ASAP

Build your own Stirling engine.

A step by step guide to building this engine using common materials

Table of Contents

Introduction

How does the Stirling engine work ? *Here's the basic principle :*

Stretch a balloon over an opened tin can :	**Put the tin can in hot water**	**Now put it in cold water:**
		
This is the equivalent of the displacer cylinder.	The air heats up causing it to expand and push the balloon outwards.	The air inside contracts, The atmospheric pressure is greater outside and pushes the balloon inwards.

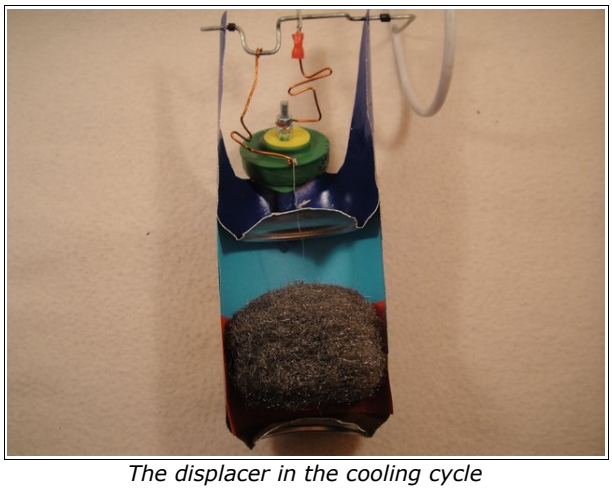
It's inefficient and impractical to repeatedly heat and cool the entire displacer cylinder. Instead, we keep one end of the tin hot and the other end cool, now instead of heating and cooling the tin can, we can add a device called a *displacer.*

What is a displacer ?

The displacer *displaces* the air in the displacer cylinder moving it from the hot end to the cold end. **Bingo!** You no longer need to heat and cool the entire tin can. We can just move the air around instead. The picture on the right shows a cross section of the ASAP engine. The displacer is near the top of the engine, this leaves most of the air at the bottom where it can be heated. It is heated causing it to expand, this pushes the diaphragm (balloon) outwards, turning the crankshaft.

The displacer in the heating cycle

As the crankshaft turns, allows the displacer to fall back down. This displaces the air up towards the top of the coke can where it cools down, causing the balloon to be forced back to it's starting position. The cycle repeats!



The displacer in the cooling cycle

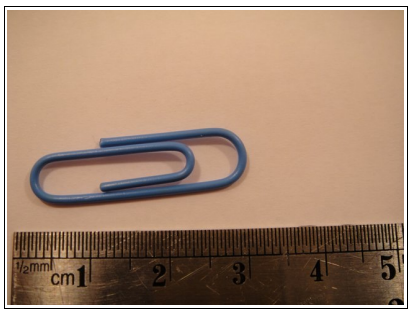
Reverend Dr Robert Stirling

Rev Robert Stirling invented the *regenerator,* a device designed to improve the efficiency of the hot air engine. The engine this guide covers has a moving regenerator which is also the displacer. The regenerator is made from steel wire wool which has lots of surface area to absorb and store the energy between cycles. The first useful Stirling engine was built in 1818, it was used to pump water from a quarry.

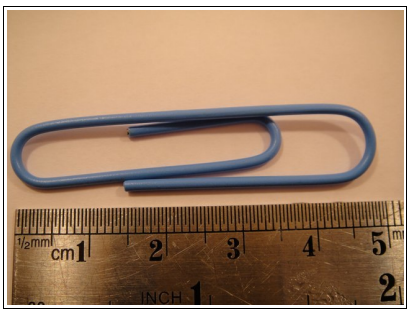
Materials and tools required

Materials :

3 Coke Cans

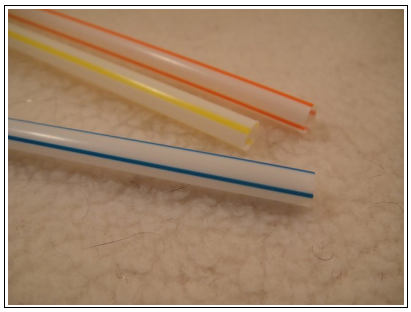


2 Paper clips



A jumbo paper clip

Fine steel wire wool



Plastic straws

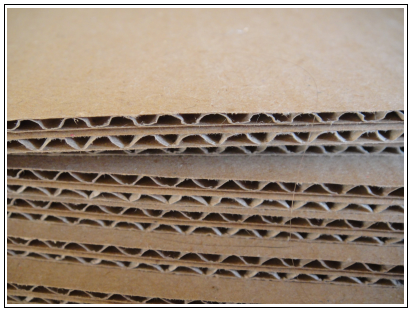
Drinks bottle lid

3 Milk bottle lids

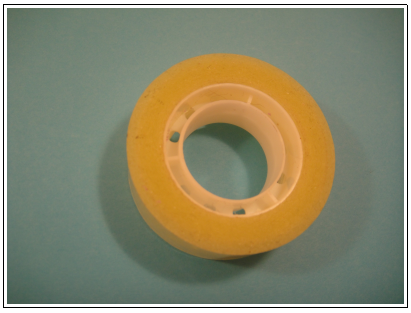
A balloon

Glue stick

5 minute epoxy



Corrugated card - 40cmx40cm



Clear tape

About a foot of 0.4 – 0.6mm fishing line.

An M4 X 40mm machine screw and 3 matching nuts.

A small sewing needle

Tools required :

Only basic tools are required to build the Stirling engine here's a list of all of the tools you'll need:

Drill

Drill bits 5 and 8mm

Wrenches /Spanners to suit machine screw nuts

Pliers

Ruler

Screwdriver to suit machine screw

Drawing pin

Scissors

Needle nose pliers/tweezers

Compass

Utility Knife

Can Opener

Important!

Some homebuilt engines fail to run, your engine may fail too, if you are not careful enough when building the engine. If you follow these plans closely you'll have good chance of success. Although the plans show the steps for each stage of the construction you must take care throughout, to ensure that there is minimal friction in all of the moving parts, and that the displacer cylinder and diaphragm connections are airtight. The only exception to this is the seal around the displacer wire – this will always leak a little, but it should slide freely up and down. This guide assumes that you will keep an eye on these things throughout.

Important things to remember :

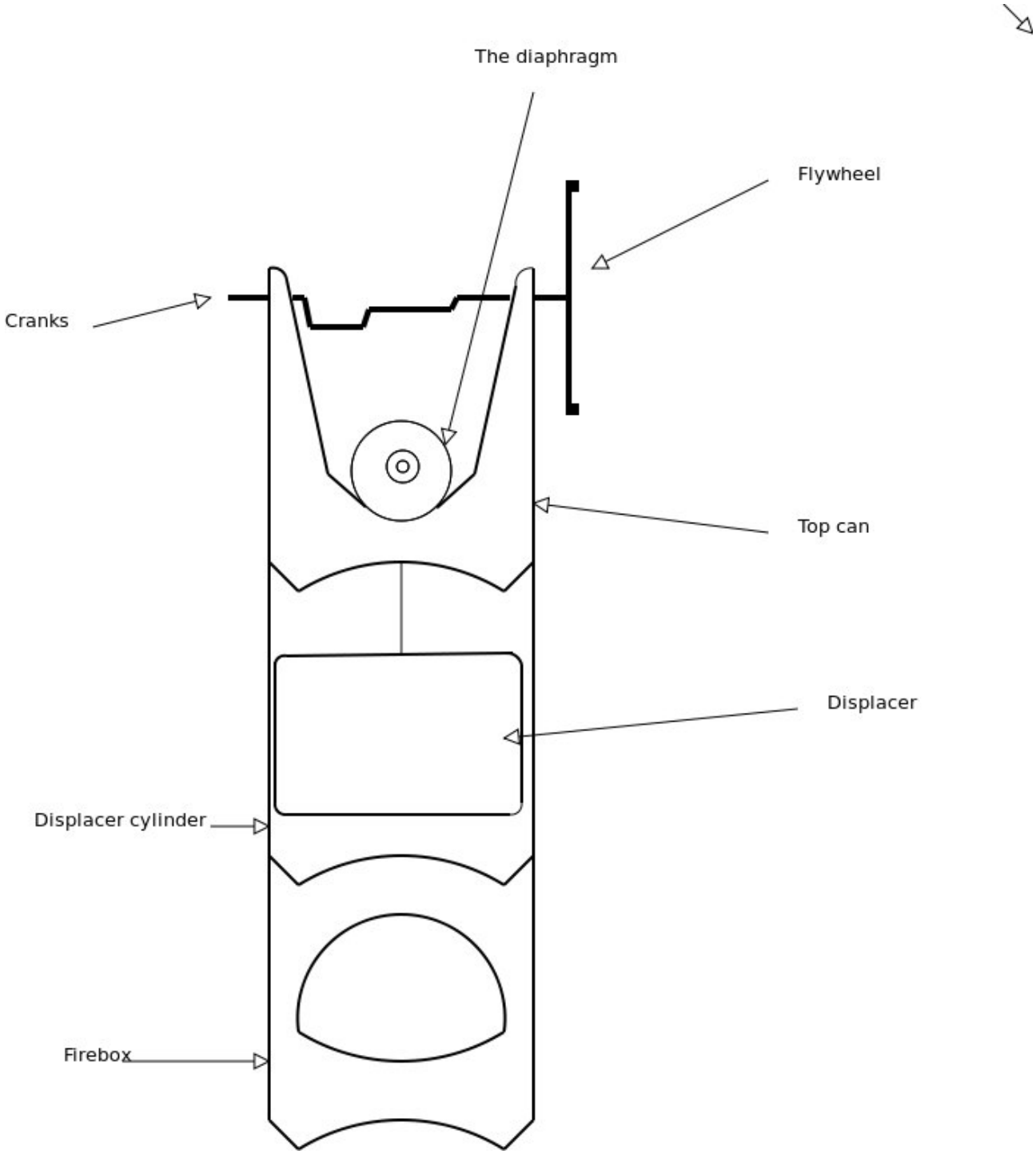
- Keep the displacer cylinder and diaphragm air tight
- Keep friction to a minimum
- Follow the instructions! Don't take short cuts.
- Wear appropriate safety gear at all times! Some of the steps in this book can cause injury if you do not wear proper protective equipment. You are responsible for your own safety if you choose to build this engine.

About the fishing line :

The fishing line needs to be 0.4 – 0.6mm line. If the fishing line is too thin, it will leave a large space around the displacer wire hole, allowing too much air to leak out. If this happens, the engine will not run.

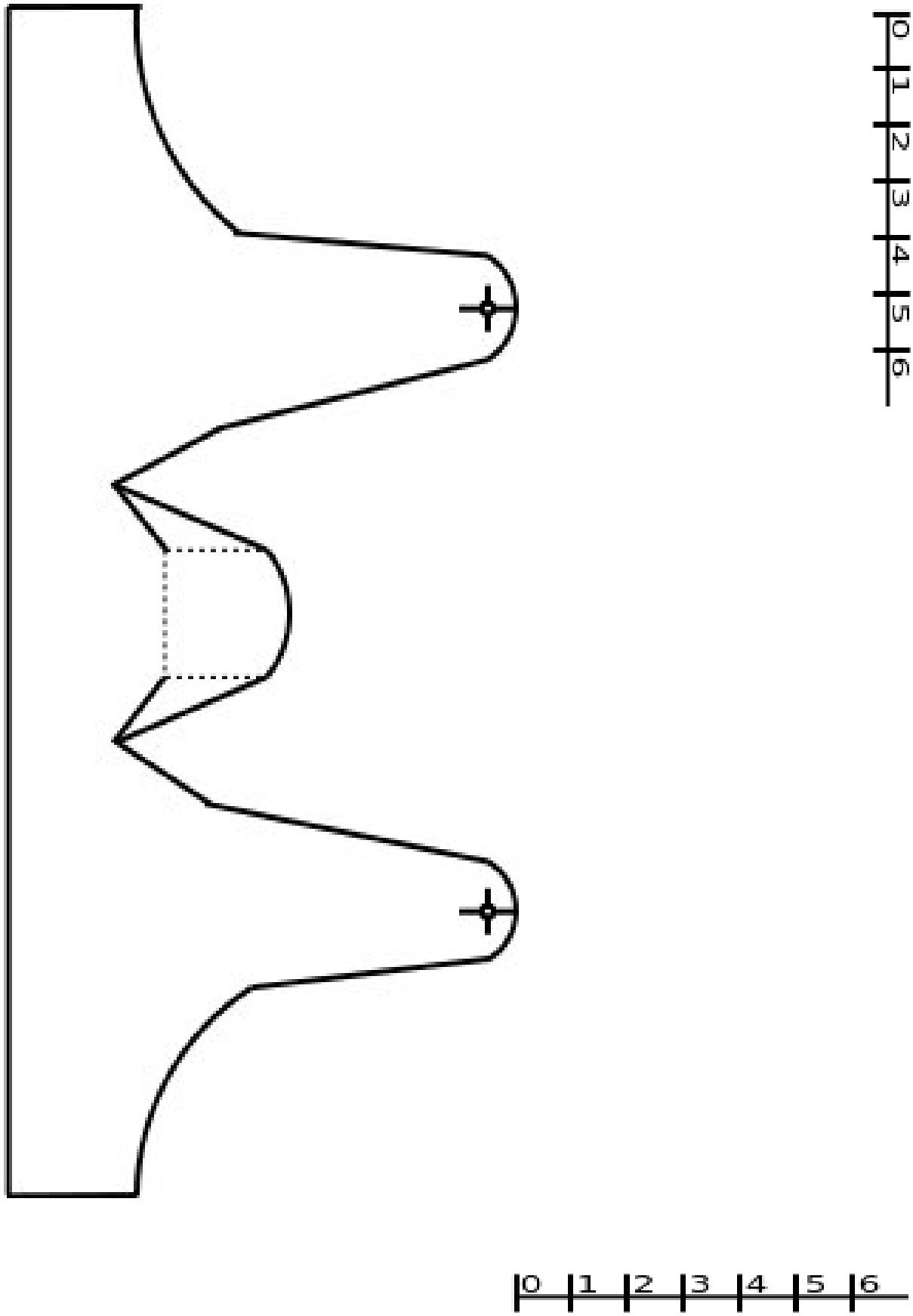
The main parts of the ASAP engine

The diagram shows the main parts of the engine and how they fit together.

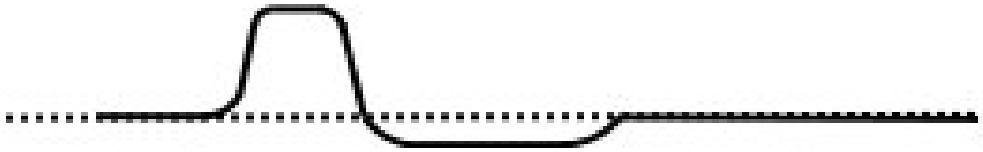


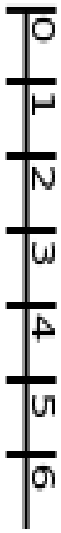
ASAP Templates

Top can cut out template:

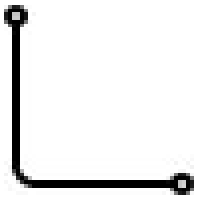


Cranks :

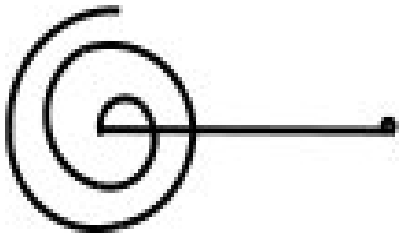




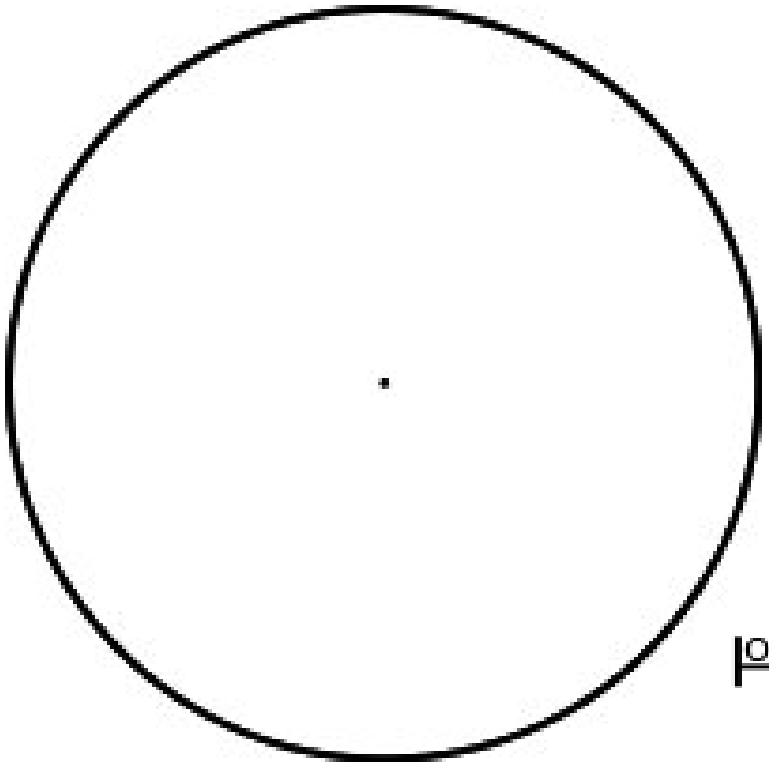
Displacer Connecting rod



Displacer support wire

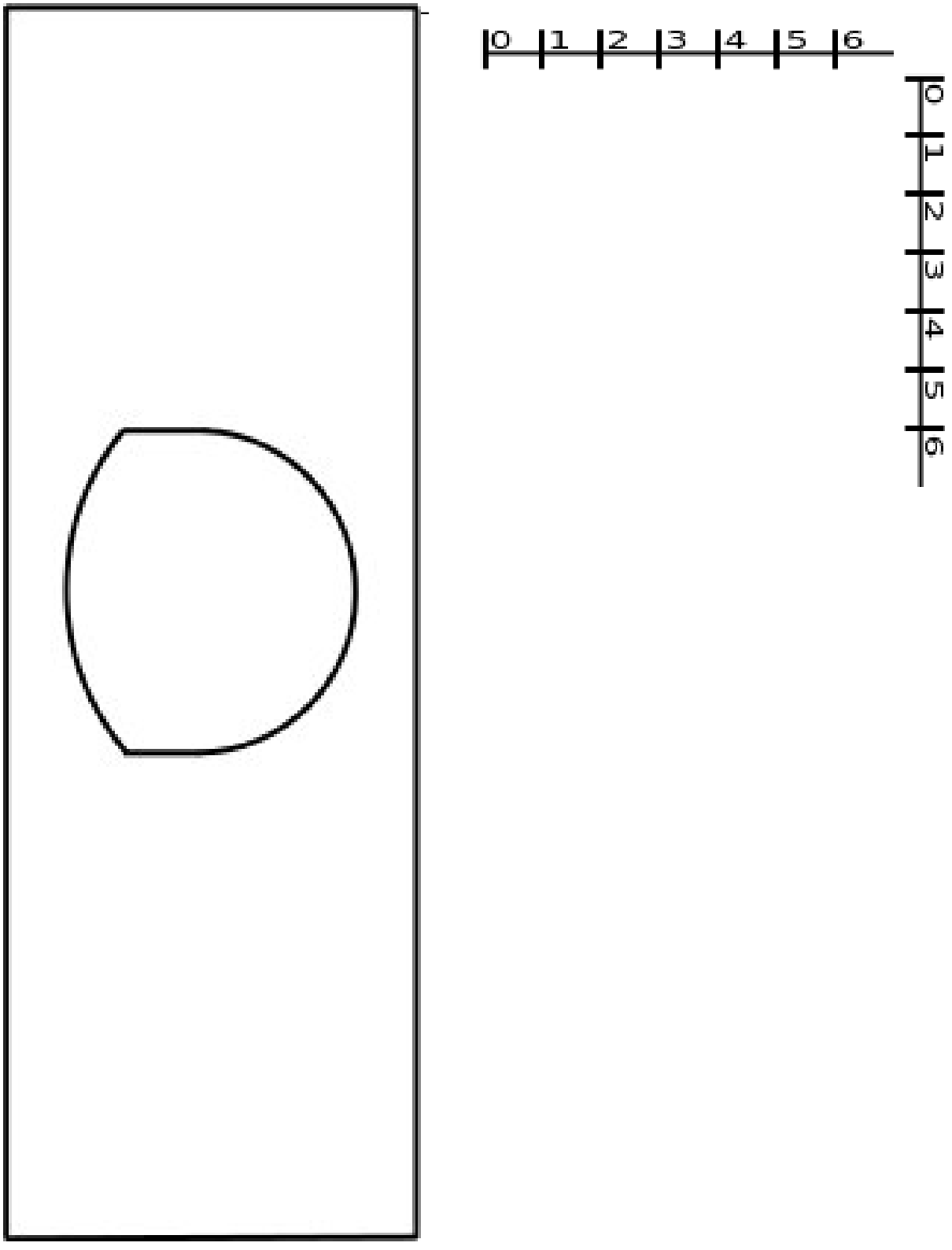


Flywheel



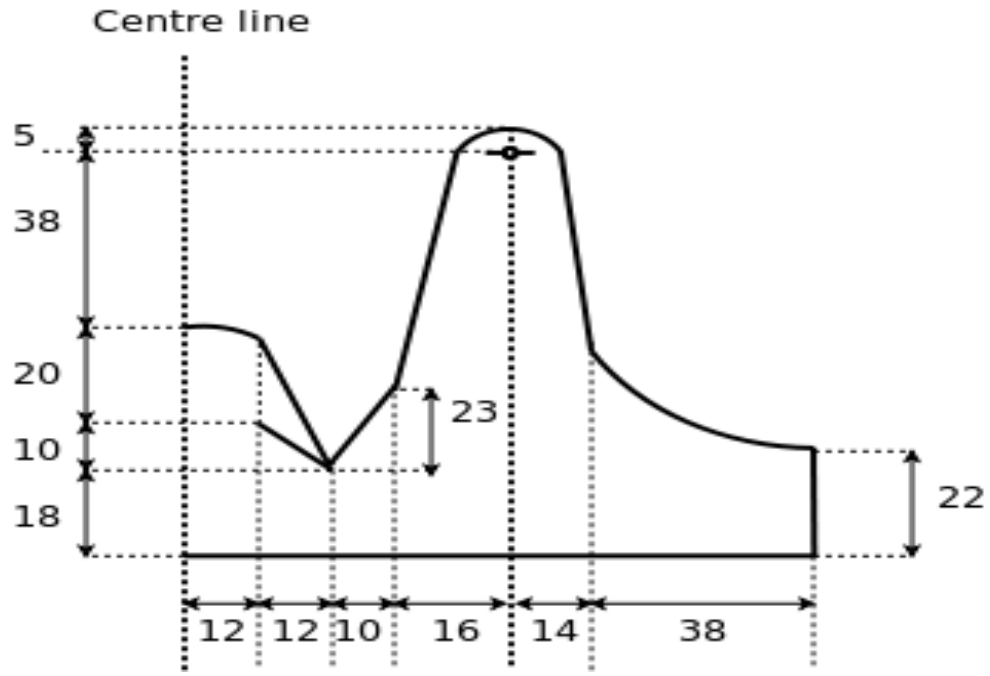
Diaphragm push rod

Fire box :

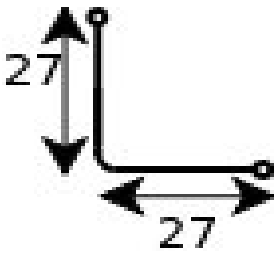


If you don't have a printer, or can't get them to print

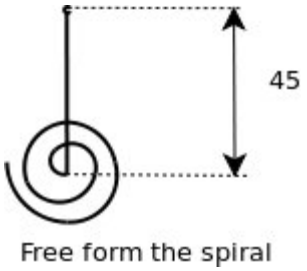
If you don't have a printer, you can draw the templates yourself. The top can template is the most important. All dimensions are in mm.



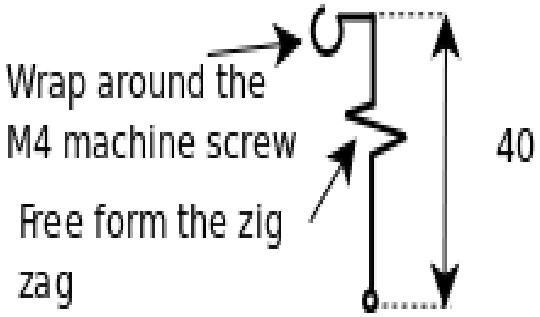
Displacer connecting rod :



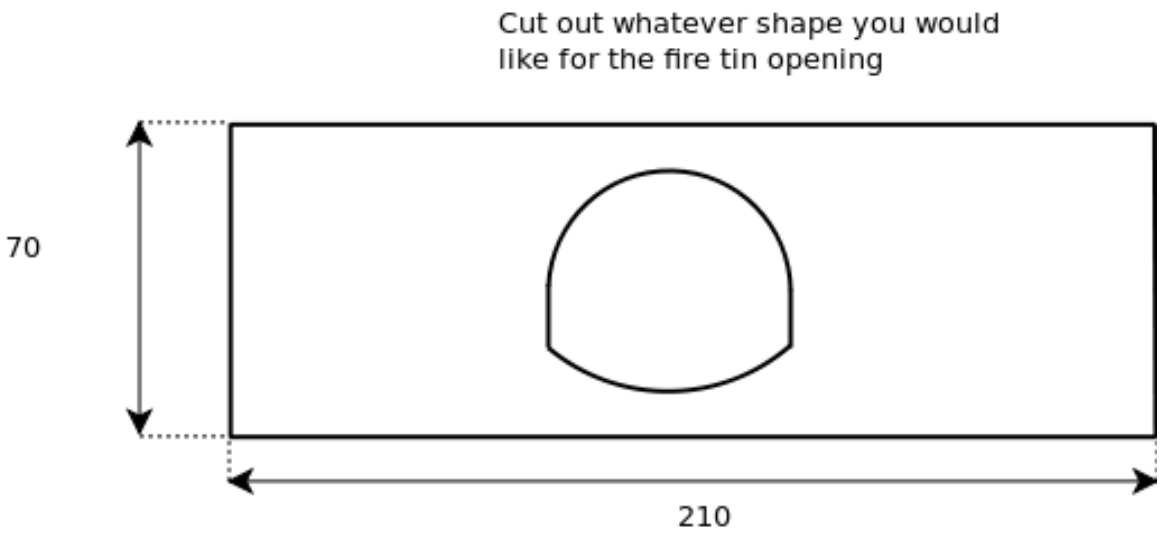
Displacer support wire



Diaphragm connecting rod :



Fire tin:



Flywheel: The flywheel can be drawn using a compass set to 45mm between the points

The displacer cylinder

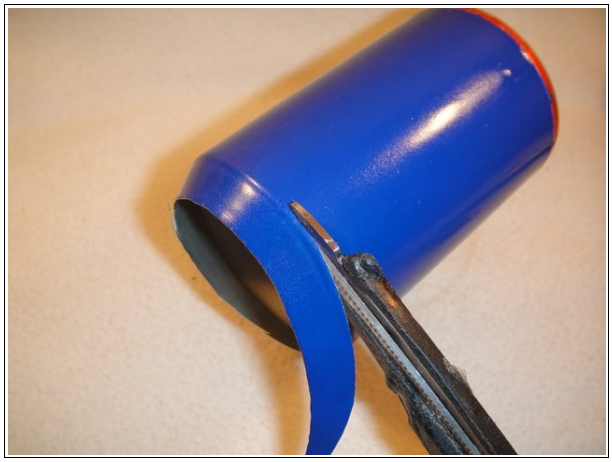
We'll start with the simplest part of this engine, the displacer cylinder. The displacer cylinder is the part that will contain the working gas (air), and the displacer.

When the engine is complete and running, the bottom of the displacer will be kept hot and the top of this cylinder will be kept cool. The displacer that sits inside will move the air between the top and bottom of the cylinder.

Remove the top with a can opener

Step 1 : Cut the top off a can

Remove the top from a can with a can opener.



Cut around just below the bevel

It should look like this when it's done

Step 2: Cut around the top

Cut around the top just below the bevelled edge using the scissors.

The displacer

The displacer displacer the air from either end of the displacer cylinder. In this engine it is made from fine steel wire wool. The steel wire wool works as a regenerator too.

Step 1: Roll the steel wire wool

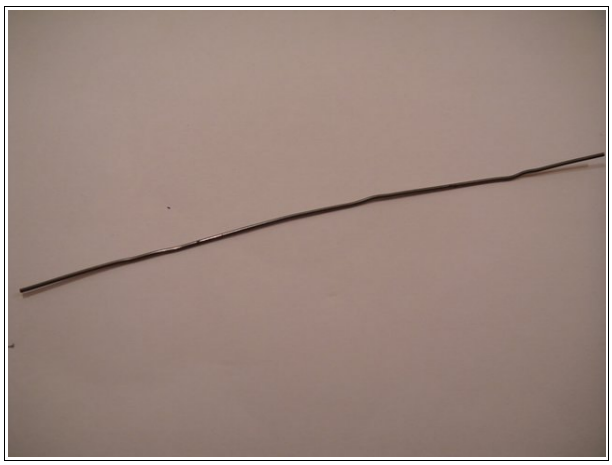
Roll the steel wire wool around a plastic straw until it is about 5mm smaller than the displacer cylinder.

Step 2: Test the fit in the displacer cylinder

There should be space all around - the displacer should be a loose fit in its cylinder.

Step 3: Cut the displacer to size

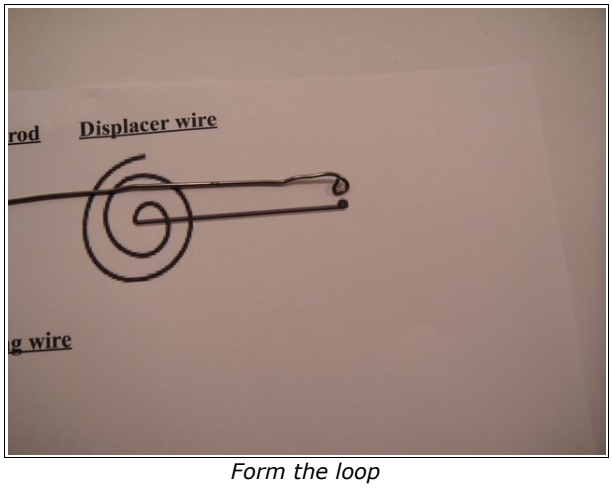
The displacer should be about 50mm long and small enough in diameter that it falls freely to the bottom of the displacer cylinder.



Straighten the paper clip

Step 4: Straighten a paper clip

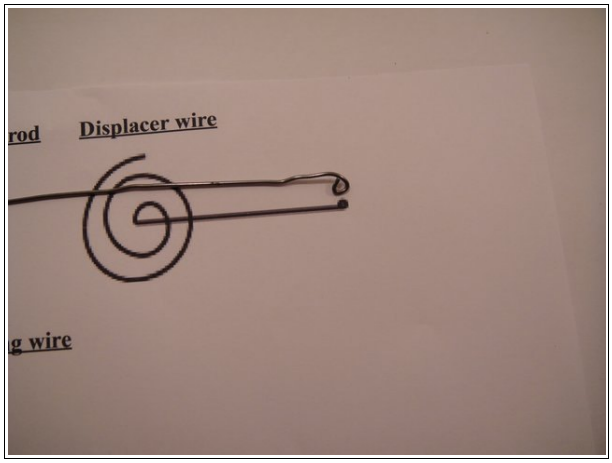
Take one of the smaller paper clips and straighten it out, then remove the plastic covering with a knife.



Form the loop

Step 5: Form a loop

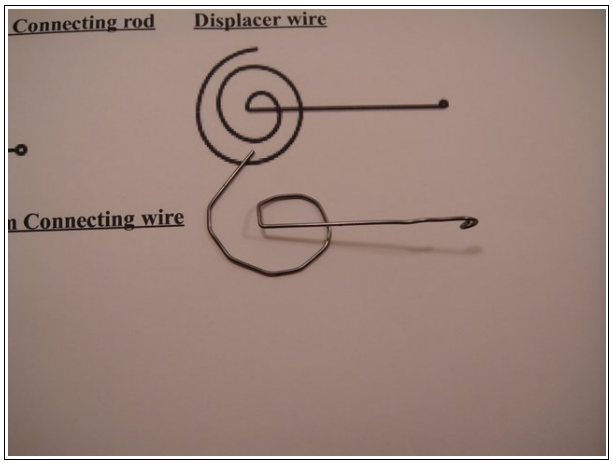
Form a loop on the end of the wire - the exact size is not important, around 2mm should do.



Form the displacer wire

Step 6: Form the displacer wire

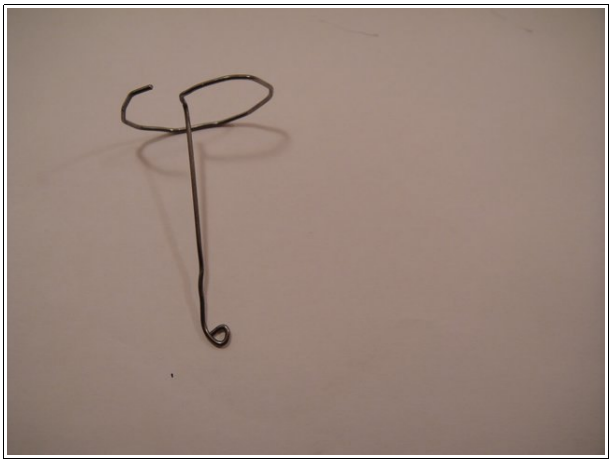
Form the wire around the displacer wire template - only straight section needs to be correct, just free form the spiral.



It should look like this

Step 7: It should look like this now

It should look something like this now. Remember to make the small loop on the end of the straight section.



Step 8: Bend it upwards

Bend the straight part upwards so that it faces up when the spiral is flat on the table.


Thread the displacer wire through

Step 9: Thread the wire through

Thread the displacer wire through the centre of the steel wire wool , into the space left by the plastic straw.

Tie on the fishing line

Step 10: Tie on the fishing line

Tie on the fishing line to the loop in the displacer. Double tie the knot to prevent it coming loose when the engine is running.

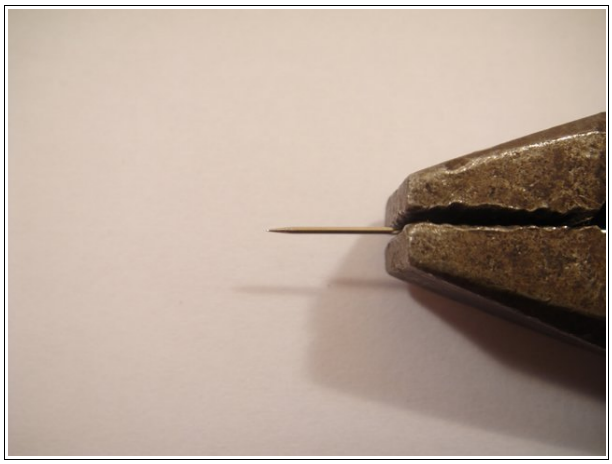
Test the displacer

Step 11: Test the displacer

The displacer should fall freely in the displacer cylinder. If it doesn't, make adjustments by cutting and compressing the steel wool.

The top can

The top can holds the crankshaft, diaphragm, flywheel and it connecting rods. It's the most complicated part of the engine, but I've broken it down into easy to follow steps.



Grab a needle

Step 1: Grab a needle

Take a sewing needle and grip it in the pliers.

Pierce a hole

Step 3: Pierce a hole

Pierce a hole in the centre of the coke can. You can find the centre by using a compass set to 33 mm and drawing arcs from the outer edge of the can.

Tape on the template

Step 3: Tape the top can template

Cut out around the top can template and tape it around the can. The long flat edge goes along the bottom of the coke can. You should tape it in a few different places so that it doesn't move when you cut out the shape.

Cut along the bottom lines

Step 4: Cut along the bottom lines

Using the utility knife, cut along the both of the bottom lines of the diaphragm shelf.

Pierce the bearing holes

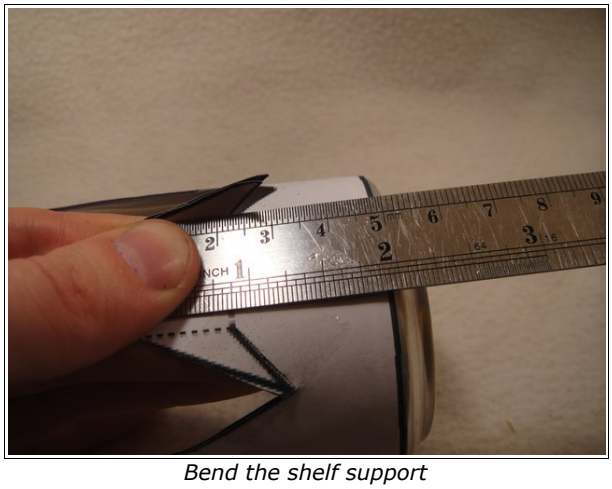
Step 5: Pierce the bearing holes

Using a pin, pierce the two bearing holes. Remove the top of the can using a can opener.

Cut around the template

Step 6: Cut out the rest

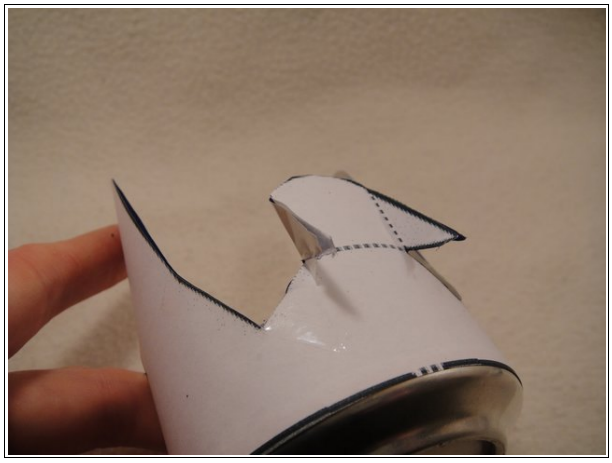
Cut out around the rest of the template using the scissors. It's easier to cut roughly about 5mm away from the lines first, then make a final clean cut.



Bend the shelf support

Step 7: Bend the shelf support

Bend the edges of the shelf support along the dotted lines, it's helpful to use a ruler to bend the edge



Doe the same for the other side

Step 7: Bend the shelf support

Do the same on the other side

Tape the shelf back

Step 8: Tape the shelf back

Bend the whole shelf backwards and tap it in place

Apply epoxy

Step 9: Apply epoxy

Apply epoxy all around the shelf support.

Don't let it drip too much

Make sure that you use plenty, but at the same time, keep moving the can so that the epoxy doesn't run towards the bottom of the top can. If any epoxy runs onto the bottom edge, remove it as soon as possible as it will prevent the two cans fitting together to form an airtight seal.

Drill a hole in the lid

Step 10: Drill a hole in a lid

Take one of the milk bottle lids and drill a hole close to the edge, the same diameter as the straws you have.

Drill a hole in the top can

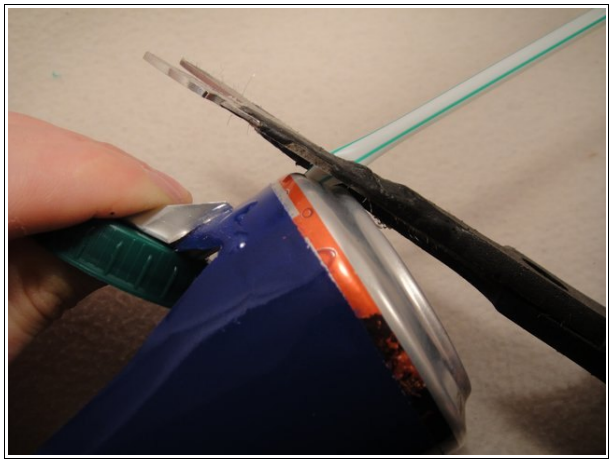
Step 11: Drill a hole in the top can

Drill a hole the same size as the straws approximately in the centre of where the diaphragm shelf is.

Thread the straw through

Step 12: Thread a straw through

Take the straw and thread through the top can and through the milk bottle lid, with the bottle lid resting on the diaphragm shelf.



Trim the straw

Step 13: Trim the straw

Trim the straw to size.

Sand the lid

Step 14: Sand the milk bottle lid

Sand the milk bottle lid using coarse sandpaper. Bottle lids seem to have an oily surface which prevents the epoxy from bonding properly, sanding improves the bond of the epoxy.

Epoxy the lid

Step 15: Epoxy the lid

Apply some epoxy to the diaphragm shelf and push the milk bottle lid into this epoxy, making sure that the holes line up. You can epoxy this step, step 16 & 17 at the same time – no need to wait for them to set between the steps.

Epoxy the straw

Step 16: Epoxy the straw

Push the straw through the hole in the lid. Epoxy all around the straw with plenty of epoxy - it must be airtight here.

More epoxy

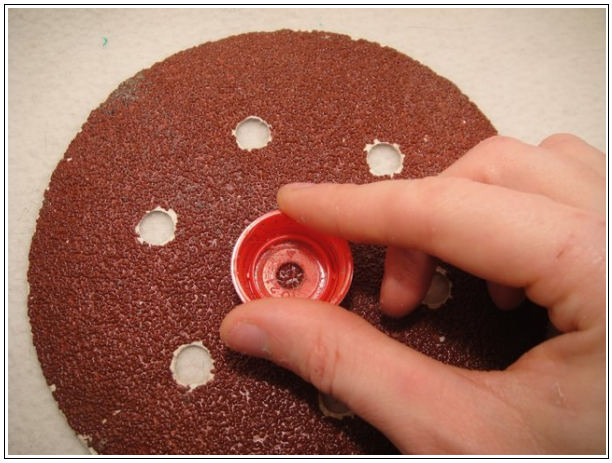
Step 17: More epoxy

Epoxy around the straw where it passes through the drinks can. Hold the can at an angle whilst the epoxy sets, this is to keep the epoxy around the straw. This part needs to be airtight.

Drill a hole

Step 18: Drill a hole

Drill an 8mm hole through the drinks bottle lid.



Sand the lid

Step 19: Sand the lid

Sand the lid with coarse sand paper to help the epoxy bond.

Epoxy the lid

Step 20: Apply Epoxy

Apply plenty of epoxy to the flat out section of the lid.

Epoxy it in place

Step 21: Epoxy it in place

Epoxy the lid in place, centre it around the needle hole you made earlier.

Test that it's watertight

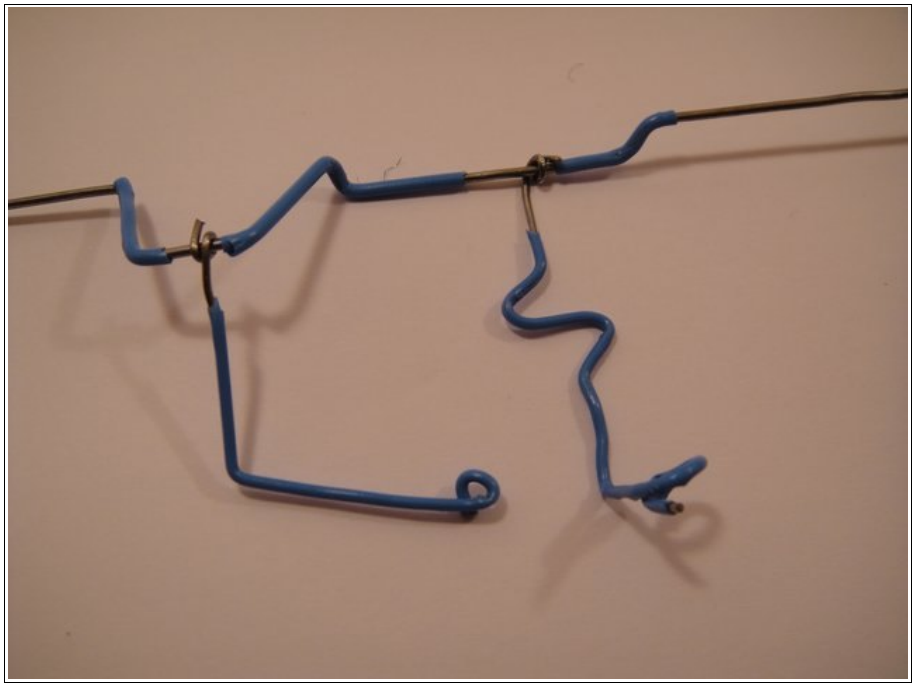
Step 22: Test that it's watertight

Fill the space on the outside of the lid with water to check that no water can leak into the needle hole. The lids' job is to keep water from getting into the engine, but allow the top of the can to be cooled.

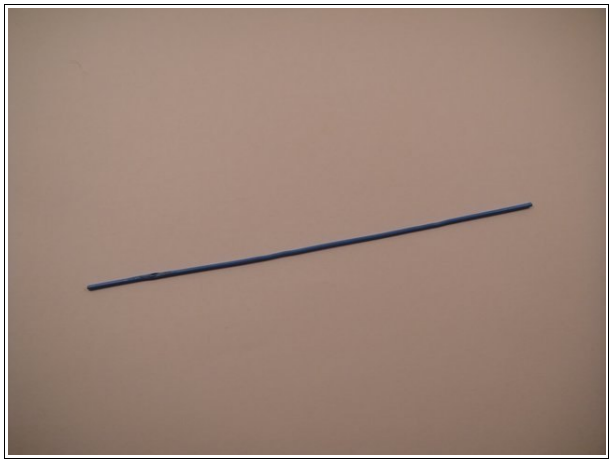
The cranks

The cranks, the all important spinning part of an engine. They also serve another purpose besides being an axis for the flywheel and push rods to rotate on. The cranks have a sort of timing mechanism built in the keeps the engine turning, the part of the cranks that the displacer is connected to is rotated around 90° so that diaphragm is always chasing the next part of the cycle.

The cranks are made out of a jumbo paper clip that has the plastic covering removed at all of the bearing points. To connect the diaphragm and displacer to the crankshaft, there are two small paper clips formed into small push rods.



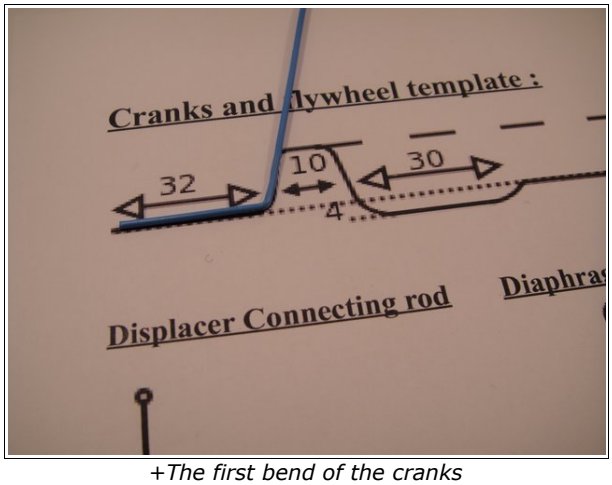
The crankshaft and push rods



Straightened paper clip

Step 1: Straighten the paper clip

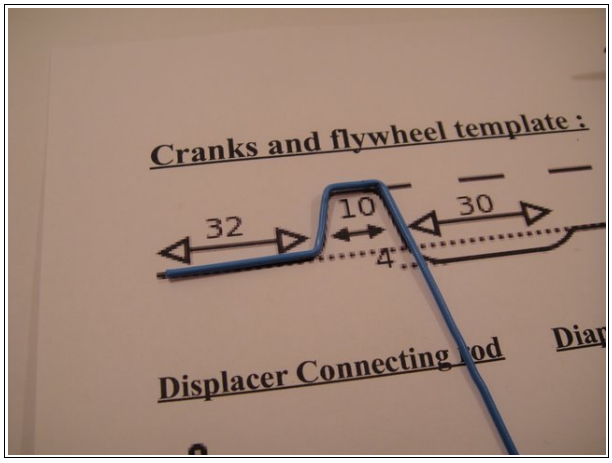
Take the jumbo paper clip and straighten it out – as straight as you can get it.



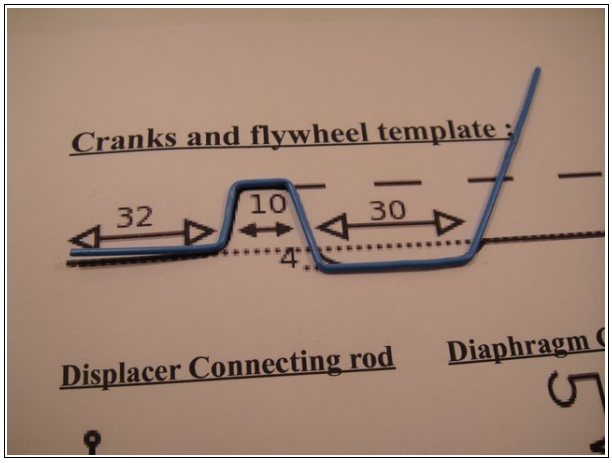
+*The first bend of the cranks*

Step 2: Bend the crankshaft

Start forming the paper clip into the shape of the crankshaft template as shown in the next. It doesn't need to follow the template exactly, but it should be within a few mm. Make sure that it spins true between the ends, where it will rest on the bearing holes.

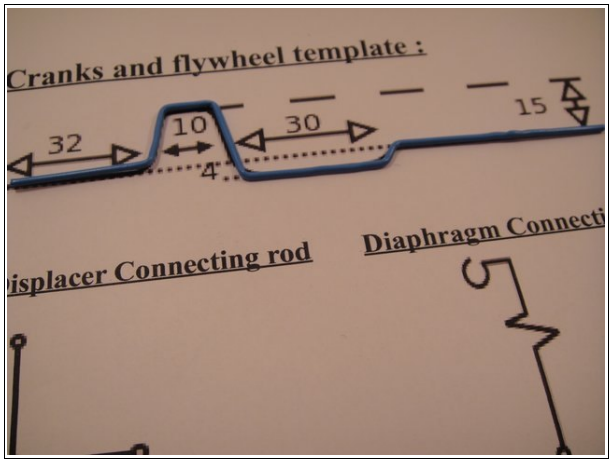


The displacer arm done.

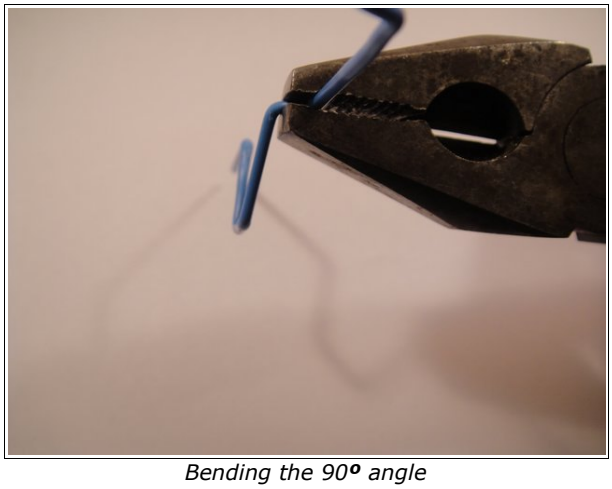


The diaphragm arm

When it's done, it should look like this :



The cranks formed to the template

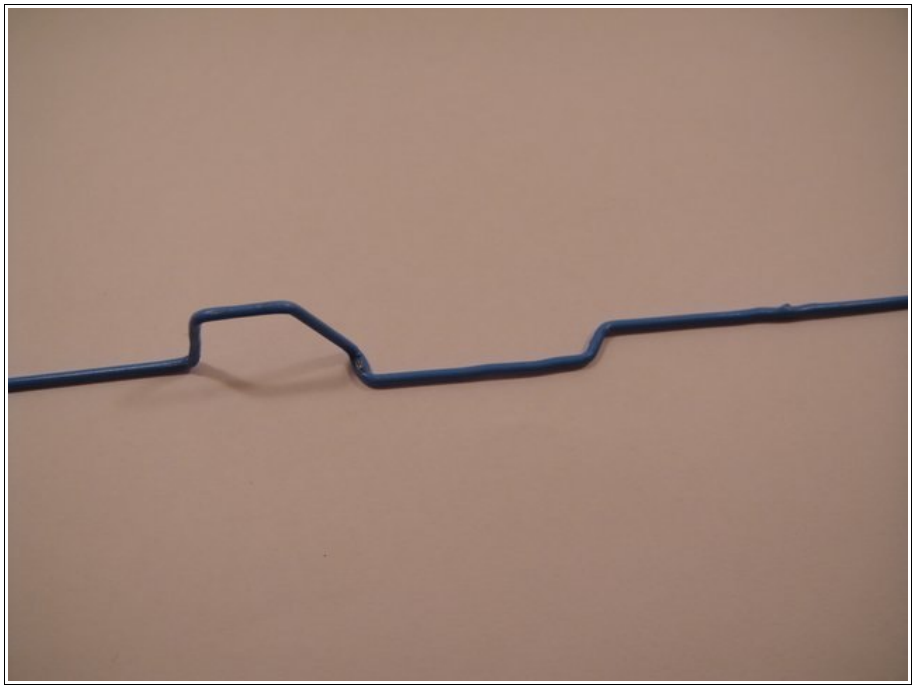


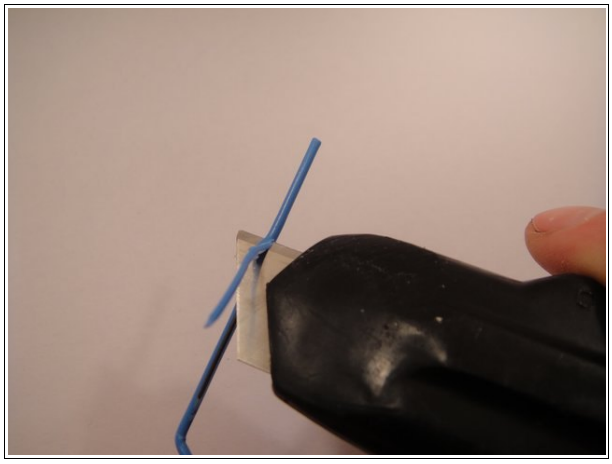
Bending the 90º angle

Step 3: Bend the 90º angle

Hold the crankshaft where the displacer arm meets the diaphragm arm and bend the displacer arm so that it's rotated through 90º. This will probably distort the rest of the crankshaft a little so check that it still spins true.

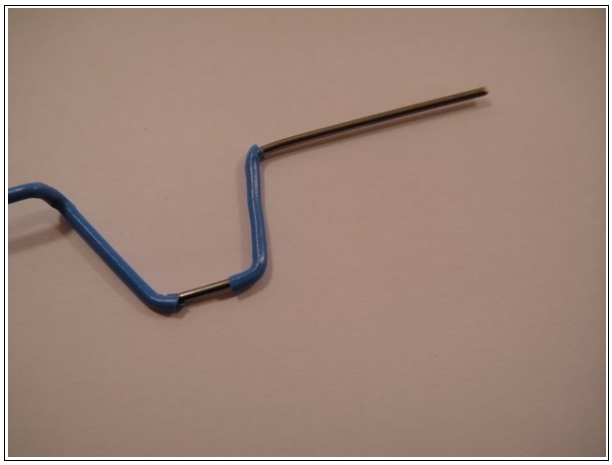
The displacer arm is pointing up with the diaphragm arm flat on the table.

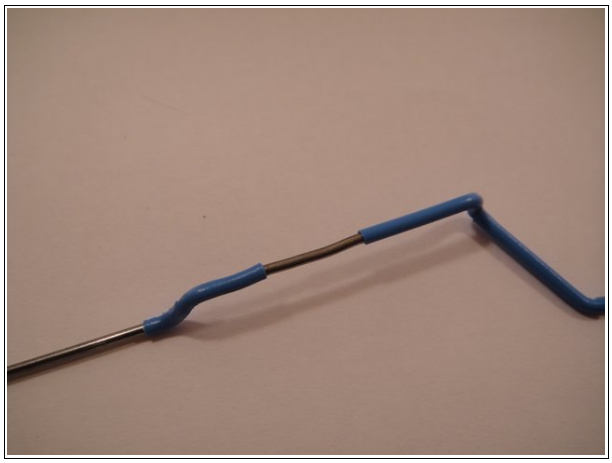




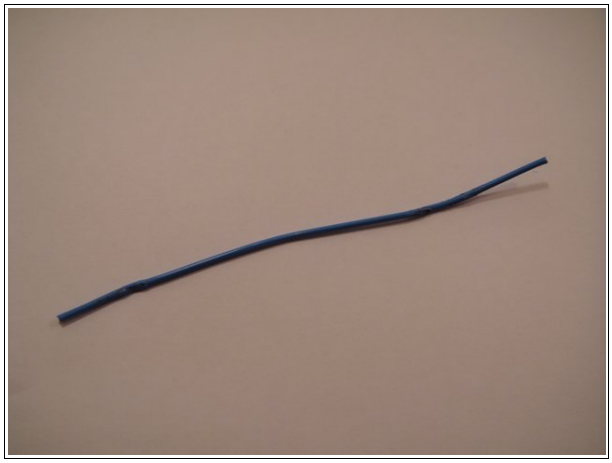
Step 4: Remove the plastic

Remove the plastic at the four bearing points exposing the bare metal.
You're might be wondering “why not just remove it all ?”, the reason is that the plastic will stop the push rods from sliding along the crankshaft when the engine is running.





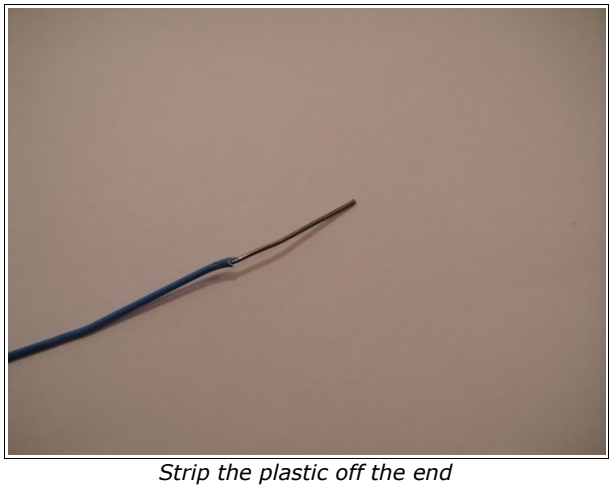
The push rods



Straighten the paper clip

Step 1: Straighten a paper clip

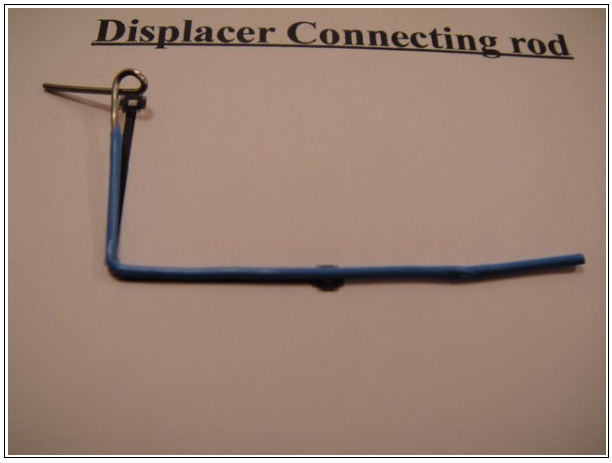
Take one of the small paper clips and straighten it out.



Strip the plastic off the end

Step 2: Remove the plastic

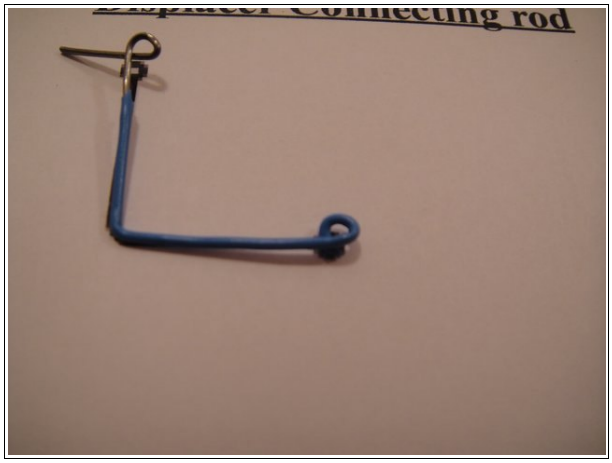
Strip about an inch of the plastic off the end of the paper clip, you could remove all of the plastic if you like, but I decided to leave it to match the crankshaft which has some blue plastic.



Bend it the template shape

Step 3: Form a loop

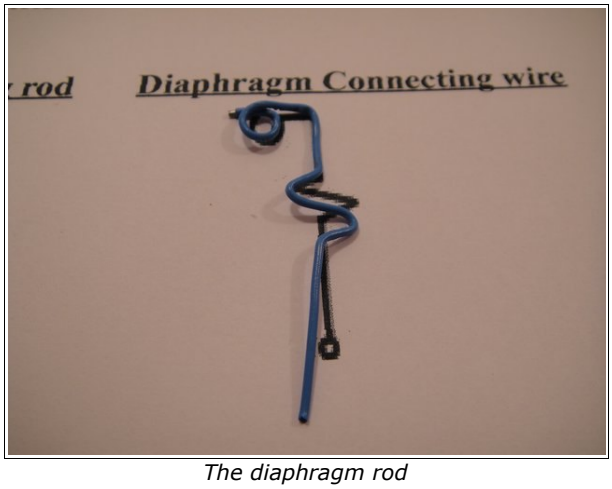
Form the loop in the end where you stripped the plastic off. Bend the rest of the clip in the shape of the displacer connecting template. Don't make the loop too small yet as it has to slide over the plastic on the crankshaft.



Form the other loop

Step 4: Form the other loop

Form the other loop as shown on the template. This should be about 2mm diameter. The fishing line will be tied onto this later on.



The diaphragm rod

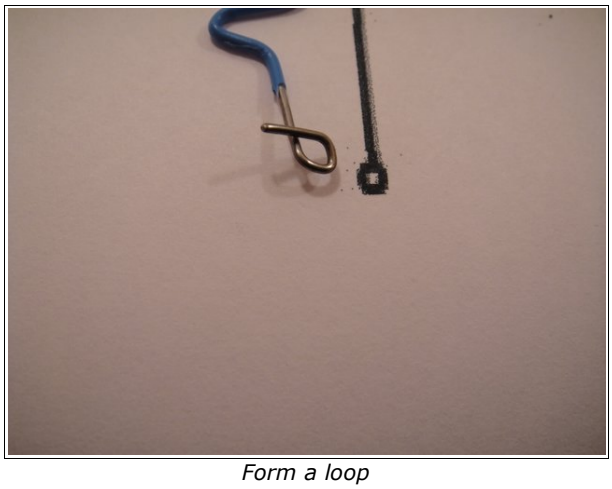
Step 5: The diaphragm rod.

Straighten another paper clip and form it into the shape of the diaphragm connecting wire, in the same way as the diaphragm connecting wire.

Strip the plastic off the end

Step 6: Strip the plastic off

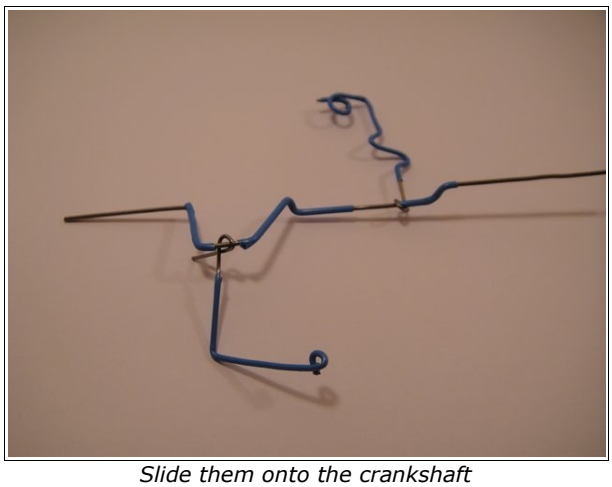
Strip the plastic off about an inch from the end, like you did on the displacer connecting rod.



Form a loop

Step 7: Form a loop

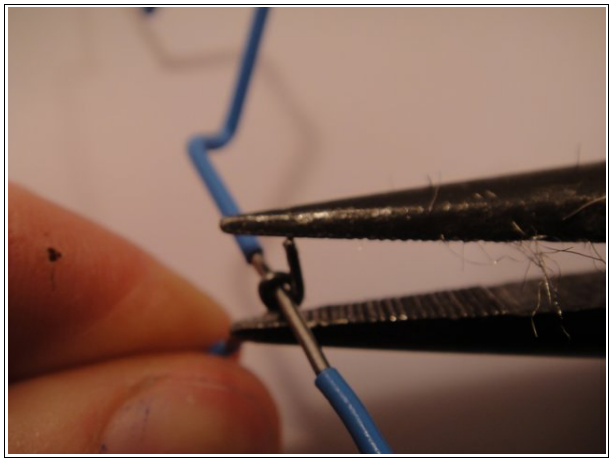
Again, form a loop to connecting to the crankshaft



Slide them onto the crankshaft

Step 8: Slide them onto the crankshaft

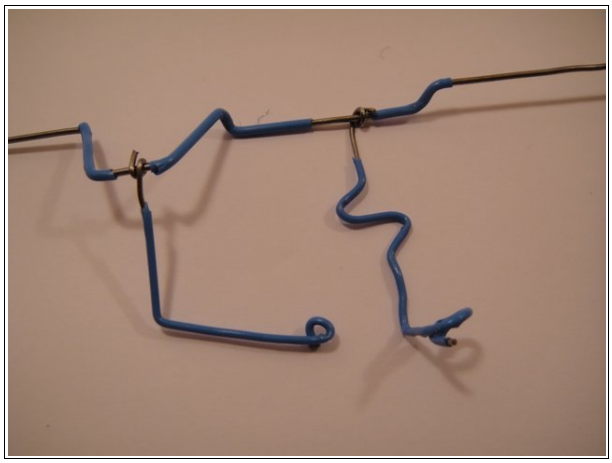
Slide the two push rods onto the crankshaft, position them where you stripped of the plastic.



Tightening the loops up a little

Step 9 : Tighten the loops

Tighten the loops so that they can't easily slide past the plastic but are loose enough to allot them to rotate easily. It's a fine balance but you should be able to get it right, perhaps after a few adjustments.



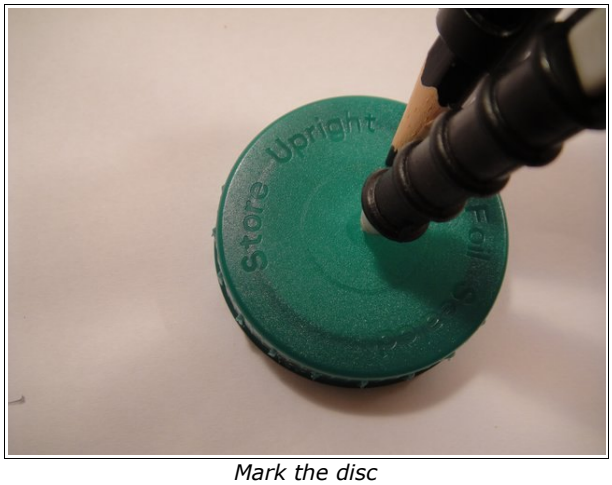
The finished crankshaft

The finished crankshaft

The diaphragm

The finished diaphragm

The diaphragm converts the pressure (or lack of) inside of the engine into the motion to turn the crankshaft. The diaphragm is made from a balloon. The balloon is sandwiched between two plastic discs which give the flexible balloon something solid to push on.



Mark the disc

Step1 : Mark the disc

Mark a circle about 15mm diameter on the top of the two remaining milk bottle lids.

Drill a hole

Step 2: Drill a hole

Drill a 4mm hole in the centre of the lid to thread the bolt through.

Cut out the circle

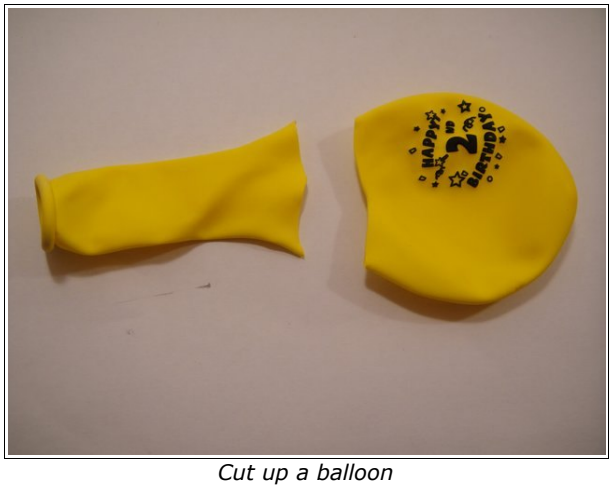
Step 3: Cut out the circle

Cut out the circle you marked in step 1. You'll now have a small plastic washer.

Repeat

Step 4: Repeat!

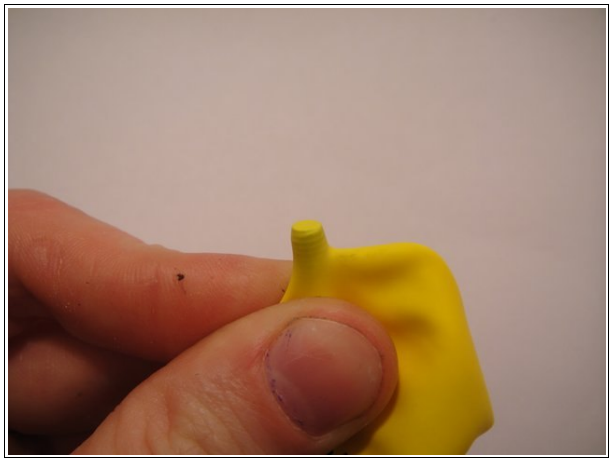
Repeat steps 2 and 3 so that you have two plastic washers.



Cut up a balloon

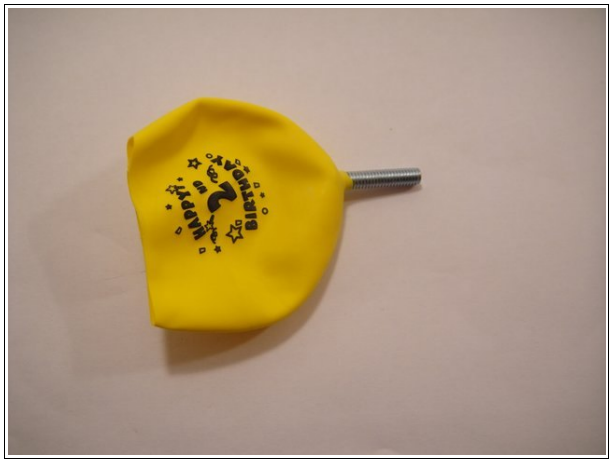
Step 5: Cut up a balloon

Take your balloon and cut the neck off.


Fit the bolt

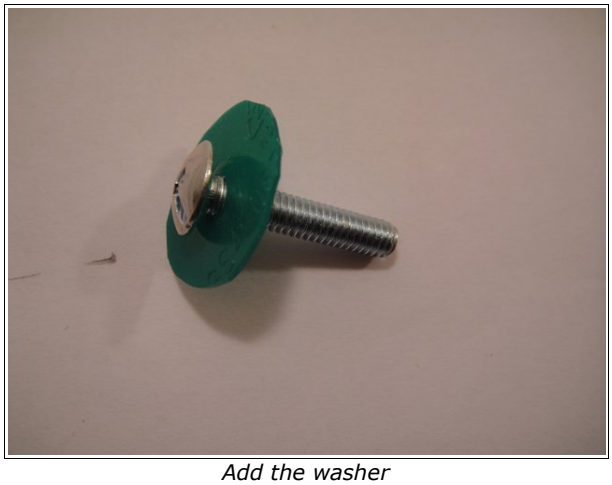
Step 6: Fit the bolt

Take the balloon and force the machine screw through the approximate centre of the balloon.



Thread the bolt through

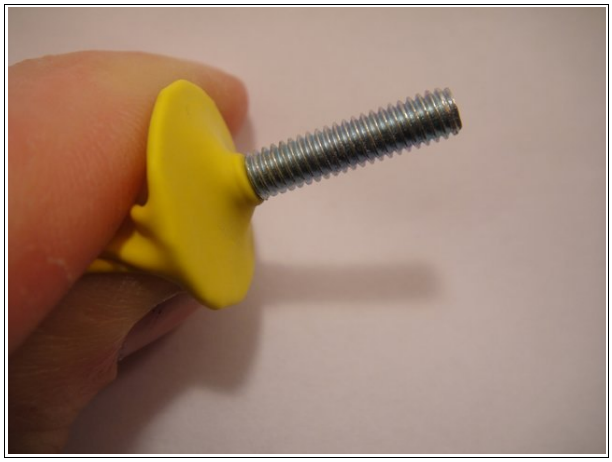
The machine threaded through.



Add the washer

Step 7: Add the washer

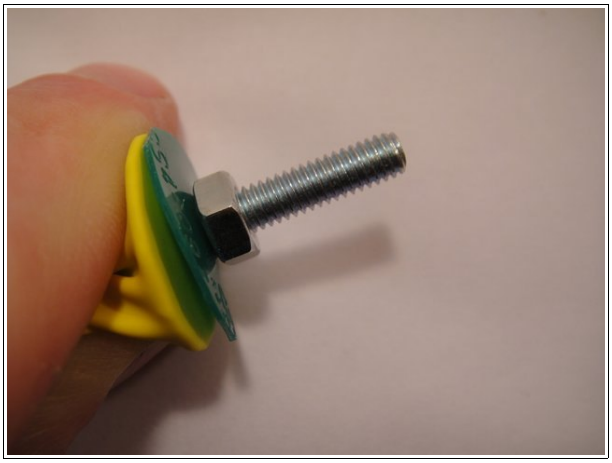
Remove the machine screw from the balloon and thread one of the plastic washers onto the machine screw.



Thread it back through

Step 8: Thread it back through

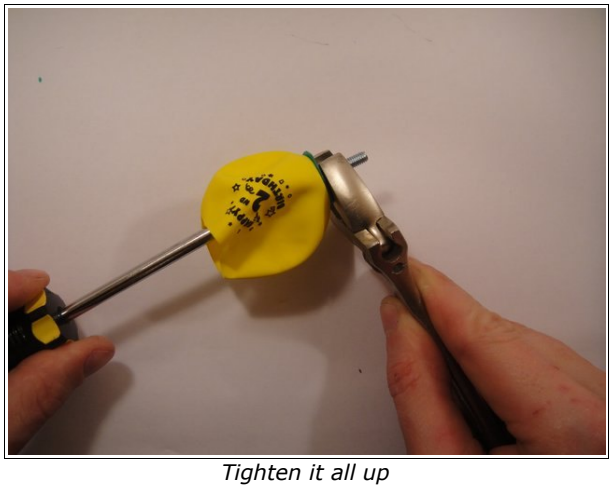
Thread the machine screw and washer back through the balloon and stretch the balloon tight over the washer.



Add the other washer

Step 9: Add the other washer

Add the other washer, then thread a nut on and tighten it as much as you can by hand.

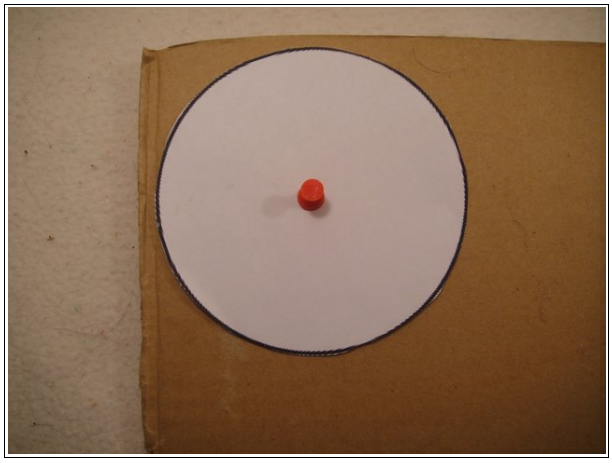


Tighten it all up

Step 10: Tightening

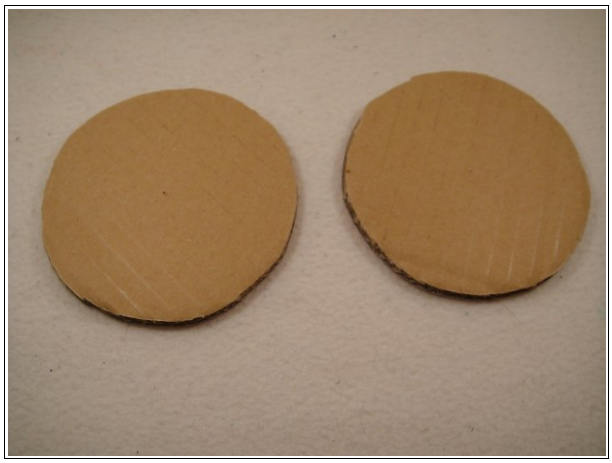
Now you can tighten it all up properly.

The flywheel



Step 1: Pin the template down

Cut out the flywheel template and pin it down to the cardboard, make sure the pin goes through the centre dot, so that the centre is marked on the cardboard.



Step 2: Cut them out

Cut out enough discs to make the flywheel thickness up to around 1cm

Step 3: Glue the discs together

Glue all of the cardboard discs together using the glue stick.

The fire tin

The fire tin is simply a coke can that holds the candle beneath the displacer cylinder.

Tape the template down

Step 1: Tape the template down

Cut out the fire tin template and tape it down.

Cut the top of the can

Step 2: Cut the top of the can

Pierce a hole in the can so that you can cut the top off in the next step, the top part of the can where it tapered inwards is needed so don't damage that.

Cut around the top

Step 3: Cut around the top

Cut around the top of the can using the scissors, keeping the top part of the can.

Trim the top

Step 4: Trim the top

Trim the top part of the can along the edge where the bevel meets the straight part of the can.

Remove the ring pull

Step 5: Remove the ring pull

Remove the ring pull from the can. This is the part that the candle will sit on.

Cut around the top of the template

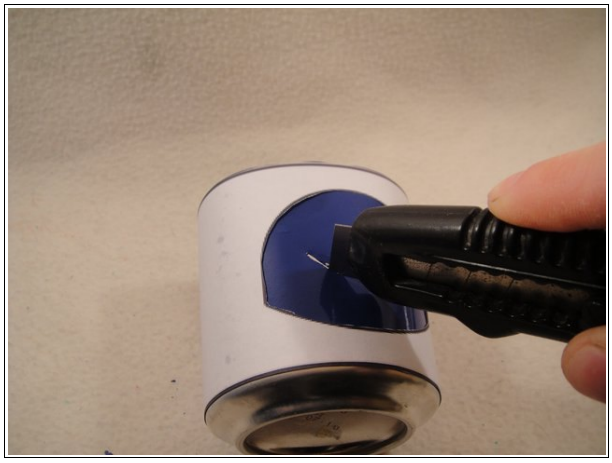
Step 6: Cut around the top of the template

Cut around the top of the template.

Push in another can

Step 7: Push another can in

Get another coke can and push it into top of the fire tin. This is to make it easier to assemble later on.



Pierce a hole

Step 8: Pierce a hole in the can

Pierce a hole in the centre of the can so you can cut out the opening for the candle

Cut around the template

Step 9: Cut the opening out

Cut around to template to make the opening for the candle.

The finished fire tin

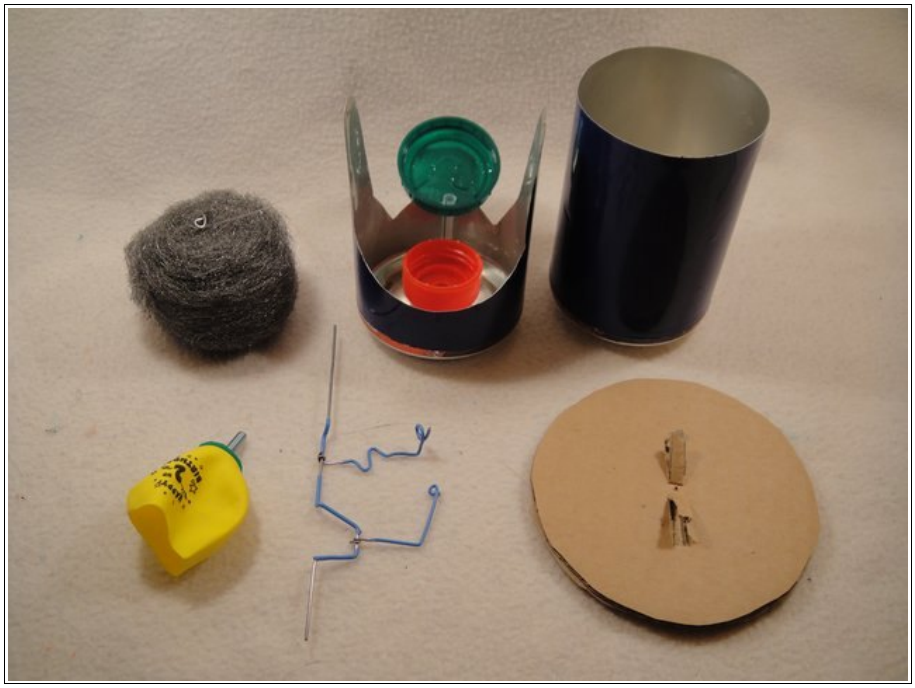
It should look like this now.

Put the candle stand in

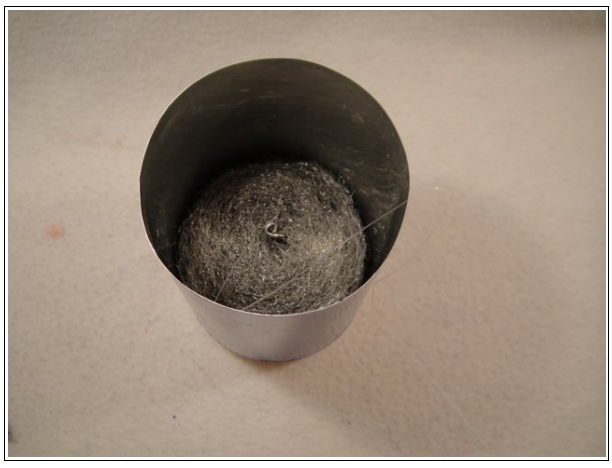
Step 10: Put the candle stand in

Put the top part of the can that you saved earlier into the fire-tin. This is to provide a flat surface for the candle to sit on.

Assembly



Now you should have a collection of mysterious parts. Don't worry, you'll soon have these parts assembled into a cool coke can Stirling engine. Take care to keep friction to a minimum by testing all of the parts as you assemble the engine, and keeping everything properly aligned.



Step 1: Fit the displacer

Put the displacer into the displacer cylinder. Check that it can be moved up and down freely. You'll always get a little bit of friction from the stray strands of the steel wool, but overall it should fall quickly and freely inside of the displacer cylinder. The hook with the fishing line attached should be facing the open end of the can.

Step 2: Thread the line through

Take the loose end of the fishing line that is tied to the displacer and thread it through the hole in the base of the top can.

Step 3: Fit the top can

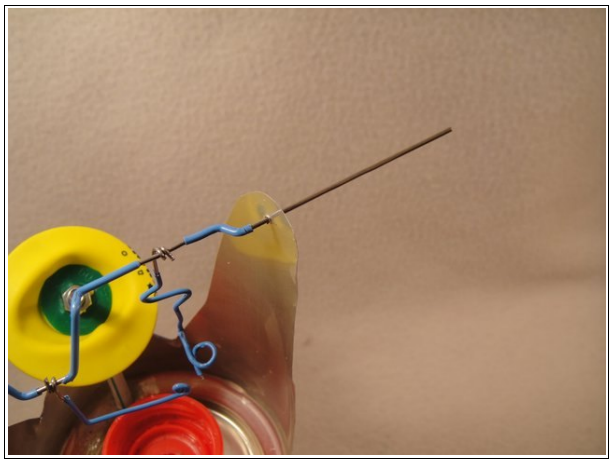
Place the top can on top of the displacer cylinder and pull any excess fishing line through so that it doesn't get caught around the edges of the can in the next step.

Step 4: Push the top can down

Push the top can about 5mm down into the displacer cylinder. This creates an airtight cylinder. Don't push on the milk bottle lid as you'll break the epoxy. Push around the base of the top can instead.

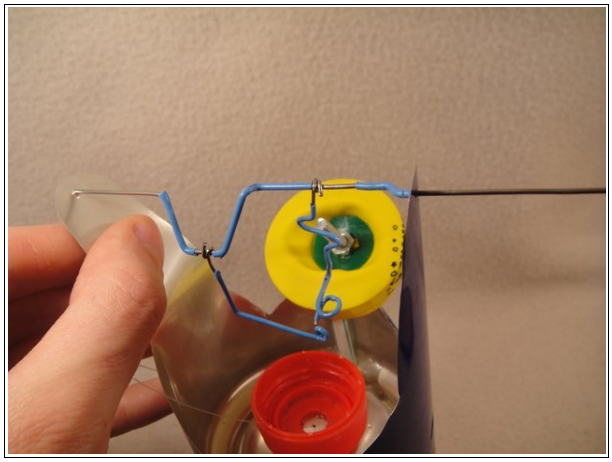
Step 5: Fit the diaphragm

Stretch the diaphragm over the milk bottle lid. The diaphragm shouldn't be too tight or too loose – the exact tension will take a little trial and error to find later on.



Step 6: Fit the crankshaft

Thread the long end of the crankshaft through one of the bearing holes, which ever side you want the flywheel to be on.



Step 7: Fit the crankshaft

Thread the other end of the crankshaft through the opposite bearing hole. You might have to bend the top can a little, to squeeze the crankshaft in. If you can't get fit it in even after bending the top can a little, then it must be too long, trim it a little.

Step 8 : Tie on the displacer

With the displacer crank arm at the lowest position and the displacer at the bottom of the displacer cylinder, tie the fishing line onto the displacer push rod. You'll probably have to double knot to prevent it coming loose later.

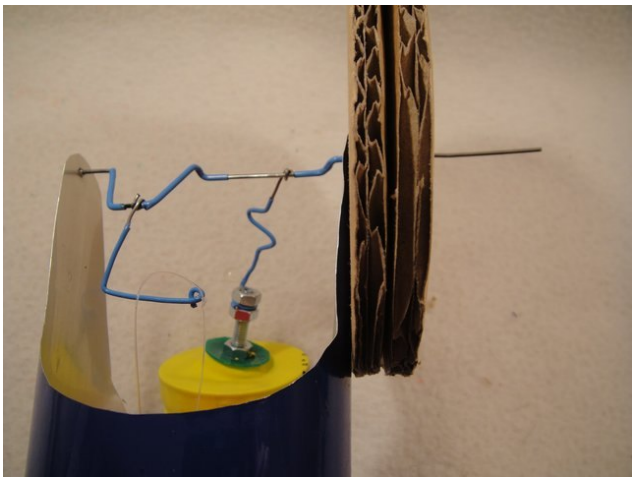
Turn over the crankshaft and check that the displacer isn't hitting the top or bottom of the displacer cylinder.

Tie the fishing line on

Bolt the diaphragm down

Step 9: Connect the diaphragm

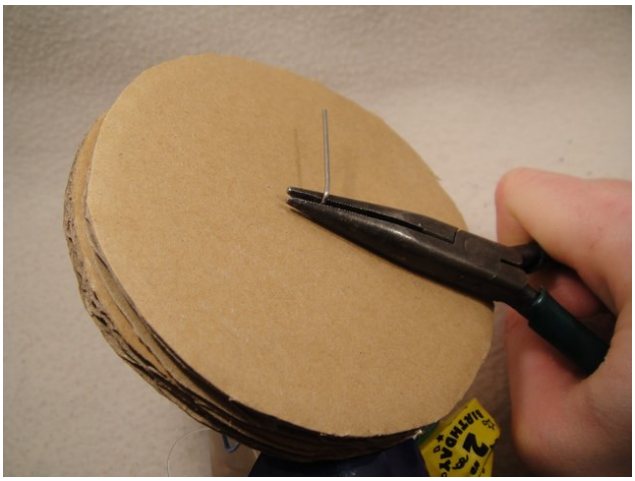
Bolt on the diaphragm connecting rod using two nuts.



Fit the flywheel

Step 10: Fit the flywheel

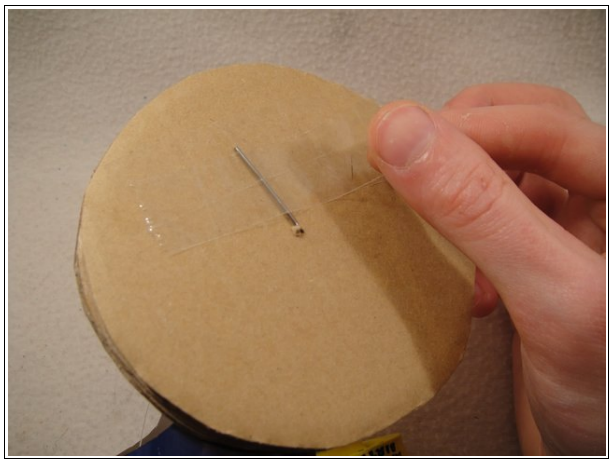
Slide on the flywheel .



Bend the crankshaft over

Step 11: Bend the end of the crankshaft

Bend the end of the crankshaft over so that you can tape the flywheel to it in the next step.



Tape it down

Step 12: Tape it down

Tape the bent piece of the crankshaft and tape it down to the flywheel.

Step 13: Push the fire tin on

Push the fire tin onto the bottom of the displacer cylinder. Try and avoid pushing around the opening as it is very weak there and will collapse.

It's finished! How to run the engine:

Light a candle

Step 1: Light a candle

To start the engine. light a candle and carefully place it in the fire tin :

Add some water

Step 2: Add some water

CAREFULLY fill the space around the lid in the top can with cold water. You MUST not get water in the lid as it will seep inside of the engine creating steam, stopping the engine working and possibly blowing the top can off.

Turn the crankshaft

Step 3: Turn the crankshaft

Leave the engine to heat up for around a minute. Turn the cranks to start the engine. I don't recommend turning the flywheel as it relatively weak, but you can use that to start the engine. The direction of rotation varies between engines, so try it both ways.

I hope you enjoy running your engine, it should be a fun introduction to the the world of hot air engines!

Troubleshooting

There really isn't much that can go wrong in these engines, so hopefully yours will be running perfectly. If you're having trouble and can't get the engine to work properly, here's some tips. There's no substitute for time spent tinkering with the engine until it works, but these tips will help you point you in the right direction.

These are the main problems you're likely to have with this engine :

An air leak : To find an air leak, submerge parts of the engine in warm water and push on the diaphragm to raise the pressure in the engine, any air leaks will be evident by the air bubbles coming out of the engine. Do not submerge the hole for the displacer wire in water, as it will leak. If you get water inside of the engine, it will not work. You can patch any air leaks using epoxy adhesive

Too much friction : The engine should rotate freely. If the loops on the bearing points are too tight, or they sit at an angle, they'll probably create too much friction for the engine to run. Make small changes to the alignment of the parts, keep testing if the engine runs between changes.

Crankshaft angle incorrect : For the engine to work, there must be a 90º angle between the displacer crank arm and the diaphragm crank arm. If the everything in the engine seems to be correct, but it will only rotate itself part of the way around, it could be that this angle is not right.

Diaphragm tension incorrect : Keep trying different tensions of the diaphragm, until you find the best performance. This is best done whilst the engine is running. You can make small adjustments to the diaphragm, while the engine is running, by pulling the rubber around the sides of the diaphragm lid.

Counterweights : Those of you who are familiar with the Stirling engine, may have noticed that I have not put any counterweights on this engine. The displacer is extremely light weight. If did not balance this engine as it is top heavy - the rocking motion from the counterweight causes the water to spill into the displacer wire hole. There was little difference between the engines I balanced and the ones that I didn't balance.