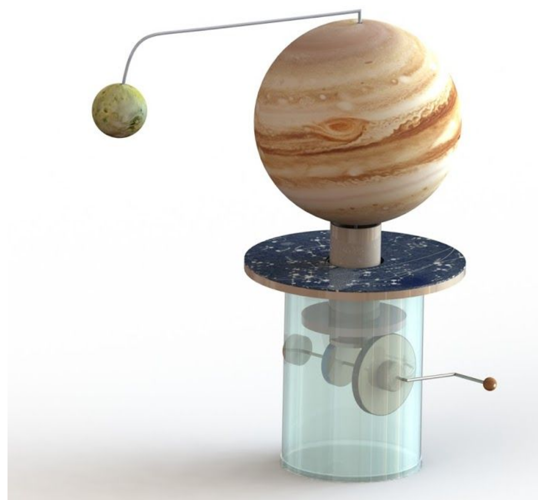
Planet and Moon Automata V3

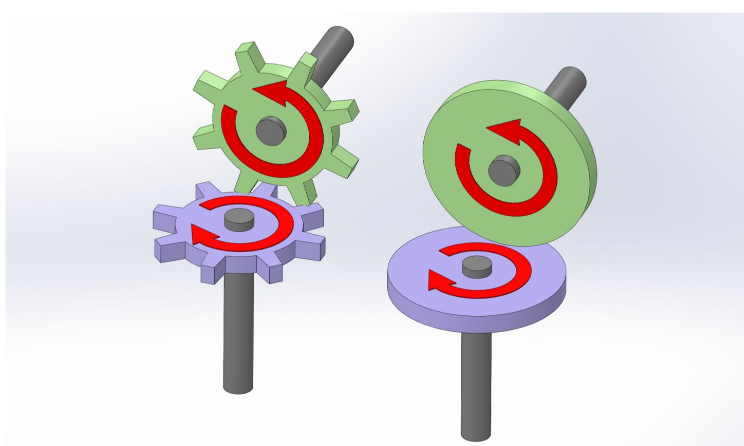
Designed by Justin Miles 2016



What is an automata? An automata is a fancy name for mechanical sculpture. It is also known as kinetic or *moving* art. These sculptures use simple mechanical movement to make a snapshot of a story or scene say from a movie. They use simple machines such as levers (which could be hinges), gears of various types (like you see in car engines and clocks and wind-up toys), or simple contact friction to make two objects react between each other. They are powered by springs, weights of some kind, sometimes even air, but for our project, we're going to use the mechanical energy from our body by using our arm to turn what is called a crank.

In this project we're going to use a couple basic mechanical principles and use them to make an simple movement. We're going to try to make a "Planet and a Moon" that will spin in opposite directions and use only simple supplies you can collect from your recycling container at home. You can use this same basic concept to create a different scene while utilizing the same components and movements. I chose to make mine of Jupiter because, well, Jupiter is pretty awesome. But you can choose whatever planet or scene you want. It doesn't even have to be even be a Planet. Have some fun with it.

We're going to use two disks that will make contact at right angles, and will move together using friction. The principle can be seen below. It's similar to using two interlocking gears, but we'll make it simpler by using friction instead.

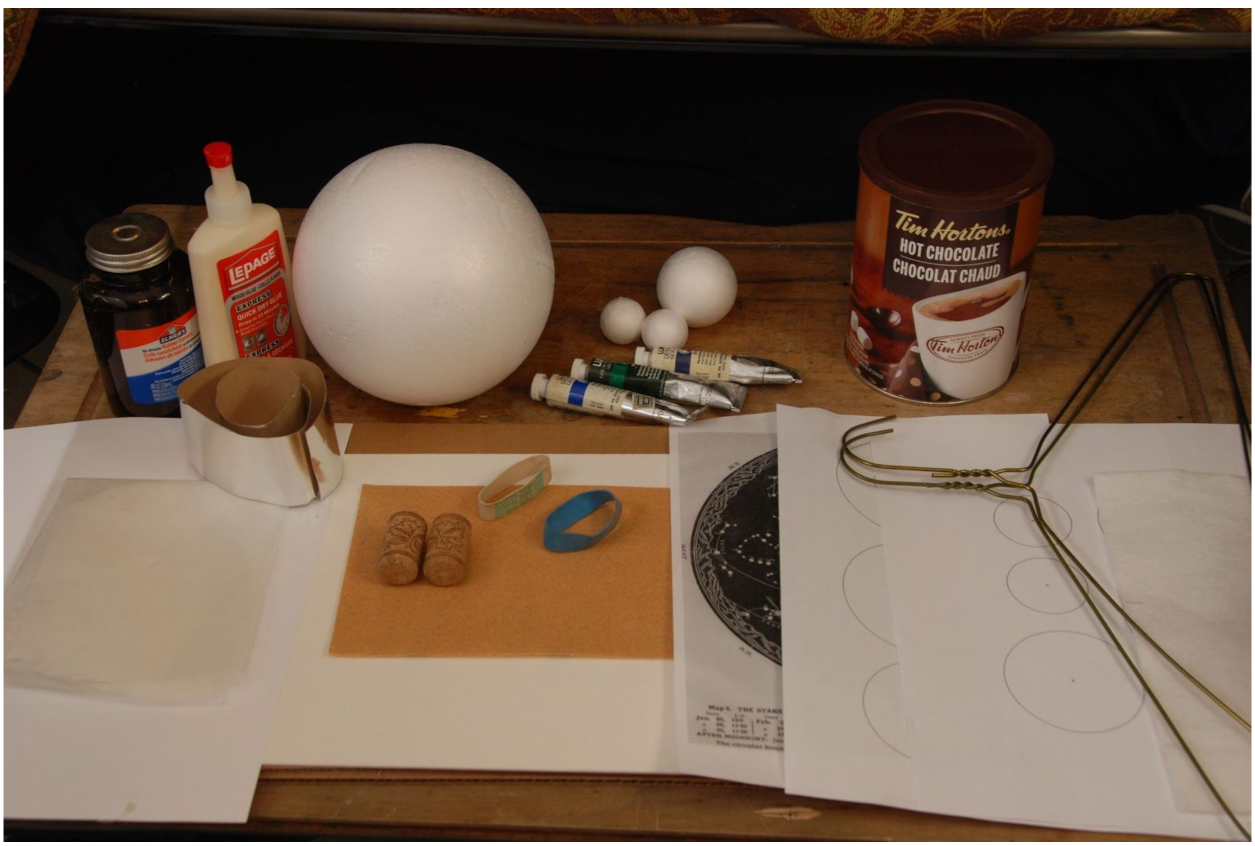


In order to be successful in making a working automata, you have to be very precise and careful when fitting parts together. It is very normal to test parts and retry a few times to get the mechanics to work, but when you do make it work, it is well worth the effort. That is part of the fun of making automata, it's almost like a puzzle. Eventually you will solve it. You may have some difficulties, but don't give up.

Safety first. Be very careful when using sharp tools. If you are using a box cutter, ***always* cut away from yourself.** If possible try to use sharp scissors instead.
NOTE: If the cardboard is too hard to cut, try using thinner cardboard that you can cut with scissors, say cereal box cardboard, and then glue multiple layers together to make the disks the same thickness as normal cardboard. Better to be safe than hurt yourself.

Step 1 - Supplies.

1) Old hot chocolate can - usually 4 inches wide
2) Cardboard - regular box cardboard and/or an old large cereal boxes
3) Coat hanger wire
4) A stiff cardboard tube, preferable from a tin foil or plastic wrap box - has to be narrow and thick walled. (Note: a toilet paper tube <u>will not</u> work)
5) All purpose white glue
6) Two styrofoam balls, large and small (You can buy these cheap at a dollar store)
7) One sheet each of 60 and 120 grit sandpaper
8) Small, 1cm wide rubber bands (like the ones around broccoli in the supermarket)
9) A few corks, new (or used saved ones from your folks)
10) Rubber cement
11) Printouts of all of the disk patterns provided with this manual (print them at 100 % scale)



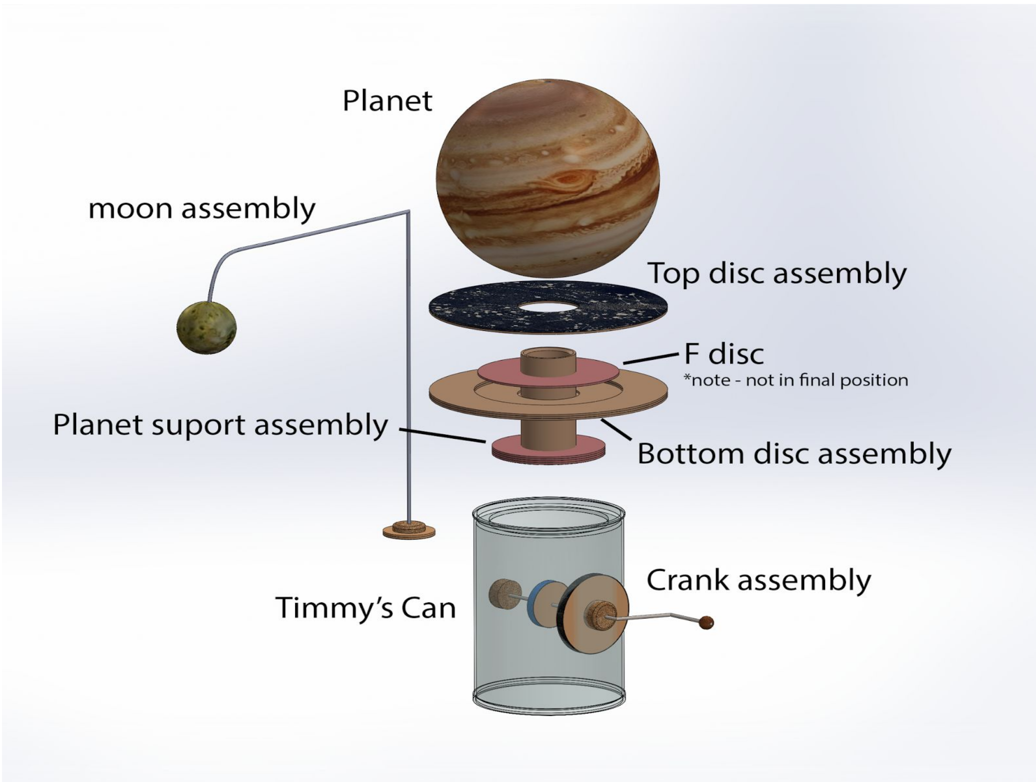
Step 2 - Tools.

1. Strong sharp scissors
2. A Hot glue gun
3. Compass
4. 2 large bulldog clips
5. Ruler and square
6. Cutting mat or an old work surface you can cut on
7. Wire cutting pliers
8. Blunt or Needlenose pliers, two pairs.
9. Sharpies, and a pencil
10. Xacto blades/ box cutters
11. Very pointy nail, or use compass with a sharp tip.

Step 3 - Organizing the parts, or ‘assemblies’.

We are going to use a method used in factories to make this automata. Usually machines are made from a group of what are called assemblies. These assemblies in turn are made from simpler groups of parts called subassemblies. Factories use the system of organizing parts of machines to make the manufacturing of our cars, iphones tvs and everything else you use day to day run more efficiently. This approach usually reduces the amount of mistakes made in making the devices. In our case it will also help us understand how the Planet Automata will work.

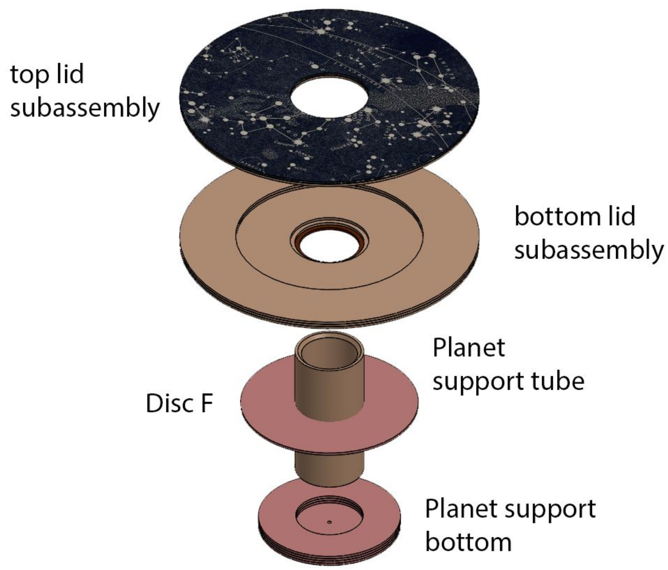
Below is a breakdown of the basic parts needed to make the Planet Automata.



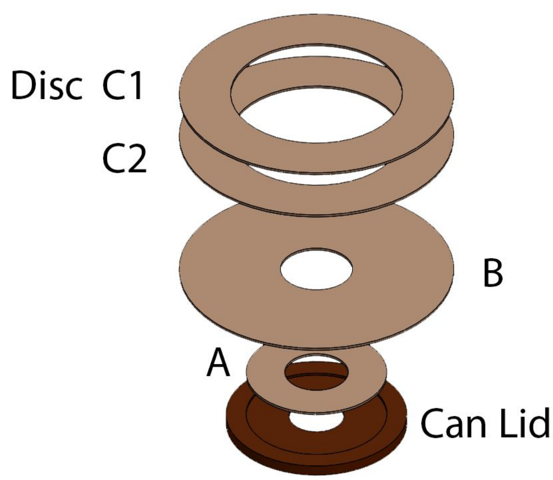
We’re going to make all these parts separately and then put them all together in a precise pattern to make it all work properly. Do not skip a step or race ahead - it might not work if you do so.

Top and Bottom Disk Assembles

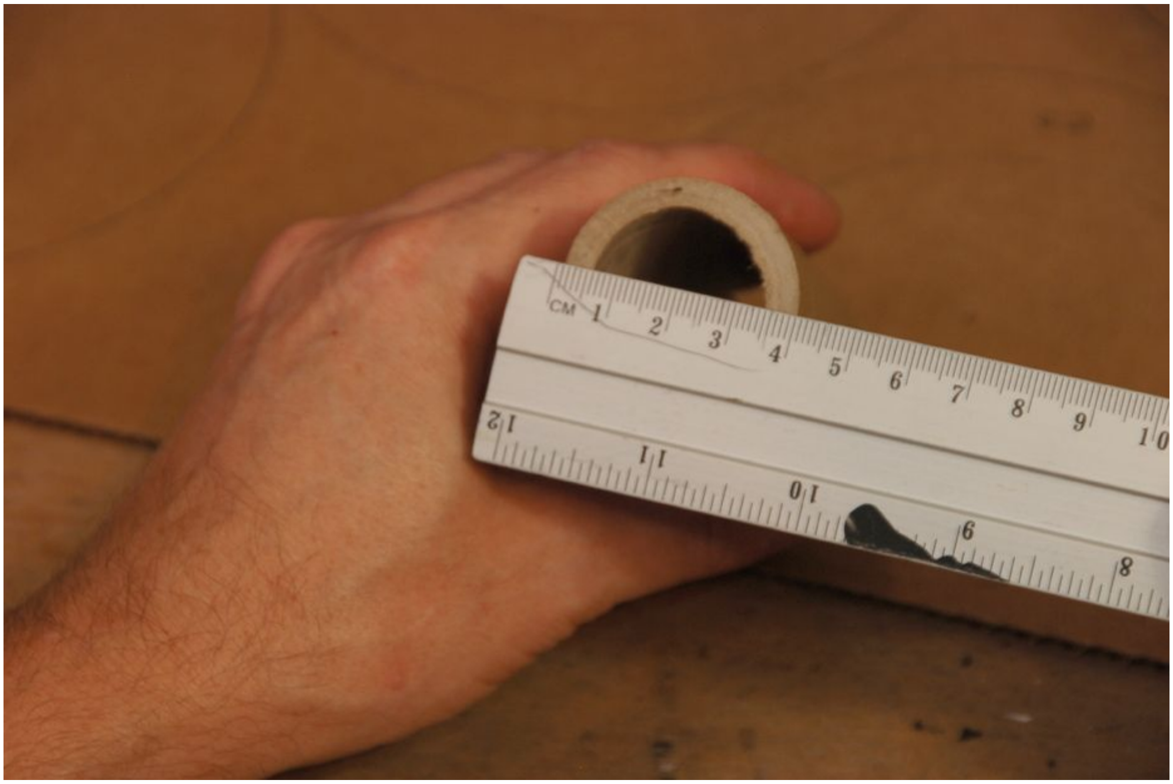
Take all of the printouts of the disks and glues them to nice flat cardboard. Once they are completely dry carefully cut out the smaller holes with a boxcutter (remember always cut away from yourself) . Then cut the outside with sharp scissors. Be as precise as you can. Any disks with a grey smaller hole that says ‘adjust size to match tube’ - set these aside for a moment. Below is an overview of those parts:



1) Bottom lid assembly is made of these parts:



Take the cardboard tube from your supplies and carefully measure it.



Take disk A and adjust the size of the hole so that it about 2mm larger than the width of the tube.

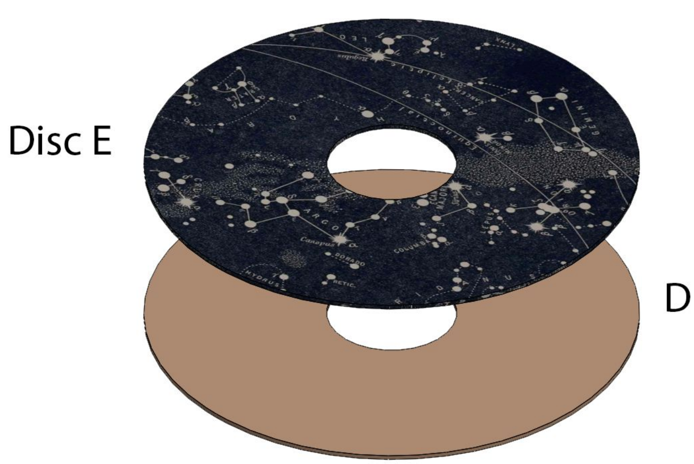
Now, take disc A and center it on the top of the lid. Take a permanent marker and trace the inner circle of disc A onto the lid. While tracing, make sure to hold Disc A in place. Now cut out the hole.

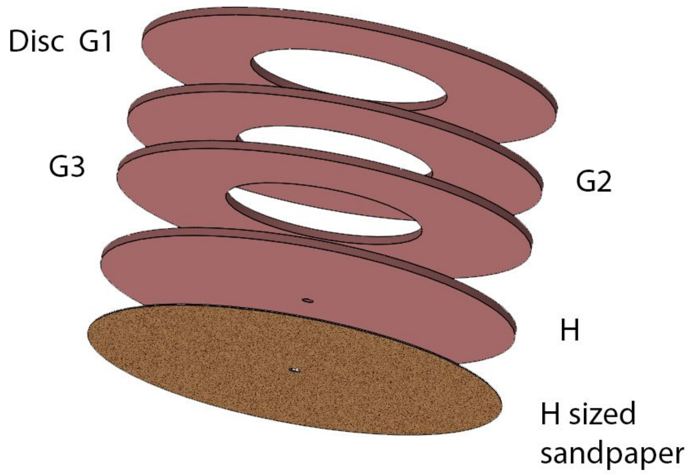
Now glue disk B, C1 and C2 together. When dry, glue the B+C1+C2 onto the top of disk A, being careful to align the openings.

Take your square and test to see that the tube is exactly 90 degrees to the disc assembly. Check in a few places around the circumference. When you feel it's exact, glue into place with hot glue. This is your Planet Support assembly.

2) Next make the Top Lid assembly:
Glue Disc E and D together. Set both top and bottom assemblies aside.

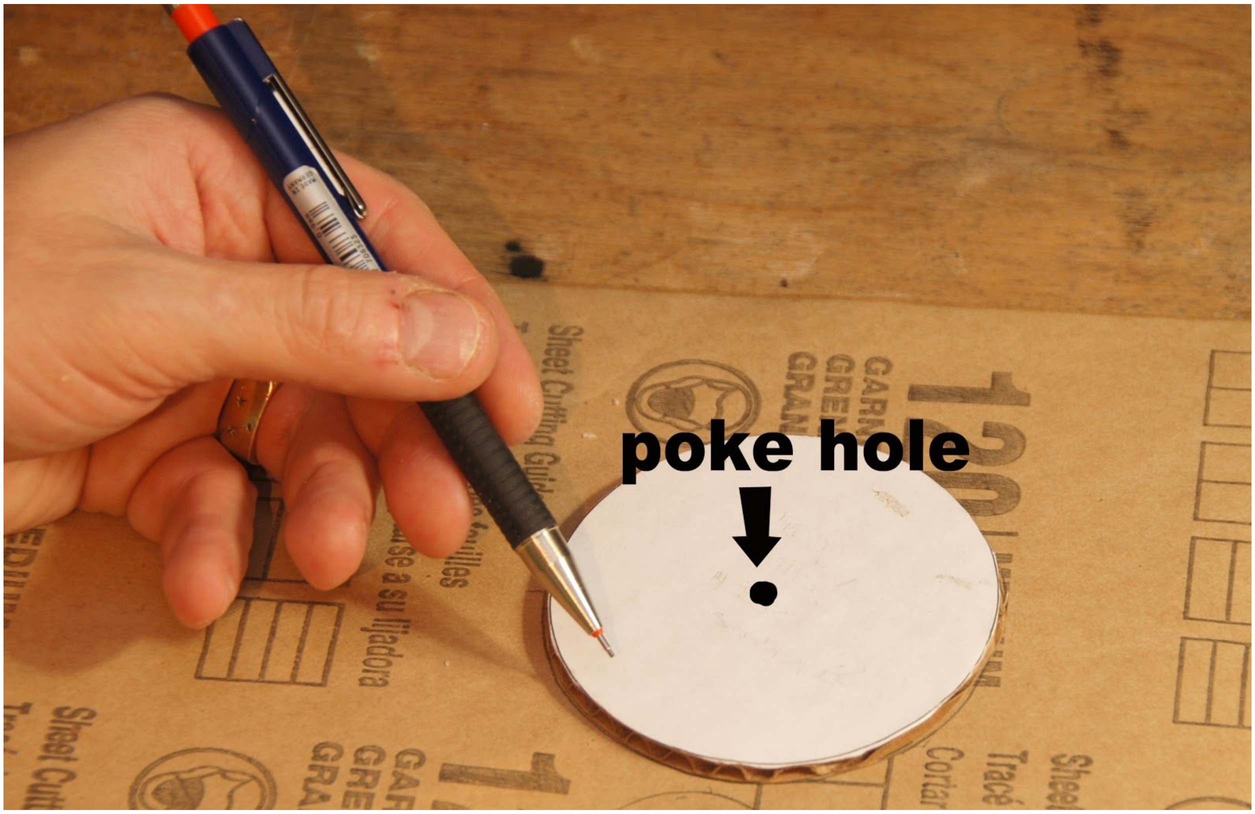


3) Make the Planet support tube assembly:

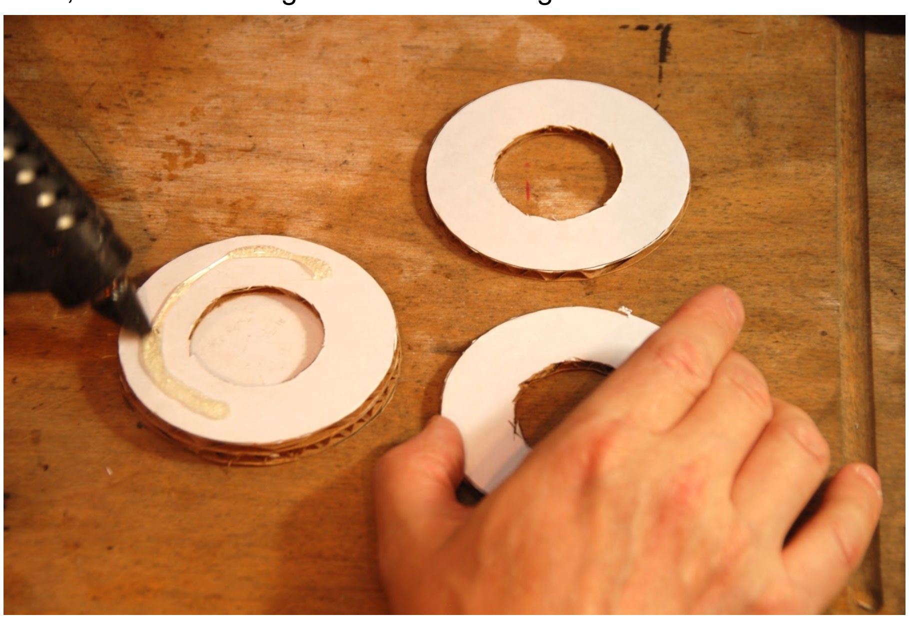


Take the measurement of the tube and transfer that to the opening in discs G1 to G3. Make sure that these discs fit tightly over the tube. When they do, finish the assembly by gluing G1,G2 and G3 together.

Meanwhile take disk H and trace it’s circle onto a sheet of sandpaper. Cut this sandpaper out and glue to the bottom of disc H.

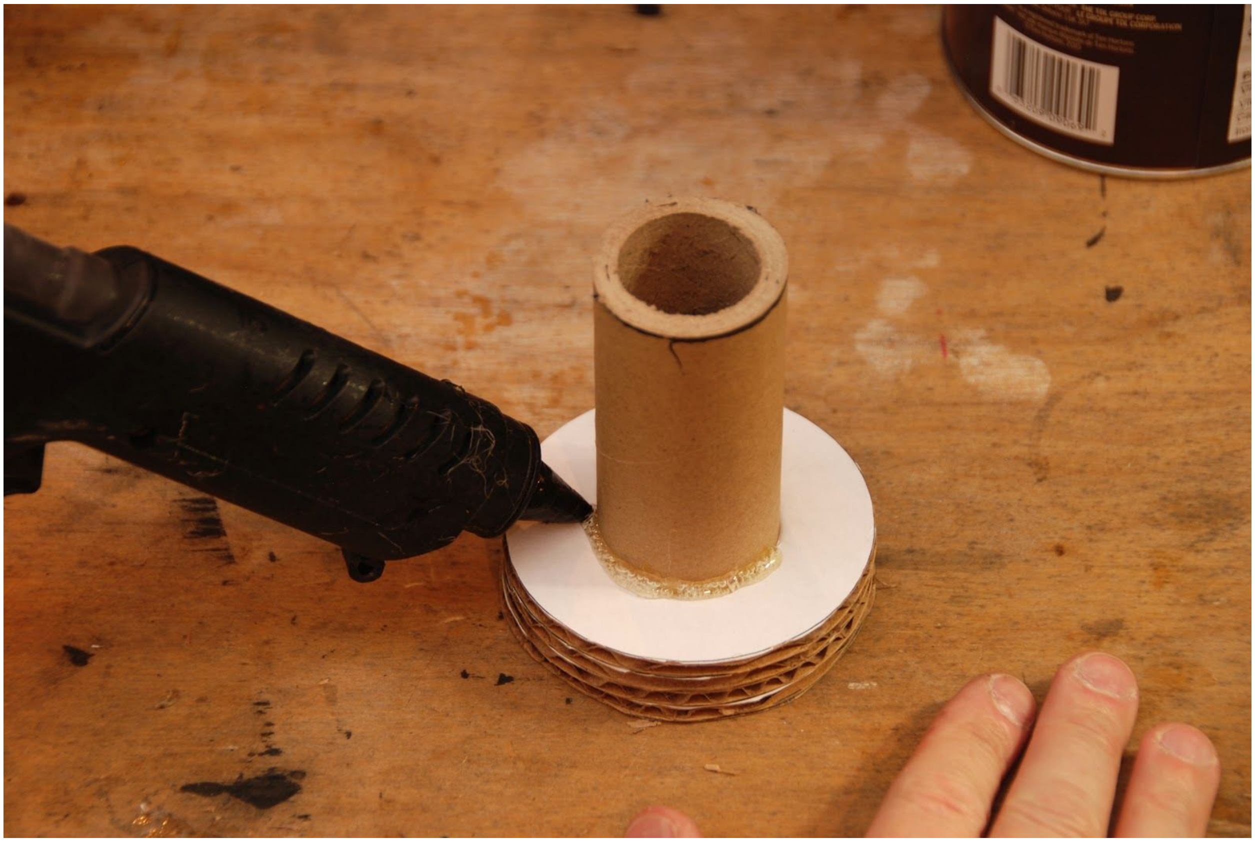


Now, glue the sandpaper disc to the bottom of the three G discs. Now, take your pointy compass or nail and poke the a hole through the exact center. Make it wide enough for the coathanger wire to fit loosely through. When you are done, glue the sandpaper onto on of the G discs, then stack and glue all 3 G discs together to make the Planet Support Tube Assembly.

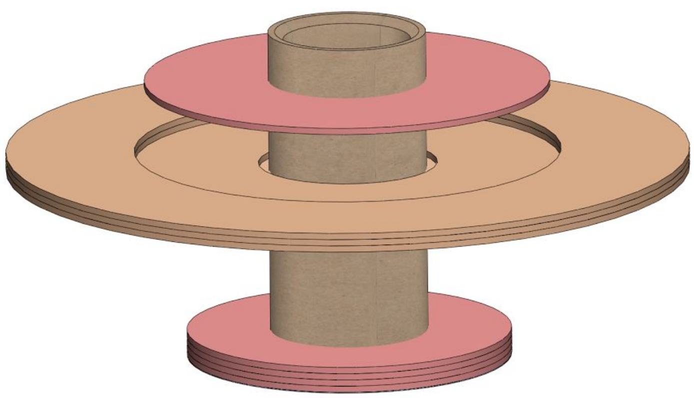


Now,take the tube and cut it to roughly 10 cms long. Force it into the thick hole in the Planet support disk assembly. It’s a good idea to use a mitre box to make sure your cut is straight, but it’s not 100% necessary.

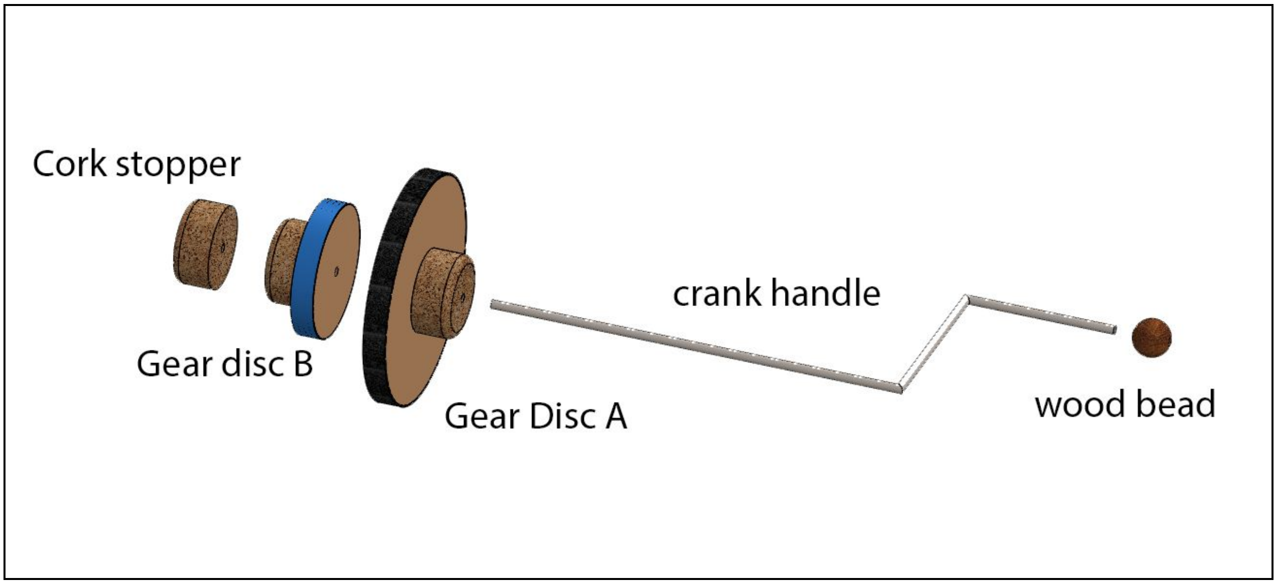
If you cut your tube without a mitre box, grab your square and test to see that the tube is exactly 90 degrees to the disc assembly. Do this by lining up the side of the square with the bottom of the tube and Check in a few places around the circumference. When you feel it’s exact, glue into place with hot glue. This is your Planet Support assembly.



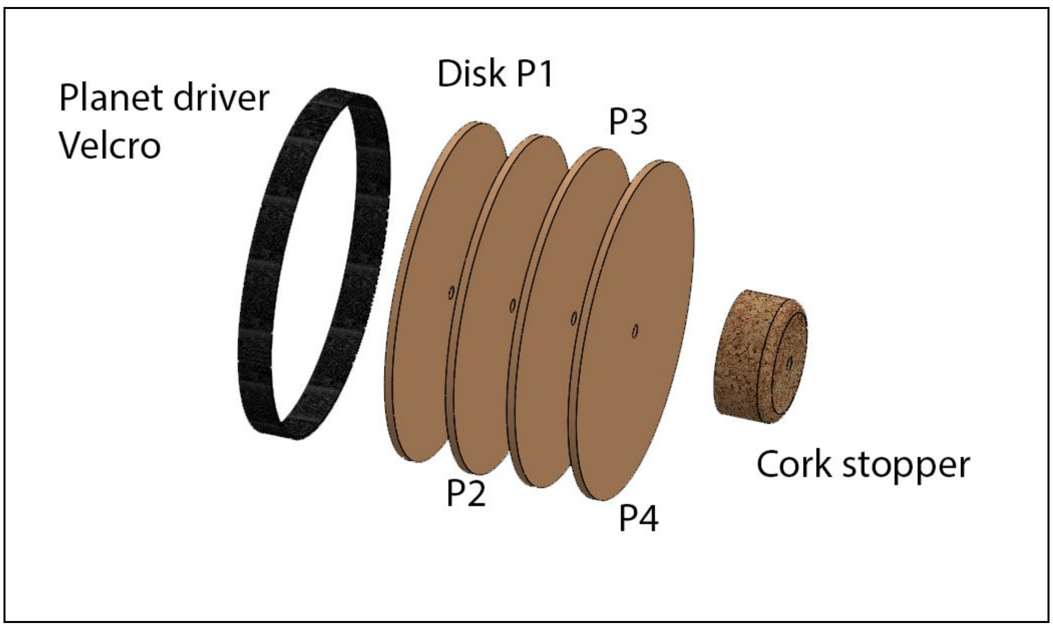
Now take the Bottom Lid assembly and slip it over the tube of the Planet support. Slip disc F over the tube **but do not glue it yet**; it should be a tight fit. Now set this aside.



4) Make the Planet Crank Assemblies



Glue together the parts for Gear disk A - here is the order.

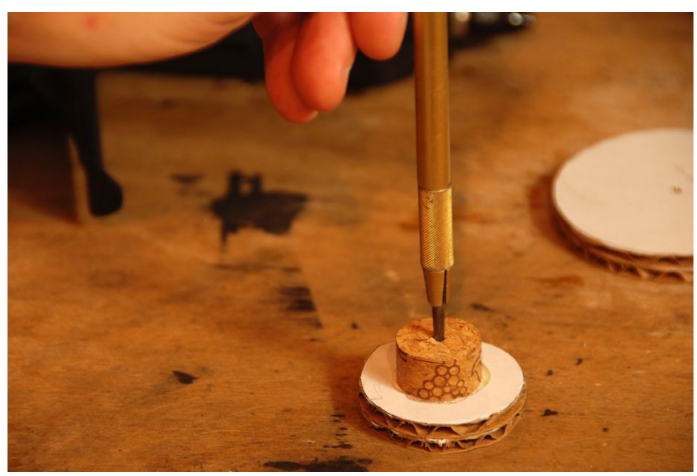


The finished disc should be about 1cm thick. Us the ‘extra’ disks to get it close to that thickness if your cardboard is thin.

Using a couple wine bottle corks, cut **three** 1cm long pieces - The safest way is by using a mitre box and a small clamp-or get help with this part.

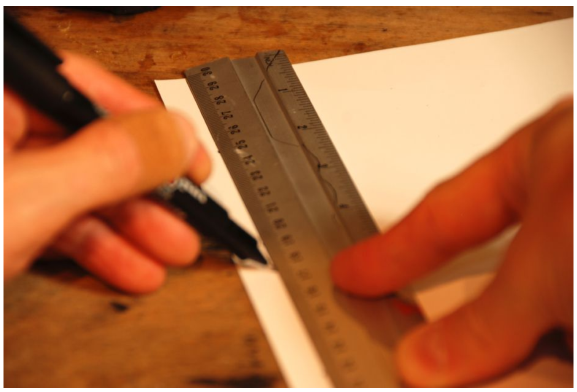
Place cork on your work surface and using compass/nail to poke through the center of the cork. Gently and carefully push the compass.nail/pokey thing all the way through your cork until it comes out the other side.

Take you Gear disc A and hot glue on your cork. Use the pointy thing to find the center to place on the cardboard disc. Remove the nail after it has cooled

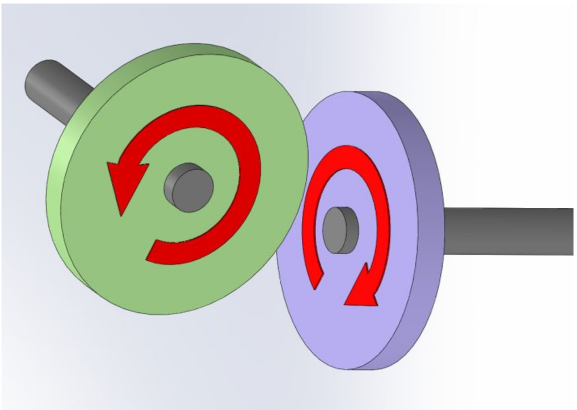


Now with some thin cardstock, like the thickness of greeting cards, cut a 1cm wide strip

Stick this around the circumference of the disc with white glue, but don’t let it overlap- **you don’t want any bumps at all**. Ideally the outside of the disc should be exactly the same distance from the center all the way around. When this disc makes contact at right angles with the Planet Driver disc (made earlier in Step 3) it should always be in contact.

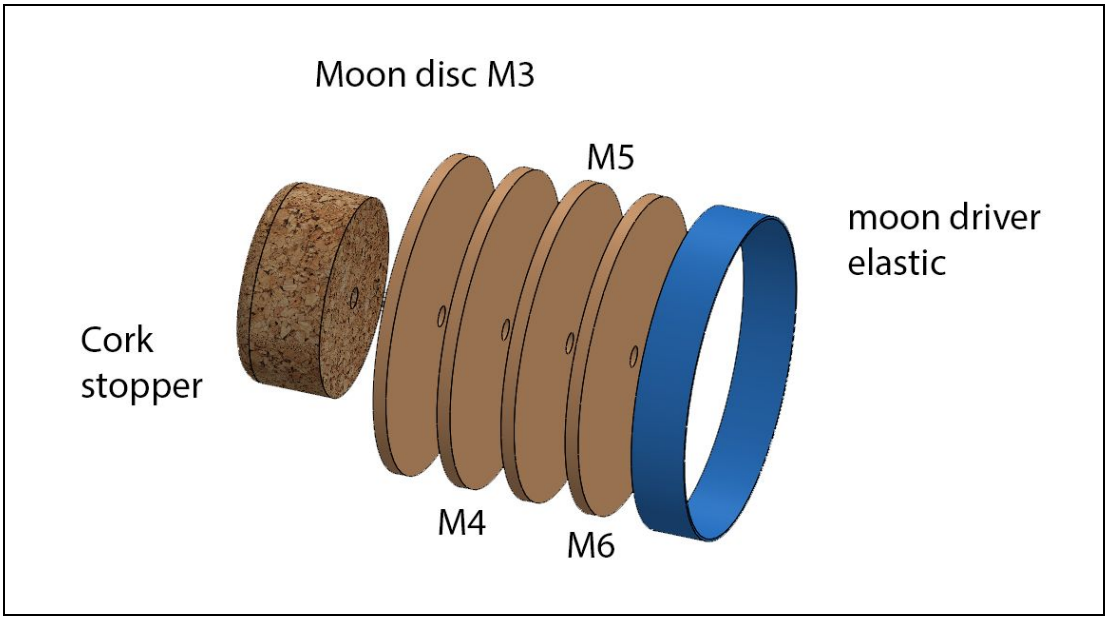


Refer to the earlier diagram - imagine that if either of the disks were bumpy, they may not always touch each other and make each other turn.



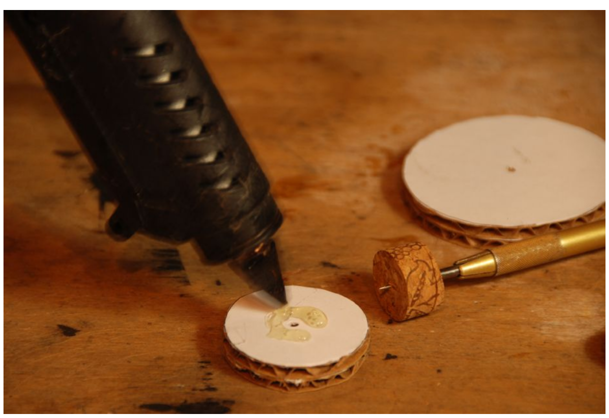
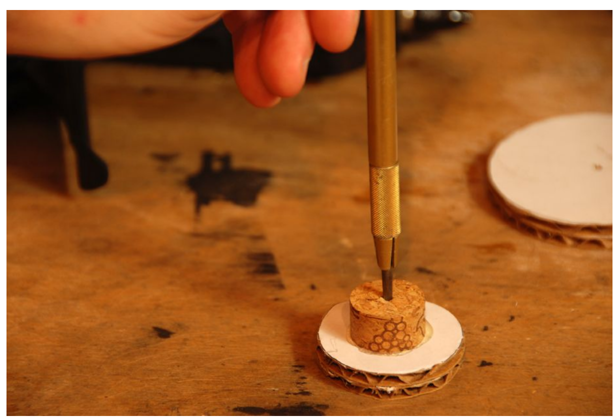
Cut a 1cm wide x 22 cm long strip of velcro (sticky back velcro preferable) glue along the edge of your larger corked disc. Use white glue (not hot glue - the hot glue will make it bumpy.) Make sure your velcro doesn't overlap and cut off the excess.
Spend a good amount of time making sure this part is as good as you can make it, it will make your planet turn better in the finished piece if you do.

Glue together the parts for Gear disk B - here is the order.



Again, the finished disc should be about 1cm thick. Us the ‘extra’ disks to get it close to that thickness if your cardboard is thin.

Follow the same step used for Gear disc A to align and stick the cork stopper to Gear disk B


Take the glued Gear disc B and wrap a small blue elastic band around it. Set it aside.

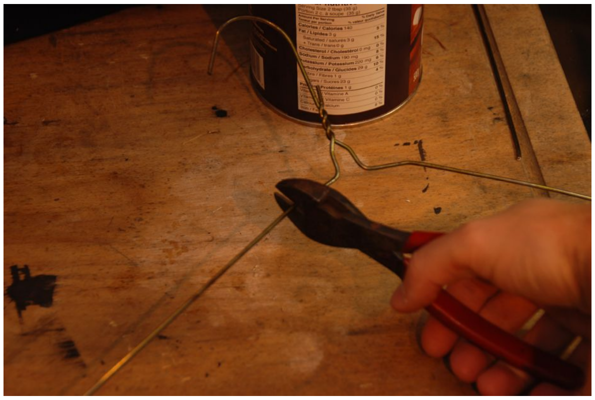
Before we cut and bend the coat hanger wire into a crank handle, we need to prepare the hot-chocolate can. We need to make a couple of holes that are perfectly straight through the can, about halfway from the bottom.

Measure the height of your can. Find halfway point and make a mark, then draw a line from the center to the bottom of the can.

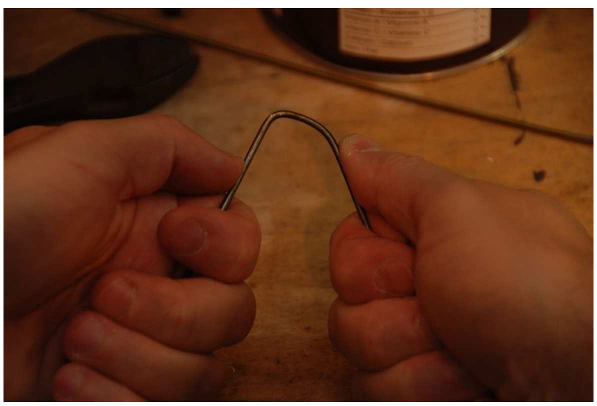
Transfer the line to the bottom (make sure its exactly in half) then up the other side of the can. Measure to double check the height of the line from the halfway point of the height to the bottom is exactly the same on both sides.
It's a good idea to take a ruler and measure a few times - be as exact as you can.

Carefully poke a hole on both sides of the can at the halfway points you've marked.

Next, let's make the crank from the coat hanger wire.
Using your wire cutters cut the coat hanger into two equal parts, discarding the twisty top part.

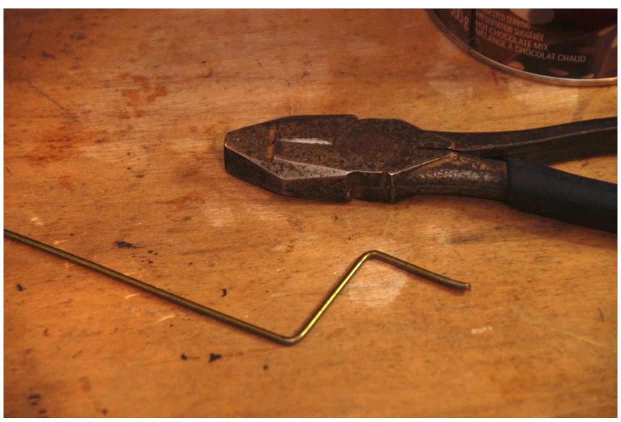
 

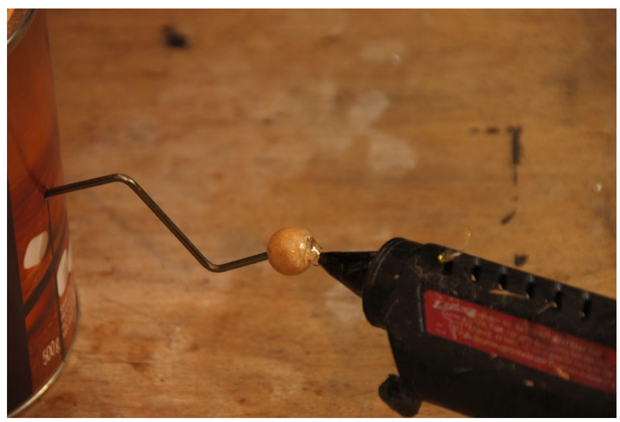
With one of the two bits of wire, take your pliers, or if you're strong, your hands, and try to bend the corner so it is closer to a 90 degree angle.



Push the wire you just cut through the can. One end should be poking out only about a centimetre, the other should be longer.

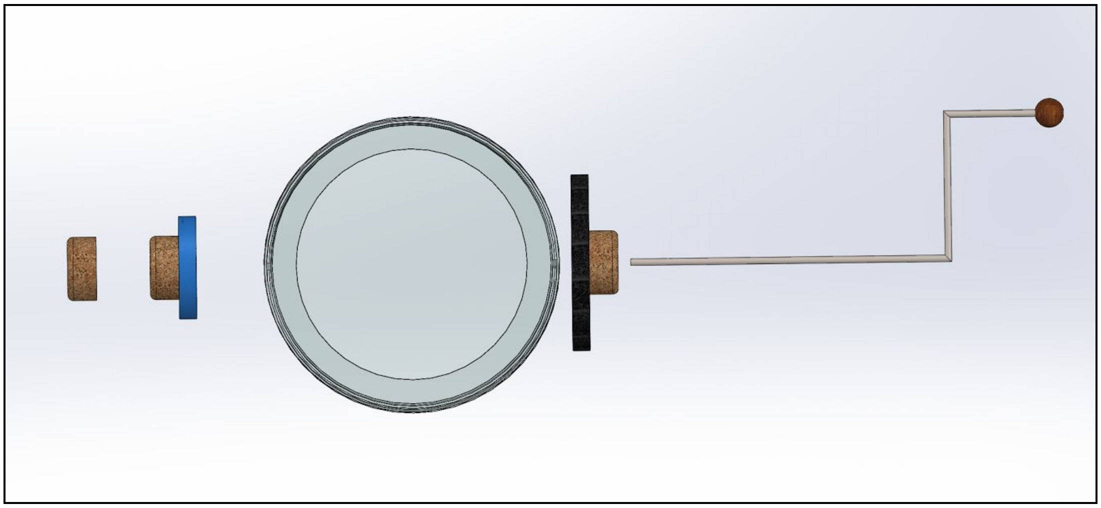
On the long side, mark the wire on the place where the wire is exiting the can. Now take out the wire and bend the wire 90 degree at the mark-this will be your handle. Now, at the halfway point of your handle, bend the wire again to make a crank for your handle.



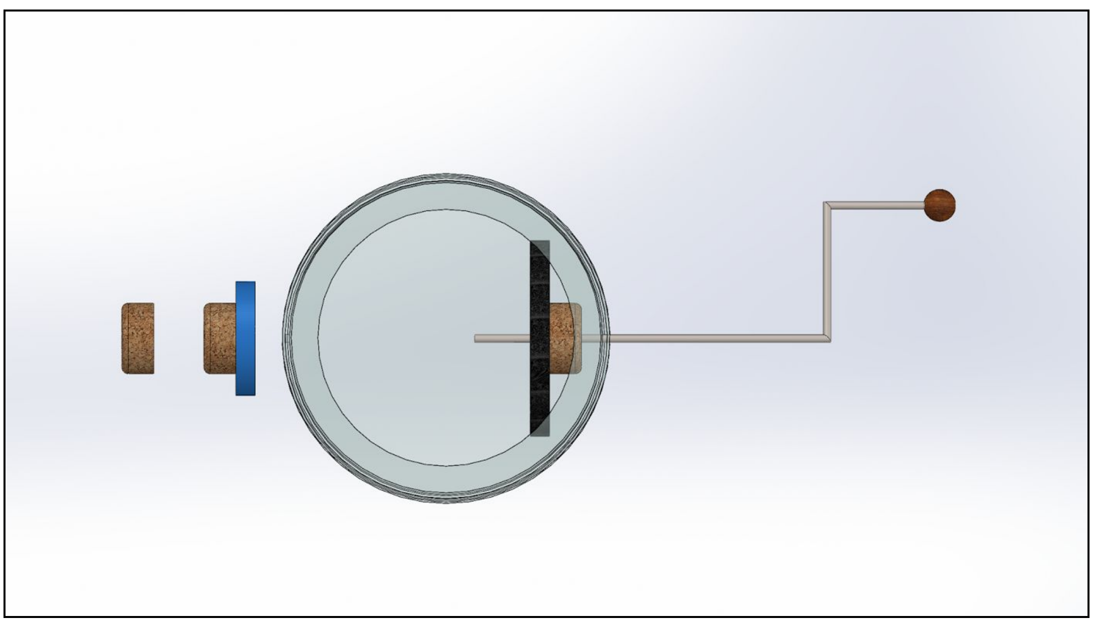


5) Assemble the planet crank into the hot chocolate can.

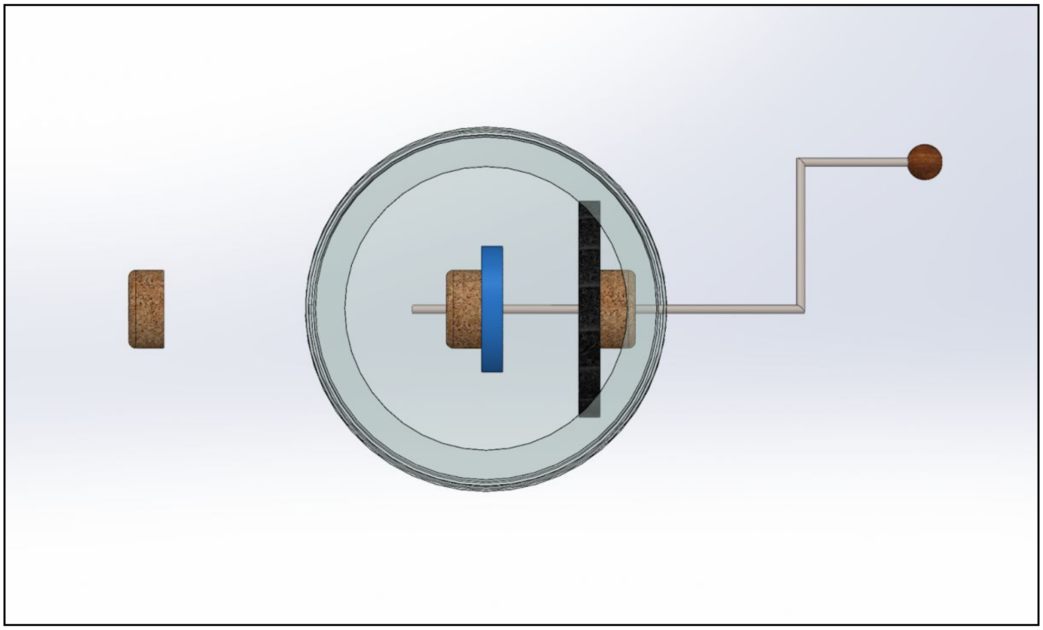
First line up all your parts, or ‘subassemblies’



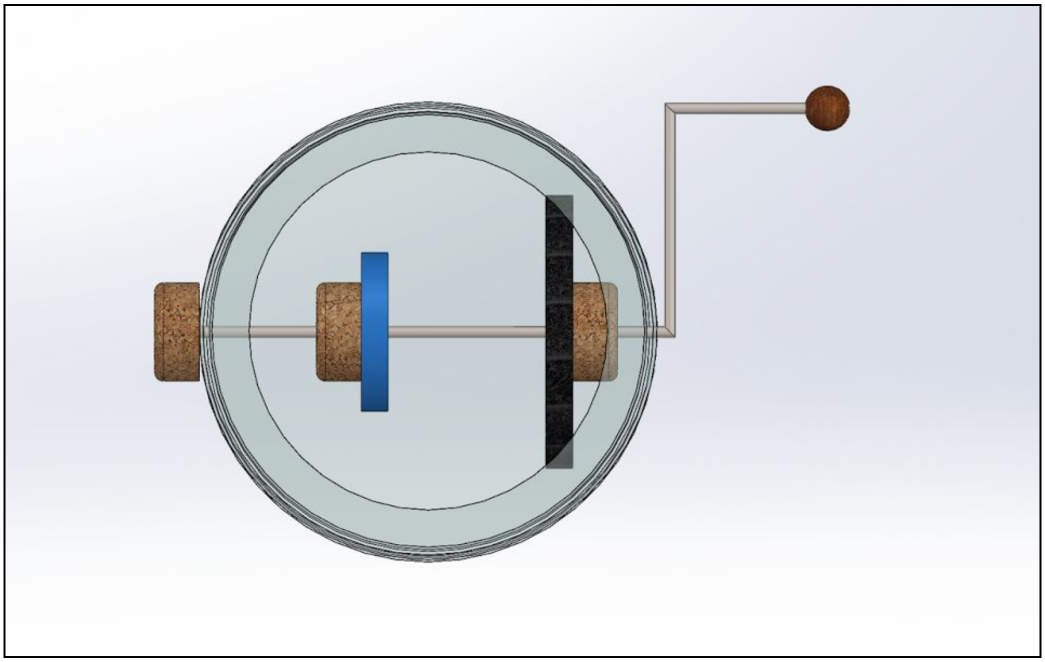
Push the long end of your wire halfway through the inside of your can. Now, take the large disc (with the velcro and cork attached) and place it on the wire inside the can. Very carefully force the wheel onto the wire about halfway.



Now add the smaller disc with the elastic on. The cork on both wheels must be facing out outside of the can.



Very carefully slide your discs along your wire. Push your wire through other side of the can. Give your handle a crank to check if your discs are touching the sides of the can. If they are, make them over so they don’t rub the edges.

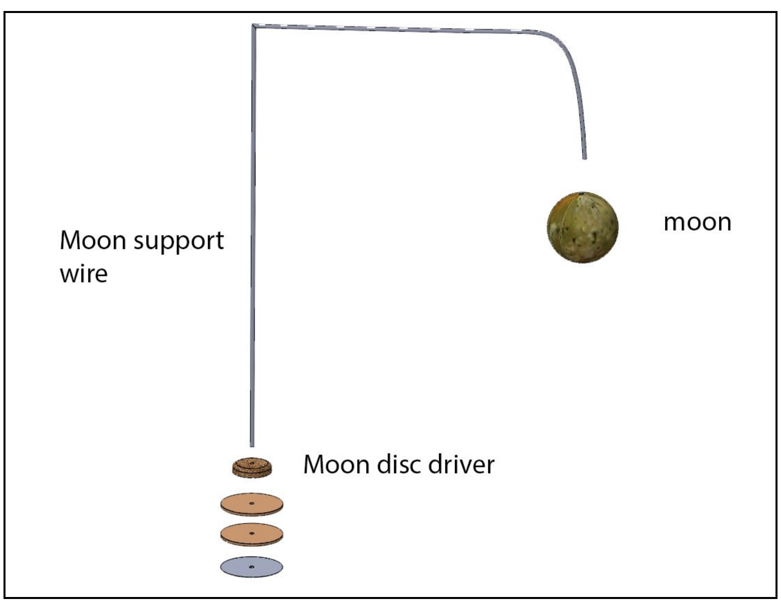


Move the small disc with the elastic over so it is just 1cm from the left of center inside the can.
With the third cork piece, poke a hole in the very center. We will use this as a stopper for the smaller end of your wire. Poke the wire through the cork, and add glue on the

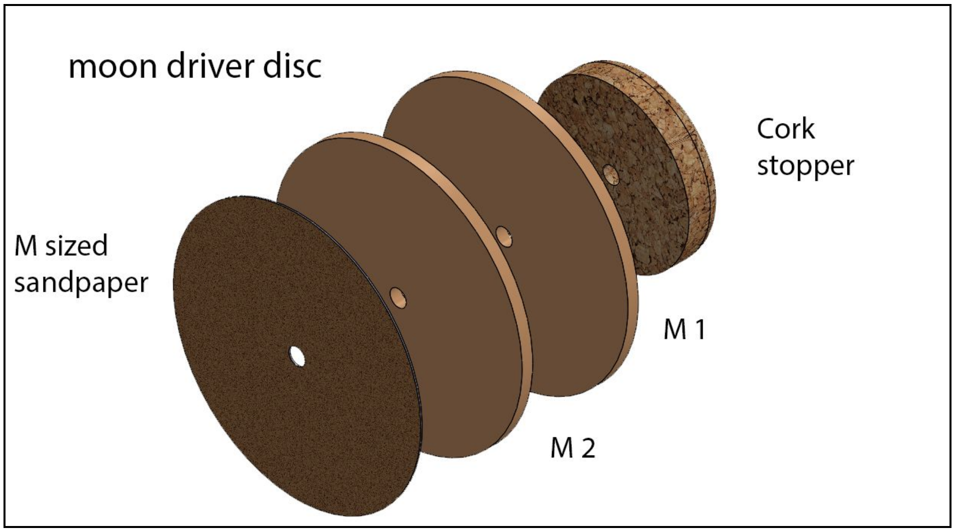
outer side of the cork.

6) Prepare the Moon Assembly parts

Before we start to put everything together we need to prepare the remaining parts, bending the Moon support wire, and glueing the 'Moon disc driver' together.



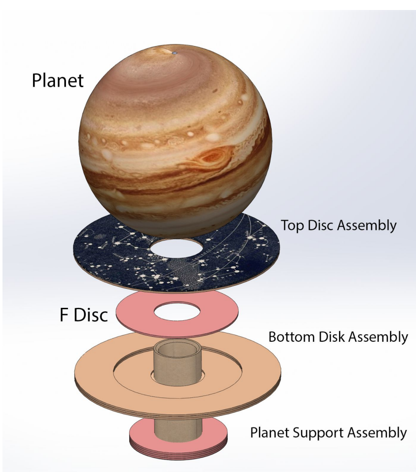
Glue together the parts for Moon disc driver - here is the order.



Use the same method as before to glue this disk together. Use one of the M discs to trace onto 120 grit sandpaper. Cut the sandpaper out and glue to the bottom. Glue the cork section on the top side last, and be sure the hole is poked in the exact center. Eventually the wire will poke into the cork and into a few layers of the cardboard, but not all the way through.

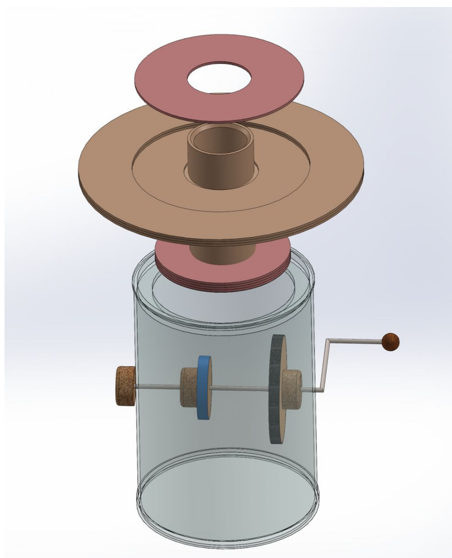
7) Prepare the Planet Subassembly parts

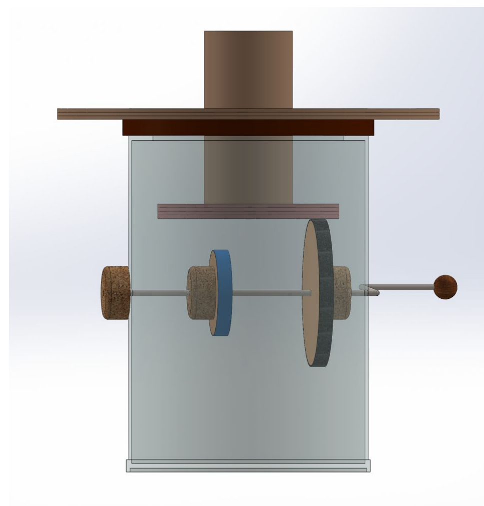
Here are the parts needed for the Planet subassembly.



8) Glueing the F disk into place.

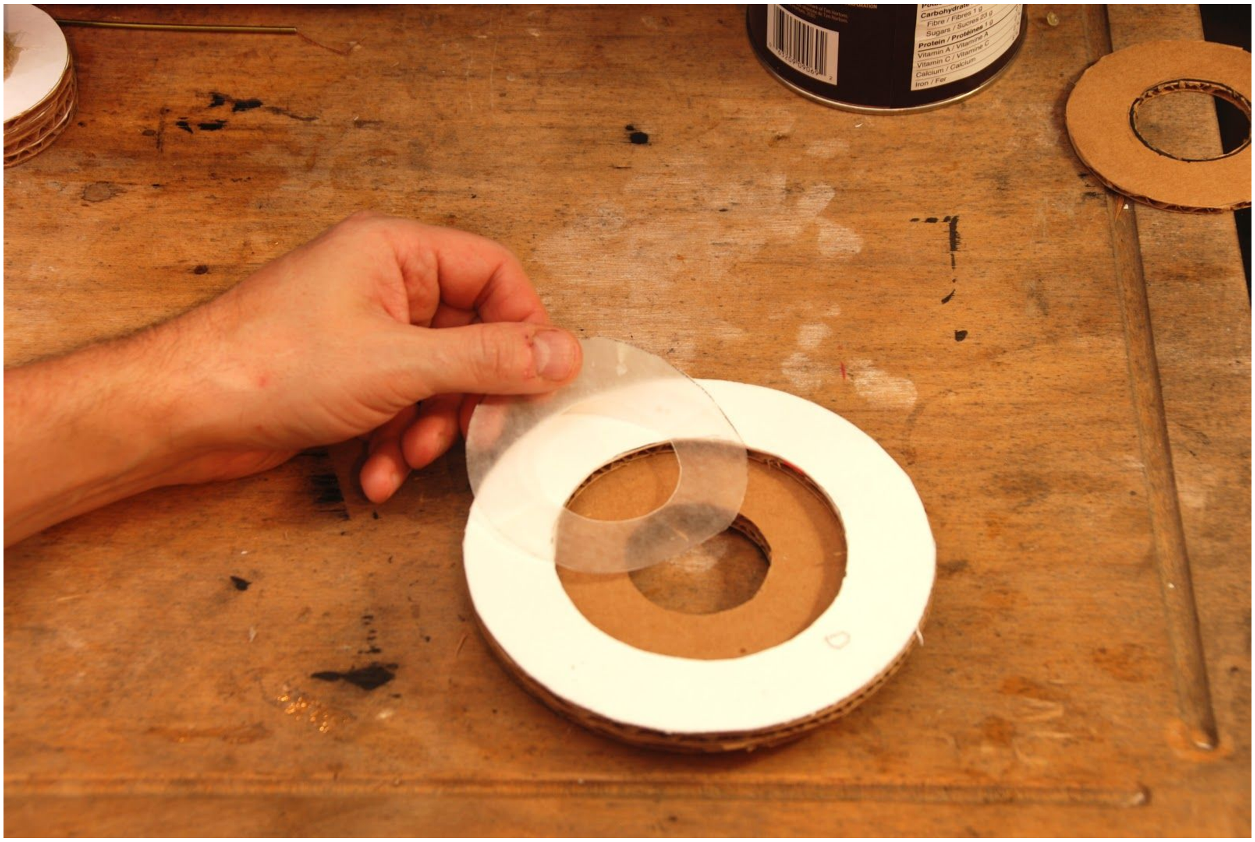
Take the bottom disk assembly you made in step 3 and place it on top of the can, snapping the brown lid into place. Slide the tight fitting F disc down the tube so that it is resting on in the opening we've made in the Bottom Lid Assembly.
But carefully (not too hard!) Make sure disc F is flat and not angled whatsoever in its place.





The edge of the F disc should not rub on the sides at all, so if they do carefully remove the disc and trim the edges with scissors.

Repeat until there is no interference. You may want to cut a pair of donut shaped wax paper rings to rest on either side of the F disk; this may help it turn better.

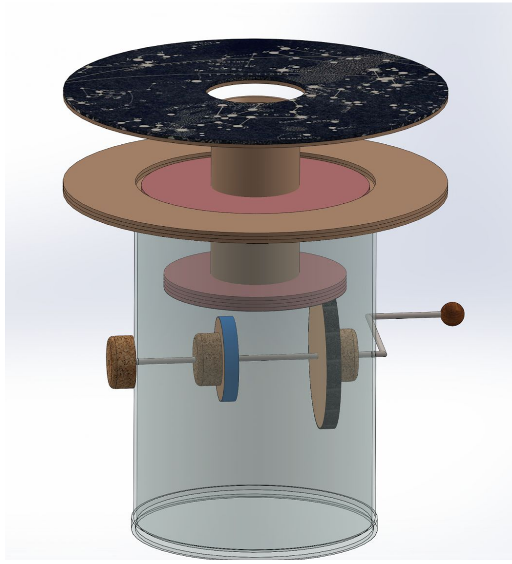


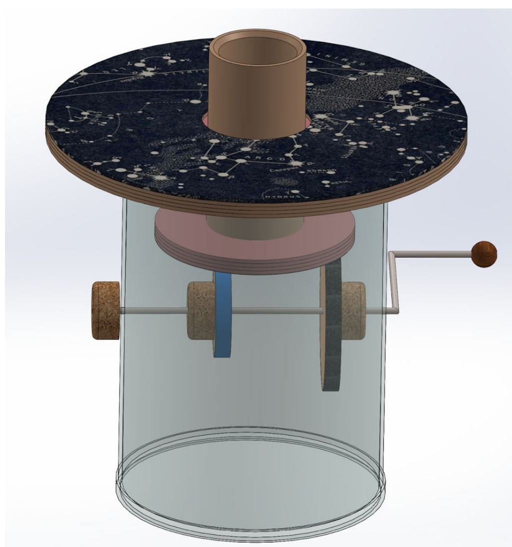
Be very carefull with this step, Make sure the Planet driver sits at 90 degrees to the Planet support disk. Adjust the height of the F disk until this seems perfect.

Now use your crank on the side of the can. It is doesn't turn, then you'll have to remove the lid and add hot glue to the Planet driver disc (the one with velcro) to the wire inside. Use lots of glue, but try adding layers between letting it cool. Let the glue completely cool down otherwise when you turn the crank the glue will just twist and not drive the Planet driver.

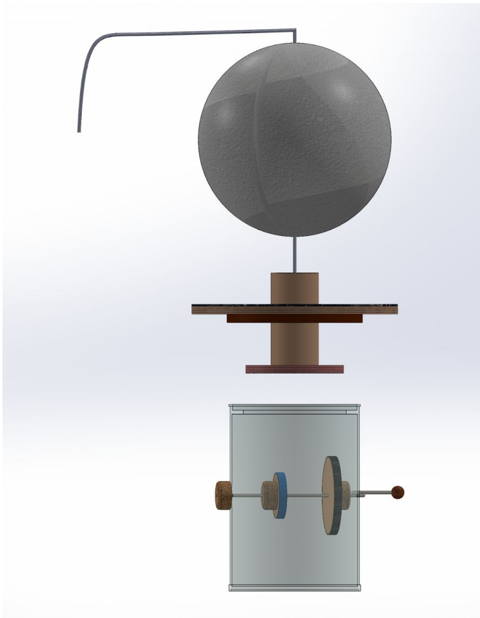
Reattach the lid and try the crank. If it moves that's great! If the tube seems to move in a complete circle, even better. Once you are satisfied this part is working, take some white glue (let it dry completely if you do) or a little bit of hot glue and glue the F disk into place. **Remember not to move the position of the F disk.**

Now take the Top Disk Assembly and with a couple of large bulldog clips (or use green painters tape), clamp it temporarily over the Bottom disc Assembly and try the crank. If the planet support tube seems to be rotating freely, carefully glue the Top Disc onto the bottom disc, **being very careful not to get any glue near the F disk**. Let it dry.



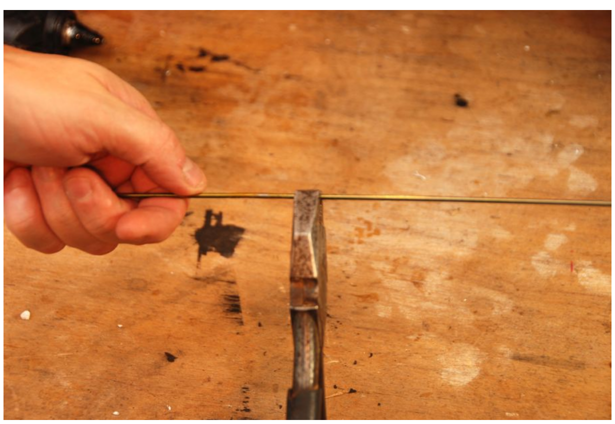


9) Final assembly



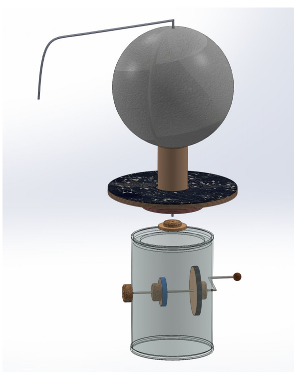
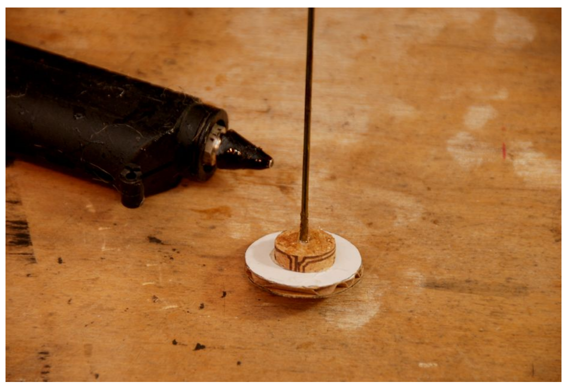
Temporarily remove the Lid assembly.

Take the remaining coat hanger wire and straighten it out as much as possible. One way to tell if it's straight is to roll it along a table top. Poke the end through your styrofoam ball, making sure that the hanger is straight as it passes through the ball.



Once that's done, let the planet rest on the planet driver. If it looks like the wire is centered right up the middle of the tube, hot glue the planet onto the planet support. Hold it in place until the glue cools.

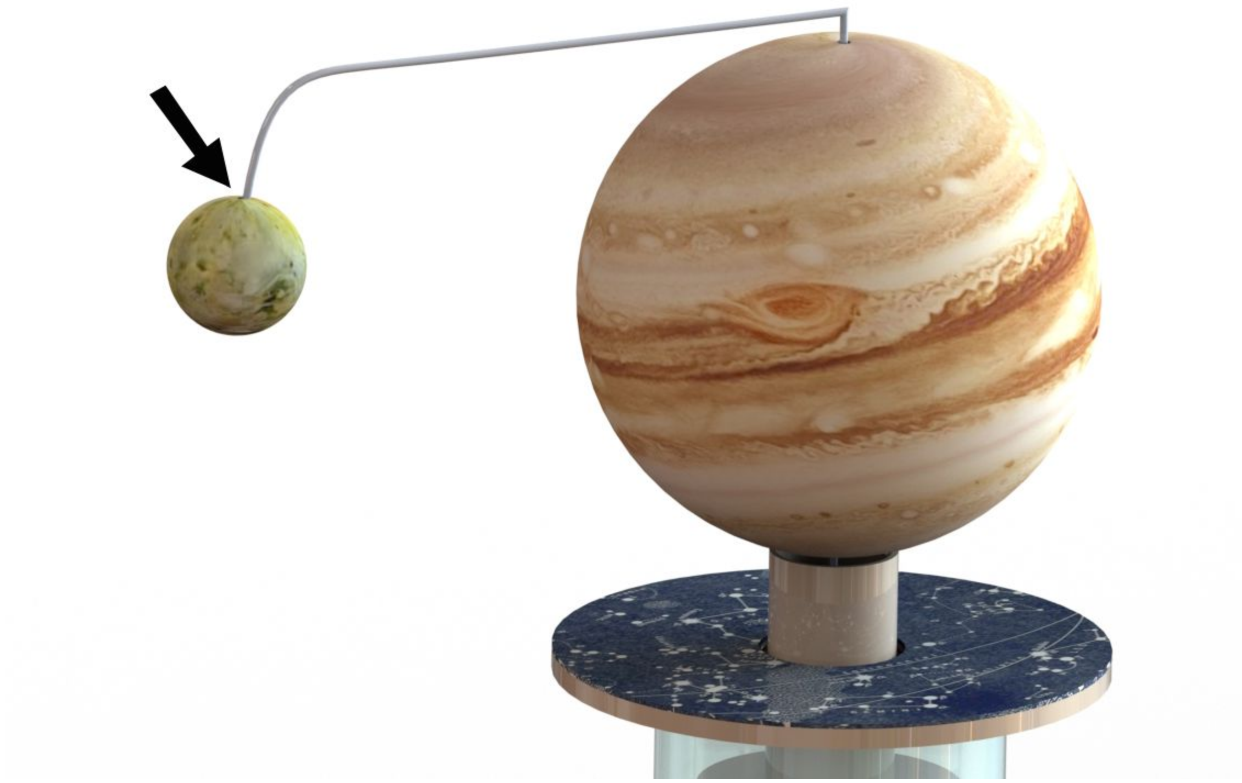

Take the wire out of the foam ball. Poke the wire into the exact center of the cork on the Moon driver disc (with sandpaper on the opposite side). Make sure the wire is straight up and down, When it is, temporarily detach the MoonDriver disc, place the wire back through the Planet, **reattach** the Moon driver disc, but this time hot glue it into place.


Place the Lid assembly back onto the top of the can. Let the Wire with the Moon driver disc rest on top of Gear disc B (the one with the rubber band inside the can)
Make sure the Moon driver disc does not rub against the side of large disc on the crank assembly. Remove the lid and Planet assembly and trim that Moon driver disk carefully. Reattach. Repeat until it does not contact the side of the larger disk.

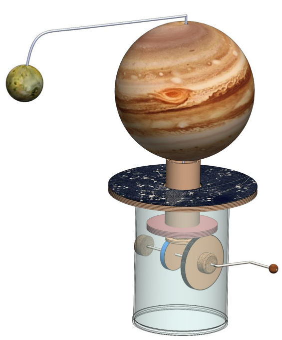
Now take one of the two pairs of pliers you have and firmly grasp the wire about an inch above the top of the planet. Being careful not to pull the moon disk up and away from the small disc on the crank assembly, using the second pair of pliers **bend** the wire 90 degrees. Bend an arc into the wire so that is curves outward around the Planet, something like in the picture below.

If you are happy with the shape, poke a small hole into your Moon styrofoam ball and hot glue the moon onto the end of the wire.



10) Decorate!

You can paint it any way you like!




ADD DISC PRINTOUT PAGES BELOW

Math Questions!

(credit Graeme Adamson from Zaber - he figured out the math behind my questions)

Problem 1 - Based on our Planet and Moon Automata, or ‘model’, if the crank is rotating at a speed of 10 RpM (revolutions per minute) what is the speed at a point on it’s surface?
What's the speed of the moon’s orbit?
What’s the relation of the moon’s orbital speed to the surface of the planet?

Problem 2 - What’s the ratio of the speed of the real Moon’s orbit in relation to the speed of the rotation of the Earth?
Why does the Moon seem to move from day to day?

Problem solutions:

Problem 1:

Question: Based on our Planet and Moon Automata, or ‘model’, if the crank is rotating at a speed of 10 RpM (revolutions per minute, or rev/min) what is the speed at a point on it’s surface?
What's the speed of the moon’s orbit?

What's the relation of the moon's orbital speed to the surface of the planet?

Answer: **S-planet**, or speed of the rotation of the planet, is determined by speed of one crank of the handle, or **S-crank**.
In our model, the two disks that contact each other at right angles and drive the Planet are roughly the same diameter, so we can say the ration of the two discs is 1 to 1. So in turn, if the crank is turned one time, the planet will turn once around. '+1' refers to the direction of rotation. For now this keeps the calculation simple. In this model '+1 rev Planet' over '1 rev crank' both calculate to a value of 1. But if we changed this ratio, there will be differences.
We next need to determine how fast the planet is rotating with reference to a point on the surface. To do this let's assume we are standing still on it's surface at the equator. The distance traveled in one revolution of the planet is calculated by using the formula for circumference of a circle, C = 2 x pi x R. If the styrofoam ball used for Planet model is 20cm across, we divide that number by 2 to determine the radius, or R.
S Crank speed, or 10 revs a minute x 2 x 3.14 x 10 cm equals out to a value of 628

Planet's rotational speed

$$S_{Planet}\left[\frac{cm}{Min}\right] = S_{crank}\left[\frac{rev}{Min}\right] \times \frac{+1 \text{ rev Planet}}{1 \text{ rev crank}} \times \frac{2\pi r}{+1 \text{ rev Planet}}\left[\frac{cm}{rev}\right]$$

$$S_{Planet}\left[\frac{cm}{Min}\right] = 10\left[\frac{rev}{Min}\right] \times \frac{1}{1} \times \frac{2 \times 3.14 \times 10}{1}\left[\frac{cm}{rev}\right]$$

$$S_{Planet}\left[\frac{cm}{Min}\right] = 10\left[\frac{rev}{Min}\right] \times 1 \times 62.8\left[\frac{cm}{rev}\right]$$

$$S_{Planet}\left[\frac{cm}{Min}\right] = 10\left[\frac{\cancel{rev}}{Min}\right] \times 1 \times 62.8\left[\frac{cm}{\cancel{rev}}\right]$$

$$S_{Planet}\left[\frac{cm}{Min}\right] = 628\left[\frac{cm}{Min}\right]$$

We repeat the same calculations for the Moon.

The moon’s distance will be measured as the point from the middle of the Planet to end of the wire supporting the Moon. Let's say that number is 50cm.
With this we come to a value of -1570.
To find the ratio of the planet's surface speed to the speed of the moon’s orbit, we simply divide the moon’s orbital speed value by the planet’s surface speed value.

S-moon / S-Planet
(-)1570/628
= -2.5
A ratio of 1:-2.5

For every full rotation of the planet, the moon travels -2.5 times as fast **in relation to the surface of the Planet.**
(We say minus (-)2.5 because the moon is rotating in the opposite direction to the rotation of the Planet model.)

Moon’s orbital speed

$$S_{Moon}\left[\frac{cm}{Min}\right]=S_{crank}\left[\frac{rev}{Min}\right]\times\frac{+1\text{ rev Moon}}{1\text{ rev crank}}\times\frac{2\pi r}{+1\text{ rev Moon}}\left[\frac{cm}{rev}\right]$$

$$S_{Moon}\left[\frac{cm}{Min}\right]=10\left[\frac{rev}{Min}\right]\times\frac{-1}{1}\times\frac{2\times 3.14\times 25}{1}\left[\frac{cm}{rev}\right]$$

$$S_{Moon}\left[\frac{cm}{Min}\right]=10\left[\frac{rev}{Min}\right]\times -1\times 157\left[\frac{cm}{rev}\right]$$

$$S_{Moon}\left[\frac{cm}{Min}\right]=10\left[\frac{\cancel{rev}}{Min}\right]\times -1\times 157\left[\frac{cm}{\cancel{rev}}\right]$$

$$S_{Moon}\left[\frac{cm}{Min}\right]=-1570\left[\frac{cm}{Min}\right]$$

Problem 2:

Question: What's the ratio of the speed of our Moon's orbit in relation to the speed of the rotation of the Earth?
How does that relate to how the Moon seems to move from day to day?

Answer:
Find out the speed of Earth's rotation. (It's 1670 Kmh)
Find the circumference of the Earth (It's 40075 Kms)
Find the speed of the Moon's orbit. (It's 1.022 km/s, or 3679 Kmh)
Find out the circumference of the Moon's orbit (It's 2415216 Kms)

Earth and Moon speed ratio

$$\frac{S_{Moon}}{S_{Earth}} = \frac{3679}{1670}\left[\frac{km}{hr}\right] = 2.20\left[\frac{km}{hr}\right]$$

1 :2.21 - for every time the Earth rotates, the Moon travels 2.21 times faster than the surface of the Earth.

In other words, for every time the Moon rotates around the Earth, the Moon travels 60 times farther than the surface of the Earth does in the same time.

Earth and Moon circumference ratio

$$\frac{C_{Moon}}{C_{Earth}} = \frac{2415216}{40075}\left[\frac{km}{hr}\right] = 60.2\left[\frac{km}{hr}\right]$$

But because the Moon is farther away, at 384,403 km, it moves a little in the sky everyday. If the ratio was 1:1, the moon would seem to stay still in the sky.