 x M10 nuts
- Escapement Anchor Assembly
- Escape Wheel Assembly

Install Escape Wheel
Install escapement Anchor Assembly



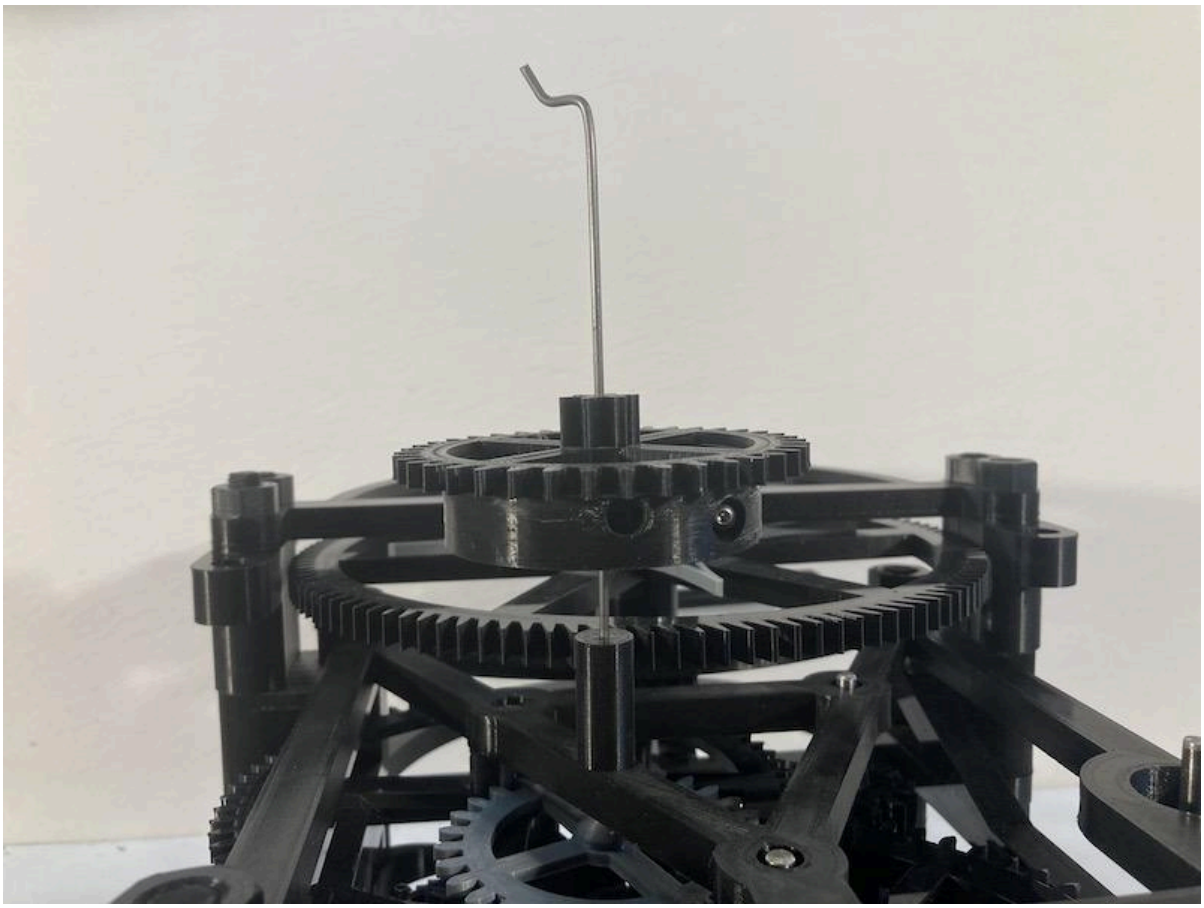
Install side spacers, M10 rods and nuts



Install clutch

- Clutch assembly

With the clutch assembly on a 2mm rod, guide the assembly onto the shaft and push in place



Tighten retaining screw on Stop Ring
Allow a little axial play

And adjust tension of clutch

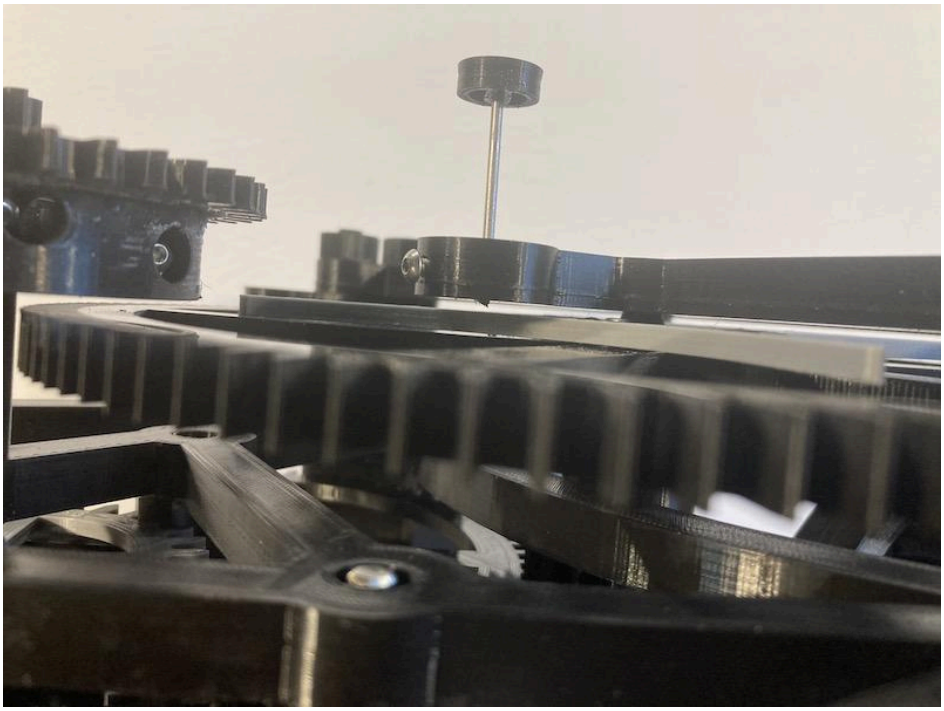
Install Hands

- Hands Assembly
- Washer

Install Hands assembly with a washer between assembly and Frame

Tighten maintaining screw

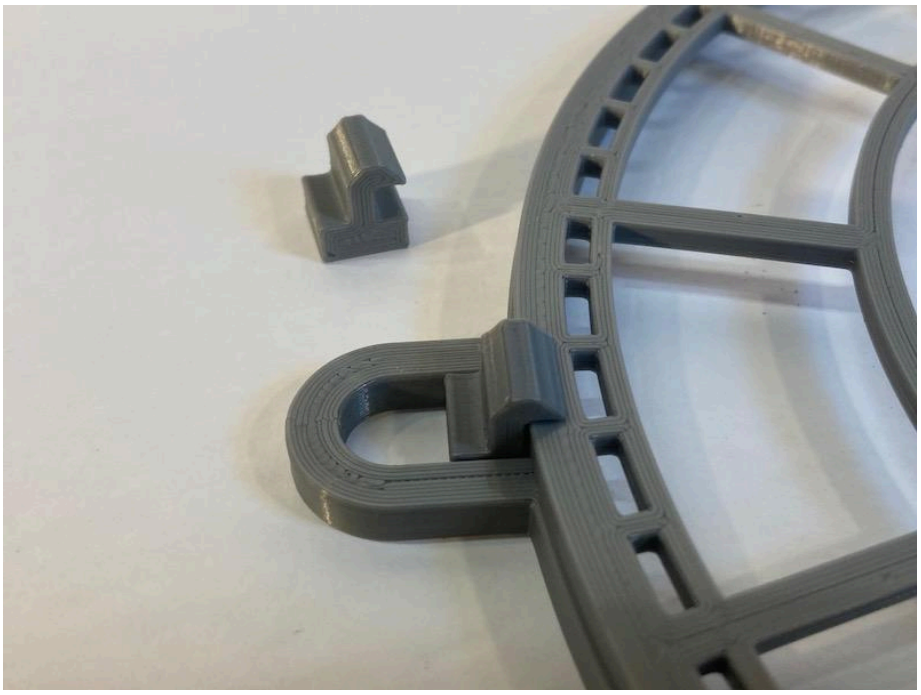
Check for clearance at back of frame, Shaft should be flush with frame
(shown with hands for clarity)



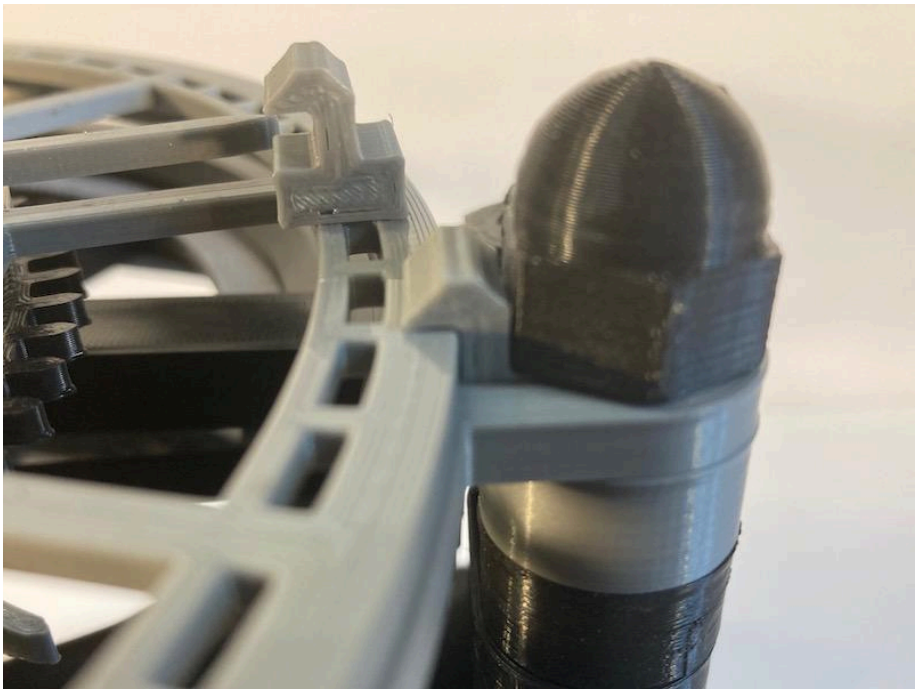
Install face

- Face
- Face Holder
- 2 x face locks
- 4 x spacers
- 2 X M10 rods
- 2 x M10 nuts
- 2 x M10 Acorn nuts

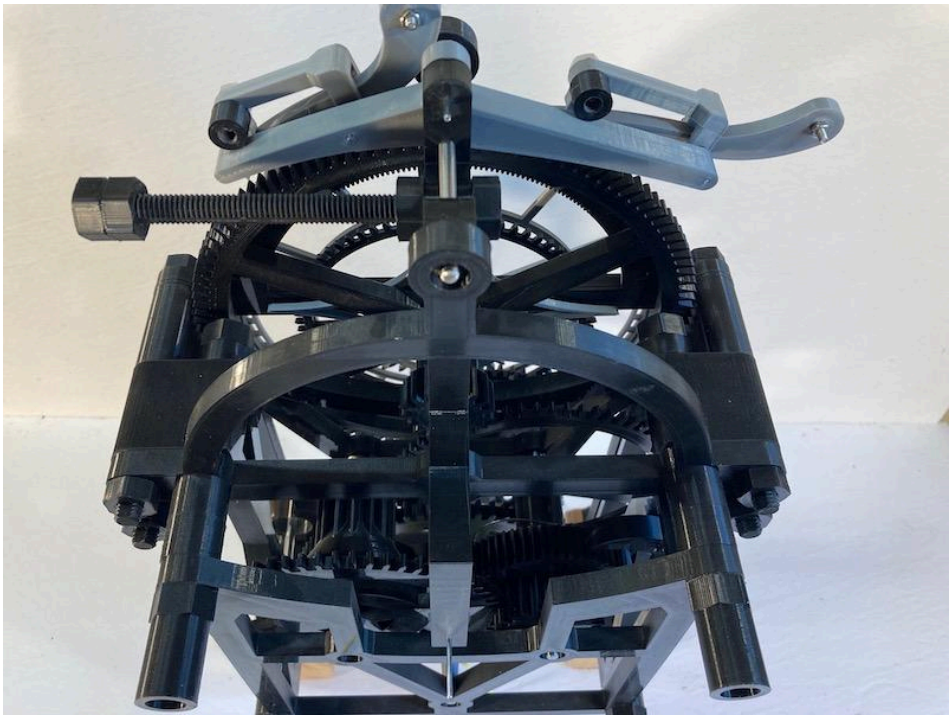
Face lock detail



Install Acorn Nut on rod
Install Rod and rear nut



Balancing escapement anchor



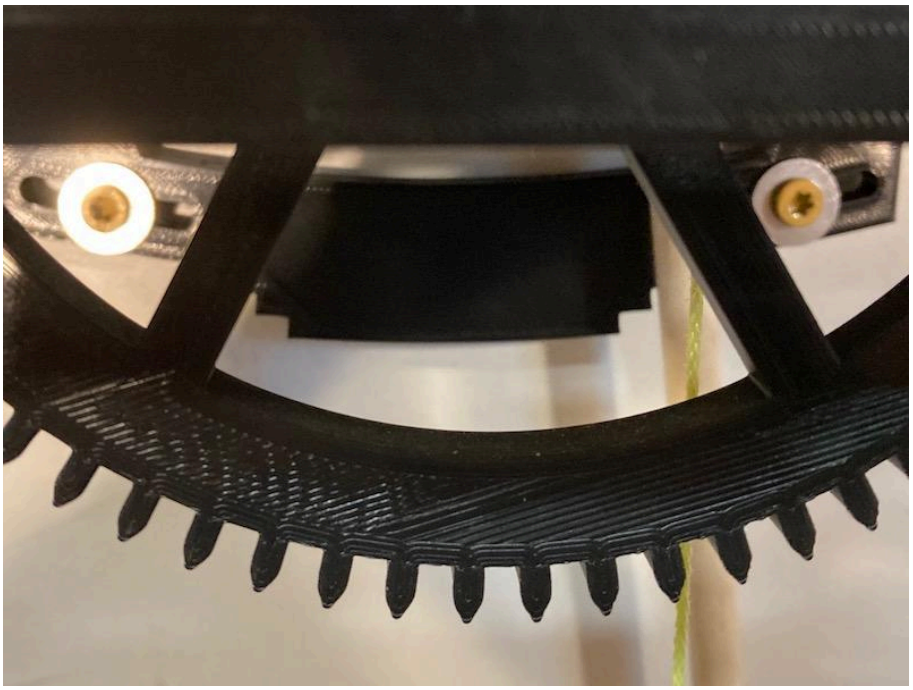
Hang the clock

Detail view of back frame hooked to wall frame
The escapement crutch need to engage the slot in pendulum
There is a small range of motion for the final leveling of the clock

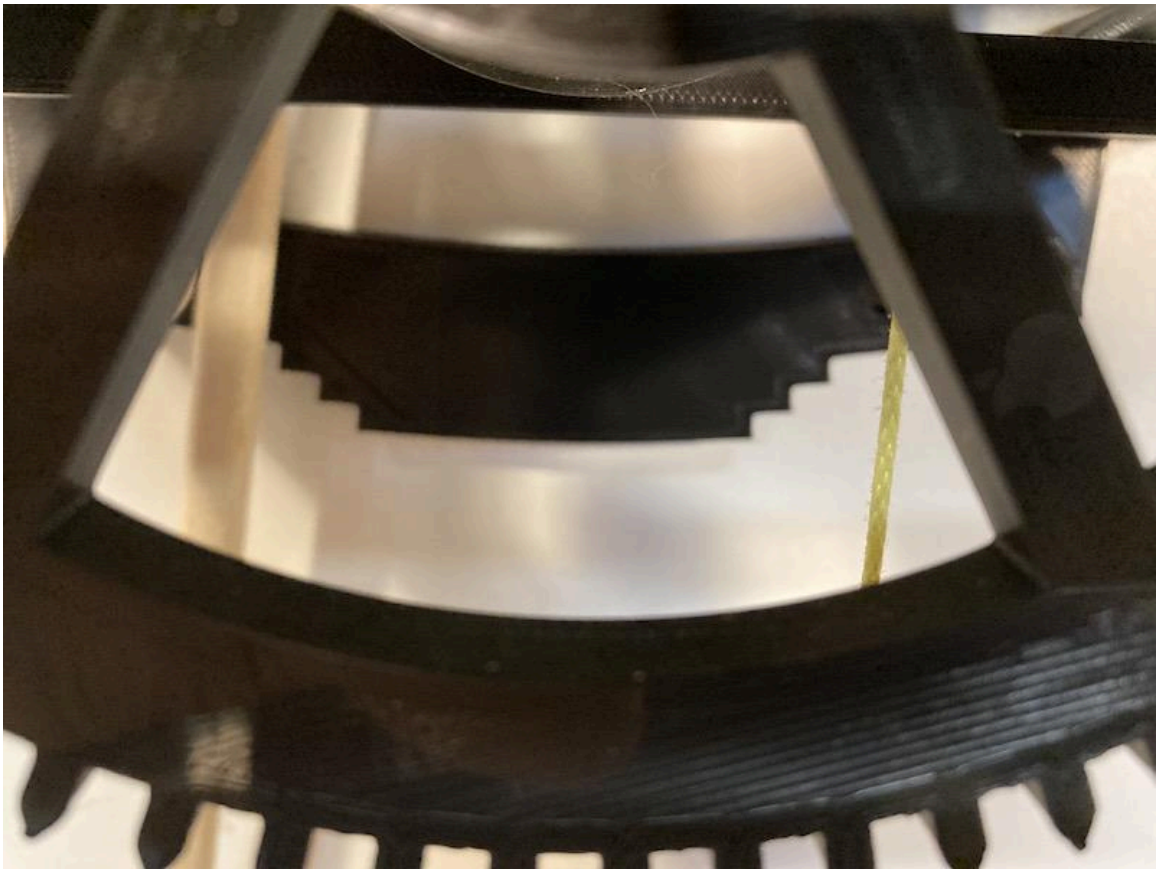
Once the clock is hooked up, slide in the lower frame look

It might help to pre drill holes

Level the clock, install two screws with washer to lock the clock to wall



Observe the swing of the pendulum
There are 3 swing angle indicator
The narrower indicator is 6 degree each side, total 12 degree
That is the minimum angle needed for good operation of escapement
Then increment by 1 degree to 7 or 14 degree total
The 3 rd one is 8 or 16 degree That is more than needed
John Harrison suggest that 12 is ideal, 15 should be the max
Adjust the swing by adjusting the drive weight
My clock runs with 3,5 kg, and that is slightly too much
However it was not enough the first day I run
It is possible that there is some breaking in that has happened

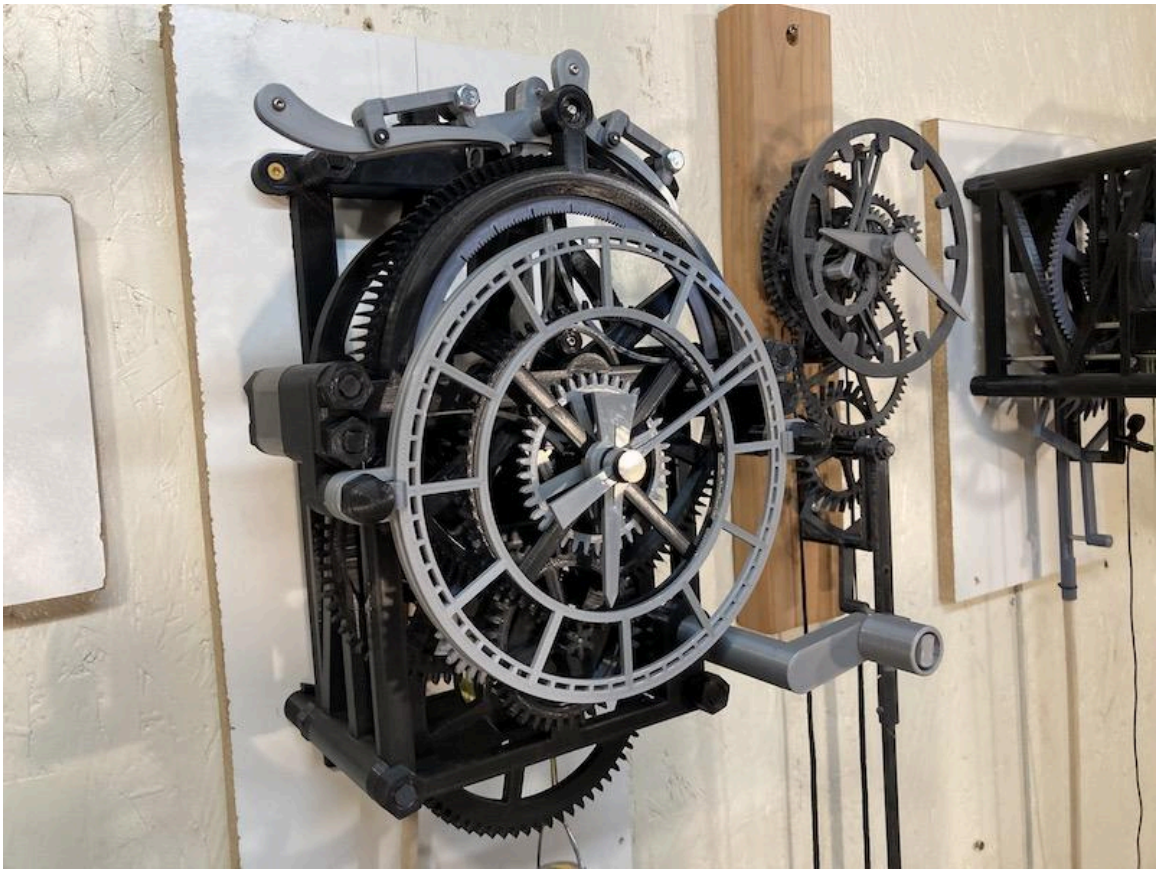


Starting the clock

Warning!
The escape wheel on a grasshopper escapement clock can run away!
Pallets and or escape wheel can get damaged

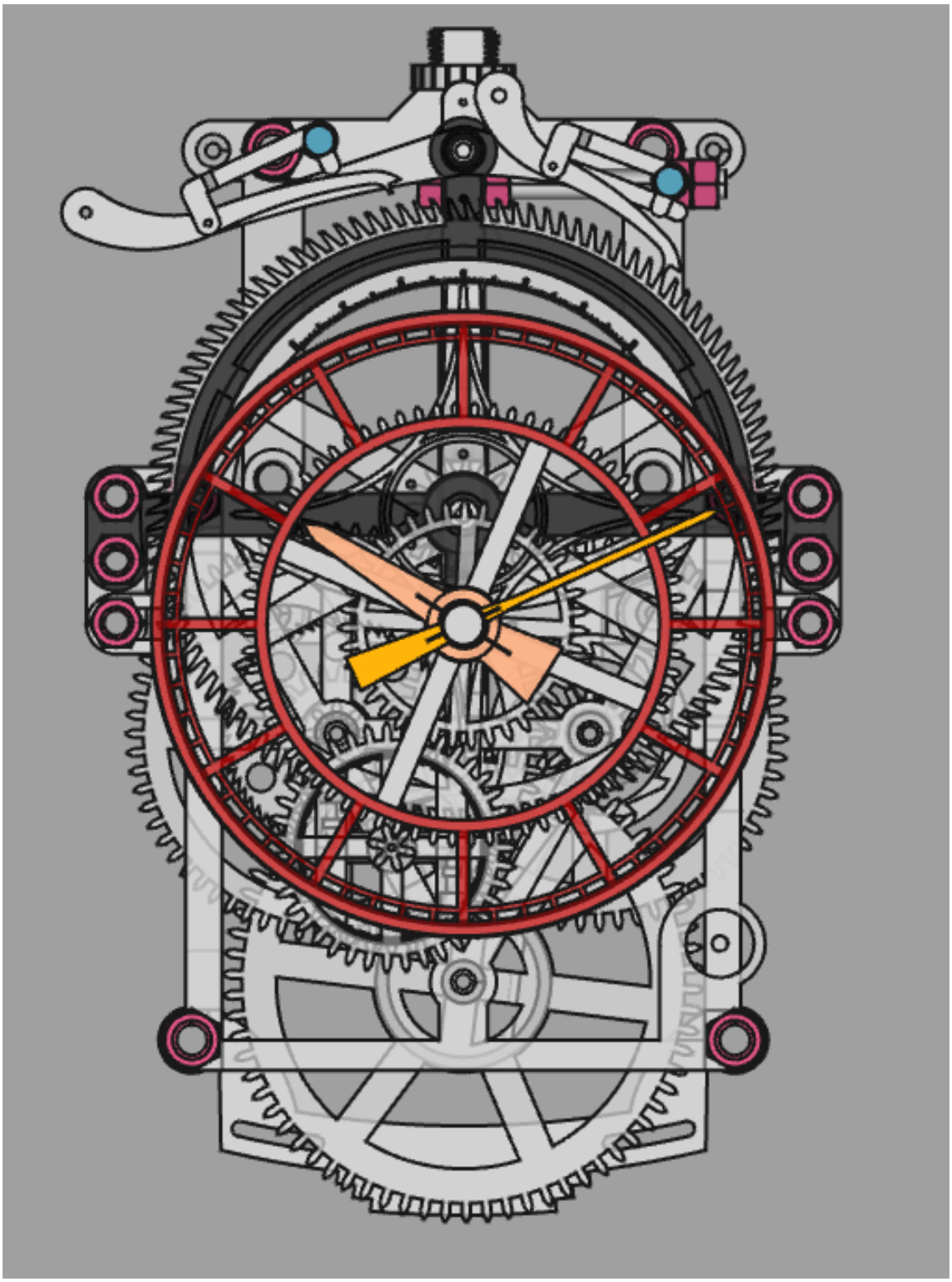
Safest way to start the clock:

Unwind the cord, hook up the weight and let it rest on the ground
Engage one of the pallet with the escape wheel
Start rewinding the clock to get some weight on the cord
Lift just a centimeter for now
Pull the pendulum bob out the side the pallet is engaged
At same point the opposite pallet will engage the escape wheel and the near one will release
Now slowly move the bob the other way
The pallets should switch again
Check that the pallets and composer move freely
Check that the pallets engages fully the escape wheel
Check that amount of swing needed right and left is roughly the same
If it looks OK
Pull the pendulum bob another centimeter and let go
The clock should start ticking
When the clock runs nicely with the right amount of swing
Rewind the clock all the way and start checking the time
Start adjusting the bob distance at the bottom of pendulum
I like to catch the bob when it is fully on the left side with my left hand
Lengthen or shorten as needed with right hand
And let go
I start with counting 10 seconds, the 30 seconds, then a minute
Then let it go for 24 hours
Once it is within or less than a minute a day of drift, you can start the final adjustment with the top nut

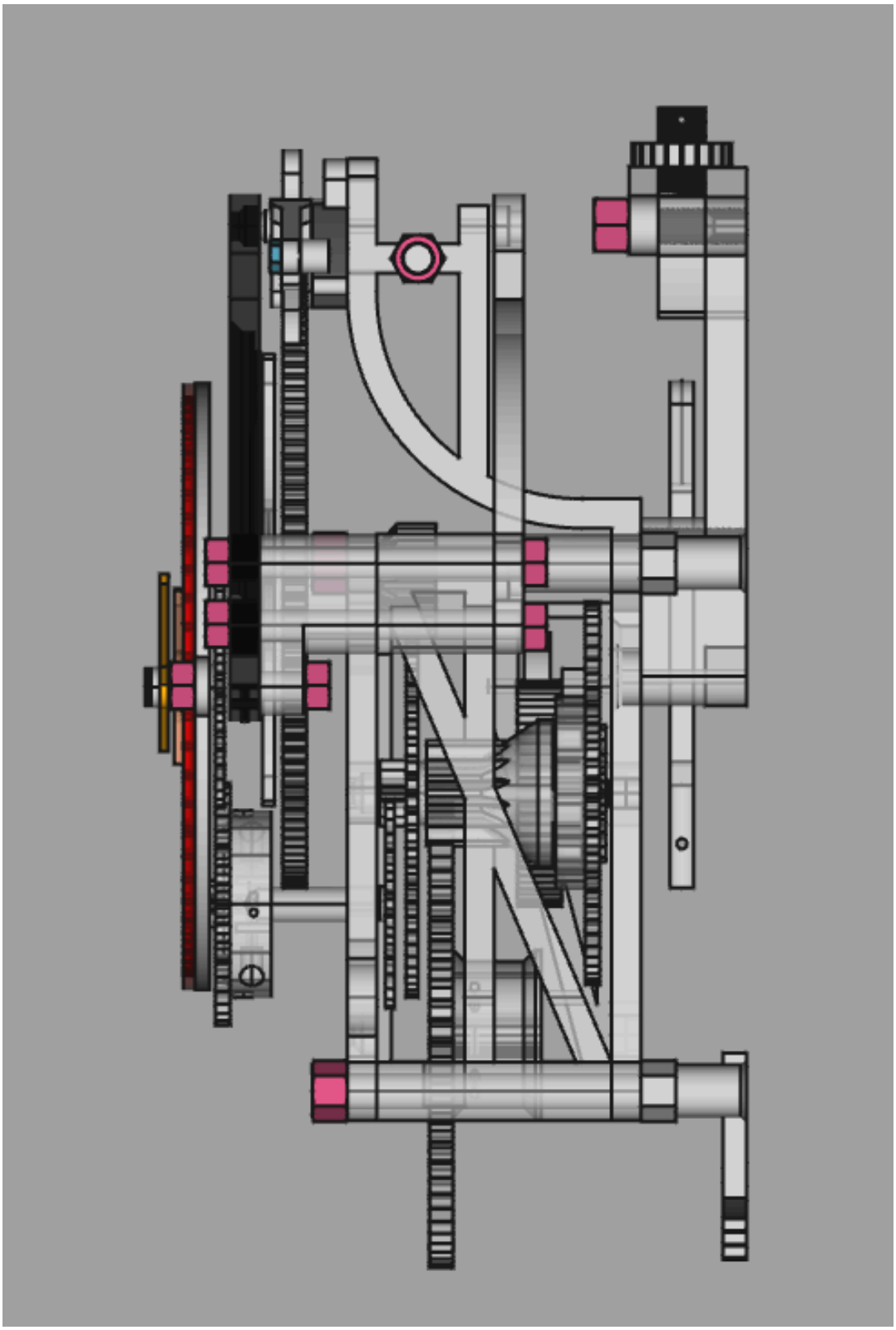


3D views

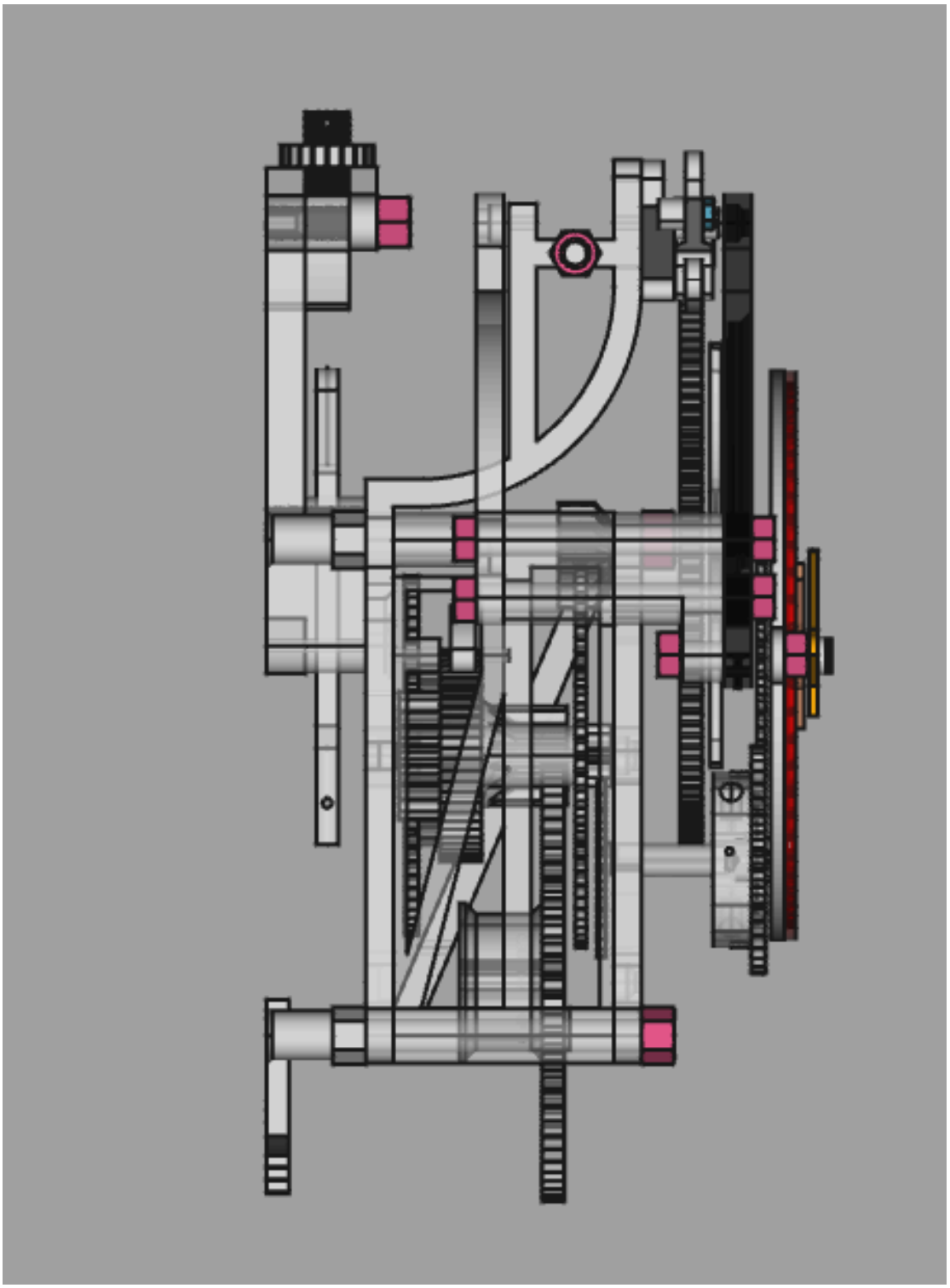
Front



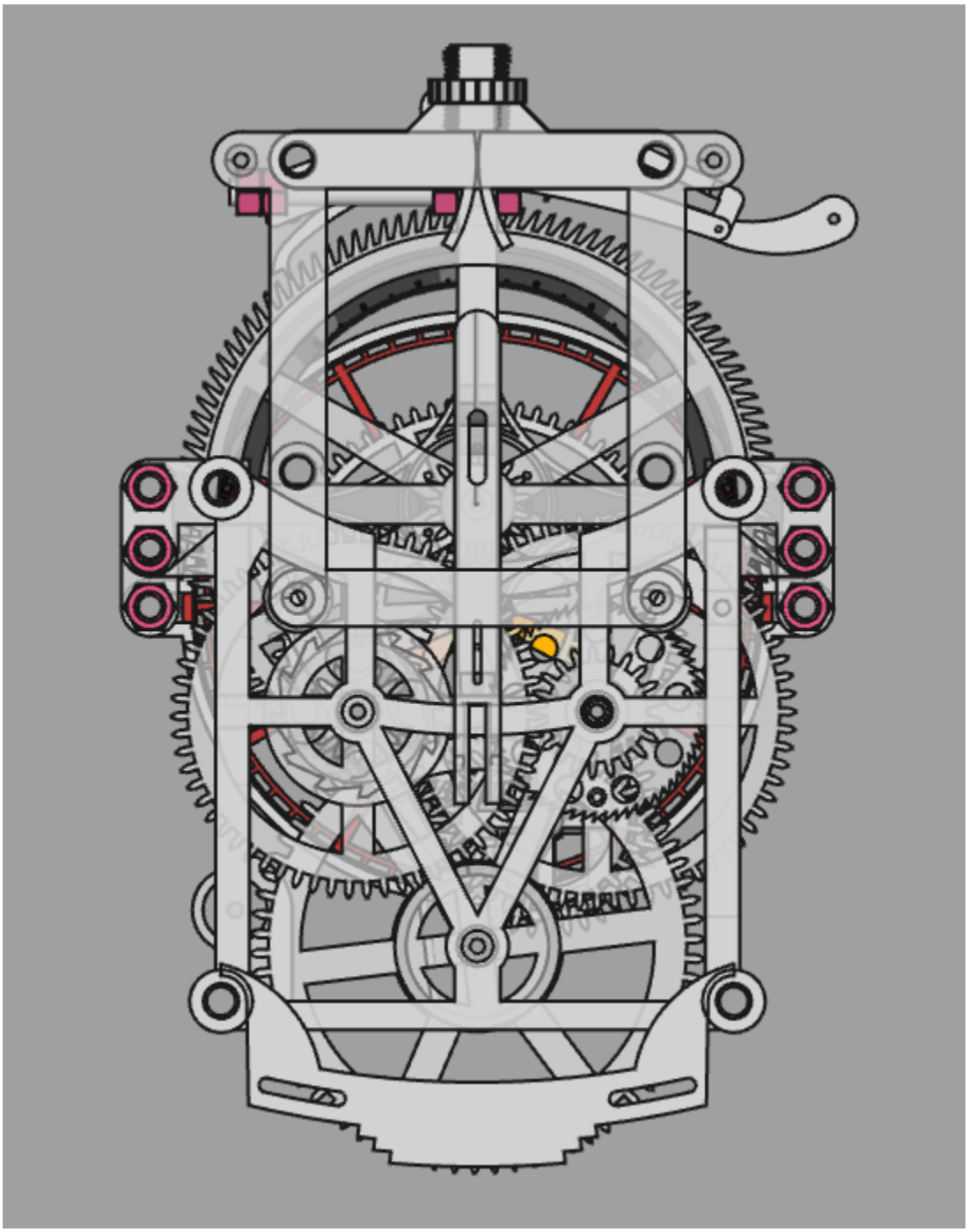
Right



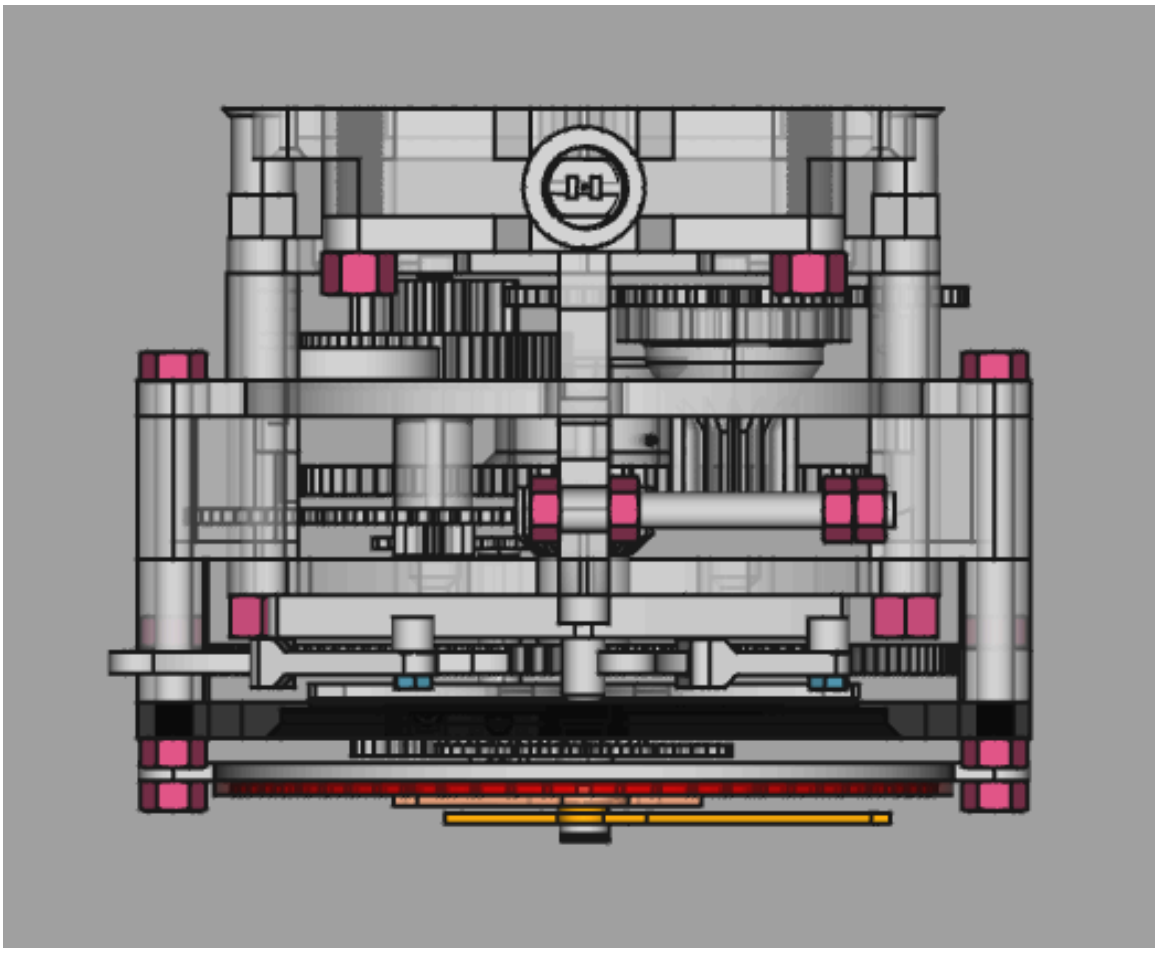
Left



Back



Top



Bottom