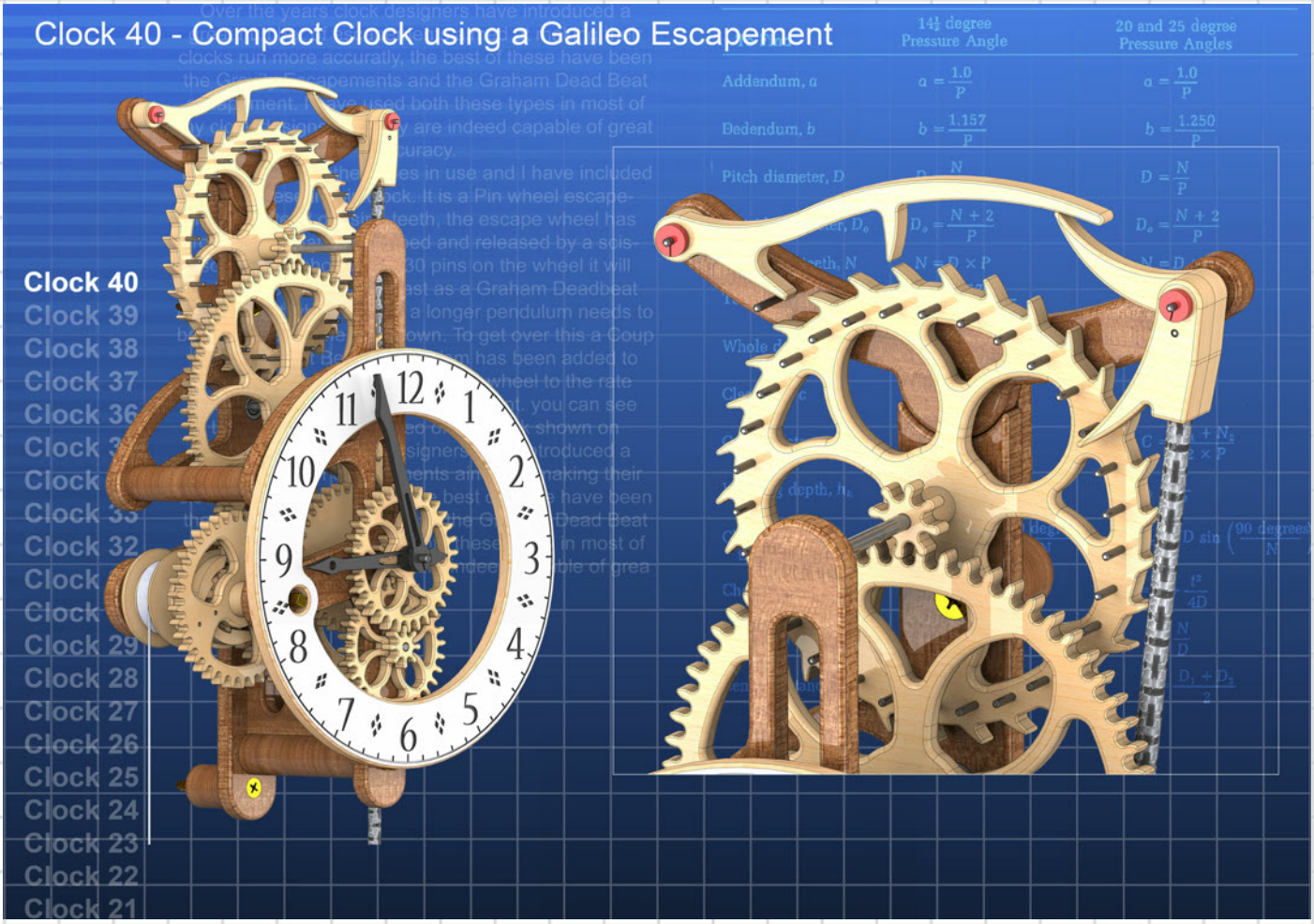
Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40



I have been experimenting with various types of escapement used in earlier clocks and have by now incorporated quite a few of them in my wooden clock designs. There is however been one design that I have never gotten around to, and that is the escapement designed by Galileo, used in a clock design he developed from his pioneering work on the pendulum. He described the design to his son who produced a drawing of it, unfortunately, they had both died before they could see the clock completed. This is my tribute to that design, I have tried to stay close to the original by retaining the teeth, Pin and finger arrangement shown in the original, but included more teeth to keep the gear ratios manageable. This is not as accurate an escapement as the Graham escapement nor as efficient as it only picks up the impulse on one side of the pendulum swing, but it is non the less an interesting designed carried entirely on the front face of the back panel so the whole of the mechanism is completely visible.
It is quite a compact design and can be made either by hand on a scroll saw or using a CNC router or even 3D printing.

Equipment

The following equipment is desirable:

CNC Router or Laser or Waterjet and if not one of these then a Scrollsaw or a Bandsaw. Small Lathe, this is not essential but it would make making the clock a lot easier for all the round parts that are needed.
Small Milling machine or **Pedestal Drill** with work holding vice. There is a lot of holes to be drilled and cleaned up after CNC machining and fabrication so the drill is pretty much essential. It may be possible to get away with an ordinary electric drill in a stand but a work holding vice is still necessary.

Drill Bits in the following sizes, Ø1.4, Ø1.5, Ø1.9, Ø2 mm, Ø2.1,Ø2.9, Ø3mm, Ø3.1,Ø4 mm ,Ø4.1 mm, Ø6.5

Router Cutters Ø 2, Ø3 and possibly Ø6 for cutting out the larger frames.

Hand tools; all the normal things that are used in the workshop, Files, screwdrivers, hammer, pliers etc.

If you want to save a lot of time, then look at a **Sanding disk** and a **Drum sander** but these are really nice to have.

Consumables
Sandpaper in various grades from rough to fine
Danish oil for finishing.
Gorilla Glue
PVA wood glue
Dry Film Lubricant in a spray can for the gears after everything is finished.

Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

Materials

For all the wooden Parts

The choice of material to build the clocks from is a very personal one and is really down to you to decide. I prefer to use actual timber, Cherry for the frames and Maple for the gears and other parts. I use timber machined to a standard size of 125 mm x 6 mm and 125 x 9 mm and these are fabricated into blanks for the larger components by gluing two strips together.

You can, however, use a high quality grade of plywood (Marine Ply) or MDF this route is a lot quicker as you can layout multiple parts on a sheet and have the whole thing cut out in a day, still need to put in the time cleaning up the parts and making all the other bits, but generally speaking the whole thing can be done more quickly.

You can also use Perspex with which you can create some colourful clocks

Whatever you use, the flat 2D parts are all laid out for you on the Profile cuts sheet, this comes as a DXF file that is 1200 mm square, you can manipulate this in your own CAD program, which you will probably need to do, to be able to feed the files into your CAM program.

For all the other parts

Ø4 mm Drill Rod or Silver Steel 300 mm Long for all the shafts and numerous pins.

Ø2 mm Drill Rod or Silver Steel 700 mm Long

The 30 Ø2 x 15 mm pins used in the Pinwheel can be bought on the Internet instead of being cut individually from a longer rod. Search for ‘Dowel Pins Ø2 mm’

Ø 50 Wooden dowel 100 mm

Ø16 Wooden dowel 75 mm

Ø10 Wooden dowel 20 mm

No 5 wood screw 12 mm long for constructing the weight.

Woodscrews

6 MM Threaded rod 500 mm long

Ø8 mm Brass Rod 110 mm for the Drive Shaft

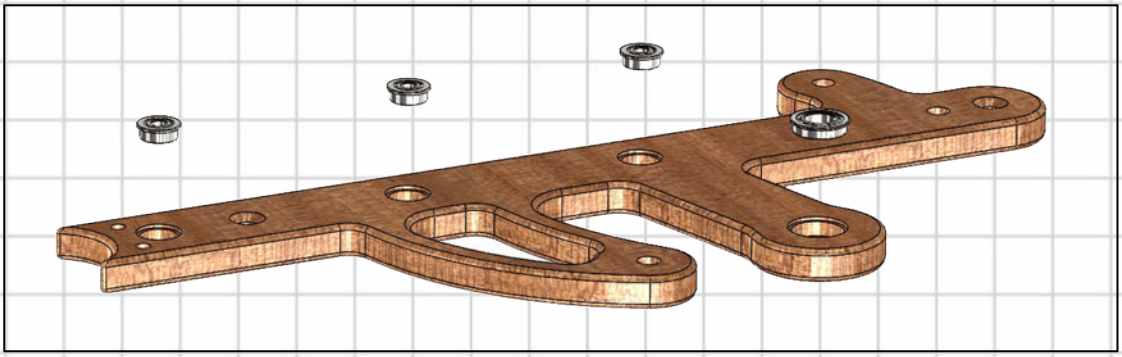
1 mm, 2 mm, and 3 mm Plastic sheet for hands and pallets, ABS or HIPS

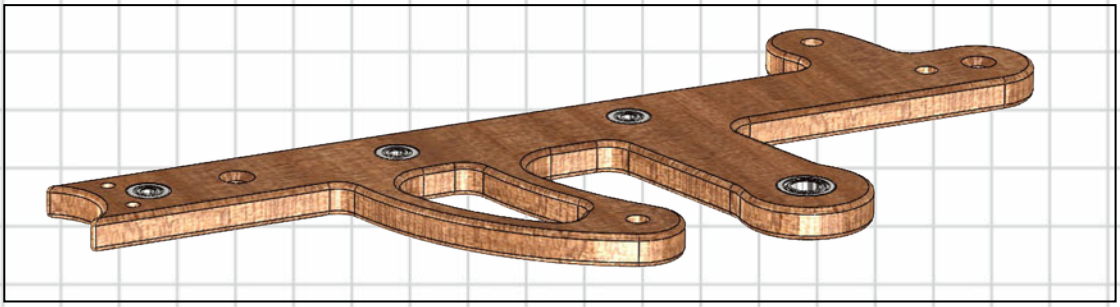
Note these are the minimum amount of material necessary to build the clock I used more in the prototype and you may well be advised to by extra to cover those accidental losses that occur. If I have missed anything here, you will find them in the parts list for the clock anyway.

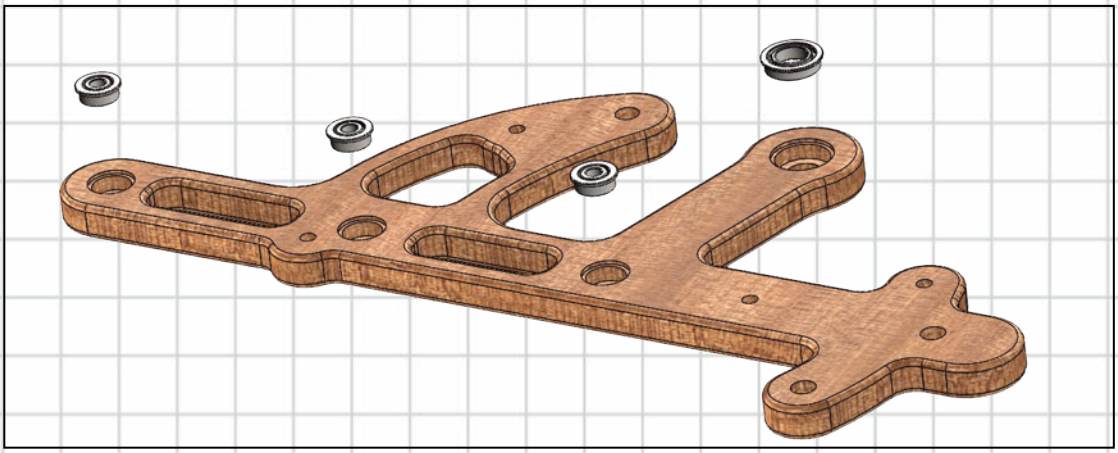
Clock 40-Compact Clock with Galileo Escapement

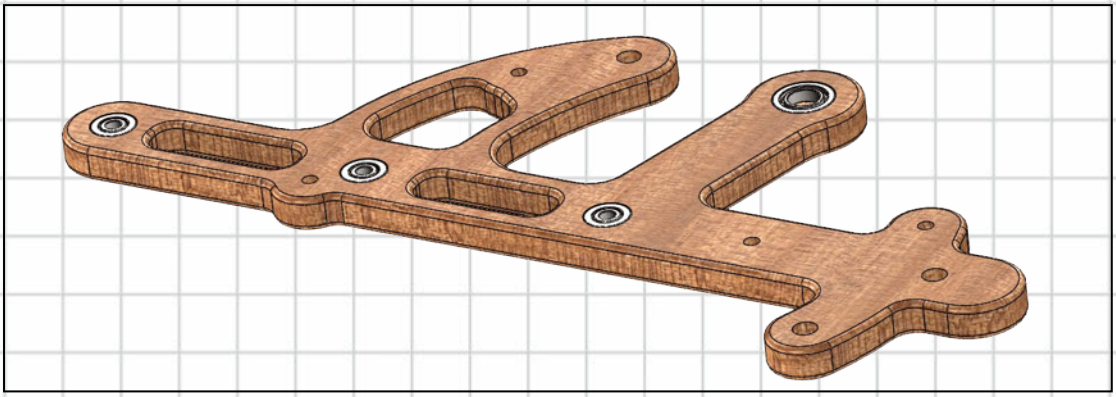
Construction instructions for Clock 40

Step 1 Preparation of the Frames





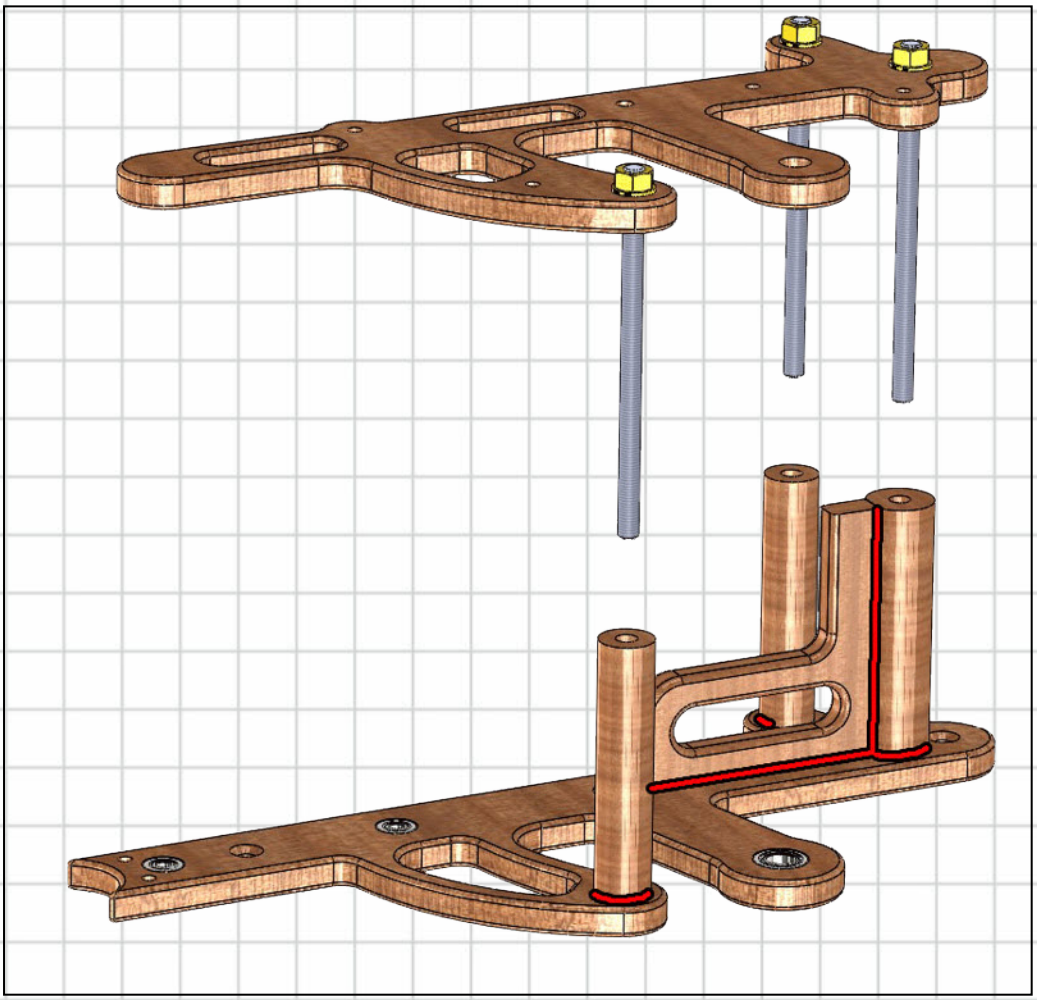


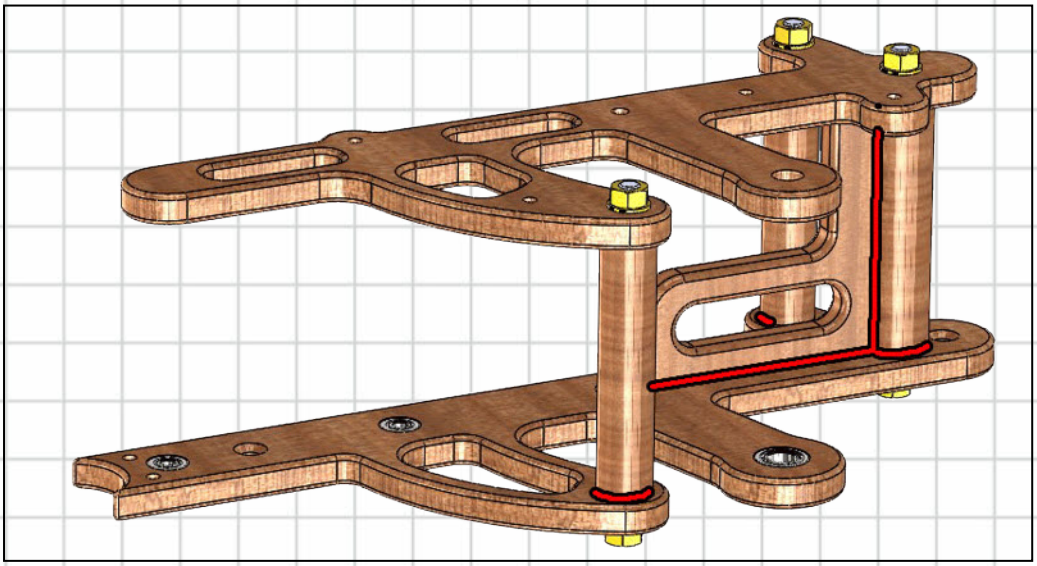


Fit Bearings into the Front and Back frames

Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

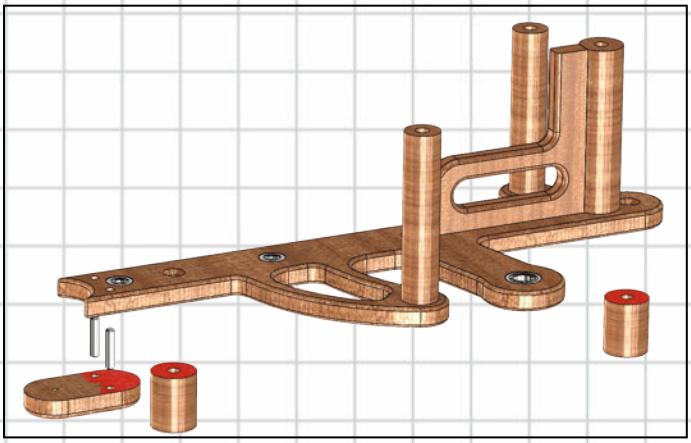


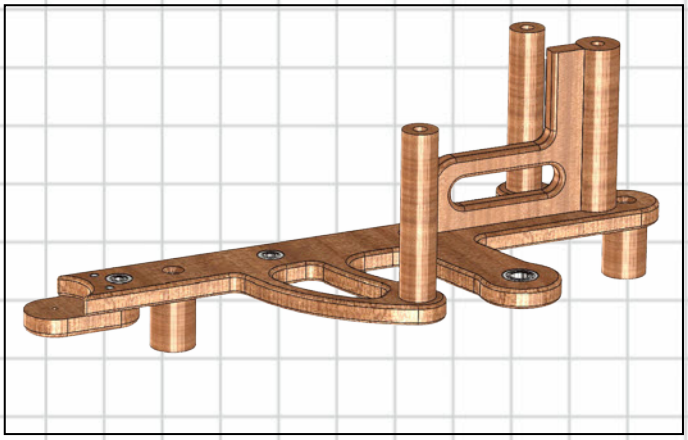


Glue the Frame spacers, and Brace to the front side of the Back frame as shown by the red lines and clamp both the Front and Back frames together using the Threaded rods and the M6 Nuts and Bolts to hold the frames accurately together as the glue dry's.

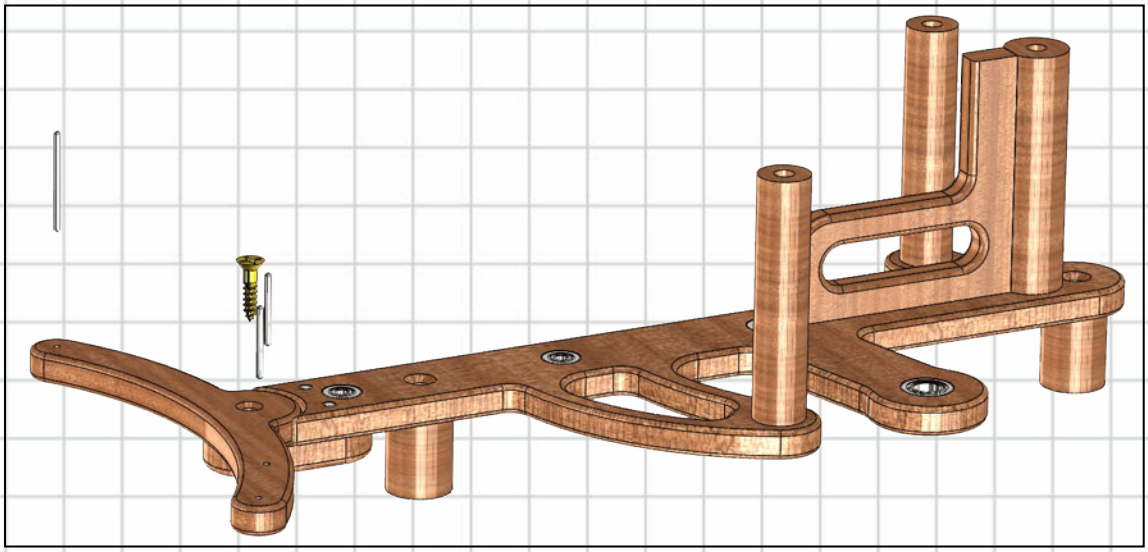
Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

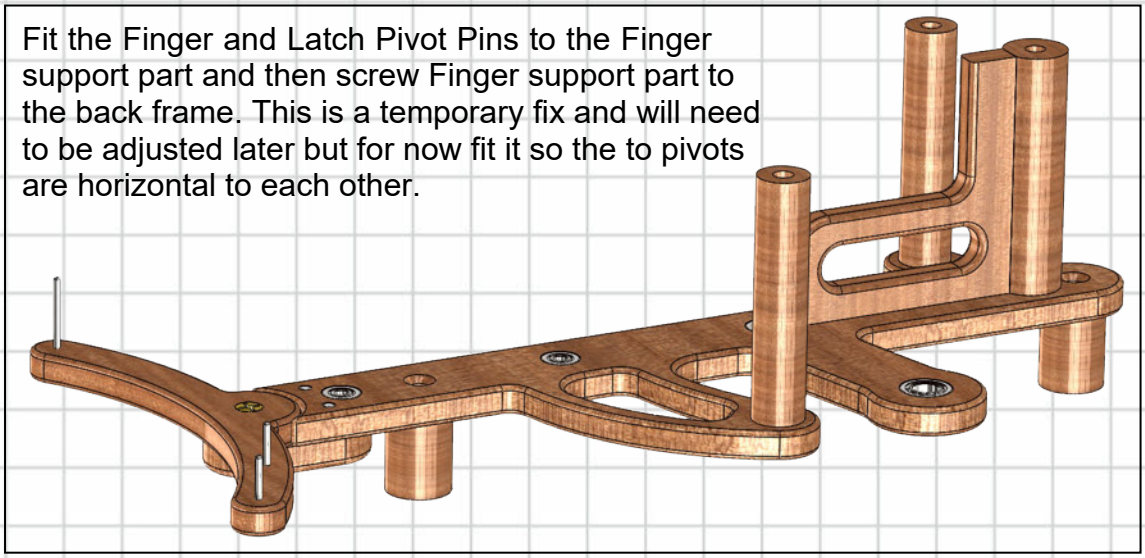




Now apply glue to the Backing plate and the tops of the two Wall spacers and stick to the underside of the Back frame. Use the Backing plate pins to locate the plate, use woodscrews to locate the Wall spacers.



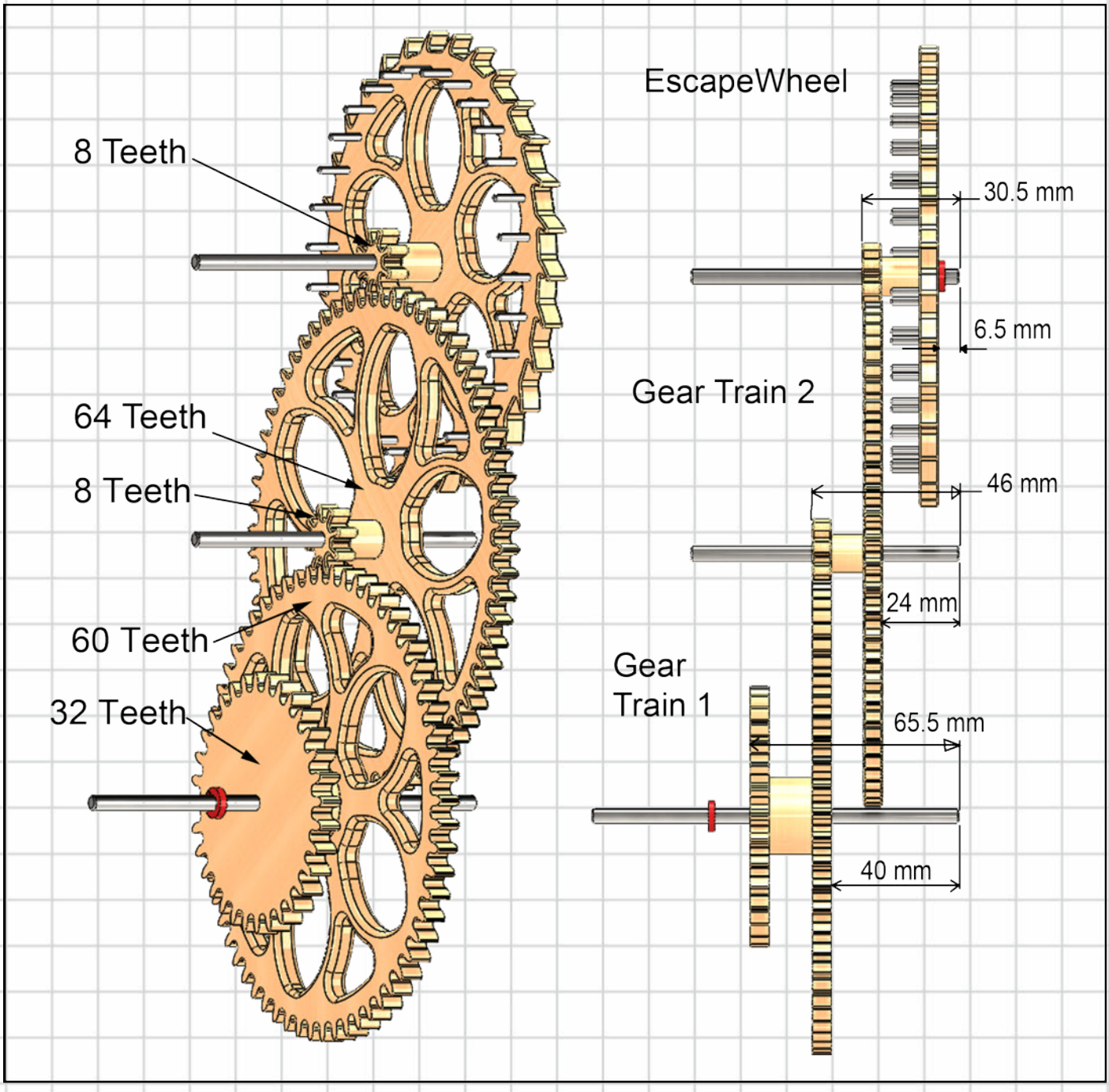
Fit the Finger and Latch Pivot Pins to the Finger support part and then screw Finger support part to the back frame. This is a temporary fix and will need to be adjusted later but for now fit it so the to pivots are horizontal to each other.



Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

Step 2 Assemble the Gear train Parts

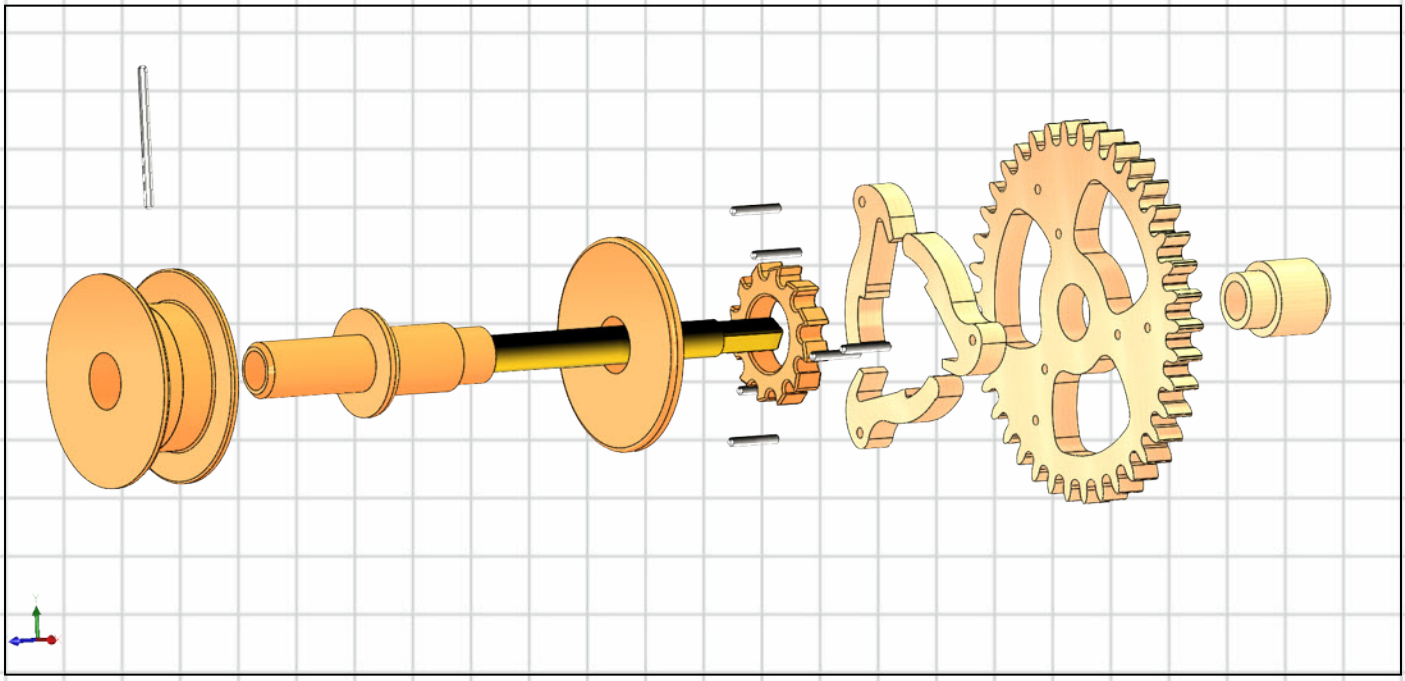


Assemble each gear train sub assembly in turn by driving the shaft through the centre holes in the spacers and gears. This should be done on a Drill press or similar setup to ensure the the shaft is fitted square to the gears. All gears should be a tight fit on the shaft and the gears and spacers should be glued together to ensure that there is no movement between the gears when a load is applied. The 30 pins fitted to the Escape wheel should be fitted first using the same Drill press setup.

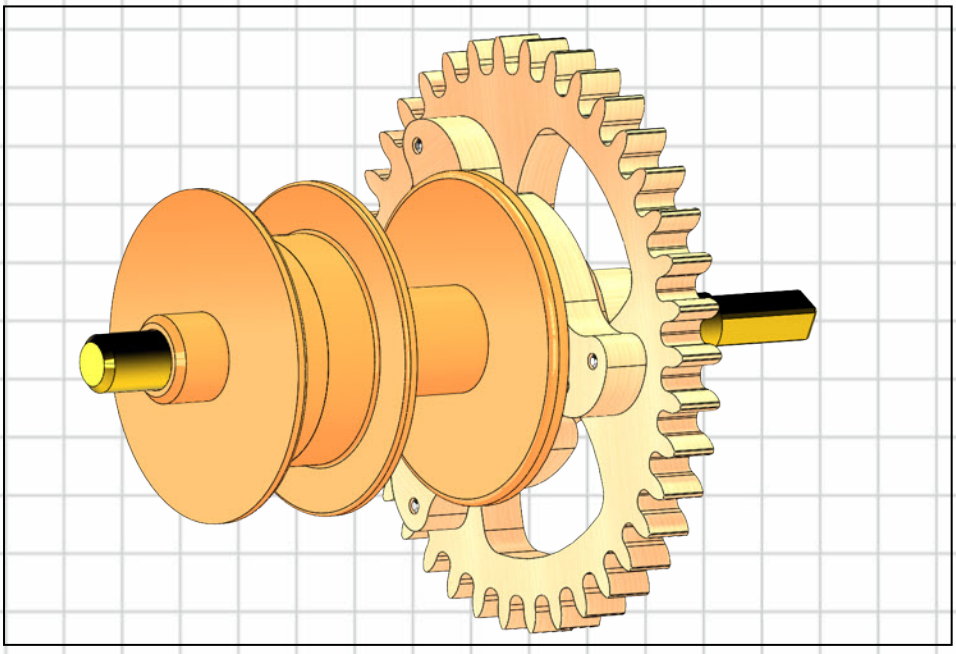
Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

Step 3 Assemble the Drive Parts



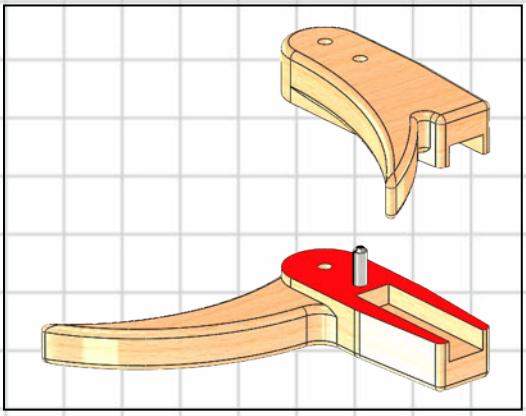
All the Orange parts should be glued together and then pinned to the Brass Drive shaft. The Pawl pins should be fitted to the holes in the 38 toothed gear. The drive gear spindle should be glued into the 38 toothed gear and be a loose fit on the Brass drive shaft. The Pawls are assembled onto the pins in the 38 toothed gear and gear and its parts slid onto the Brass Drive Shaft. Important Make sure that the ratchet and the Pawls are assembled exactly as shown above.

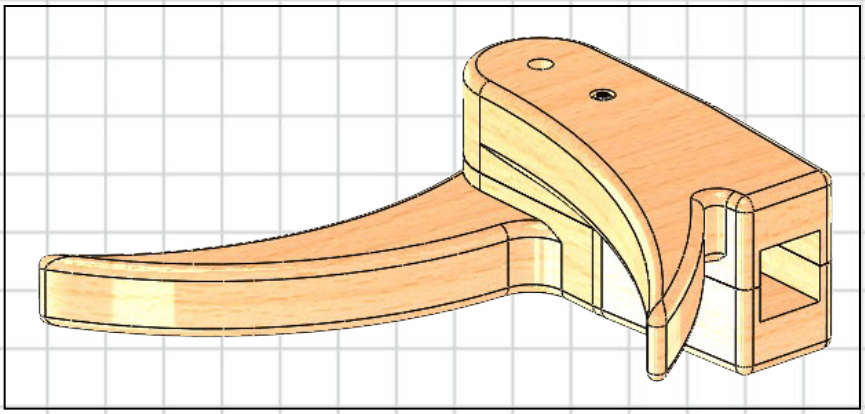


Clock 40-Compact Clock with Galileo Escapement

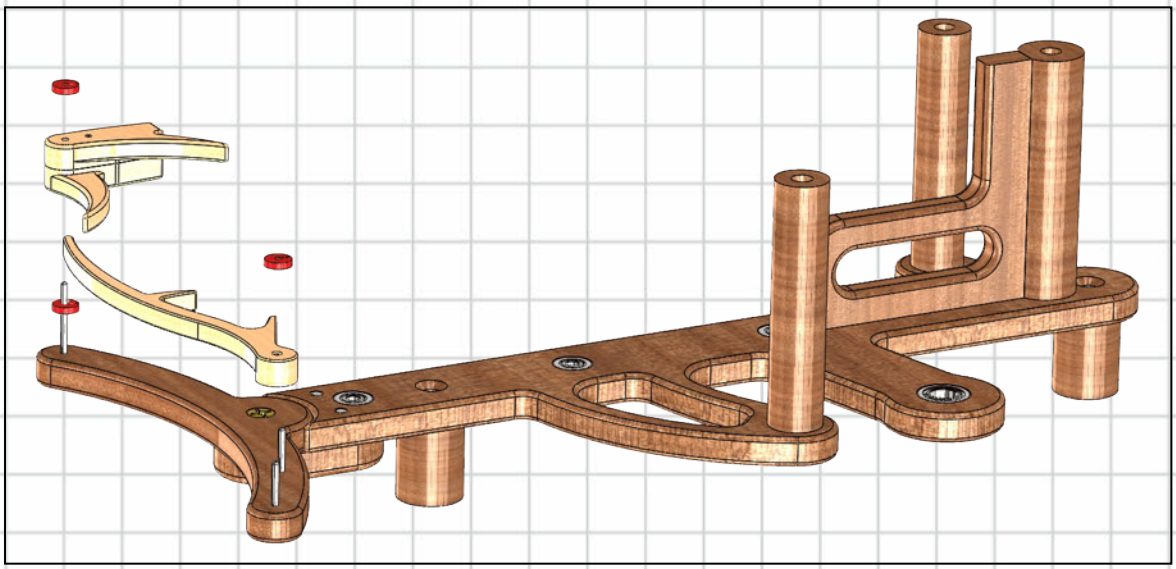
Construction instructions for Clock 40

Step 4 Fit the Escapement parts to the frame

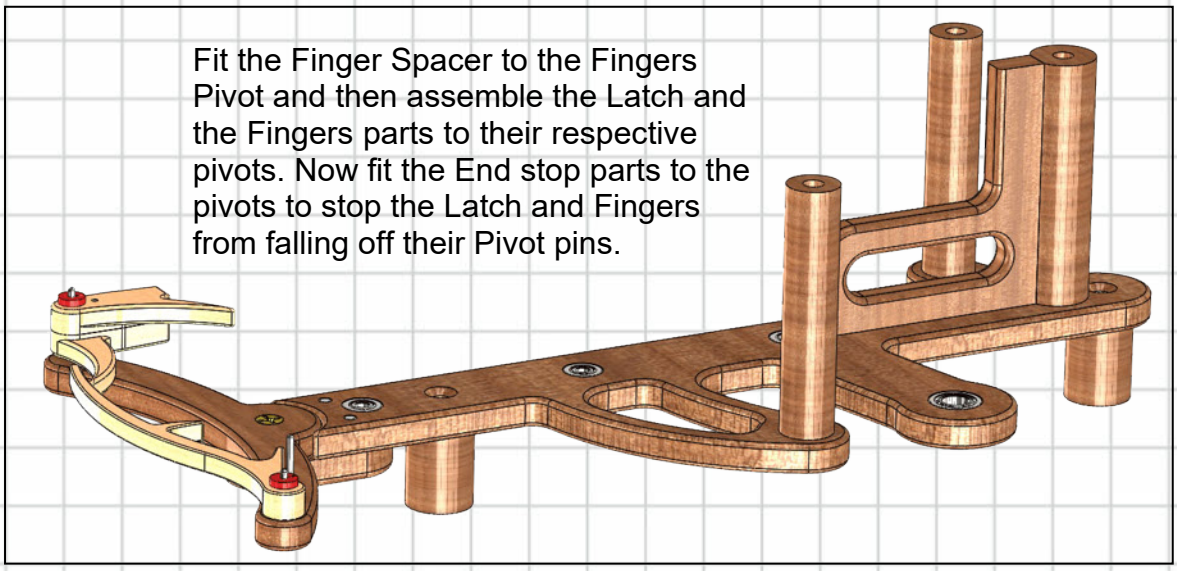




Fit the Finger pin into the Upper finger as shown and apply glue to the top face and then fit the two halves together. Fit a length of Ø2 rod temporally into the finger pivot hole to align the parts.



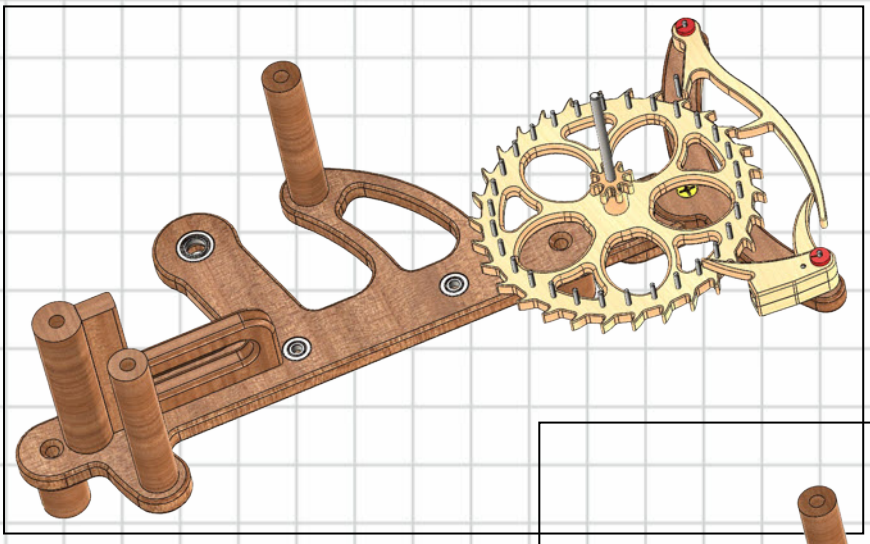
Fit the Finger Spacer to the Fingers Pivot and then assemble the Latch and the Fingers parts to their respective pivots. Now fit the End stop parts to the pivots to stop the Latch and Fingers from falling off their Pivot pins.



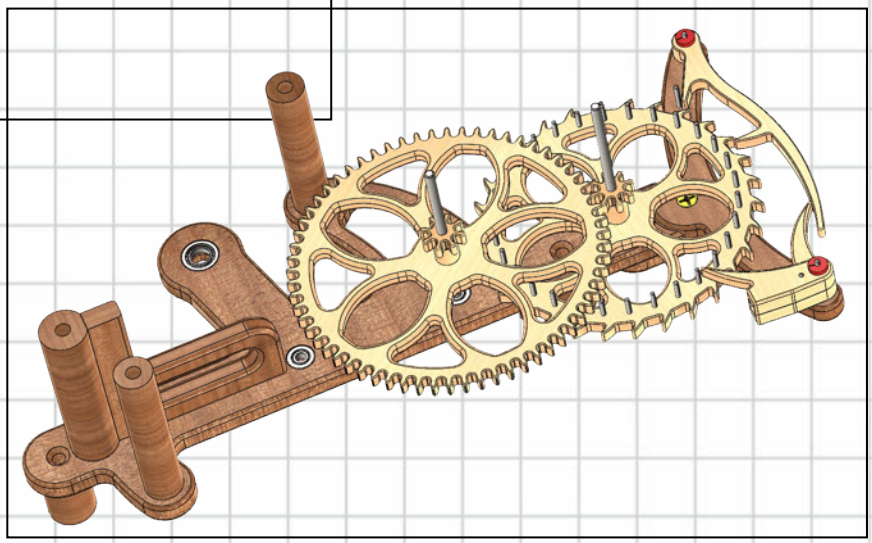
Clock 40-Compact Clock with Galileo Escapement

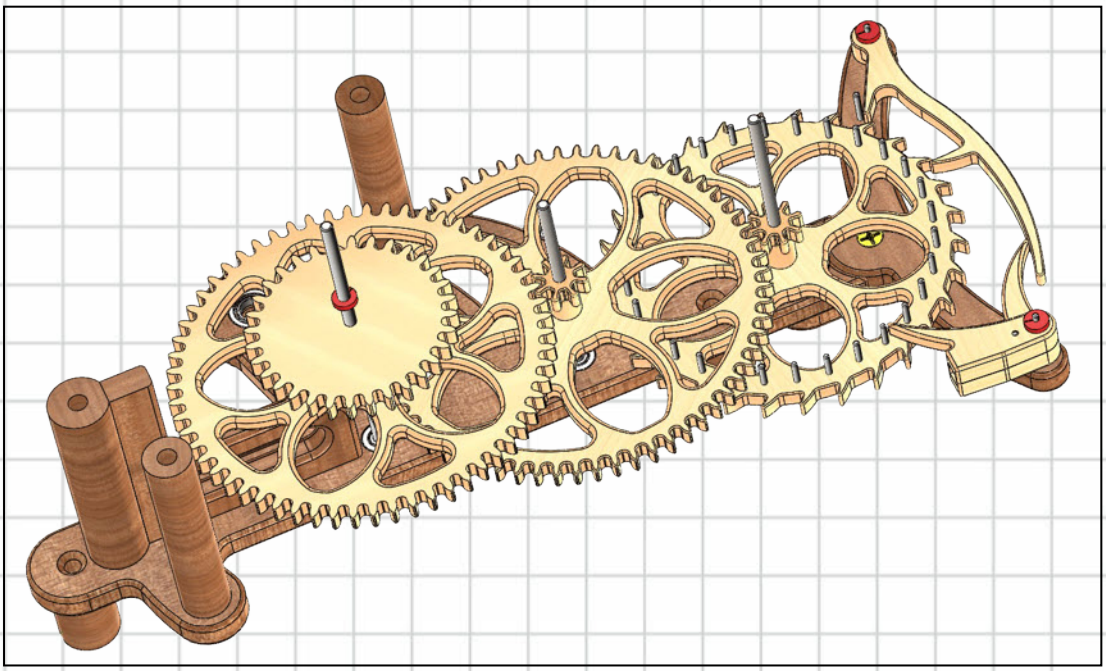
Construction instructions for Clock 40

Step 5 Assemble the Gear train into the Back frame.

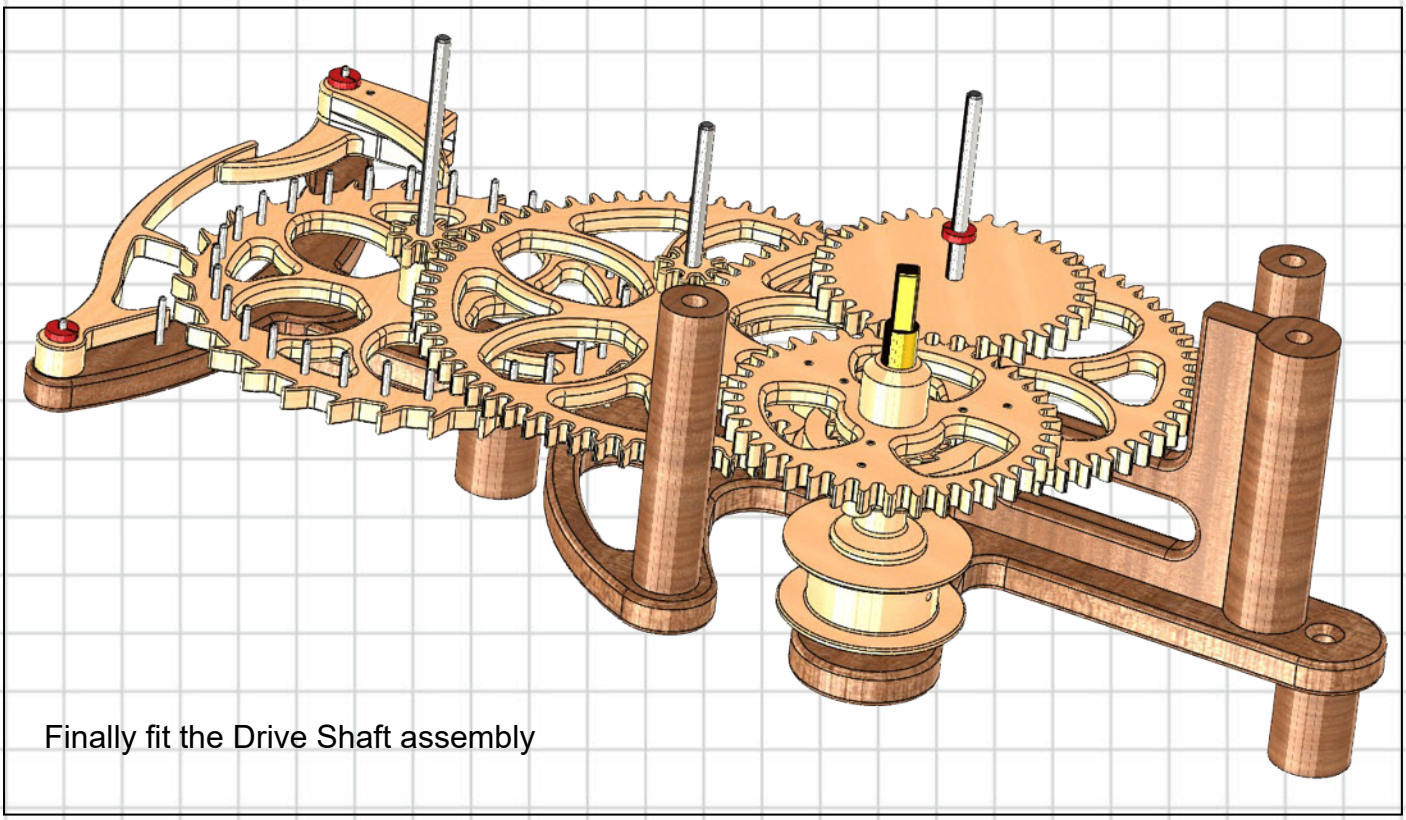


Progressively fit the Gear train sub assemblies into the Back frame





Construction instructions for Clock 40

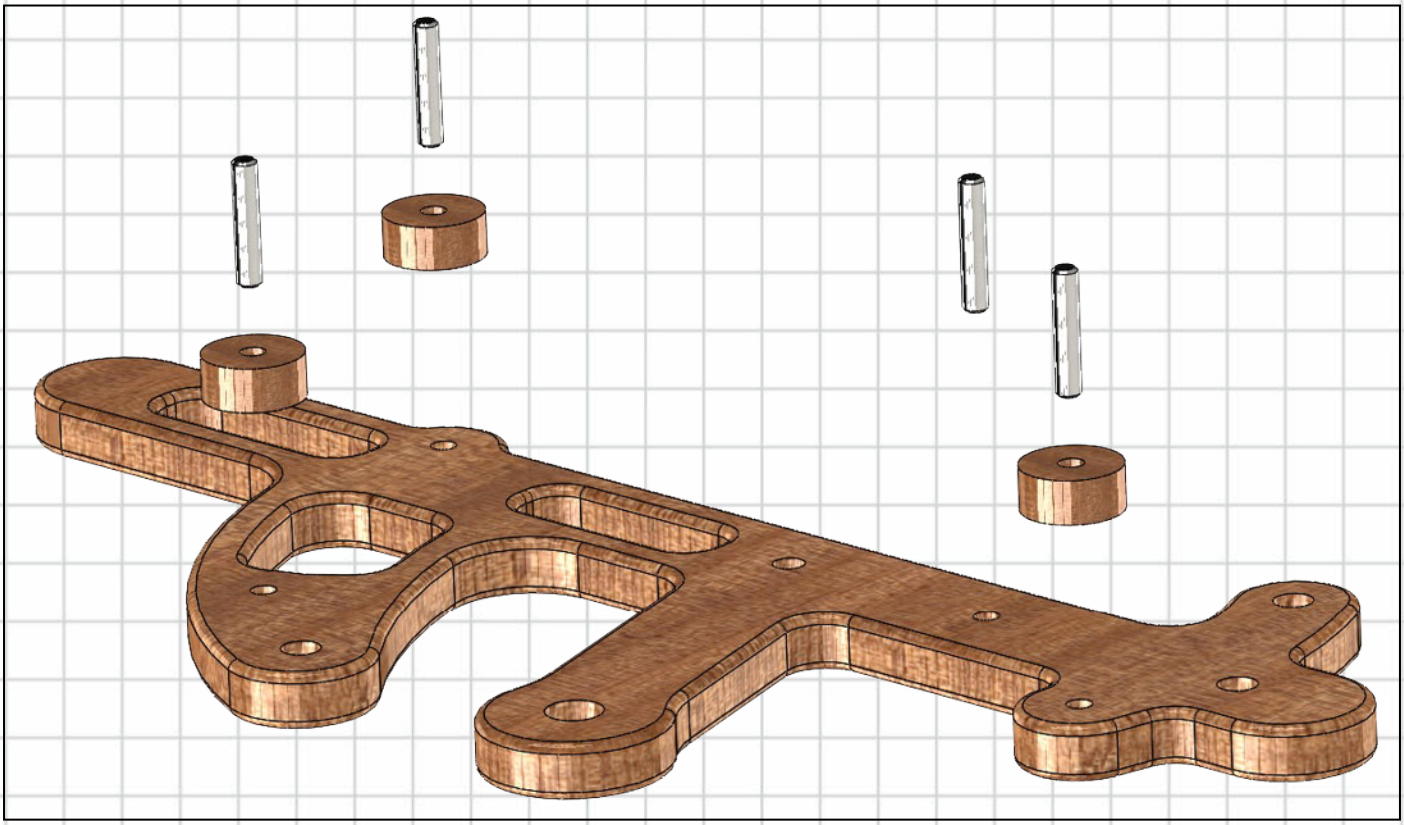


Finally fit the Drive Shaft assembly

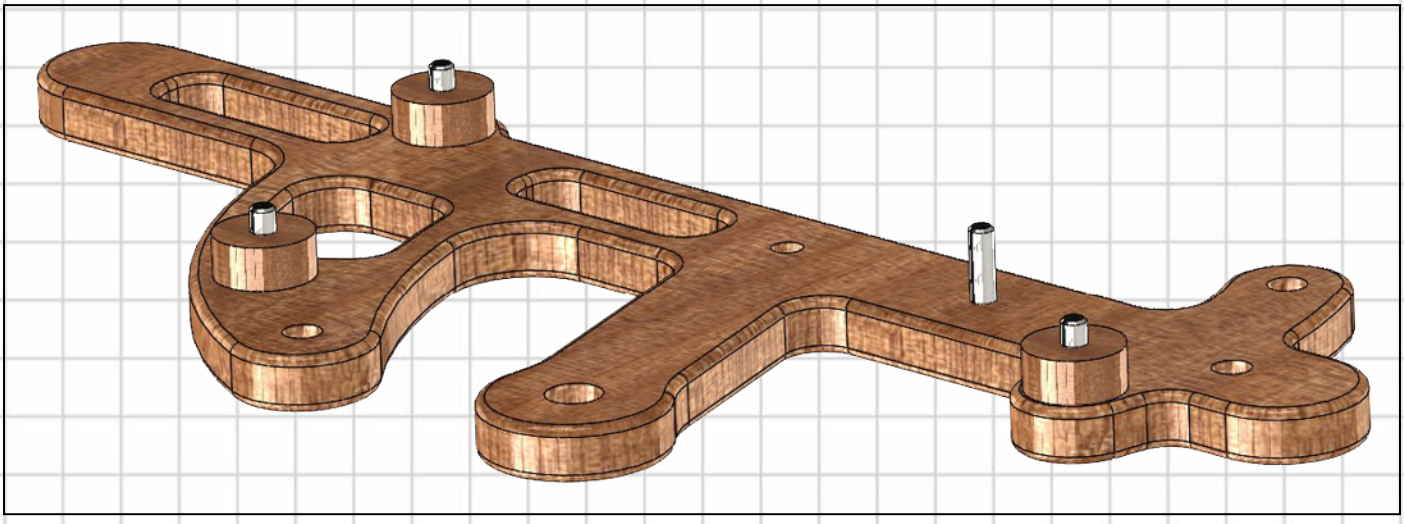
Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

Step 6 Assemble parts to the Front Frame

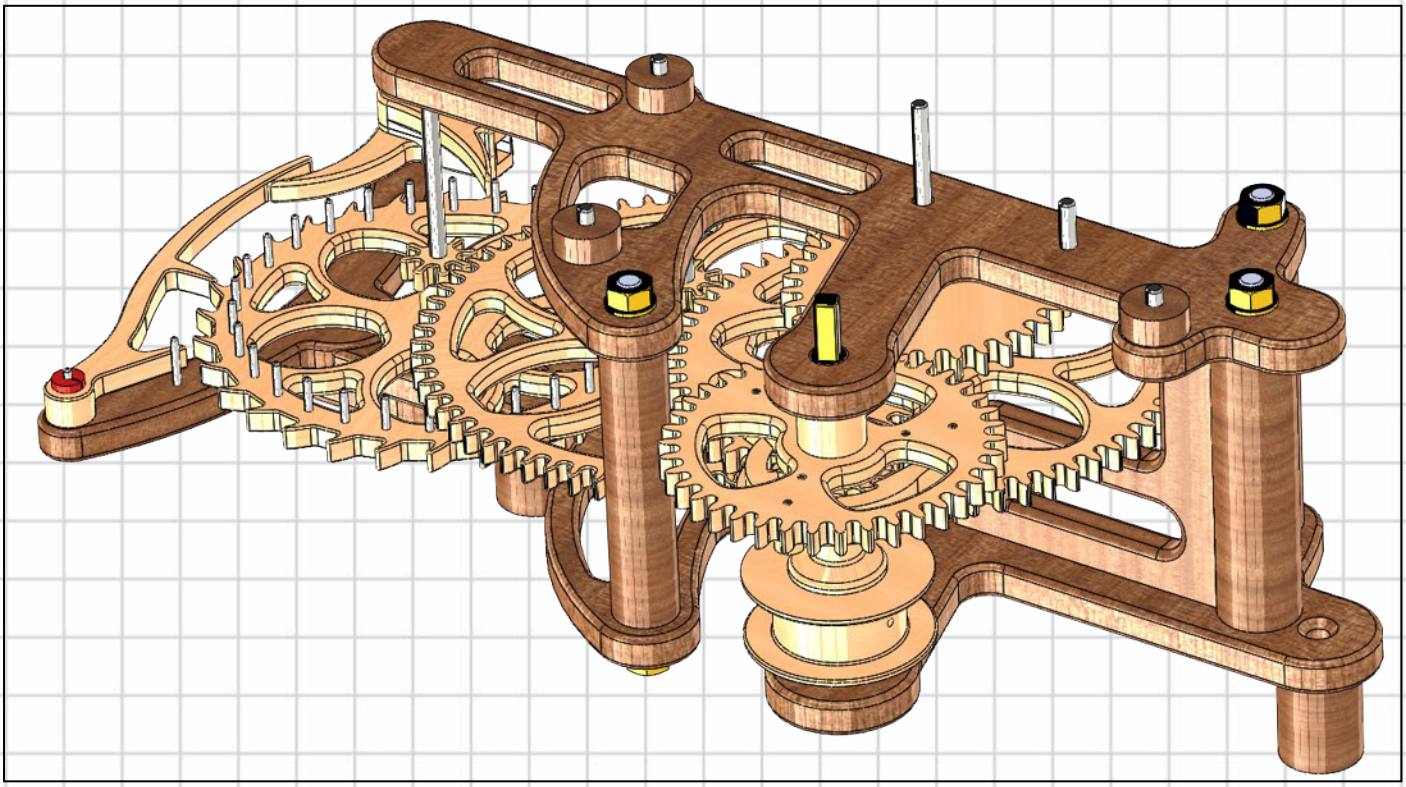


Fit the Dial Pins and spacers along with the Hour Gear Pivot pin to the front face of the Front frame. Spacers may be glued to the front frame if required.



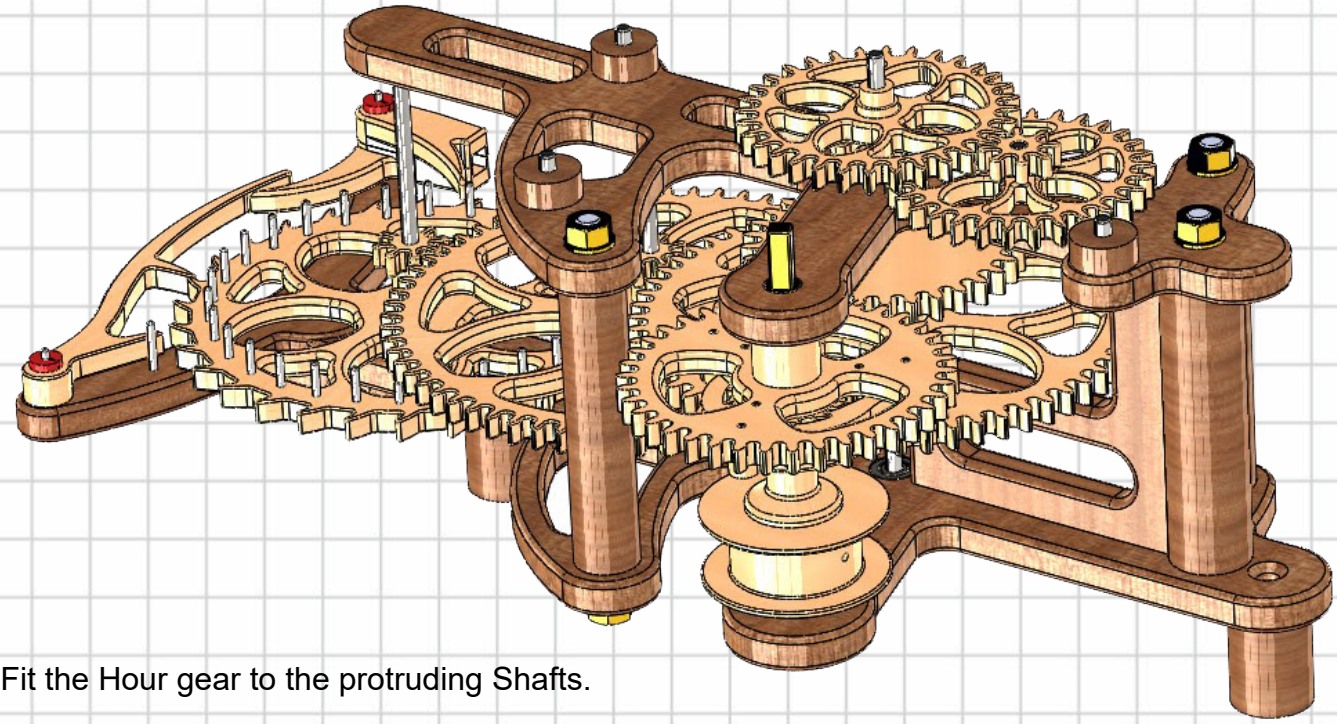
Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

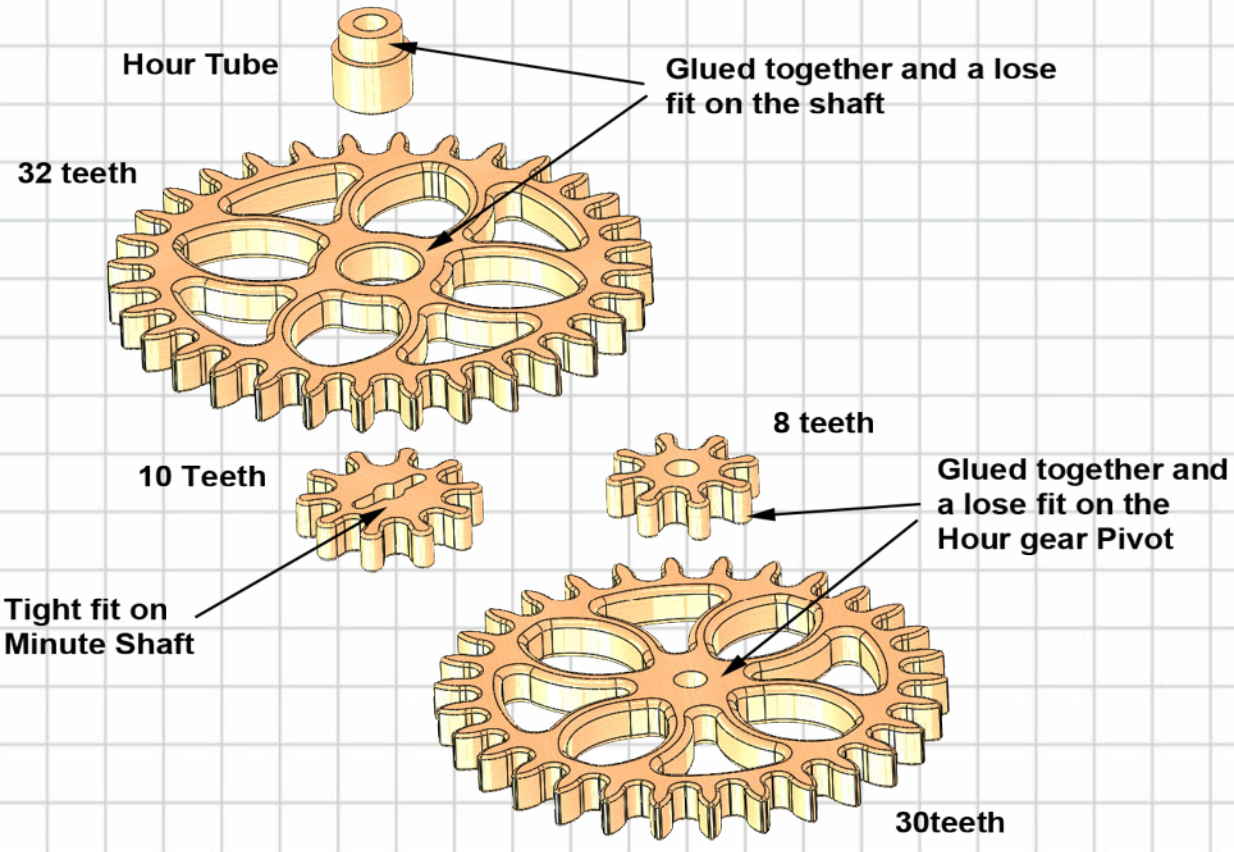


Fit the Front frame and secure with M6 Nuts and Bolts and Threaded rod

Construction instructions for Clock 40

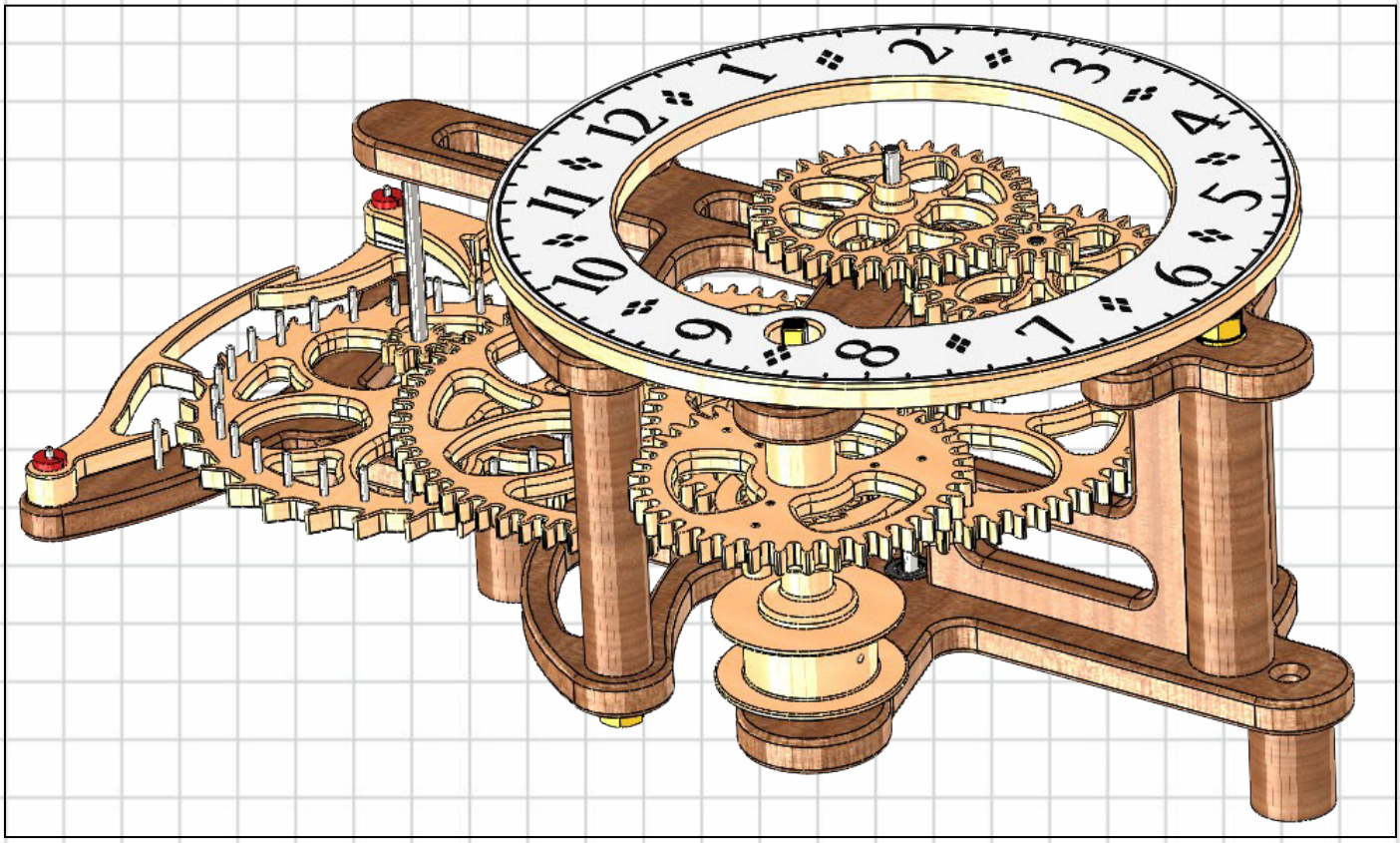


Fit the Hour gear to the protruding Shafts.

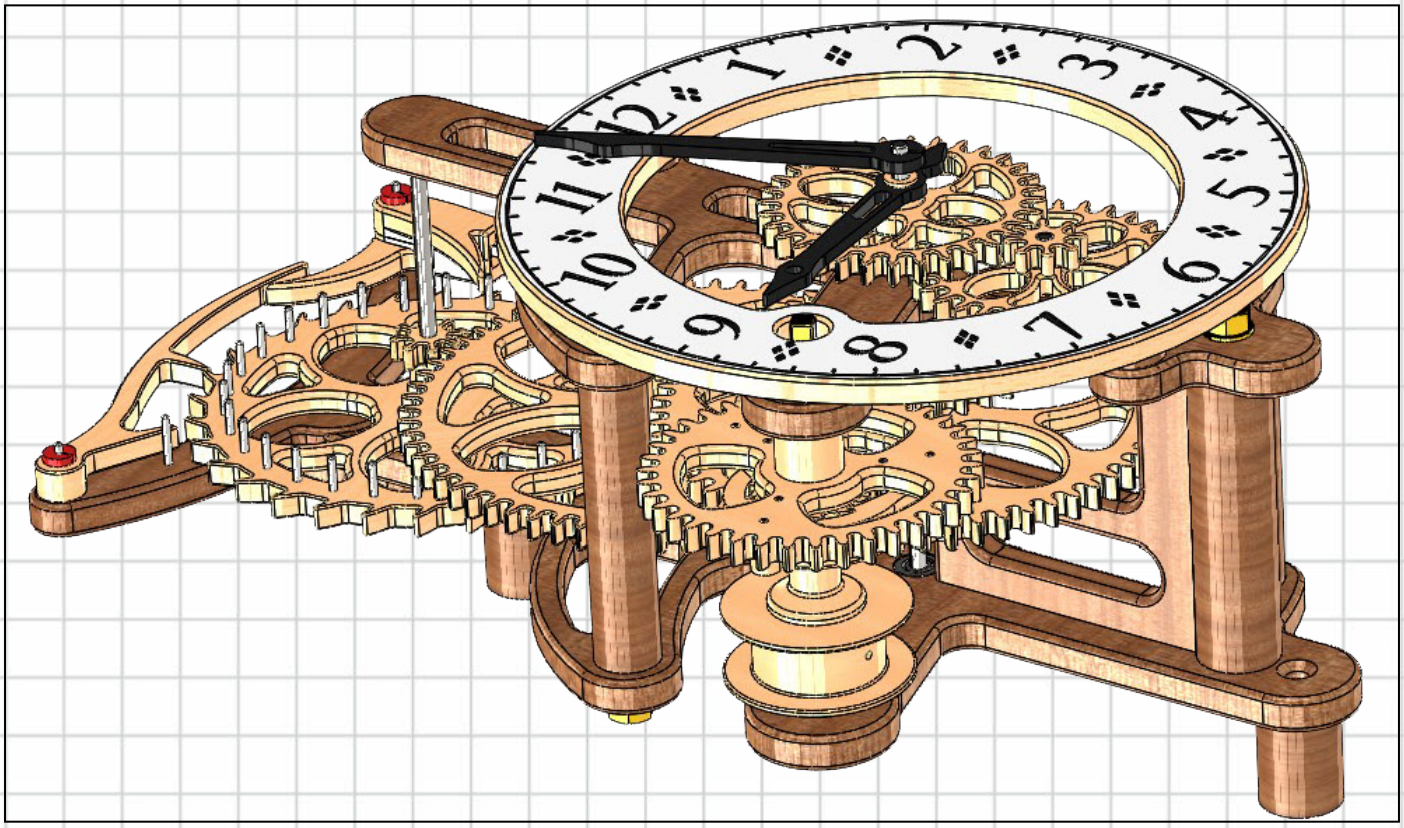


Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40



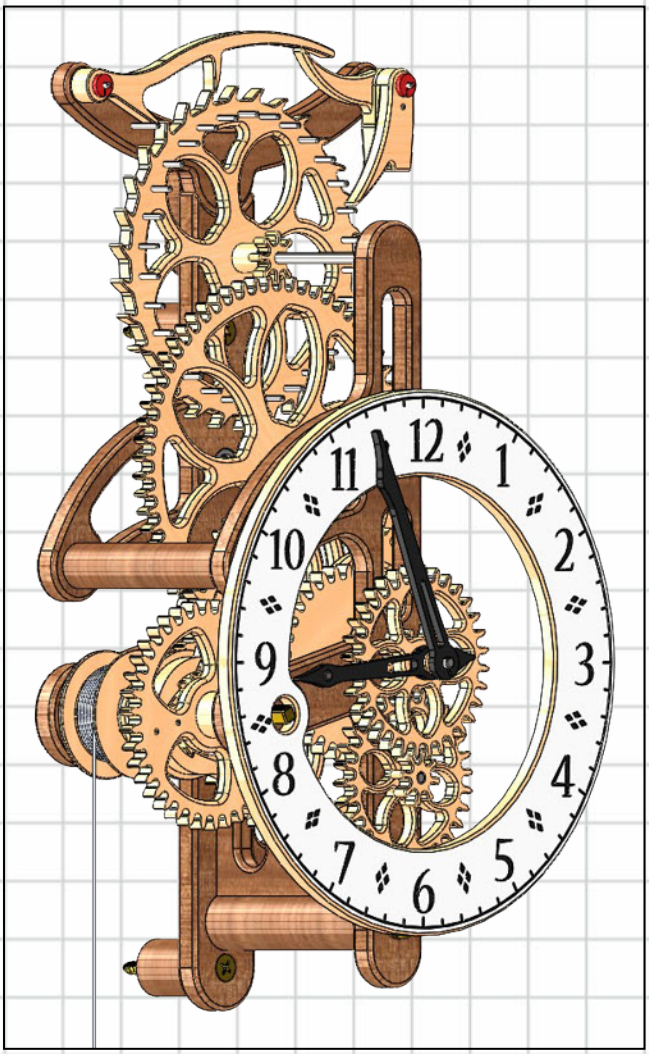
Finally fit the Dial and the Hands



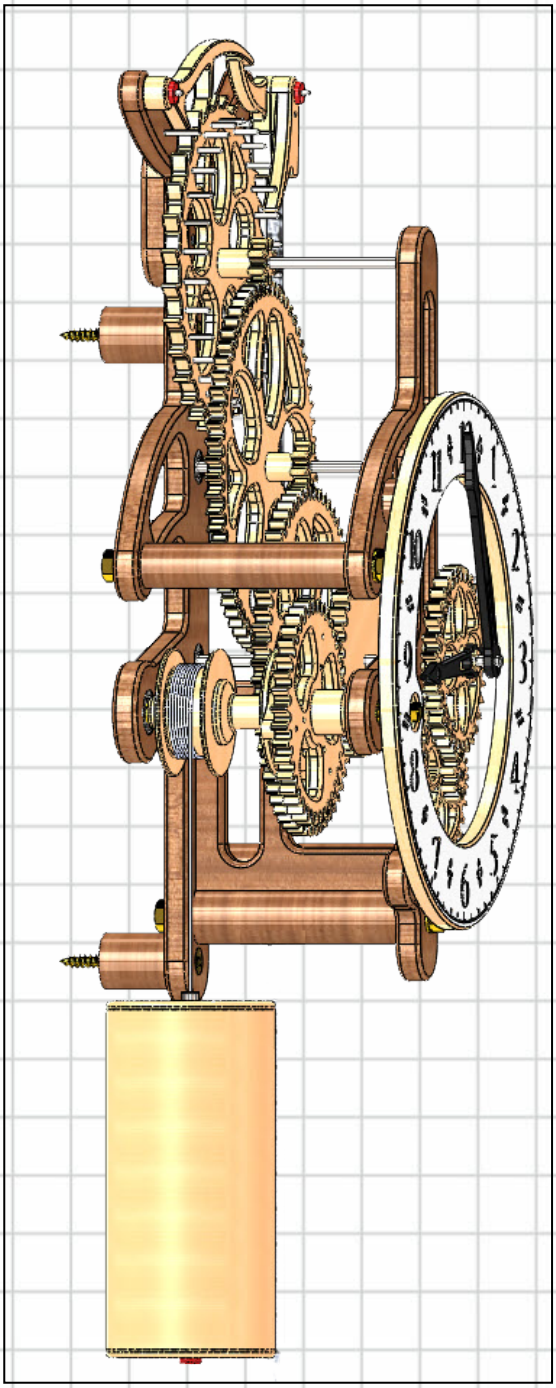
Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

Step 7 Assemble Weight



Mount the clock to the wall with the Back frame vertical and the Centre of the dial 1500 mm from the floor. Use the two woodscrews, one at the the bottom and one two thirds of the way up.
Wrap the cord around the Drum making sure the end is secured to the drum with tape,

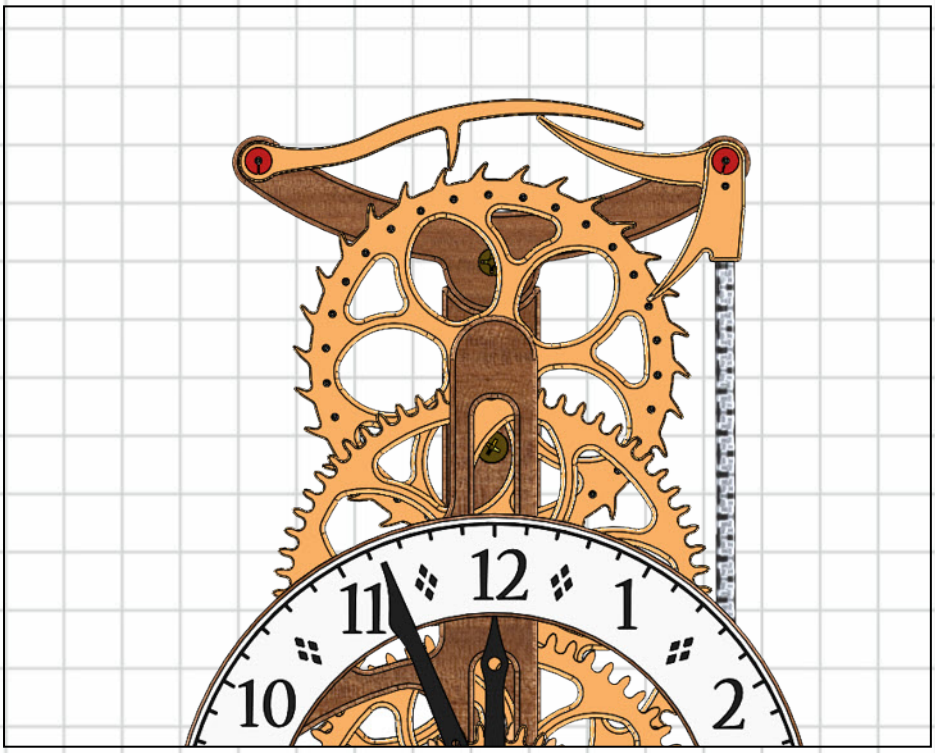


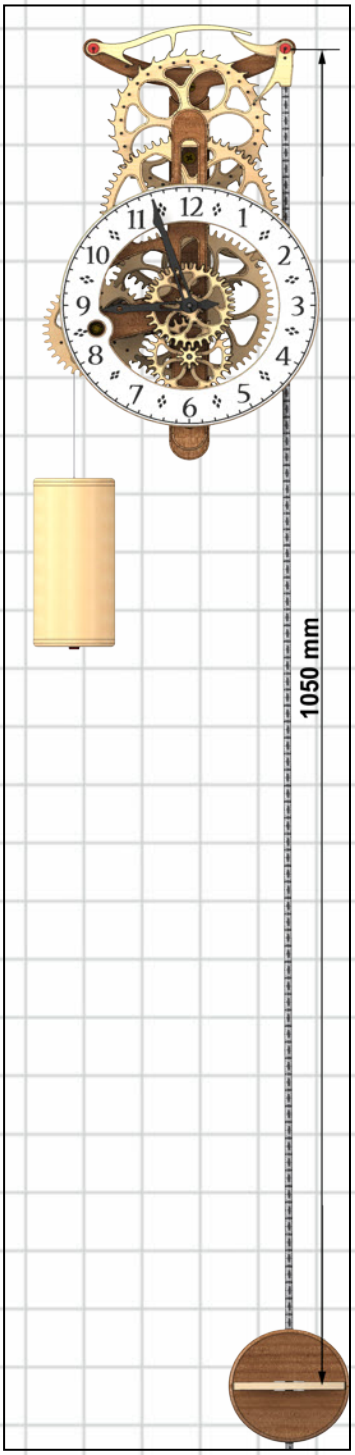
Thread the cord through the plastic tube in the centre of the weight and secure to the Button or Weight tie-off parts.

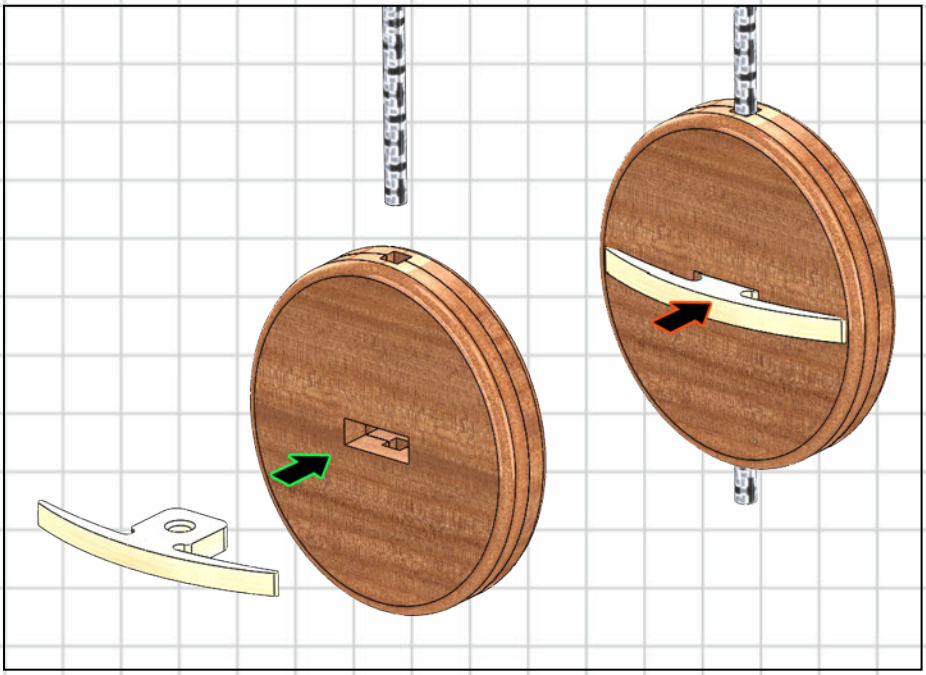
Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

Step 8 Fit Pendulum





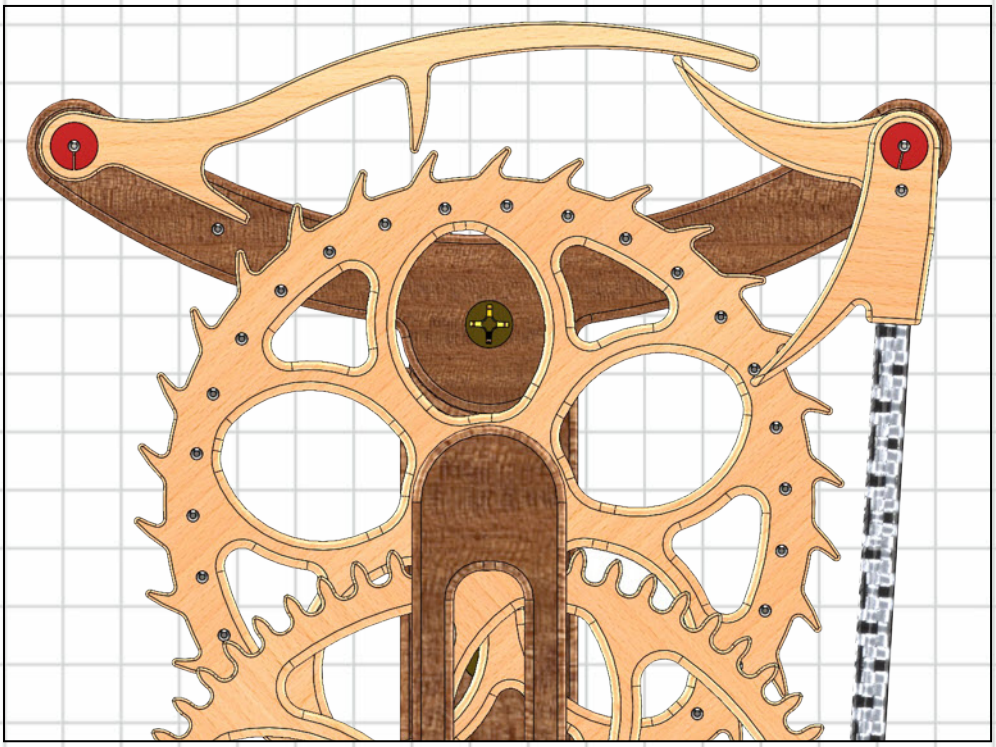


Make sure that the Finger support is horizontal and the securing screw tightened. Now Glue the Pendulum Rod into the hole in the Bottom of the Fingers part.
Push the Pendulum Bob Lock into the Pendulum Bob as shown and then slide the Bob onto the Pendulum rod, Pressing hard on the Lock is required to align the hole in the Lock. To adjust the running of the clock move the Bob upwards to Speed it up and downwards to slow it down.

Clock 40-Compact Clock with Galileo Escapement

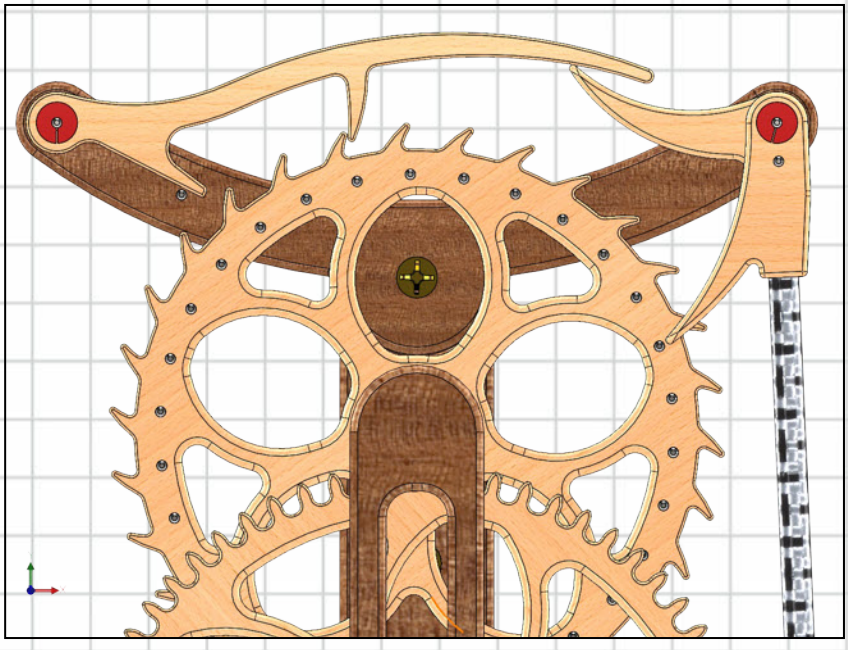
Construction instructions for Clock 40

Step 9 Adjust the Escapement



With the pendulum Hanging in the vertical position as shown on the previous page both the latch and the lower finger should be slightly engaged with the Pin and the Tooth. When the pendulum is swung it should produce an even Tic-Tock. If it doesn't then loosen the Fingers Support bar screw and move it slightly until the Tic-Tock is even, then tighten again.
If the pendulum is swinging too far and the rod is hitting against the frame then file a small amount off the bottom Finger to reduce the stroke.

Note! the short finger shown on the left hand side has been removed from the final design as it was never really doing anything as it never actually reached the stop position. It was therefore removed along with the pin it was supposed to rest on.



Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

HINTS AND TIPS

- When fitting the gear sub-assemblies into the frame make sure the mating gears engage and run smoothly. The faces of mating gears should be aligned so they fully engage with each other, i.e. the front faces of the gears are lined up. There is some clearance built into the design so that when the gears are enclosed between Front and Back frames they are free to move without rubbing on the frames.

- For the dial on this clock you could use a V bit cutter to cut out the numerals and minutes ring. I use Artcam Express which gives a good clean-cut edge and very fine detail without having to use extremely small diameter cutter. A free alternative to Artcam is a program called F-Engrave,

- If you have problems getting the clock running initially it could be that the problem is in the gear train itself, one or more of the gears may not be meshing correctly,
You need to test each pair of gears in turn, by mounting each meshing pair in the frames on their own and turning them by hand very slowly with little pressure. if any pair sticks or interferes with the other you should mark the teeth that are affected and carry on until you have turned the large gear around completely, then strip down and dress the teeth you have marked until they work together smoothly. Repeat this process for all the meshing pairs of gears are running freely.
It is not sufficient to test them when the gears are mounted in the clock and then left to run continuously unrestricted, as the free running gears will easily override any slight interference, whereas when the gears are running in the clock with the escapement in place they never run fast and so easily feel the effects of interference.
Alternatively the Pendulum / Escapement may not be running freely on the Ø3 shaft they are fitted to. The parts should be a running fit in the Ø3 mm shaft, and the Escapement-Pendulum pin in the centre lower down, should be a slightly loose fit in the slot in the Pendulum Head, if any of these fits are too loose then the parts can twist relative to each other and some impulse will be lost from the Pendulum.

- The DXF files supplied include all the parts that can be cut using the CNC router, they do not include those round items such as the turned parts cut from Doweling nor any pins or nuts and bolts, information on these parts are included in the Detail drawings supplied in PDF format.
The parts shown laid out in a single DXF files ready for you to extract and use in your CAM software. The profiles are shown on 4 separate layers , these being ‘Outside Cuts’ ‘Inside Cuts’ ‘Pockets’ and ‘Non Cutting Profiles’ The layers are colour coordinated as shown below.

Clock 40-Compact Clock with Galileo Escapement

Construction instructions for Clock 40

I need to use headed pins for some of the shafts in this clock design but small diameter Clevis pins are hard to find and so I have looked for alternatives. Round nails might work although the finish on those can be quite rough, An alternative I have used on this clock is a plain steel dowel for the shaft and a small plastic split washer that is slightly undersized, I couldn't find a source for these either but they are fairly easy to make. Another alternative is to use carbon steel ground pins for the shafts, and then fit a larger diameter Rod type magnet to cap the end and prevent any parts falling off. Best not to use these close to any ball bearings as it
can apply a drag to the rotating balls

- The Pendulum Bob needs to be fitted so that the centre of the Bob is about 1040 mm from the pivot point. This should allow the pendulum to swing a complete cycle every two seconds. The pendulum swing can be adjusted to make the clock run faster or slower by moving the Bob up to speed it up and down to make it run slower. I have found over the years that a slightly heavier Pendulum Bob is an advantage as it seems to overcome any momentary fluctuations caused by a sticking gear train, to achieve this on this clock I have fitted four 18 mm long Ø 8 mm Brass rods into four holes drilled through the Bob.

- I do not drill the three holes in the back of the Dial on the CNC, instead I temporally fix the Dial to the Front Frame with clamps or double sided tape. After measuring and adjusting its position relative to the Shaft one centre hole, and then drill with a hand drill from the back through the pivot holes, being careful not to drill right through the Dial.

- For winding the clock I would suggest you use an off the shelf Winder, the Grandfather clock Key number 13 is ideal.

- Establishing the actual weight to use for the main clock weight, is done initially by trial and error. Each clock build is different and that has an effect on the size of weight to use. I normally use a two litre Coke bottle partly filled with water to start and add or remove water to get the clock running continuously.
  You would do this finally after setting assembling the clock and making sure everything is running freely and the escapement is set up correctly. Usually, a bit of back and forth here to adjust the escapement then adjust the weight.

  The settings I have used for this clock are:-
- Main Weight 900 gram
- Distance from pivot to centre of Pendulum Bob 1040 mm
- Run time 14 hrs when dial is set at 1500 mm above the floor.

- To set up the clock first mount it to the wall and ensure the the Frame is Vertical. Then rotate the Finger Support arm downwards slightly from the horizontal so that it stops the Pendulum swinging, then slowly rotate the arm back upwards so the the lower finger just clears the pin it has just released. Thats it the clock should now run. You finally will need to adjust the pendulum Bob upwards to speed up the clock or downwards to slow it down. Start of with the Pendulum Bob set to 1040 mm below the pivot point and make small adjustments from there. It should be capable of running at around 1 minute per 12 hours accuracy.