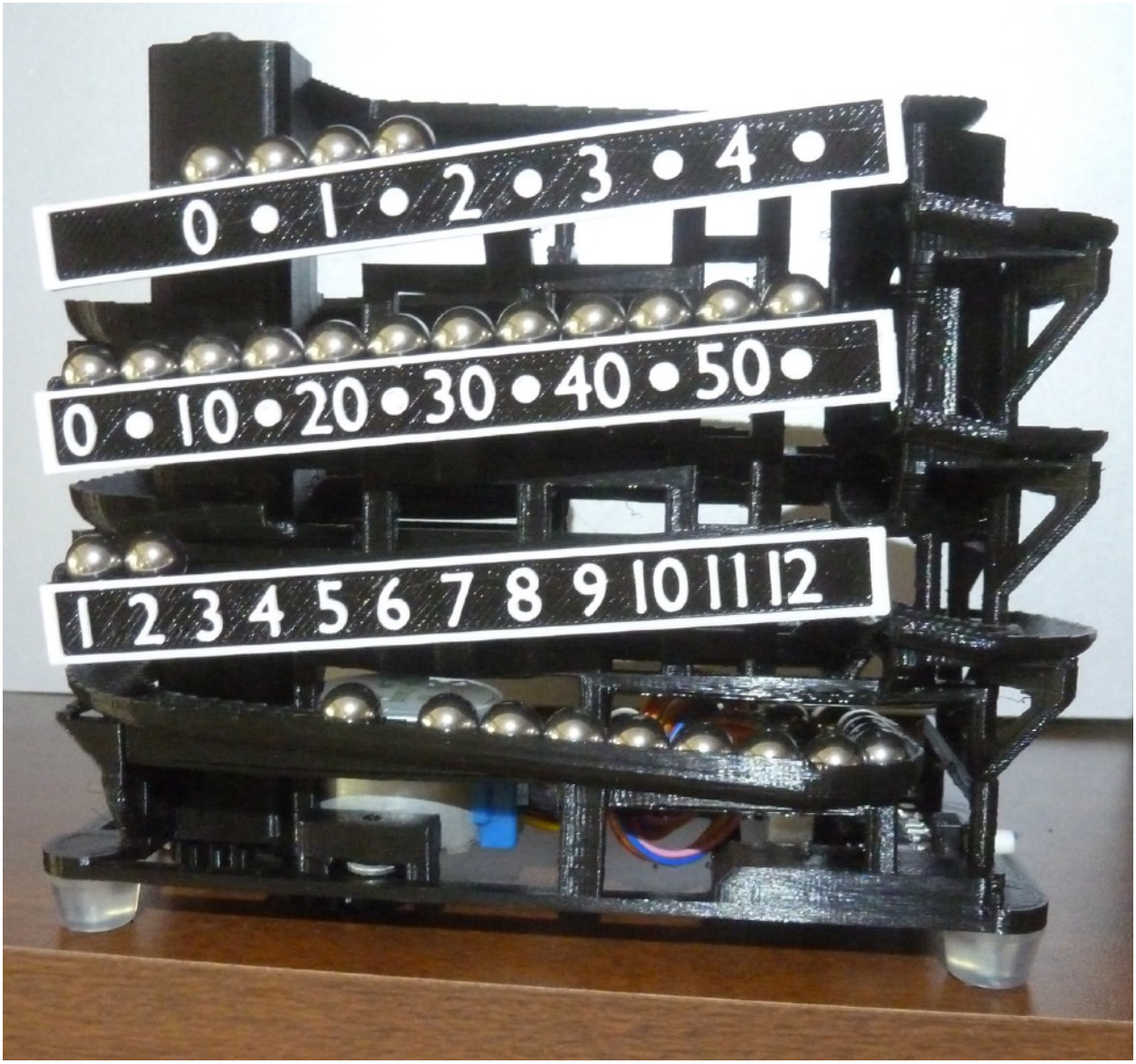
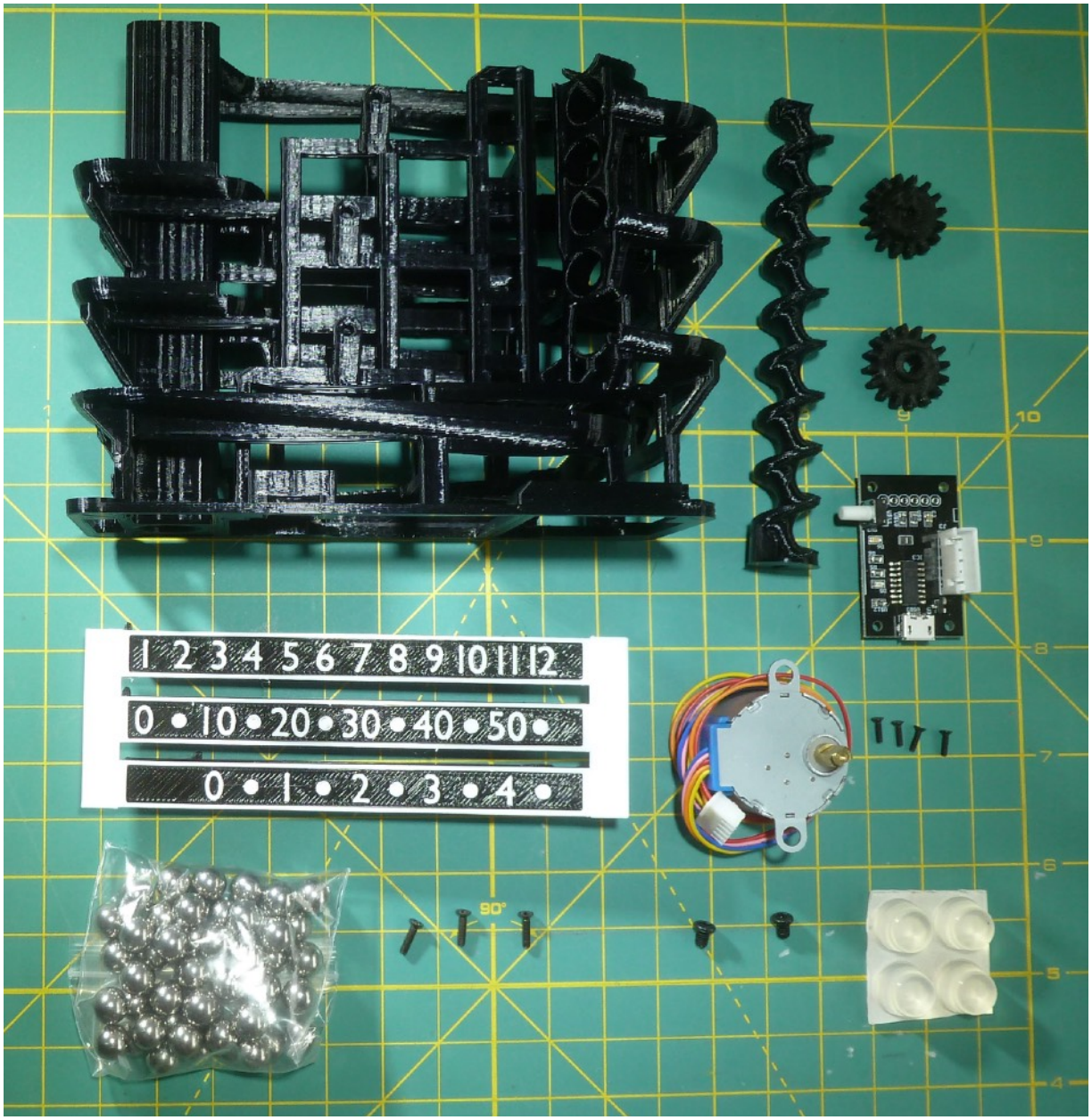
# Ball Clock
# Assembly Instructions

May 15th, 2019

Follow these instructions to assemble the USB powered Ball Clock model. You will need a Phillips screwdriver (PH0 sized is best), tweezers, a small hobby or pocket knife, and some sandpaper (200 to 320 grit). Not soldering is required, and everything else is included in the kit. Assembly should take about two hours.




**Assembled and operating ball clock indicating a time of 2:56:30**




Gather all the parts. Ensure that you have seven 3D printed parts: A lifting screw, two gears, three indicator bars (some kits have them temporarily connected, as shown in this image), and the large clock maze. There should be a stepper motor, a controller board, four rubber feet, and 48 bearing balls. There are nine screws — three 1.6mm diameter screws for mounting the controller board, two short 3mm diameter screws for mounting the motor, and four longer 2mm diameter screws for attaching the lifting screw to one of the gears, and for attaching each of the three indicating bars to the clock body. Not shown here but included in the kit is a USB cable.

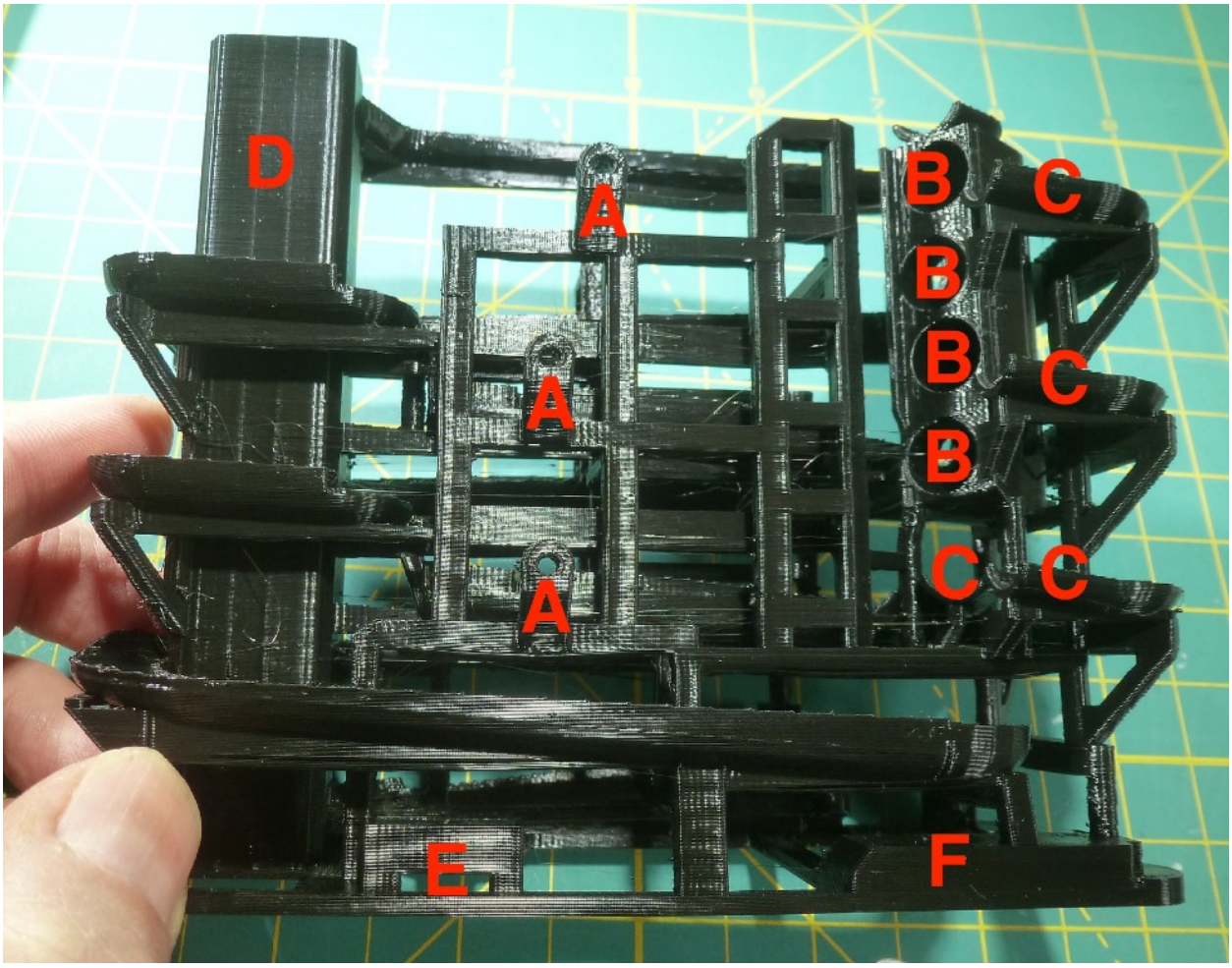
Your clock's color may differ from these images.


Not included in the kit, the tools you'll need are a Phillips screwdriver, tweezers, a small hobby or pocket knife, and a few pieces of sandpaper.

The ball clock kit is made from 3D printed PLA plastic. PLA is a rigid plastic, and fairly sturdy, but you'll still need to be careful with it. Applying too much pressure while holding it can cause it to crack, and screwing parts together too tightly may cause the plastic to strip. If either happens you can usually correct the problem with epoxy, or an adhesive such as E6000. However, your best approach is to be patient and go slowly, until you get a feel for the parts. Don't worry, they're not especially fragile.

PLA is susceptible to high temperatures, and will warp if it gets above about 104 degrees Fahrenheit, or 40 degrees Celsius. It's best to keep the ball clock indoors, and out of direct sunlight.

The ball clock uses a stepper motor and a highly accurate controller board. It collects balls at the bottom, lifts them using an Archimedes inspired screw, and releases one every 30 seconds at the top. Three carefully balanced indicators collect these balls, and each indicator releases the balls when full in such a way that most of the balls are recycled, but one ball advances to the next indicator.



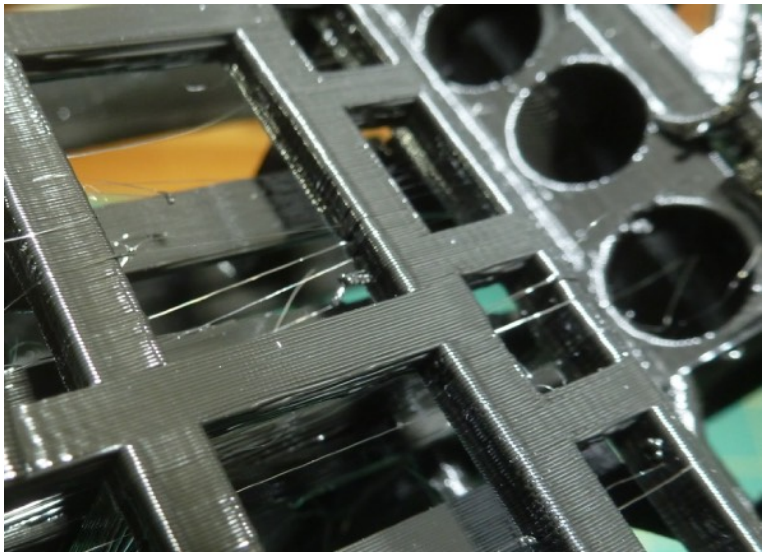

**A: Indicator Bar Mounts**
**B: Time-advance passages**
**C: Indicator bar ball exit paths**
**D: Lifting screw chamber**
**E: Motor mount location**
**F: Controller board mount location**

Inspect the 3D printed main body of the clock for any stray bits of plastic. This image shows quite a few thin bits of plastic that will need to be removed. This is called stringing. Use tweezers and sand paper to remove as much of this as possible. Pay special attention to the ball paths as they need to be very clean to ensure the balls roll freely. Take your time and try to make this as perfect as possible. When sanding, the plastic will begin to look a bit dusty, which is perfectly OK. Expect this to be the most time consuming part of the build.

The main body is printed in one piece. The sturdy column on the left is the lift screw chamber, the circular openings on the right top side are the time-advance passages, and the three small circular openings in the center-left are the time indicator bars mounting points. The motor and control board will be mounted on the bottom.

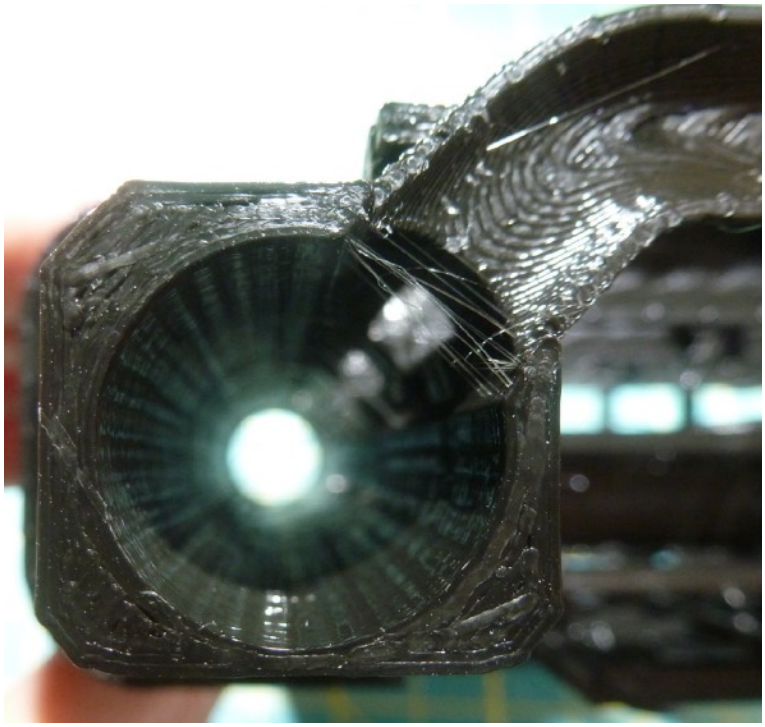
The next few images highlight some points you need to pay special attention to.

A close-up of stringing.  In some case it may not be necessary to remove the strings, for example where they don't interfere with the clocks operation, but the excess plastic in the time-advance passages must be removed. To be most reliable remove them all, since at some point in the future stray plastic may come loose and fall on the ball tracks, making the clock unreliable.

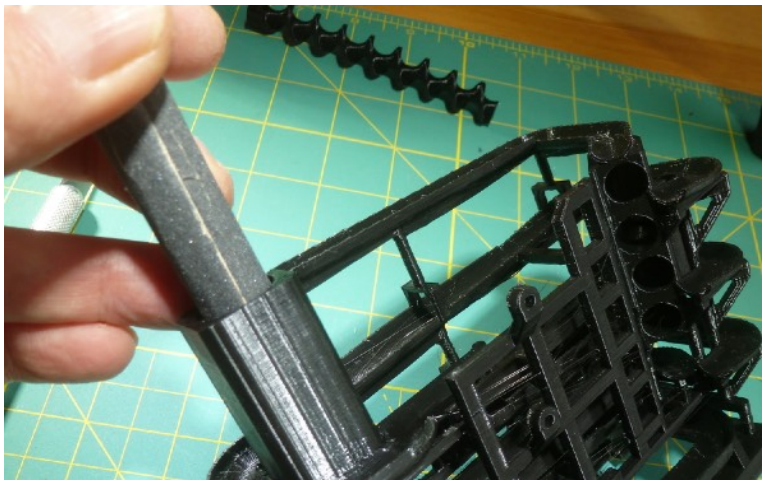


The lifting screw chamber needs to be especially smooth.  Use some sandpaper and, if necessary, a sturdy dowel such as an unsharpened pencil to sand the inside.  The chamber has a large cylinder to contain the plastic lift screw itself, and a smaller offset cylinder where the bearing balls travel upwards.  Be sure to sand both the large and small cylinder walls.

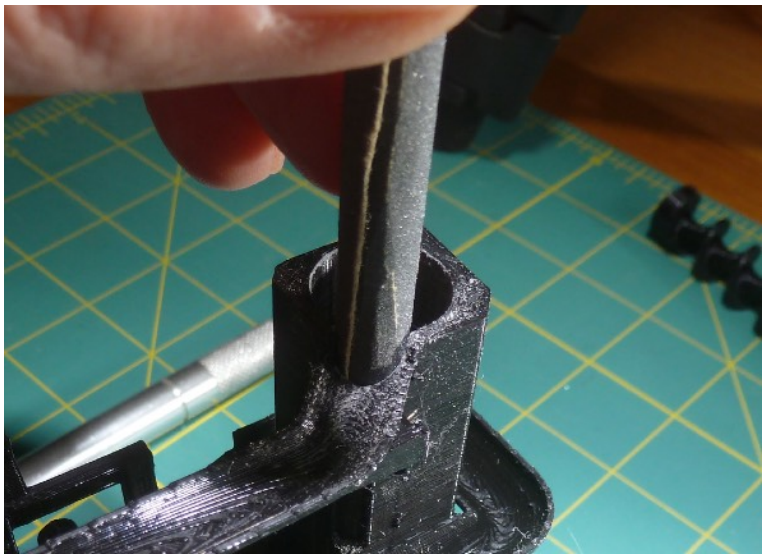
Notice there are some strings at the upper right of this image.  This is where the balls exit the lift screw, and needs to be especially smooth.  Be sure to sand this area carefully.



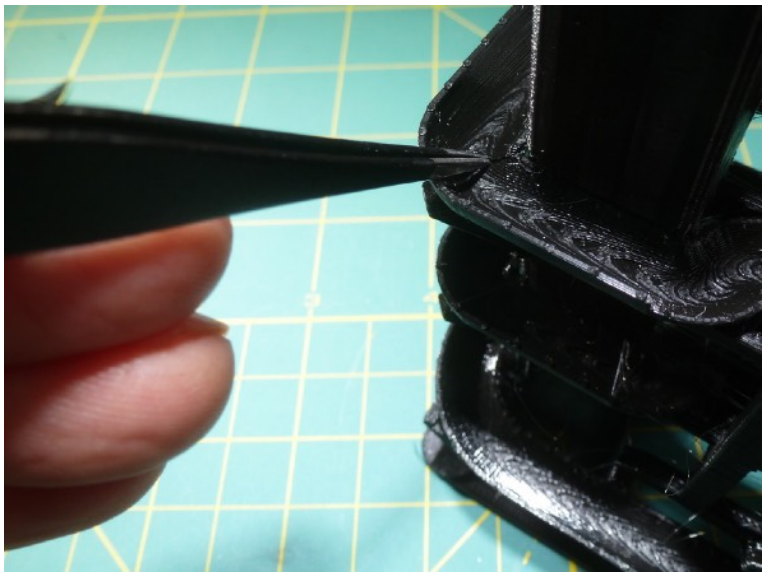
Use a long rolled-up piece of sandpaper to sand the inside of the lifting screw chamber, inserting the sandpaper from the top.  You may want to use an unsharpened pencil or other dowel to allow you to apply pressure near the bottom of the cylinder.  The very bottom of this cylinder has a smaller diameter.  DON'T sand it yet — that "flange" holds the screw in place.



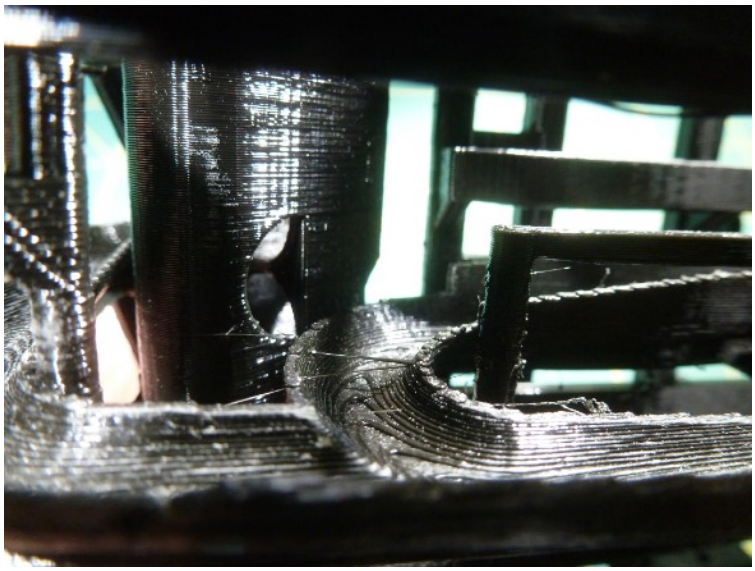
The ball lift column is offset from the screw cylinder.  Use a piece of sandpaper rolled tighter so that it gets into the 9mm diameter channel.



You may find large filaments of plastic bridging across the ball channels.  Use tweezers to remove them.



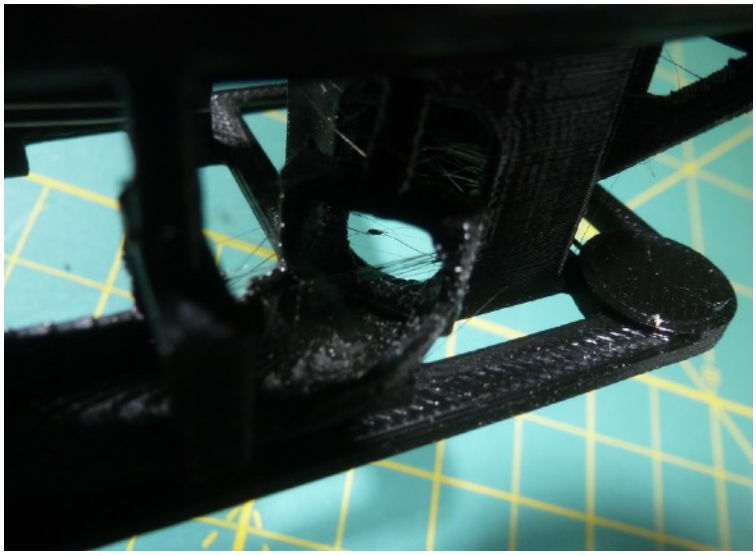
Here you can see an example of a small filament crossing the ball channel that needs to be removed.



After you've removed any plastic filaments, use a small piece of sandpaper to smooth the ball channels.  Try to get a nice matte look to the channels.  Consider using a damp cloth or cotton swab to remove any plastic dust.

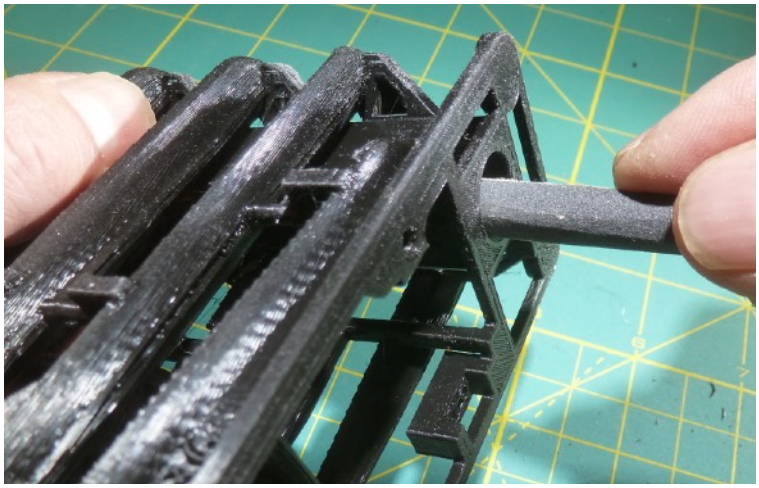
Examine the ball entrance to the lifting column.  Be sure this area is cleared of stray plastic, and sand it so the balls will easily roll into and on to the lifting screw.

The locations where the balls enter and leave the lifting screw are the most critical to get right.  Small imperfections can prevent the balls from loading, and correcting them after the assembly is complete is much harder than doing it now.

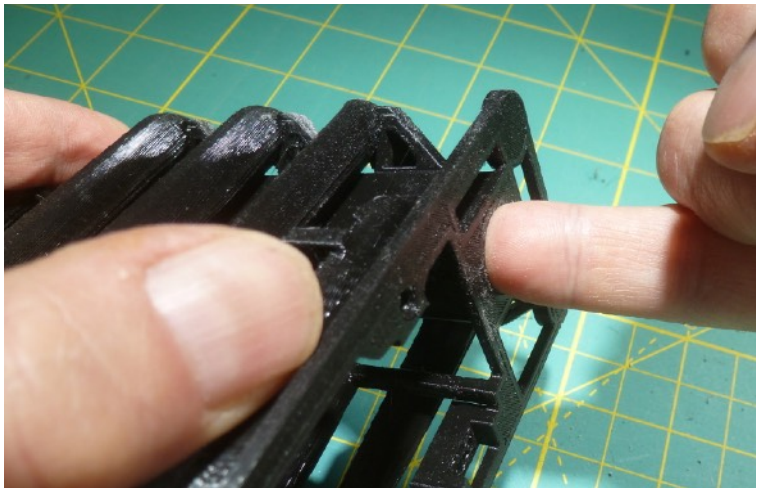


Use a bright flashlight to examine all the ball paths.  This helps to highlight any imperfections that remain.

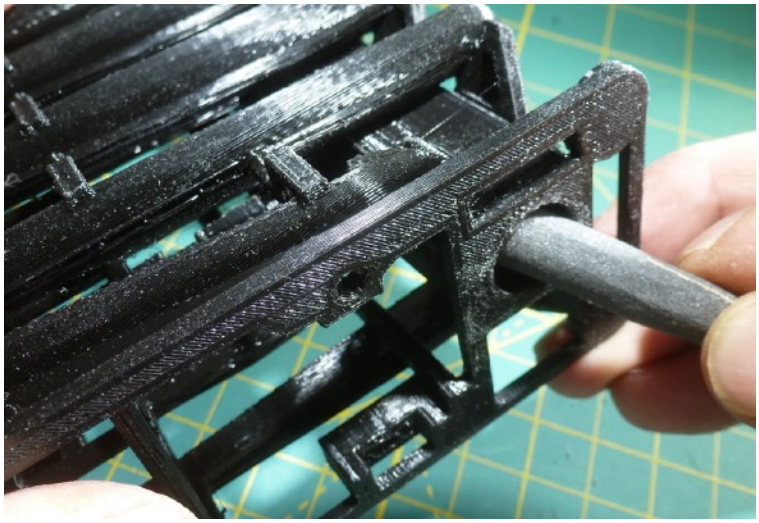
Sand the bottom of the lifting cylinder. The diameter here is smaller than the main cylinder, and is above where one of the plastic gears will attach. This flange holds the lifting screw at the proper height in the cylinder.



Use your little finger to feel the cylinder. It needs to be smooth so that the gear won't bind.



It's also a good idea to sand the the ball entry location from the inside of the lifting column, before installing the lifting screw. Use tightly rolled sandpaper at an angle to get into this tight space.



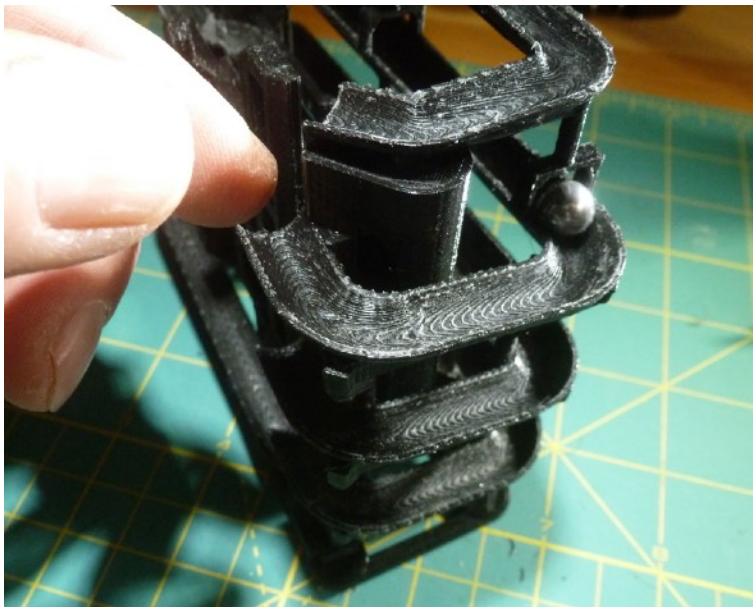
Now we'll begin testing that the balls roll freely.

The time-advance passages are the circular openings on the right. This is where a single ball is released from one time bar to the next, and is in effect the "carry" from one time indicating bar to the next. Be sure they are clean, and test that balls enter and immediately exit the passages. (The first and third holes from the top are entries, and the others are exits).

Test that balls roll freely along all the paths. If they get stuck, or if they're not rolling smoothly you've got more work to do.

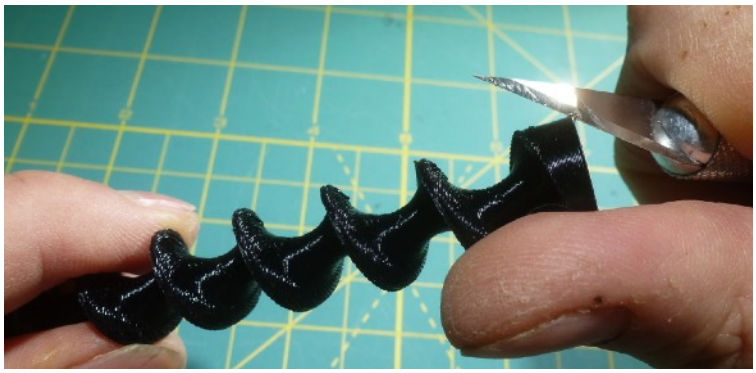
Test all three indicator bar exit paths on the right side of the clock body.

Once balls run smoothly along all the paths you're ready to proceed with assembly.



Locate the plastic lifting screw.

This part is printed vertically, and there's a brim on the bottom used to attach it to the build plate, so that it doesn't tip over while being printed.  The brim results in an undesirable flange along the bottom. Carefully remove this with a knife so that you don't feel any sharp edges.

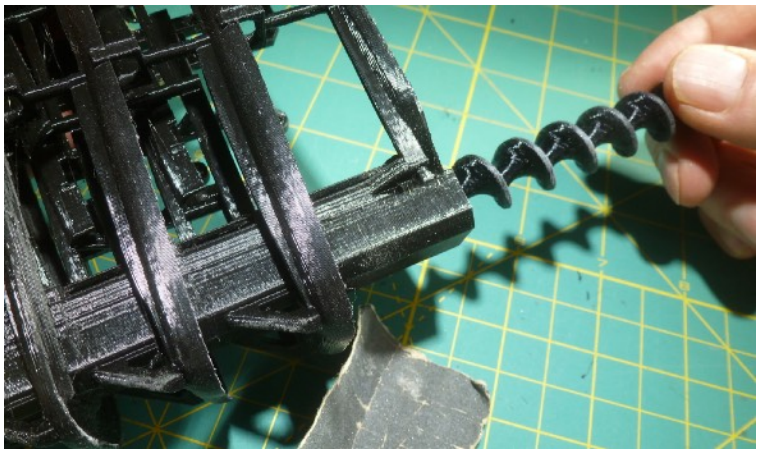


Use sandpaper if necessary to further smooth out the bottom edges of the screw. The diameter should be the same, or a little less than the rest of the screw.

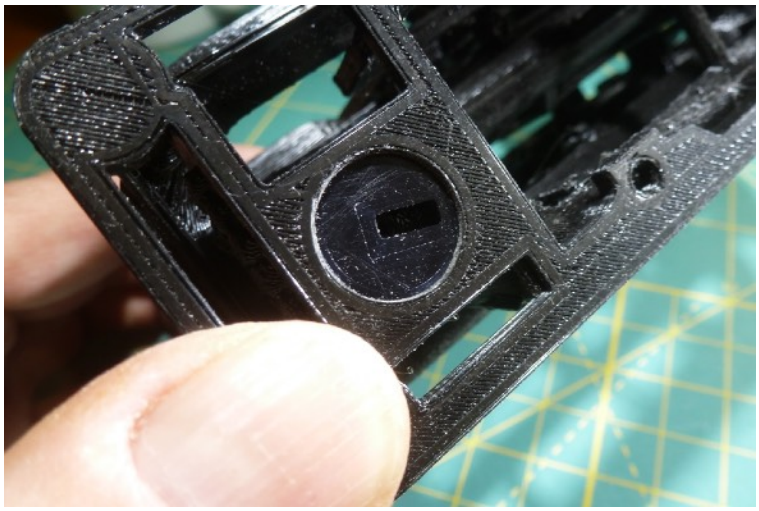
Then, use sandpaper to smooth the outer edges of the screw.  This will ensure it rotates freely when inside the lifting cylinder.

Its a good idea to examine the screw for any stray plastic that would prevent the balls from being propelled upwards.  You won't be able to correct any problems once the screw is installed.

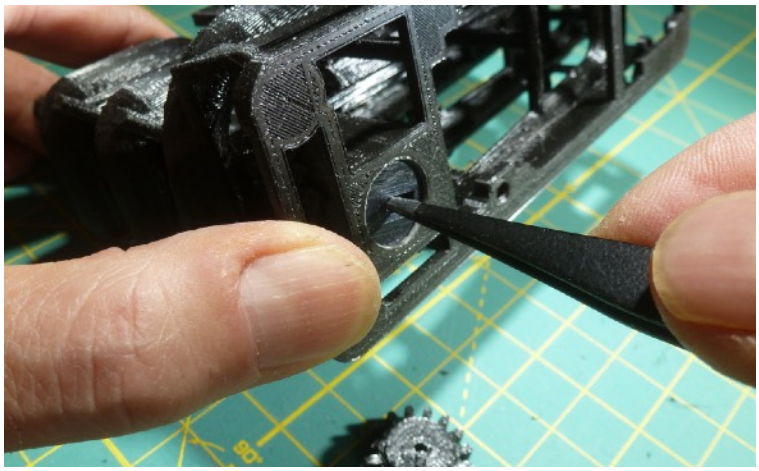
Now, insert the screw into the cylinder from the top.  The flat end, which you just sanded, is on the bottom and goes in first.  The screw should be a little loose in the cylinder.



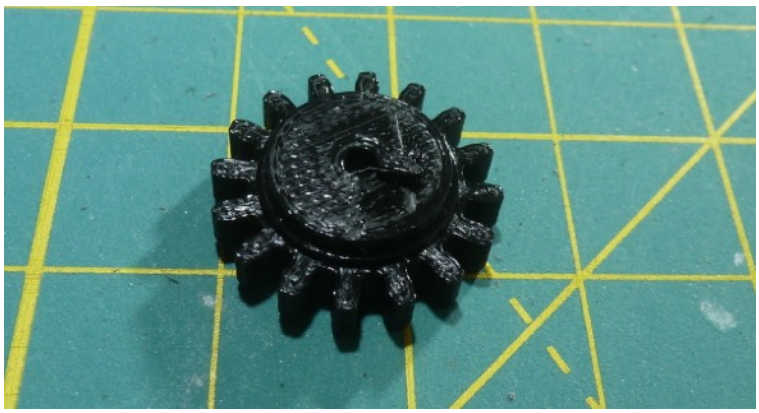
The bottom of the cylinder should look like this image.  The lifting screw is keyed so that it will firmly attach to one of the black gears, and there's a small hole inside this keyhole to accept a 2mm diameter metal screw.



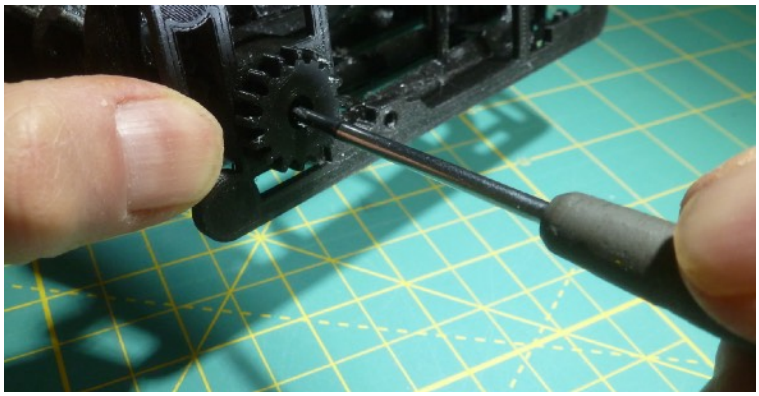
Use tweezers or a knife to ensure the gear attach screw hole in the lifting screw is clear.



Locate the plastic gear with the matching key.



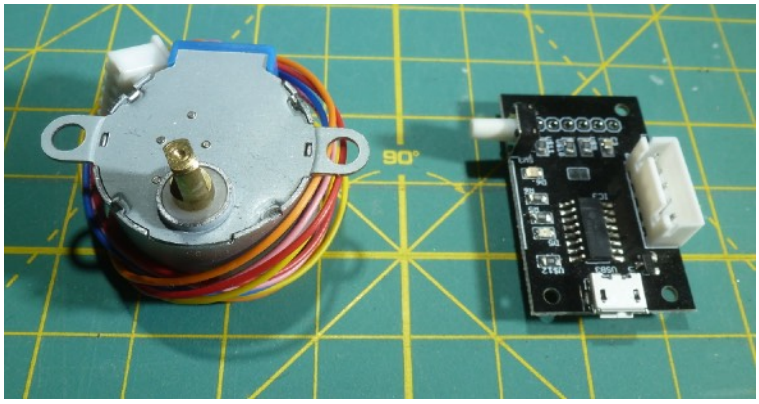
While holding the lifting screw in place with one hand, hold the keyed gear with your thumb, insert a 2mm diameter screw into the gear and tighten it to the lifting screw. The metal screw will self-tap, and you'll feel when it is tight. Don't squeeze the maze too tightly while holding it.



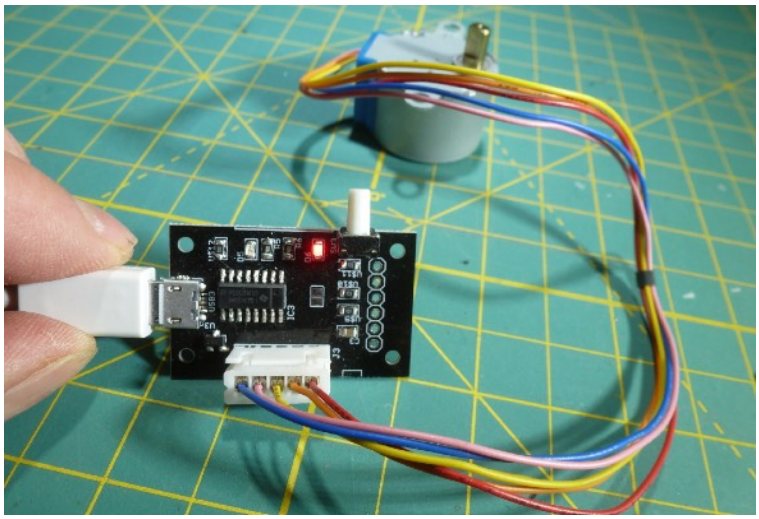
Don't worry that the gear hangs below the model. We'll be adding feet later that lifts the model above this gear.

Now's a good time to take a break. We'll next be moving on to installing the motor and controller board.

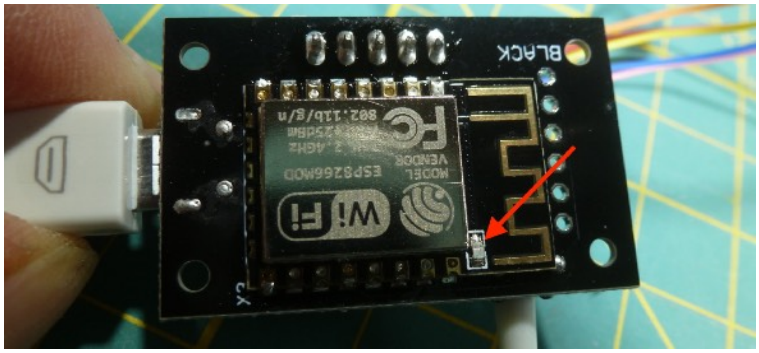
The next step is to test and prepare the motor and controller board.



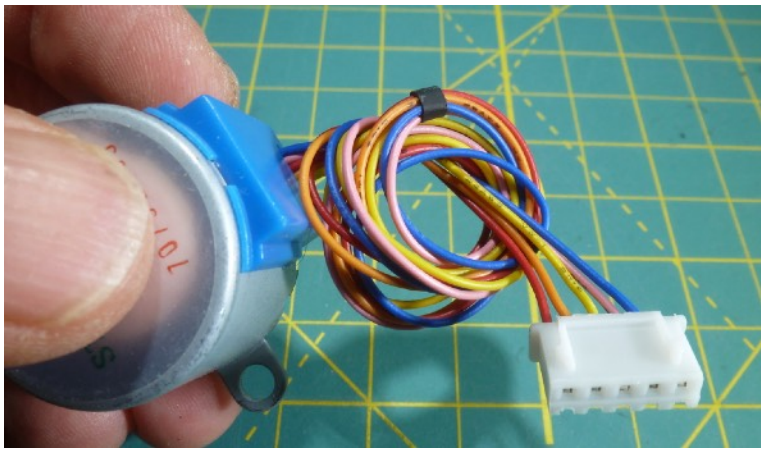

Connect the motor to the controller board and connect the controller board to a USB power source, such as a phone charger. The board should begin operating immediately when power is applied, and you'll see a red LED illuminate when the motor is running. The motor will turn 360 degrees every 30 seconds.



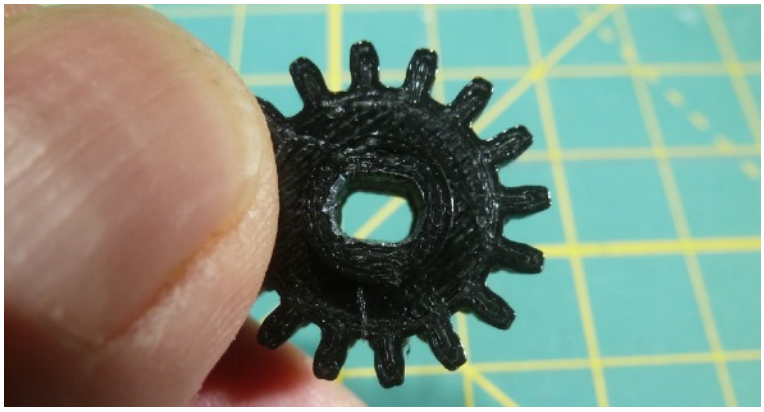
On the other side of the board is the controller module. You'll see a blue LED blink once every second.




Unplug the USB connector and the motor. The motor has a much longer connecting wire than we need. Wrap the wire around itself to arrange for a neater installation. Prepare it as shown in this image.

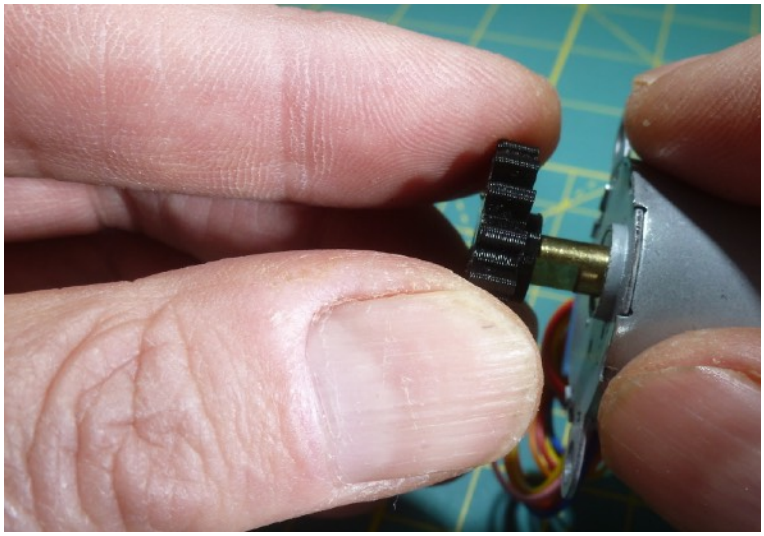


Locate the other gear.  This one doesn't have a key, but instead has a somewhat oval shape that fits the stepper motor.

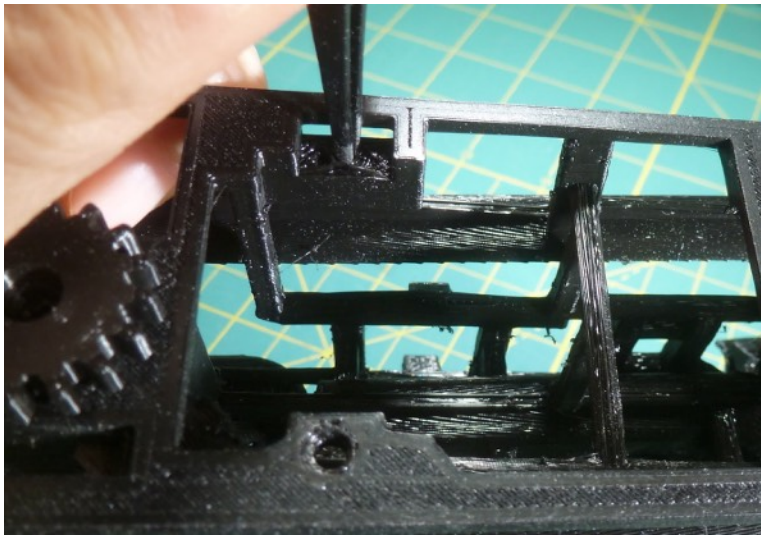


You may want to trim the edges of the mounting hole to make it a bit easier to attach to the stepper motor.

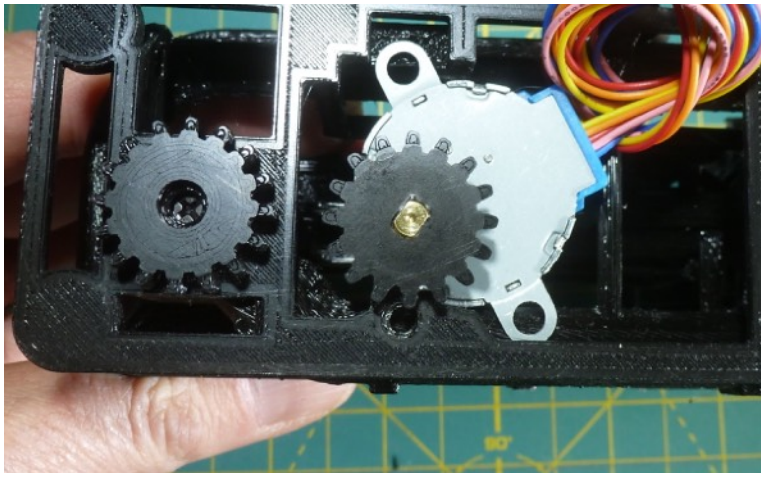
Now, slide it onto the motor with the bushing side towards the motor.  Slide it onto the shaft so that the shaft is flush with the bottom of the gear.



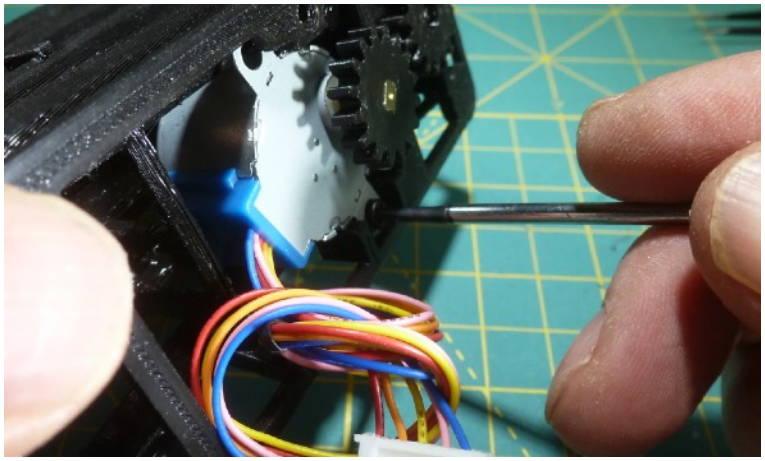
There are two motor mount holes on the bottom of the clock body.  Use tweezers or a small knife to ensure they are clear and ready to receive screws.



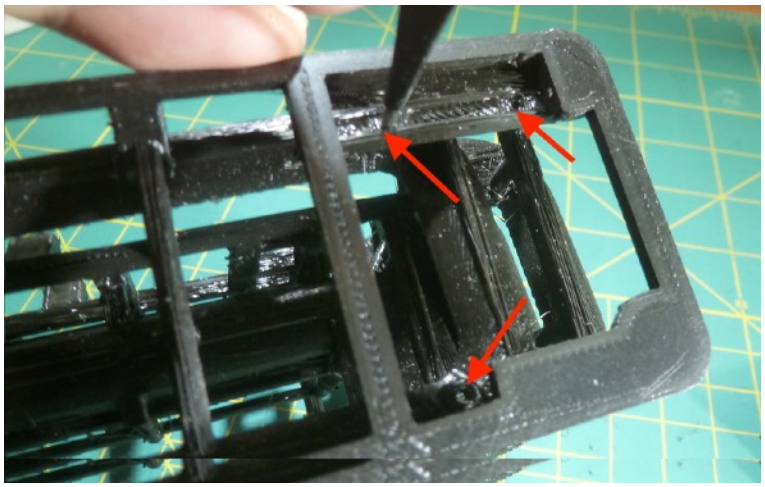
Arrange the motor as shown in this image.  At this point the motor is temporarily ajar so that the two gears do not mesh.  Notice how one of the motor mount ears is aligned with its screw hole in the clock body.



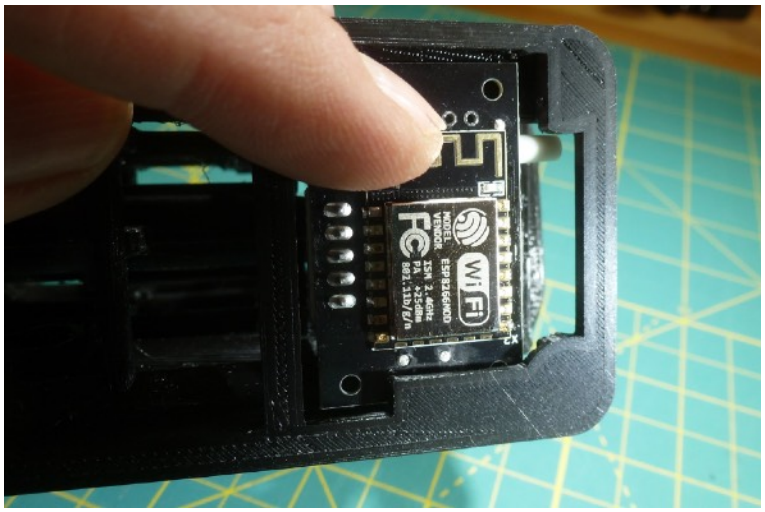
Attach the motor using a short 3mm diameter screw, but just the one screw for now.  Don't tighten it just yet. and ensure the two black gears are not meshing.



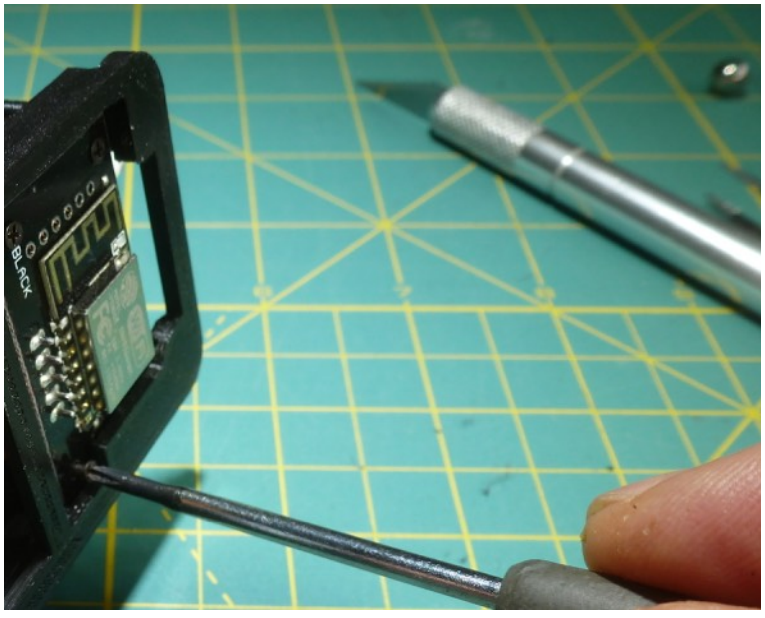
Next we'll install the controller board.  It has three screws, and their corresponding screw holes are shown with red arrows in this image.  As with the other holes, use tweezers or a small knife to ensure they are clear and ready to receive their 1.6mm diameter screws.



Insert the board into the bottom of the clock body in the orientation shown here.  Align it with the screw holes.

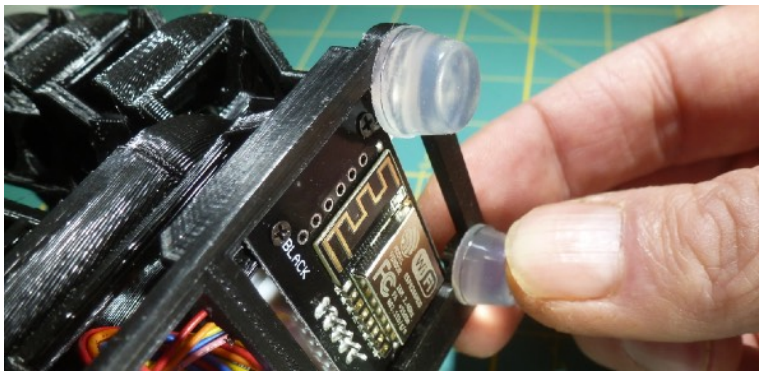


Use three 1.6mm diameter screws to attach the board.  These are the smallest of the screws.



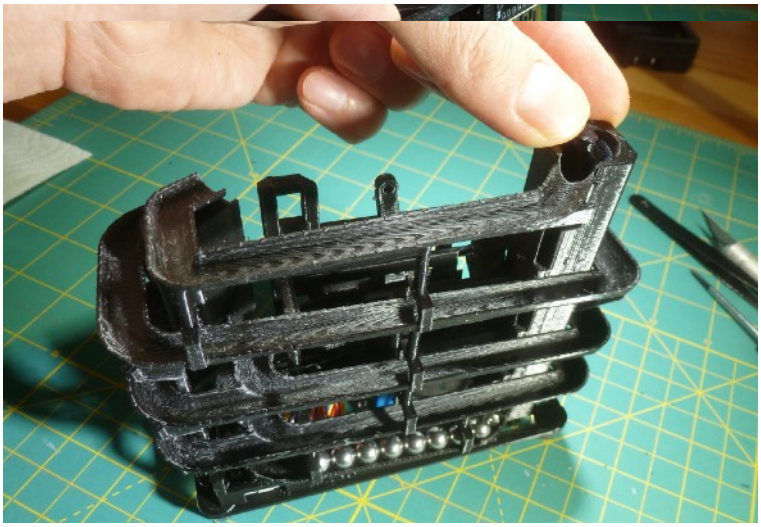
Use tweezers if necessary to reattach the motor connector to the controller board socket. Be sure the motor wires don't interfere with any of the ball paths. (If you have trouble reattaching the motor, you can temporarily detach the controller board).

Attach the four rubber feet to the bottom of the clock body.



At this point the bottom of the clock should look like this image. Notice that the gears are NOT engaged. This is important for the next step.

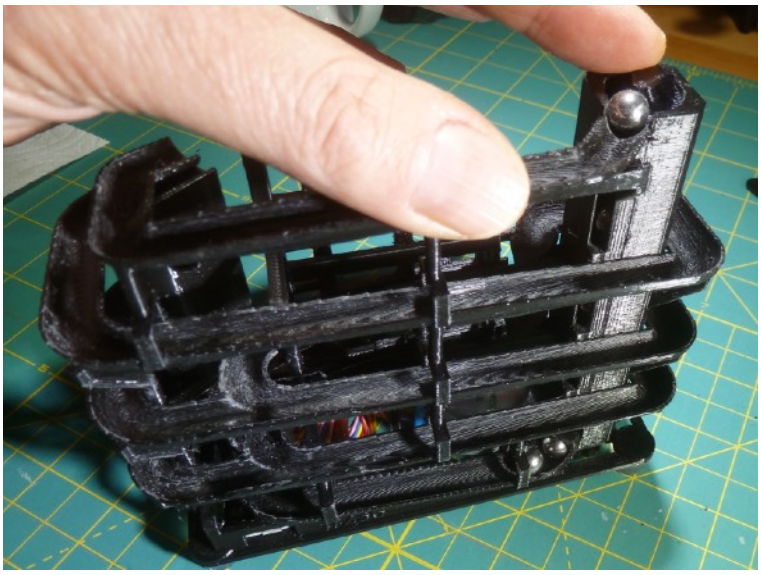
Add about a dozen bearing balls to the bottom of the clock body, as seen in this image, and using your finger rotate the lifting screw. If you have difficulty rotating it from the top you can rotate the attached gear on the bottom, but be sure to keep the clock level.



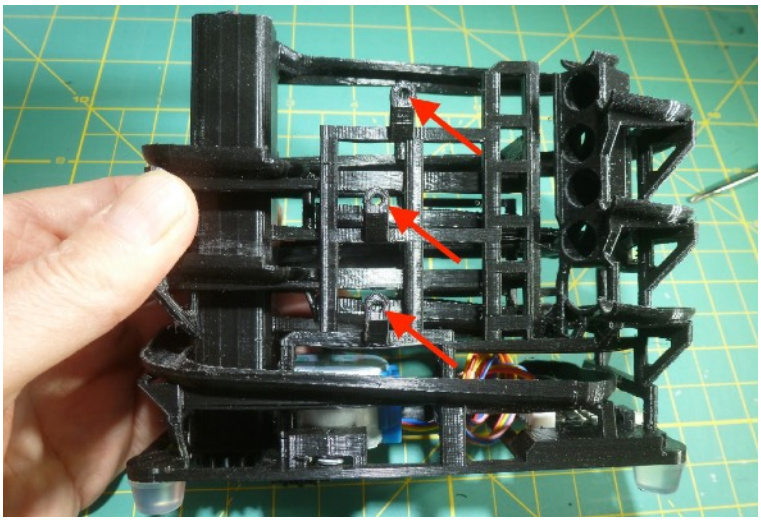
Make sure that the balls reliably enter the bottom of the screw. If they don't, examine the ball path and further clean if if necessary. You might also need to further examine the lifting screw itself.

Also, ensure that the balls exit the top of the cylinder and roll down the top ramp.

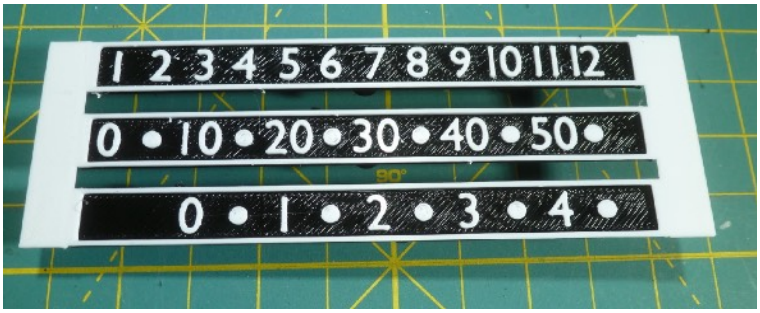
Once you've tested this function, rotate the motor into place so that the gears mesh, and use the remaining 3mm screw to attach the motor's other side. Tighten both motor screws.



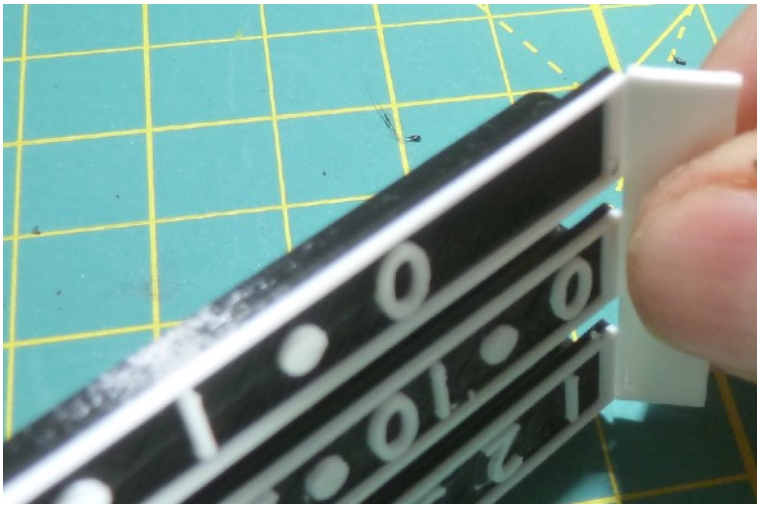
The front of the clock should now look like this image. There are three indicator bar mount holes, shown by red arrows. Each indicator bar is connected using a single screw so that it can tilt back and forth. These holes are where they are mounted.



Locate the indicator bars. In this image they are printed as a single piece and you'll need to break off the plastic wings. (Alternatively your kit may have come with the indicator bars already separated).



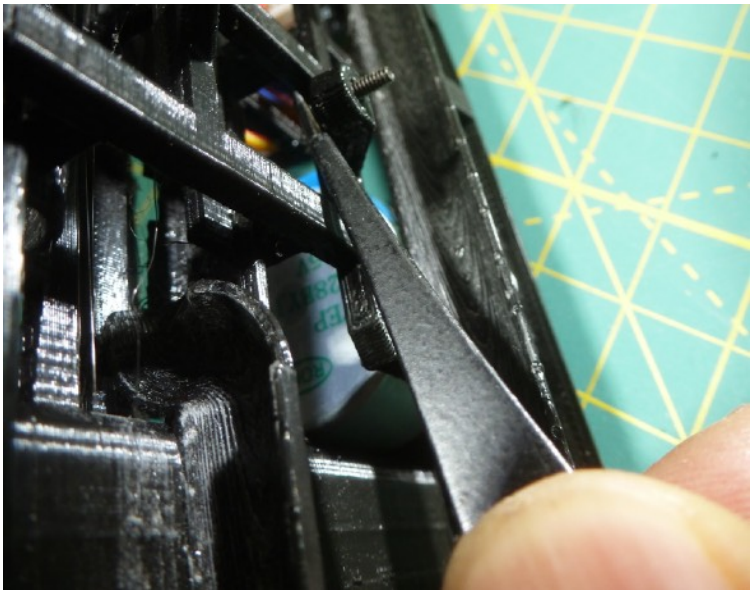

If necessary, snap off the wings. You may need to bend them back and forth a few times. These are only present to help with the 3D printing process, and can be discarded.



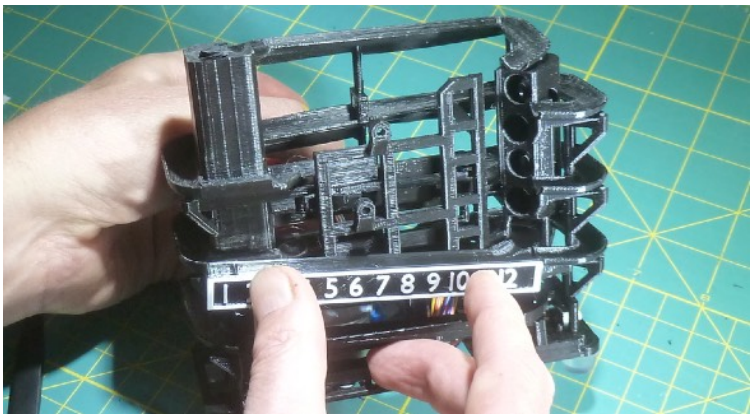
Examine each of the three indicator bars and remove any stray plastic. In this image you can see some white specks near the "10" number. Remove them with tweezers. Also examine the ball path above the numbers to make sure it is smooth.


We'll first install the hour indicator, which goes on the bottom.

Using tweezers, insert a 2mm diameter screw into the back of the bottom mounting hole.



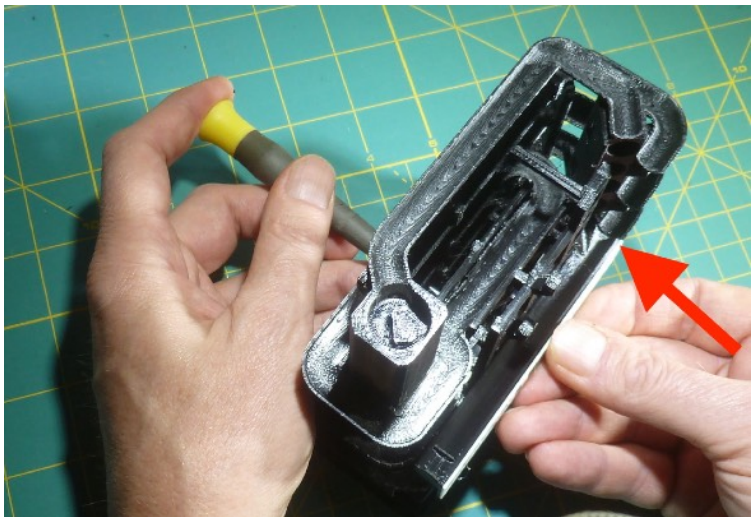
Hold the hour indicator in its ball-dump position, aligned with the screw, while holding the screw in place using a screwdriver. The ball-dump position has the indicator tilting down to the right, and the exit from the indicator is perfectly aligned with the exit ramp on the right.



Here you can see the alignment.

Now, tighten the screw until the indicator is just slightly snug. The indicator won't freely tilt back and forth, so loosen the screw just to the point where it will freely tilt. Test it a few times, then loosen it just a little more, about 1/8th of a turn of the screw.

This adjustment is important. It'll probably be necessary to further fine tune it once the clock is operating.

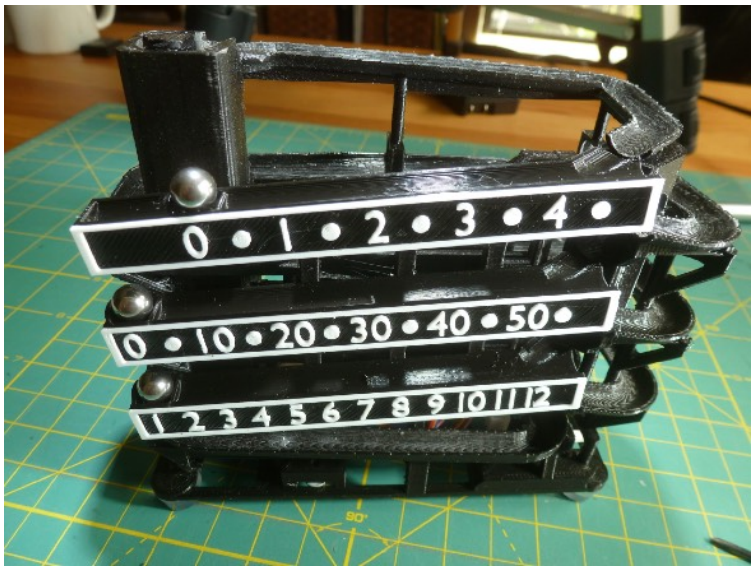


Follow the same procedure to install the 5 minute bar, and finally the 30 second bar. This image shows the 30 second bar on the top being installed.

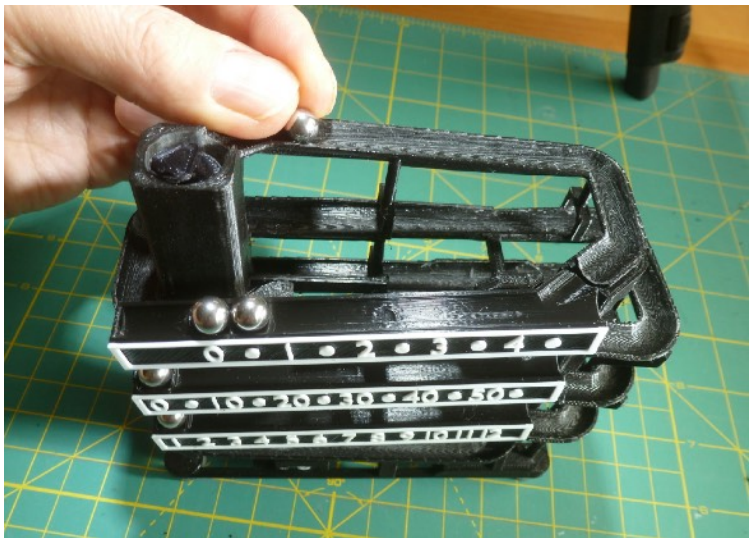
Finally place one ball on each of the indicator bars. There's a small pocket on each bar where a ball is placed, right above the zero symbol (or the 1 symbol on the hour bar). These balls never move.

Congratulations. The clock assembly is now complete!

On to testing…



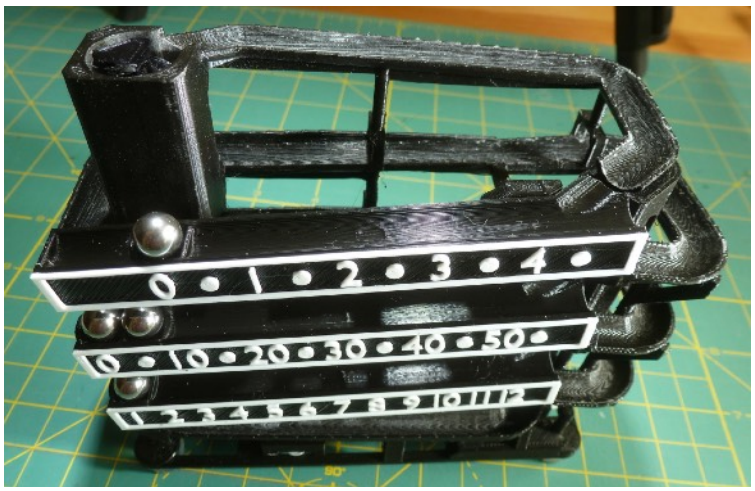

Add one ball to the top path, and make sure it rolls onto the top indicator and is accumulated there.



Continue adding balls until there are ten balls on the top indicator.

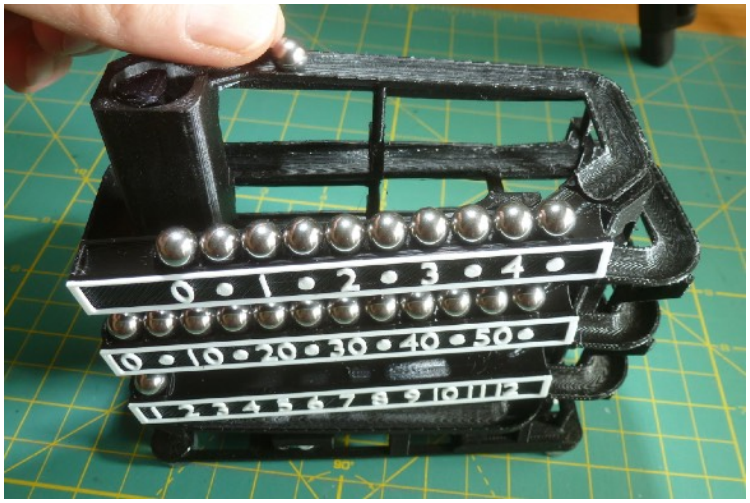

Add one more ball. The top indicator should tip to the right and nine balls should exit out that side. One ball should pass through the time advance passage and accumulate on the middle indicator. The ball above the zero shouldn't move.

In this image you can see there are now two balls on the middle indicator.



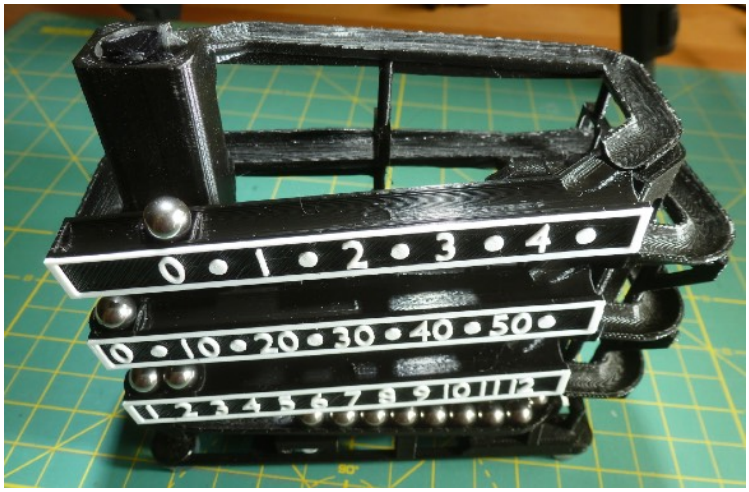

Repeat the process a few times to test for reliability. Then, fill up the middle indicator so there are 12 balls on it, and ten on the top indicator. Add a single ball. As before, one ball should pass through the time advance passage to the middle indicator, but in this case the middle indicator should overflow and pass one ball down to the bottom indicator.

If it's not working reliably you need to loosen the indicator mount screws slightly.



The result of the “double carry” is that there are now just four balls present in the indicators, and all the remaining balls have exited back to the bottom of the clock to be recycled.

You can continue the testing further to ensure the clock advances from 12:59:30 to 1:00:00, at which point your clock is ready!




# Troubleshooting

You’ll almost certainly need to spend some time tuning the clock, and it may take a few days of operation before it has settled into its reliable operation, but before referring to the following section make sure the clock is operating on a level surface, there’s no dust on any of the tracks, and the balls are clean.

Some of the problems you may encounter, and what to do to correct them…

## Problem:

Balls fall off the track.

## Fix:

This is almost always due to ball track imperfections that cause them to roll in an unstable fashion and hop off the track.  Look for any noticeable bumps in the plastic and sand or carefully cut them smooth.  If you’re not sure where the balls are falling off, place the clock on a few layers of absorbent paper so they won’t roll far.  That should help identify the location of the problem.

## Problem:

The indicator fills up but doesn’t tip when it’s supposed to, or it tips but not far enough to release the balls.

## Fix:

The screw holding the indicator is too tight.  Loosen it.

## Problem:

The clock isn't keeping time.

## Fix:

Either the balls are not reliably entering the bottom of the lifting screw, or you don't have enough balls in the model. Make sure the ball path on the back of the clock, right before the lifting cylinder entry, is smooth, and the entry itself is clear, and ensure there are 48 balls at various locations in the clock.

## Problem:

The clock gains or loses a few seconds every month.

## Fix:

The controller board includes an ESP module which as a remarkably precise real-time clock, but it isn't perfect. However, the module also includes the ability to connect with NTP, and that would allow it to keep perfect time. If you're interested and ambitious enough, contact us and we'll explain on how to reprogram the module to do just about anything you might want.

## Problem:

The balls on the front of the model, waiting for the lift screw, sometimes get stuck.

## Fix:

That's not a problem. So long as the balls on the back don't get stuck, there will always be another nine or more balls coming that will knock them down the track.

## Problem:

Something else isn't right.

## Fix:

Contact us! email: info@gualalagadget.com

Website: gualalagadget.com

Twitter: @gualalagadget