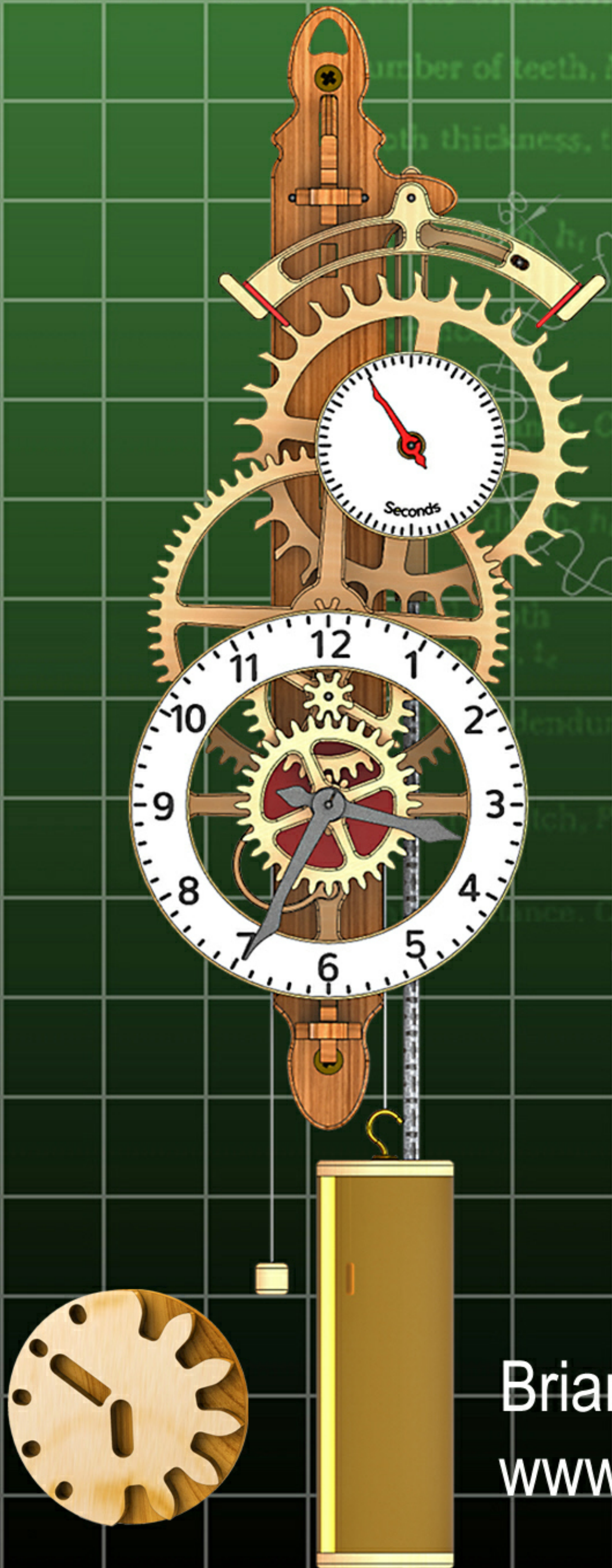
How to design and Build a

Wooden Clock



Brian Law's Woodenclocks
www.woodenclocks.co.uk

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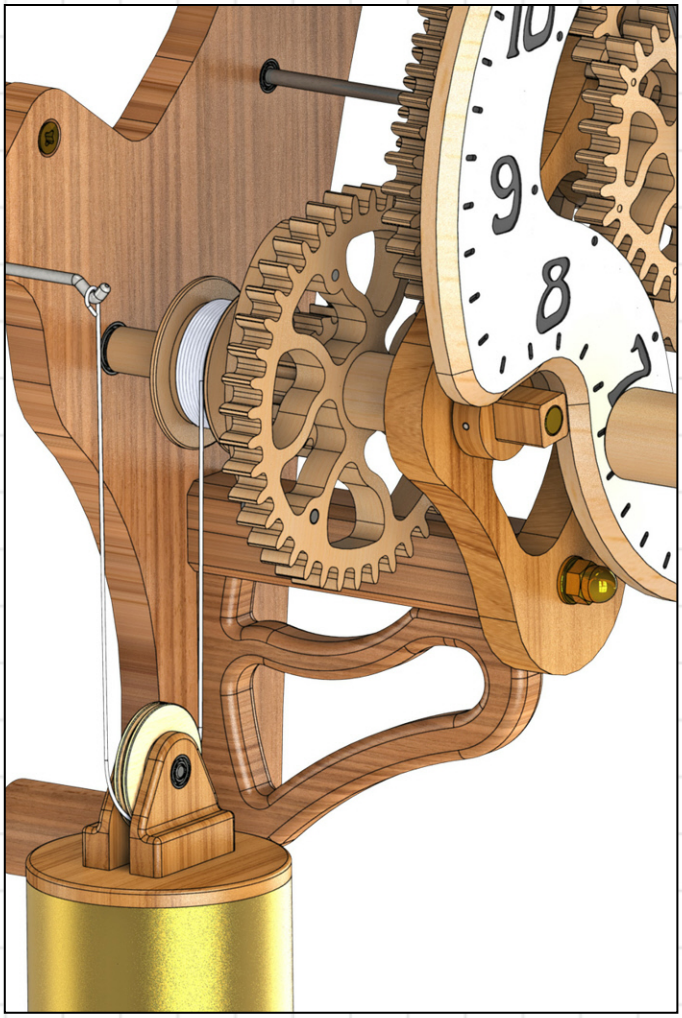
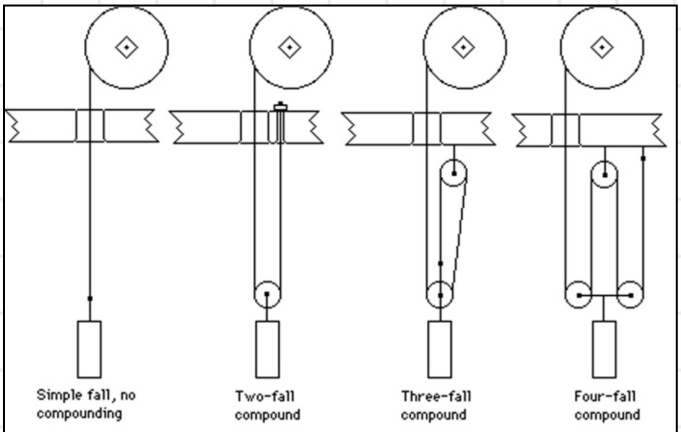


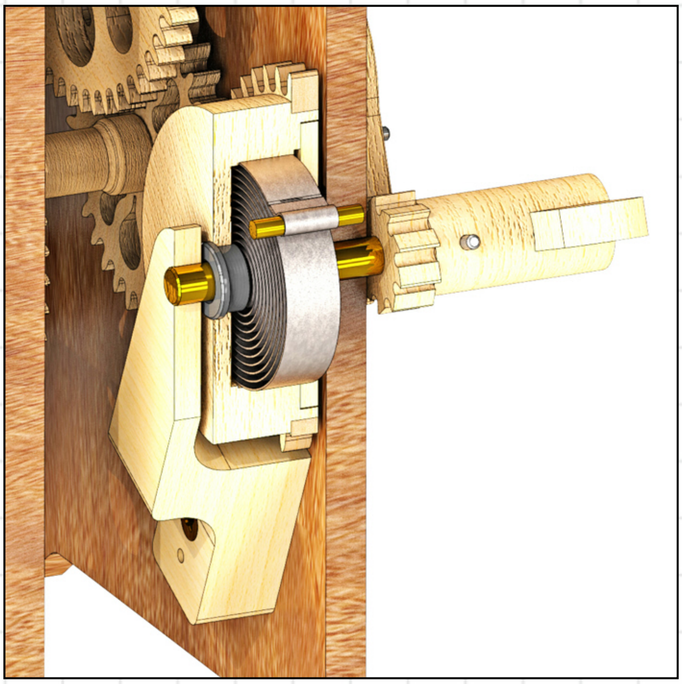
The biggest change can be achieved by adding pulleys to the weight, this example shows a simple pulley system used on Clock 23, this will double the run time of the clock and also double the weight required to run the clock.

With this simple pulley arrangement, you will get 2:1 Mechanical advantage, with the fixed end of the cord attached to the hook anchored in the clocks back frame. You can add more pulleys a shown below to get a greater mechanical advantage.

However, as you add more and more weight to the system you stand much more chance of distorting the clocks frame so it is recommended that you change the anchor point to the wall at the side of the clock.

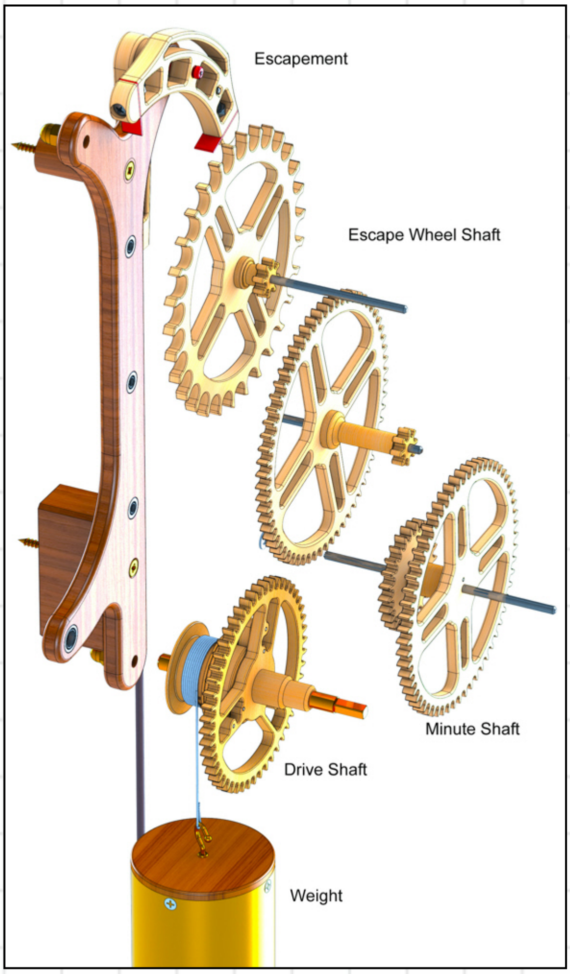


Effective forces equal the weight (W) divided by the number of falls.



The other main source of power for driving a clock is, of course, the Mainspring, I have several clock designs that use the mainsprings like the one shown, which is called a American Ansonia with a rivet looped end, it can be easy to fit into a clock design. They are compact and come in several sizes to suit the load requirements of wooden clock design. I dislike using them as they can easily cause injury and damage if mishandled and allowed to unwind in an uncontrolled manner, my clock 14 suffered considerable damage when the spring was let loose accidentally. Having said that, they do provide a compact source of power for the clock.

The Clocks Gear Train



The Gear train or Going Train is what transmits the power to the Minutes shaft which in turn drives around the Minute hand and then on up to the Escapement shaft which through the Escapement gives an impulse to the pendulum to keep the clock running.

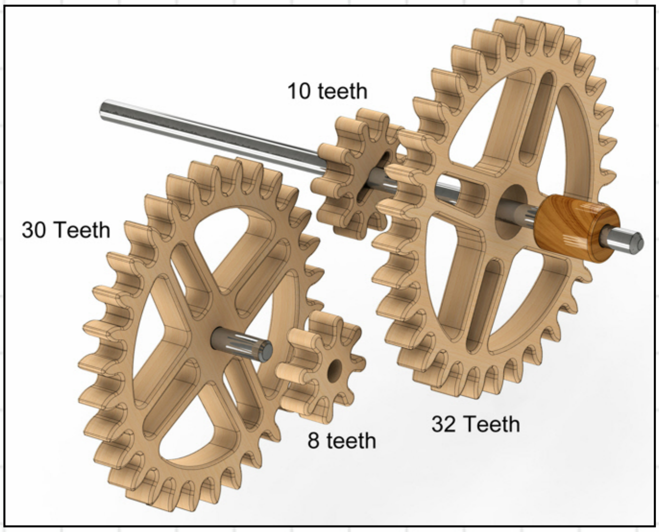
It comprises a series of gear pairs i.e., A large gear called the Wheel and a smaller gear called the Pinion. Each pair has a numerical ratio such that the total ratio between the Minute Shaft and the Escapement shaft is 60:1. Typical gear pairings for a clock could be :-
For a two shaft arrangement you could have a 64:8 x 60:8 or 70:7 x 66:11 and for three shaft arrangement 60:20 x 60:15 x 60:12 both arrangements will give you the 60: overall ratio.

60:1 is not always the case and in some instances, it could be 120: 1 for clocks that use a shorter Pendulum.

That being the case it's useful to have aid to calculate the number of teeth on the Escape wheel and the length of the Pendulum needed.

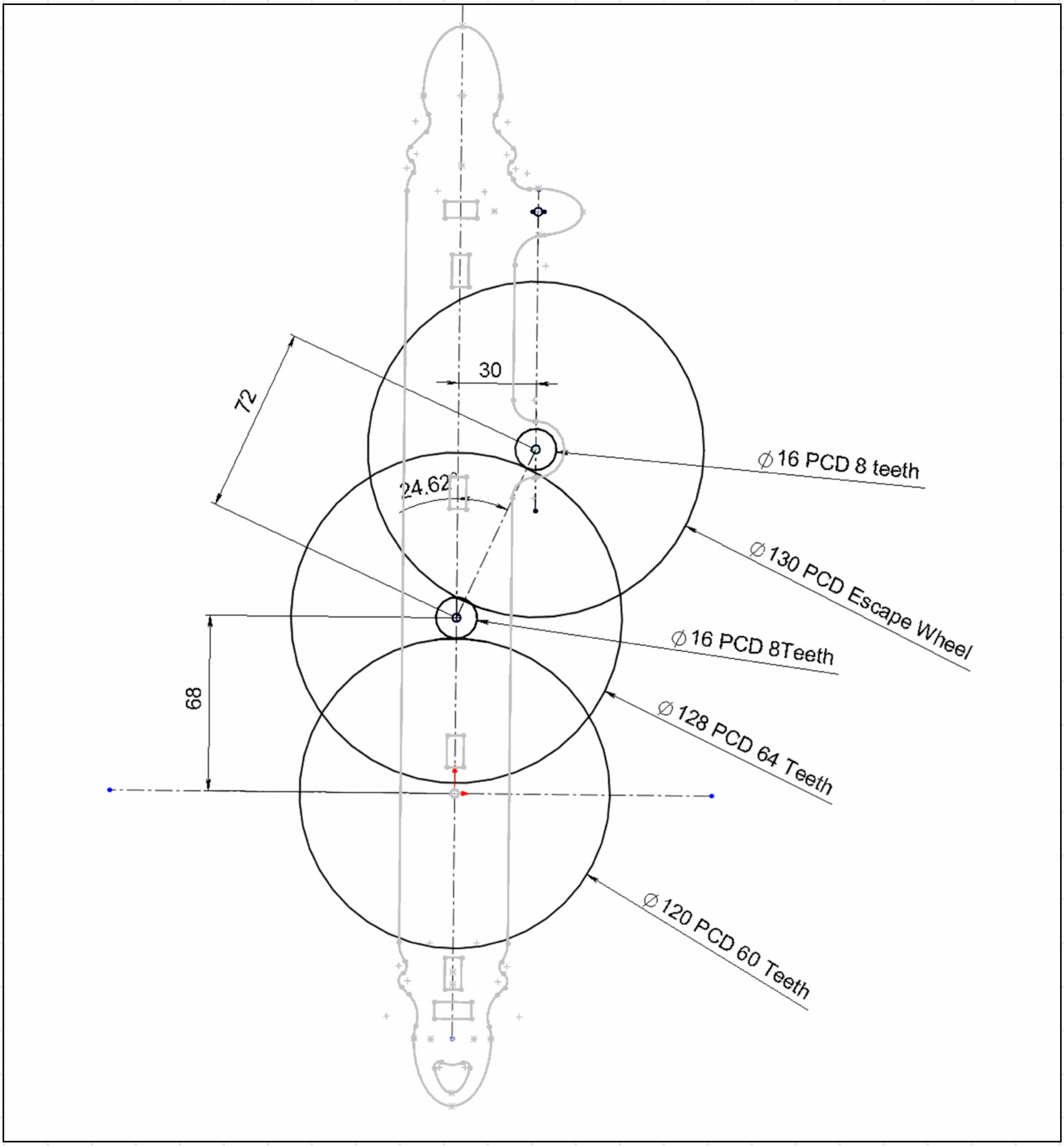
I have an Excel file that calculates your own gear trains if you want to try for something a little different

17		Wheel 1 Teeth	Pinion 1 Teeth	Wheel 2 Teeth	Pinion 2 Teeth	Wheel 3 Teeth	Pinion 3 Teeth	Wheel 4 Teeth	Pinion 4 Teeth	Escapement # teeth	Gear Ratio	Escape Wheel Rotation Secs	Pendulum period Iseconds)	Pendulum length in meters	pendulum length inches
18	2 wheels	64	8	60	8	1	1	1	1	30	60.0	60.0	2.0	0.993	39.1
19	Clock 1	60	15	60	15	60	16	1	1	30	60.0	60.0	2.0	0.993	39.1
20		60	20	60	15	60	12	1	1	40	60.0	60.0	1.5	0.559	22.0
21	Clock 12	70	7	66	11	1	1	1	1	60	60.0	60.0	1.0	0.248	9.8
22	Clock 37	60	15	60	12	60	10	1	1	30	120.0	30.0	1.0	0.248	9.8
23	Clock 35	60	12	60	15	60	10	1	1	30	120.0	30.0	1.0	0.248	9.8
24											#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
25											#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	



The other gear train used on the clock is the Hour train sometimes known as the Motion work is the small 12-to-1 reduction gear train that turns the timepiece's hour hand from the minute hand. It is attached to the Going train by the friction fit of the ten toothed pinion, so the minute and hour hands can be turned independently to set the timepiece. The 30 toothed Wheel is paired with the 10 toothed pinion and the 32 toothed wheel with the 8 toothed pinion. The 30 tooth wheel is fixed to the 8 toothed pinion so that they move in unison. The hour hand is fitted to the 32 toothed gear and the Minute hand is fixed onto the Minute shaft.

The Clocks Gear Train - Laying out the gear train



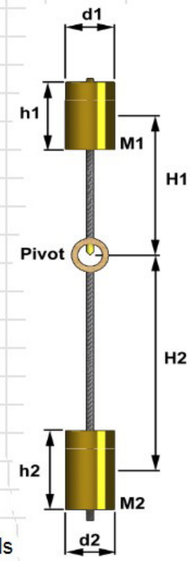
This is the layout for the Starter clock, each gear is represented by a circle whose diameter is the calculated Pitch Circle Diameter or PCD, so the 60 tooth gear at the bottom is engaged with the 8 tooth gear vertically above it, these were drawn so that the PCD's were tangent to each other. This 8 toothed gear is on the same axis as the 64 toothed gear, and it is that 64 toothed gear that engages with the other 8 toothed gear above it at an angle. When drawn this way in your CAD program it is relatively easy to move the gears around as long as you maintain tangency between the mating gears. I always start my layout of the clocks in this way so as to be sure that the gears will engage with their mates when actually fitted into the clock.

The Pendulum - Compound pendulum

If you are working on a Mantle clock design, then you are going to need a shorter pendulum and to do this without introducing another set of gears in the gear train you need a compound Pendulum in this way you can have it sitting on the shelf without the 1-meter-long pendulum protruding through it. The double-ended compound pendulum allows this because when you put a second weight above the pivot point it slows the clock down so you can shorten the length to Pendulum Bob considerably.

If you are interested in doing this, you can download a copy of the Excel file here. I have modified this slightly so that only the cells that you need to interact with are visible.

Assumes masses are cylinders		
Density of masses	0.0085	g/mm3
H1	200	mm
h1	65	mm
d1	19	mm
M1 Top Weight	156.6496272	g
H2	490	mm
h2	65	mm
d2	19	mm
M2 Bottom Weight	156.6496272	g
Period	1.987286905	seconds



The image above shows the inputs in the pale orange and the calculated values in green.

My first calculation presumes that both are going to be equal which simplifies the initial setup, but this is not necessarily how it will finish up as you can always make the bottom weight larger than the top which is normal. Not sure that it would work so well in practice if you make the top larger than the bottom.

It should be noted that the weights are presumed to be cylinders so you need for a start to input the diameter and length of the weights you are going to use. If your weight is not a cylinder in this orientation, then you need to adjust the values of diameter and length to the proportions of your weight and adjust until you get it about right.

Now input the values for H1 and H2 and you should see immediately a value for the Period in seconds.

I have a value of two seconds for the period (well almost) which is one second to swing in one direction and then one second to swing back again. I have achieved this by entering the value for H2 which is the maximum length I can have for the clock that I am designing, and then keep on adjusting H1 until the value is reached.

At this stage, you could also introduce some changes to the sizes of the weights to arrive at a solution that produces a better aesthetic to the pendulum.

A couple of things to note here are that the values for H1 and H2 are presumed to be to the centre of mass, in reality, should consider the weight of the rod as well, but it is a small difference so it has been ignored here.

The other thing is there may be other factors that will affect the movement of the pendulum over time, and in the way, the clock is constructed, so adjustment should always be allowed for in positioning the weights on the pendulum when it is finally built and running.

Generally speaking, the following rules apply:-

To increase the Period: Reduce H2 Increase H1

To decrease the Period: Increase H2 Decrease H1

Keep H1 smaller than H2 Keep M1 smaller or equal to M2

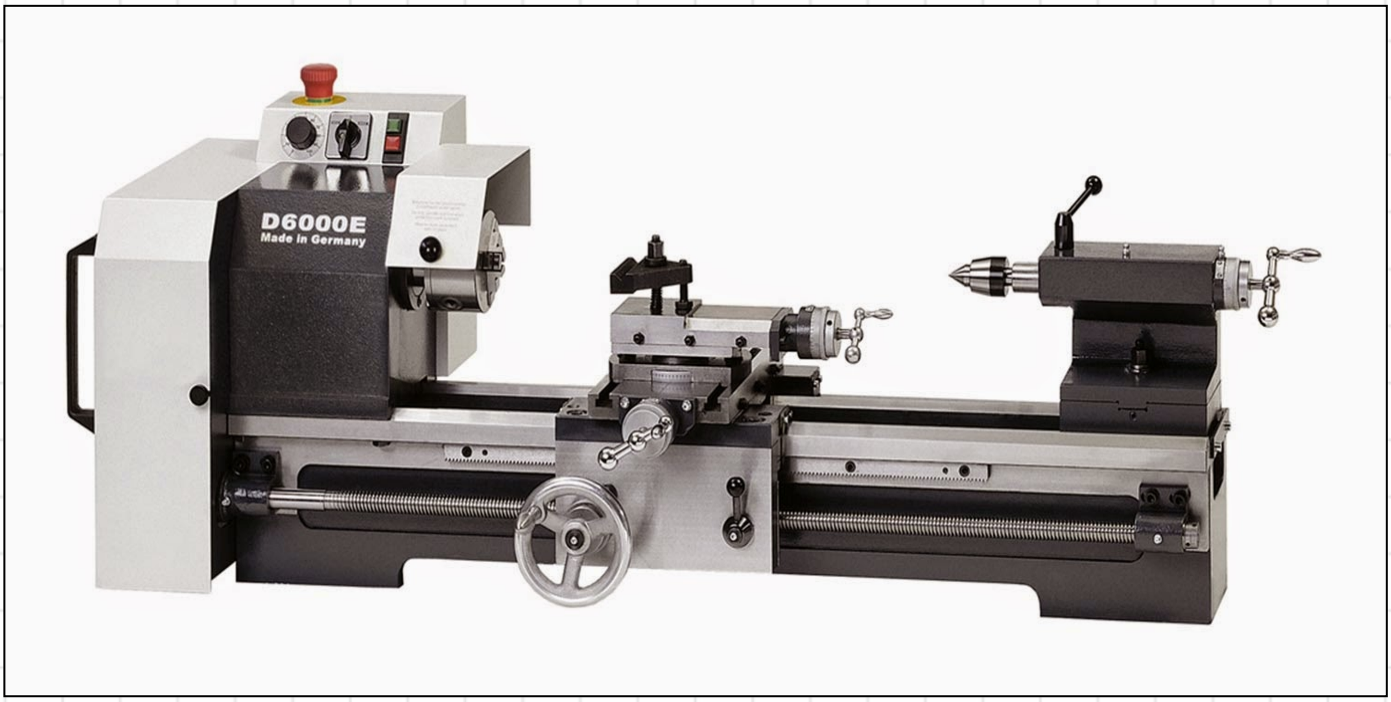
What will I need to build a wooden clock - Scroll saw and Lathe

I have shown the coping saw amongst the hand tools and I guess you could attempt to cut all the clock parts with one of those but it is not really practicable. The most common way of cutting the parts would be either to use a Scroll Saw or a CNC router.

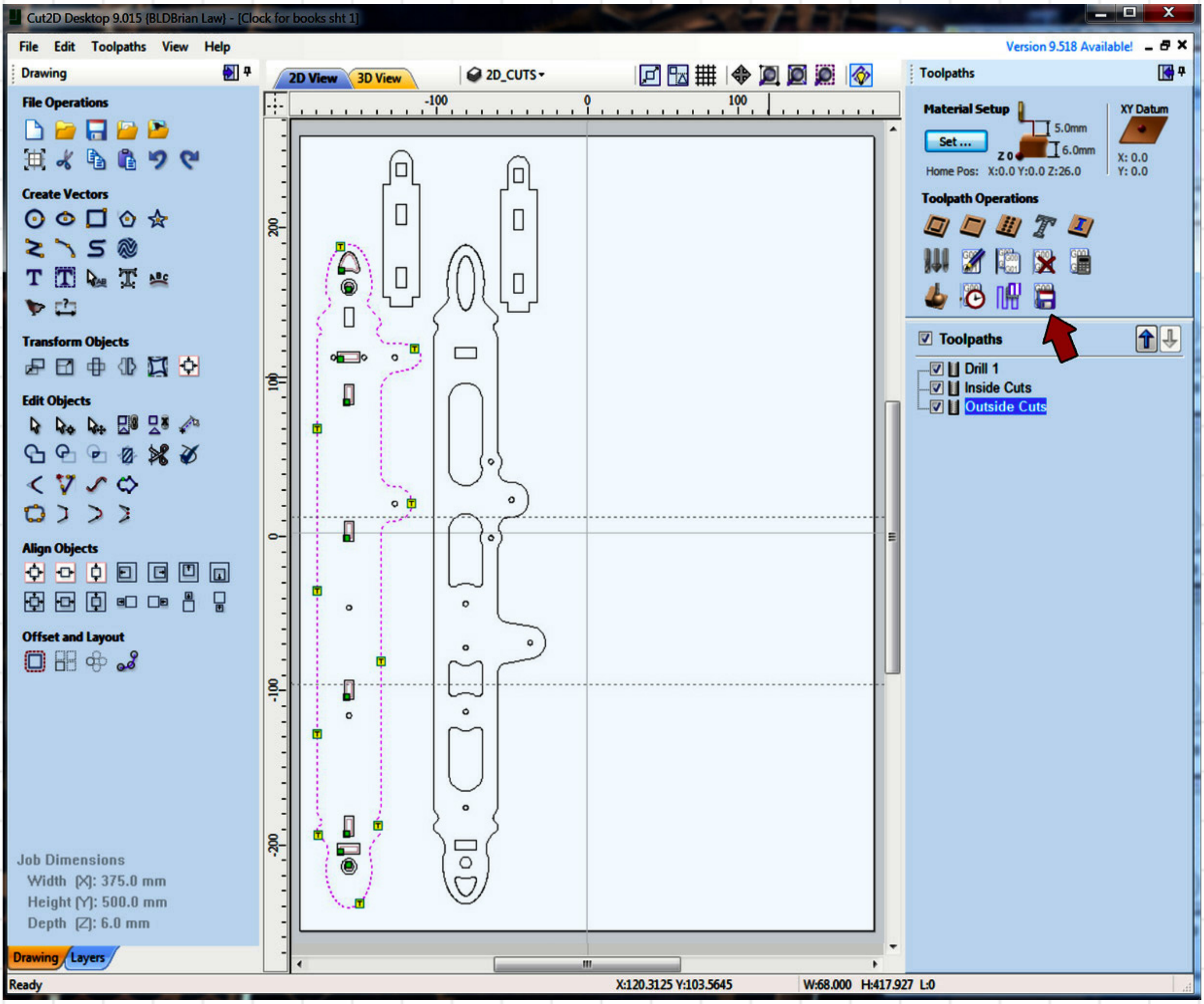
The Scroll saw shown here is ideal for cutting the gears and all the other flat parts in a clock and many of the clock builders use a saw like this to do just that. There is an alternative to this and that is to use a small Bandsaw as I did for my first clocks, but the scroll saw has more control and hence precision in the cutting.

If you are simply interested in building your clock with the above equipment you need read no farther as you have chosen the route that will not break the bank but will still give you great satisfaction but probably a lot harder work.

They're a few components in the clocks that are round and not suited to either Scroll saw or CNC routing, so you need to either out source those parts or be creative and change the design to use materials you can work with. Sleeves are an example that are ideally made on the lathe but can be made from dowel in shorter lengths and then drilled, or simply substituted with clear plastic tubing. The lathe shown below is a small bench top machine ideally suited to the needs of the clock builder.



Saving the toolpaths



With the toolpath creation complete you can save your toolpaths to take to your CNC Router. Make sure each of the toolpaths has a tick mark beside it and then Click on the Save Toolpaths button to move to the final screen.

You actually have some choices at this point as you do not necessarily need to save all the tool paths into a single file, perhaps you have used a different size cutter to drill the holes in which case you need to stop the CNC to change the cutter and then restart so a second tool path will be needed to be able to do this, or you may simply want to make sure everything is machining as it should before you commit to machining many parts.

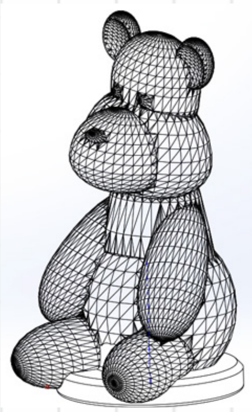
Making parts using a 3D printer

I have been using 3D Printing to produce parts for the clock prototypes I build, it started with Clock 35 which I had designed for my Grandson. I wanted it to be a fun colourful clock suitable for a young child or nursery, and the ability to print in a variety of colours was a real bonus as it meant that there was need to paint the gear teeth and possibly compromise the running of the clock. It turned out to be an excellent way to prototype parts as the turnaround for each iteration of the design was not only quicker as there was so little in the way of finishing that needed to be done but it also freed me to do other things as I was not tied to the machine whilst it was running as I was when CNC machining.

To be honest, it is not so good with the larger frame parts as they have to be split into parts to fit the smaller table, but this was OK because I could still use wood for the frame and cut it on the router.

3D printing also produces 3D components that would be more difficult to make using 2D cutting on the router, these would normally be produced in layers to enable the 3D features to be made. An example of the is the Escapement lever in Clock 37, simple to 3D print but more laborious to make by CNC machining.

This is probably the easiest way to make your clock as it is almost a one-step process, I would normally finish the parts by trimming off any supports and making sure there were no unwanted little blobs or strings of plastic. Then drill all the precision holes for the pins and shafts to be fitted, and then on to the final assembly for tweaking the set up to get the clock running to time.



The files needed for printing are STL files, these are 3D files and comprise small triangular sections, laced together to form the shape of the object being modelled. Teddy shown here is an example of how an STL looks, with course triangles like these they can be seen in the finished model but models can be saved with very much smaller triangles so the finish is a lot smoother. However as with everything else the more detail means a lot bigger file.

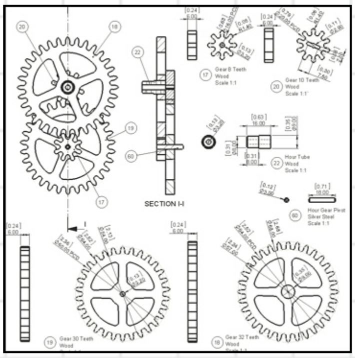
STL files can be created from the STP files I include with all my clocks, using on-line translators it is possible for you to build any of my clocks in this way. I actually have 4 smaller clocks designed specifically for 3D printing and come with the STL files and Clock 37 the last clock also has STL files the rest you would need to translate from the STP files.

If you have a 3D printer you almost certainly have the software you need to use the STL files that I have provided so I will not include any Step by Step instructions here, however, if you want to learn more about STL files and 3D printing in general go here.

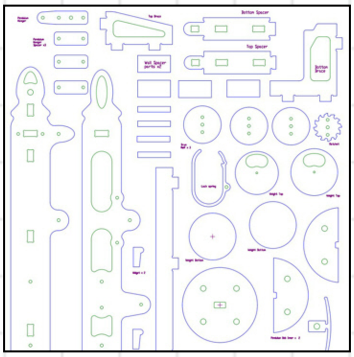
I have included all of the STL files for you to download on the download page 61. There has been some modification to the files to enable you to print the longer items like the Frames and the Rear Frame stiffener these have been split into several sections to enable you to do the printing on the normal sized table. Other items like the gears have the spacers incorporated to simplify the build. Other than those changes the rest have been translated to STL files direct.

Making the parts - Files for the Starter Clock

You will need to download the files that will be used to make all of the parts of the Starter Clock.



Download Detail Drawing files

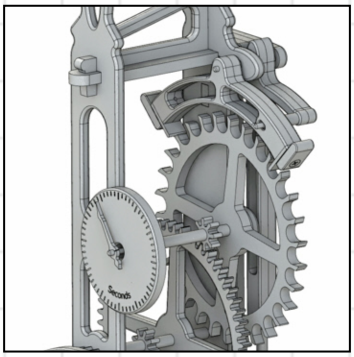


Download Profile cuts in DXF Format - Sheet 1

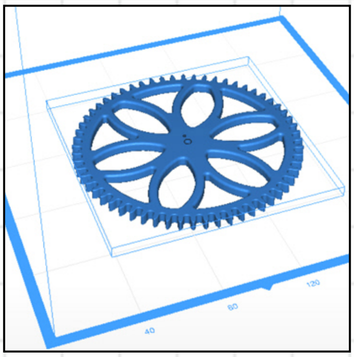
Download Profile cuts in PDF Format - Sheet 1

Download Profile cuts in DXF Format - Sheet 2

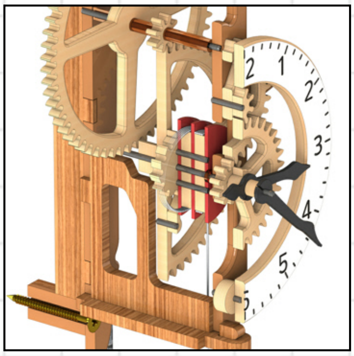
Download Profile cuts in PDF Format - Sheet 2



Download 3D Model files in IGS and STP formats



Download model files in STL format



Download Rendered illustrations sheet 1

Download Rendered illustrations sheet 2

Download Rendered illustrations sheet 3

Download Rendered illustrations sheet 4

Proprietary items- Parts and Materials

There are several parts and materials on the clock that you will need to purchase.

Material

6mm Birch Plywood 500 mm x 375 mm Boards 2 required

ABS or Hips Sheet 100 mm x 150 mm x 2 mm thick 1 Required

Plastic tube Ø6.4 x Ø3,2 x 250 mm long

Carbon Fibre tube Ø6 x Ø4 x 1000 mm (Kite material suppliers)

Silver steel Ø3 x 500 mm long. (also known as Drill Blanks in US)

Brass Rod Ø6 mm x 100 mm

Self adhesive Vinyl sheet Gold (too wrap around weight)

Parts

No 10 Woodscrew 60 mm long 2 required

No 5 Woodscrew 20 mm long 3 required

Blind Cord Ø1 mm x 4 meters

Washers Ø3 x 20 required

Small Brass screw in Hook for hanging the weight

Sources

These are going to vary according to where you live, if you live in the US then McMaster-Carr will be able to supply most things

In other countries you can search under 'McMaster-Carr equivalent'

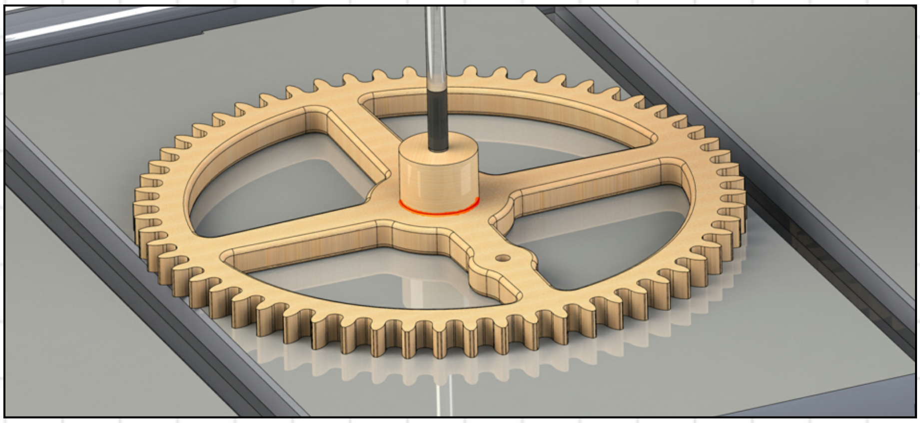
You can also search 'Design Technology Supplies' or 'Education material suppliers'

In the UK Birch Plywood can be had from Heart Educational or Hindleys

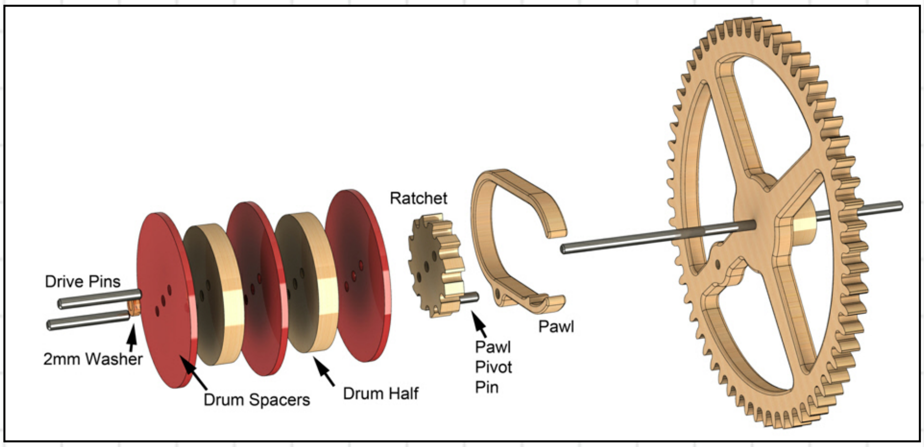
Steel and Brass Rod from Noggins End

Of course sources are endless so these can only be a guide so you will need to search locally to find your own best sources.

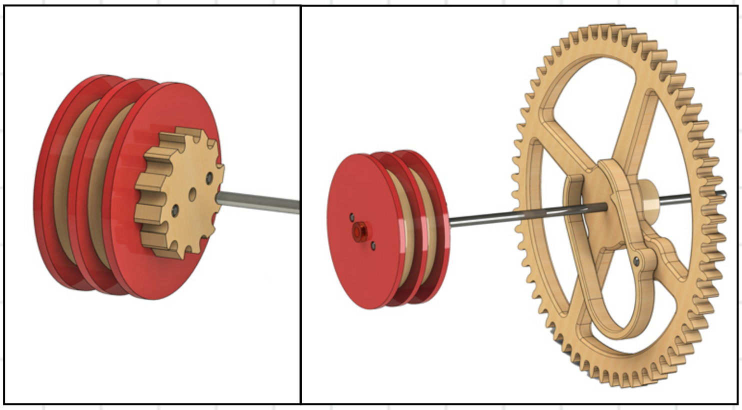
Assembly - Drive gear assembly



The main gear on the Drive assembly needs some extra support as it will transmit the Maximum load, so a bush is glued to the back of the gear, see the red line. Apart from this the procedure for fitting the shaft is the same as the previous gears, the shaft being pushed in up to the black line on the shaft. This gear is to be a tight fit on the shaft.

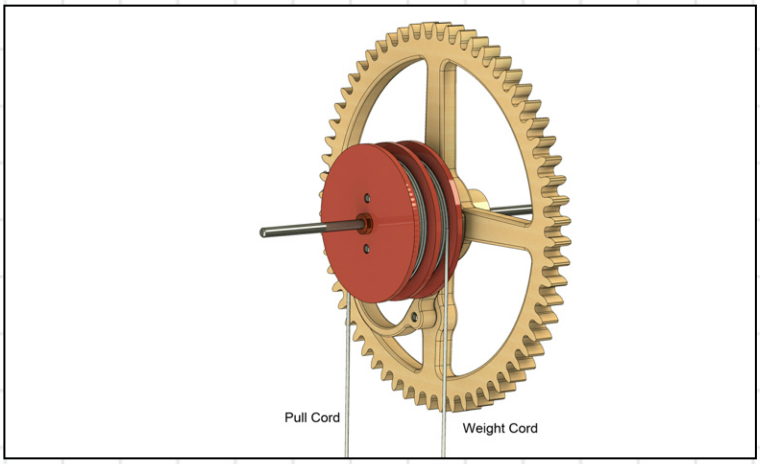


The next step is to assemble the Drum Spacers, the Drum halves and the Ratchet together on the gear shaft and then aligning them all with the two Drive Pins. The Drum spacers and the Drum Halves need to be glued together so the cords can not slip between them when the Weight is to the cord. This assembly is to be a loose fit on the shaft



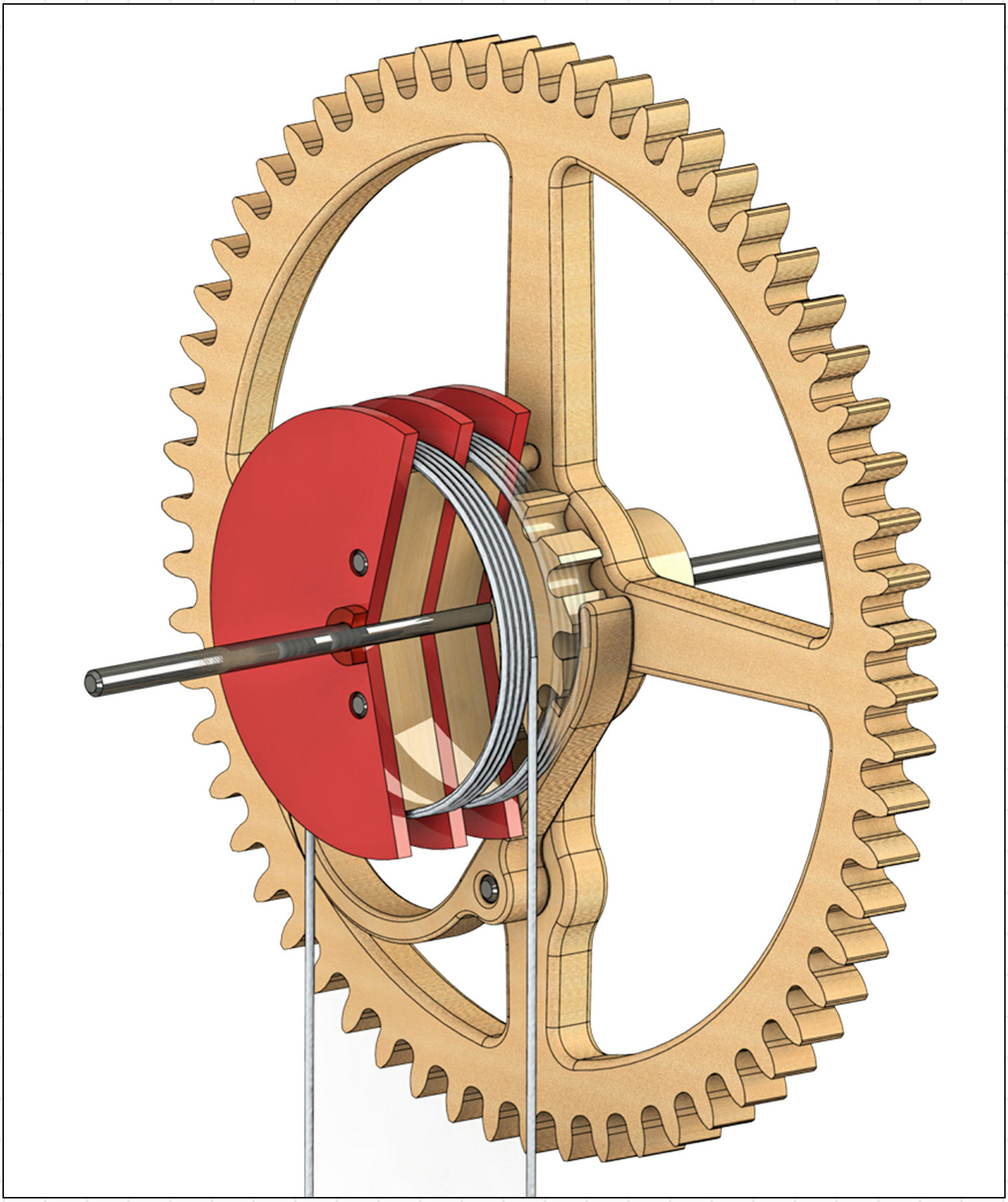
It is important at this point to ensure you have the Ratchet part on the right way round, check with the drawing at the left to make sure. OK now fit the Pawl Pivot Pin into the 60 toothed Gear and fit the Pawl onto it.

Now mount the Drum assembly onto the shaft and push and twist it up against the 60 toothed Gear so that the Ratchet engages with the Pawl.



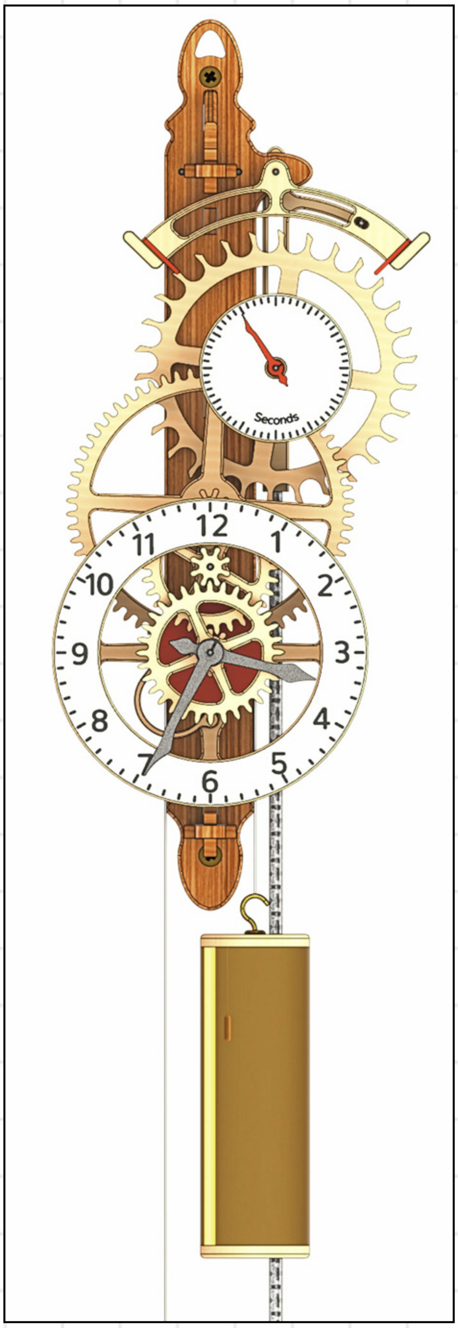
Time to fit the cords to the Drum, cut a length of Cord four meters long. Thread the cord through the outer hole in the central spacer and pull half the cord through. The cord that holds the Weight should be wrapped around five times in a Clock-wise direction so the cord hangs down to the Right of the Drum, tie a Bowline knot in the end to hold the weight. The other cord which is to rewind the clock is wound fully onto the drum in an anti Clock-wise direction with the cord Hanging down to the left about 150 mm. Attach the Pull Cord to this end.

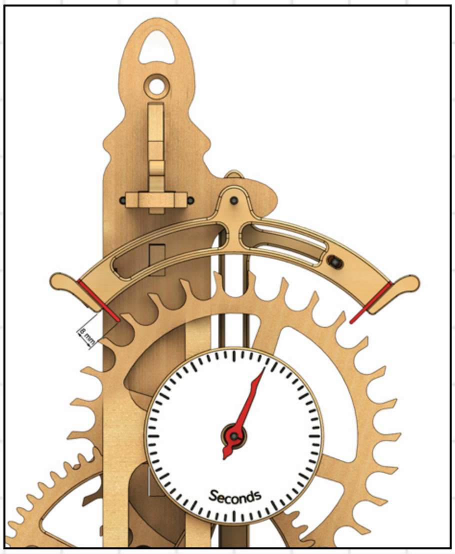
Assembly - Drive gear assembly- continued



A close view of the fully assembled Drive sub-assembly shown cut away to give a clearer view of the orientation of the ratchet and the Pawl and also showing the weight cord on the Right wrapped around the Drum, and the Pull Cord on the Left.

Assembly - Fitting to the wall and Testing





With the Pendulum Rod assembled and the Pendulum Bob attached the clock can now be screwed to the wall, I would normally hang the clock with the Dial at 1500 mm from the floor which in this case should give a bit over 8 hours of running time, if you hang it at 1700 mm then it should run for around 10 hours. The two screws, one at the top and one at the bottom are used to secure the clock, it is important however to try to have the clock mounted vertically so take some time with a spirit level against the side of the front frame to ensure that it is vertical.

Now make sure that both the pallets are sticking out 8 mm as shown and that they are penetrating the Escape wheel teeth to an equal depth. Fix the weight to the Weight cord and pull down on the Cord pull at the other side to lift the weight to the top of its travel, now push the pendulum to one side and let go. The pendulum should now swing freely and if the set up is correct you should hear an even Tick Tock as the Escapement engages the pallets. If it is not even, adjust the pallet on the lowest penetrating side so that it can even up the tick. Continue this adjustment until it is running evenly.

If there is a problem and the clock stops running it is time to check out a few possible causes. The easiest thing to try for a start is to try adding more weight, if you get up to 1 kg then the weight is not the problem. The next thing to check is if the pendulum is swinging freely if there is any stiffness then find the source and correct it, it may be rubbing somewhere it shouldn’t, try replacing the 2 mm spacers with Ø3 washers, 3 in each position.

If that does not help remove the clock from the wall and check two mating gears at a time to see if they run freely, if not mark the teeth that appear to be sticking and then carry on to determine if the problem is with the large gear or the pinion. When you have identified the problem then carefully dress the offending teeth until it runs smooth. Repeat this process for each mating pair and the try it with all the gears engaged without the escapement. When you are sure no gears are sticking and they are all moving smoothly put the escapement back on and see if the clock will run. Whilst checking any sticking gears make sure that each wheel is mounted both concentrically and squarely on its shaft, the clock will probably run if it wobbles a bit but if it is not running concentrically then it almost certainly not run properly.

When you have finished all your checks and made any modifications then re-assemble the clock try again.

When you have it running you should be able to check to see if it is keeping accurate time, if its running slow move the Pendulum Bob up slightly, if running fast the move it down. You should be able to get it to run at better than 1 minute in 8 hours.

Tips and Tricks

Bearings - Lubrication and identification

The type and viscosity of the lubrication in the "as shipped" bearing is highly significant and represents a considerable drag inside the bearing. I recommend that the grease or oil be soaked out with white spirit.

My technique is to soak and rinse the bearings in the solvent multiple times, refreshing the solvent each time, draining them on white tissue paper in between. Initially the tissue is stained, but after several repeats, the dried tissue is quite clean, so virtually little additional grease or oil is being extracted, even for shielded bearings. The solvent used should be white spirit. I always rotate the bearings in the solvent at fairly high speed to assist in the agitation.

Prefix	Suffix
S:Stainless Steel	**RS**:Single Rubber Seal
F:Flanged	**2RS**:2 Rubber Seals
MR:Metric	**Z**:Single Metal Shield
MF:Metric Flanged	**ZZ**:2 Metal Shields
R:Inch	

Recommended bearing type is stainless steel with metal shields as these do not actually touch on the balls inside whereas the flexible seals can do.

A typical designation would be:-

SMR84ZZ Ball Bearing - Ø4 x Ø8 x 3 mm

Or for a flanged version

SMF84ZZ Ball Bearing - Ø4 x Ø8 x 3 mm

This information supplied by:-
https://www.arceurotrade.co.uk/Catalogue/Bearings/Ball-Bearings-Metric/4mm-Bore

On some of my clocks there are shafts that really need to have a head on the end to hold in place parts such as gears or ratchet and pawls. If making headed pins is not possible then other solutions have to be used. The pictures on the left show some of the parts that can be used. The best, because it has a head and an accurate shaft diameter is the clevis pin, this can be cut to length and used directly. Simile a round head Nail could be used but the shaft itself is not as smooth or accurate. A small Rod magnet with a diameter larger than the shaft can be simply stuck to the end of the shaft, as long as the shaft is not stainless steel. Last a small plastic washer with a hole slightly smaller than the shaft diameter and a slit through the side to allow it to flex, can be slipped onto the end of the shaft to form a head.

Brian Law’s Woodenclocks list of clocks on site

	A	B	C	D	E	F	G	H	I	J
1	Brian Law's Woodenclocks - Feature list									
2										
3	Clock	Made From	units	Difficulty	longest	Pendulum	Weight	Run Time	Escapement	Clock
4					Part	Length		Aprox		
5										
6	1	Wood	mm	Medium	664 mm	990mm	3 kg	10 hrs	Graham	1
7	2	Wood	mm	Medium	430 mm	990mm	3 kg	10 hrs	Graham	2
8	3	Wood	inch	Medium	18.5 in		1.5 lbs	8hrs	Verge and Foliot	3
9	4	Wood	mm	Medium	406 mm		0.6 Kg	8hrs	Verge and Foliot	4
10	5	Wood	mm	Medium	476 mm	990mm	3 Kg	10 hrs	Graham	5
11	6	Wood	mm	Hard	1437 mm	990mm	3 Kg	8 hrs	Graham	6
12	7	Wood	inch	Medium	46 in	39 in	6.6 lbs	8hrs	Graham	7
13	8									8
14	9	Wood	mm	Hard	400 mm	250 mm	2 Kg	8hrs	Graham	9
15	10	Wood	inch	Medium	14.7 in	39 in	6.6 lbs	10hrs	Graham	10
16	11	Wood	mm	Medium	277 mm	990mm	4 Kg	8hrs	Graham	11
17	12	Wood	Both	Medium	330 mm	250 mm	Spring	8hrs	Graham	12
18	13 STL	Plastic	mm	Easy	275 mm	250 mm	1 lbs	10 hrs	Graham	13 STL
19	13 FDM	Plastic	mm	Easy	275 mm	250 mm	1 lbs	10 hrs	Graham	13 FDM
20	14	Wood	Both	Hard	315 mm	250 mm	Spring	8hrs	Graham	14
21	15	Wood	mm	Hard	430 mm	1330 mm	1.8 Kg	24 hrs P	Grasshopper	15
22	16	Wood	Both	Medium	391 mm	250 mm	Spring	8 hrs	Verge and Foliot	16
23	17	Wood	Both	Medium	345 mm	250 mm	Spring	8 hrs	Flying Pendulum	17
24	18	Wood	mm	Hard	530 mm	990 mm	1 Kg	24 hrs P	Graham	18
25	19	Plastic	mm	Medium	290 mm	990 mm	0.6 Kg	10 hrs	Graham	19
26	20	Wood	mm	Medium	690 mm	990mm	1 Kg	12.5 hrs	Gravity	20
27	21	Wood	mm	Easy	430 mm	990 mm	0.35 Kg	7 hrs	Graham	21
28	22	Wood	mm	Hard	455 mm	990 mm	2 Kg	24 hrs P	Gravity	22
29	23	Wood	mm	Hard	700 mm	990 mm	2.2 Kg	25 hrs P	Graham	23
30	24	Wood	inch	Hard	30 in	39 in	5 lbs	12 hrs	Gravity	24
31	25	Wood	inch	Easy	22.5 in	39 in	1.5 lbs	8 hrs	Graham	25
32	26	Wood	mm	V Hard	571 m	39 in	2.2 Kg	12 hrs	Gravity	26
33	27 FDM	Plastic	mm	Easy	190 mm	250 mm	0.6Kg	10 hrs	Graham	27 FDM
34	28 FDM	Plastic	mm	Easy	184 mm	250 mm	0.6Kg	10 hrs	Graham	28 FDM
35	29 FDM	Plastic	mm	Medium	190 mm	250 mm	0.6Kg	10 hrs	Gravity	29 FDM
36	30	Wood	mm	Easy	560 mm	990 mm	0.75Kg	8 hrs	Graham	30
37	31	Wood	mm	Easy	520 mm	990 mm	0.75 Kg	8 hrs	Graham	31
38	32	Wood	mm	Medium	570 mm	250 mm	2 Kg	25 hrs P	Graham	32
39	33	Wood	mm	V Hard	580 mm	150 mm	2.5 Kg	11 hrs	Graham	33
40	34	Wood	inch	Medium	15.5 in	990 mm	4 lbs	13 hrs	Gravity	34
41	35	Wood	mm	Hard	410 mm	250 mm	Spring	10 hrs	Graham	35
42	36	Wood	mm	Easy	330 mm	990 mm	1.3 Kg	24 hrs	Graham	36
43	37	Wood	mm	Hard	300 mm	990 mm	1 kg	12	Pinwheel	37
44	38									
45	Starter	Wood	mm	Easy	420 mm	990 mm	0.6Kg	8 hrs	Grahm	39

The chart above contains details of all of the wooden clocks on the Woodenclock’s web site, it gives all the clocks details so that you can more easily choose the clocks you are most interested in before actually visiting the site.