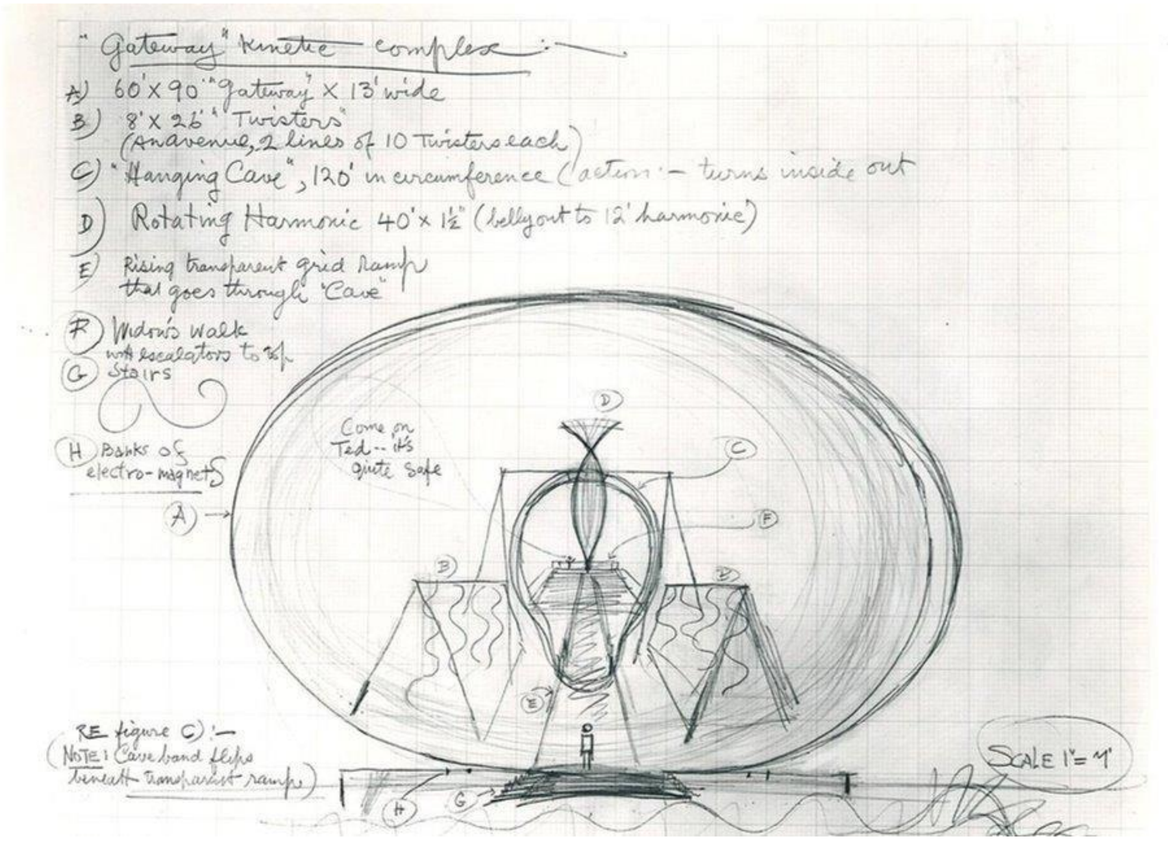
University of Canterbury Department of Mechanical Engineering

Len Lye Mini Shaker

WIECAN Workshop



January 17th 2024

Angus McGregor

Safety Instructions

Throughout this workshop, you must:

- Keep safety glasses on the whole time.
- Tie long hair back.
- Check with a technician before plugging anything into an electrical outlet.

If you need any help with these, please contact a WIECAN RA or technician at any time. There are hazards in the workshop which can be caused by yourself or others in the lab. Potentially, these might be plastic or fasteners flying, long rods vibrating near eye height, and electrical shorts.

Task Introduction

In this lab you will make a shake table similar to one of Len Lye's artworks, titled *Rotating Harmonic.*

Len Lye (1901 - 1980) was born in Christchurch, New Zealand, and his work spanned a wide array of media. He is best known for his kinetic sculptures which were first exhibited in New York in the 1960's. Over the last 20 years, the University of Canterbury has participated in the engineering design and construction of a number of Lye's most ambitious sculptures.

Rotating Harmonic was first built in New York in 1959, and can show off several energetic forms Lye called *Figures of Motion.* Over the last 20 years, the University of Canterbury Mechanical Engineering department has participated in the design and construction of a number of Lye's most ambitious sculptures. This is because these are highly complex designs which have lots of moving parts, complex motions, and highly stressed components which Mechanical engineers excel at designing.

Lye believed that if there was such a thing as composing music, then there should be a means of composing motion, and Lye thought that these *Figures of Motion* were the fundamental building blocks for his mechanical music. In Engineering, we call these figures *Harmonics*, set frequencies where a small input vibration can make a very large output.

In this workshop, you will:

- Assemble a shaker which can produce a simple-harmonic vibration
- Find several Harmonic shapes, or *Figures of Motion* using cantilevered beams called *Wands*

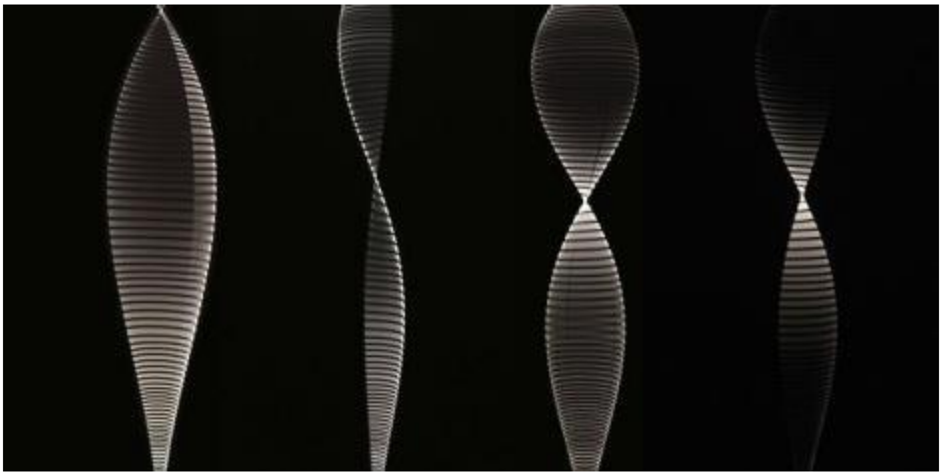


Figure 1 - Figures of Motion

Len Lye died in 1980, but left behind plans for his largest, and most physically intimidating work. Rotating Harmonic was inspirational to Lye, he intended a 12m tall version of the work, ten times larger than the version you're building today, and 1000 times more powerful.

Producing these works faithfully after Lye's death requires understanding the artists' design philosophy and intentions for the works, especially as many of Lye's works were left behind as notes and drawings for the Len Lye Foundation. The Len Lye Foundation was tasked with promoting and preserving Lye's artworks posthumously, and the close relationships between the members of the Len Lye Foundation and empathetic engineers has been essential to continue building Lye's artworks.

One of the works inspired by Rotating Harmonic is Water Whirler, which features the *figure of motion* you will produce today. Although Lye never built a version or Water Whirler, a 10m tall Water Whirler was produced in 2003. UC students helped build a prototype, and proved the artwork was possible to make at large scale. Water Whirler was overhauled by UC in 2019.

In 2000, another UC student designed and built *Big Blade*, a 4 meter tall Titanium plate which can shake the ground 50 meters from the artwork, and stares down the viewer as its vibrating blade pounds away at a cork ball. Lye thought this should stand anything up to 30 metres high and reflect light "like an Aztec monument to the sun".

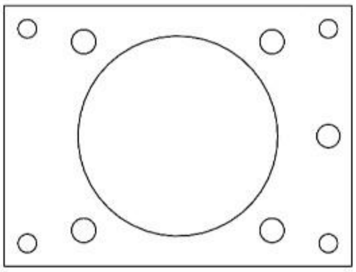
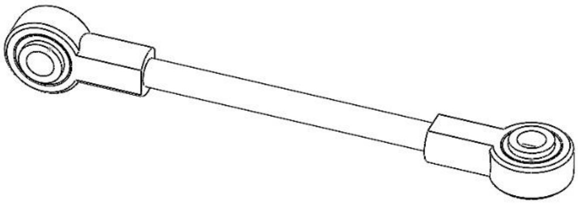
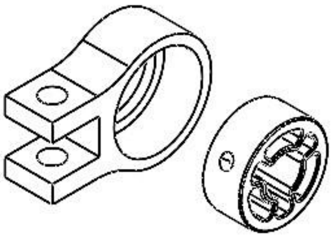
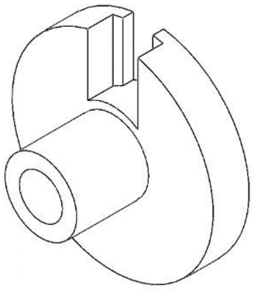
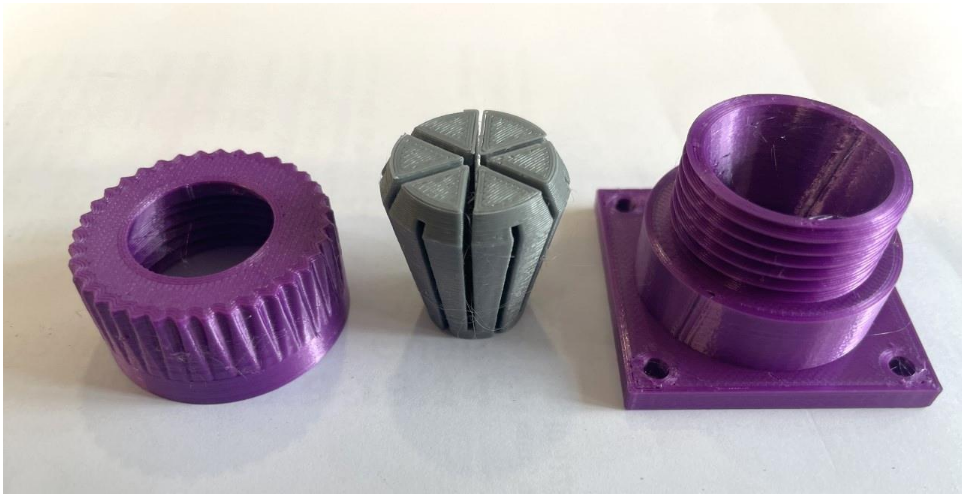
Figure 2 - Water Whirler, producing the 'whirling' mode on the Wellington Waterfront

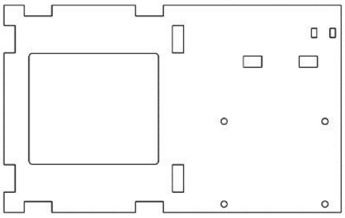
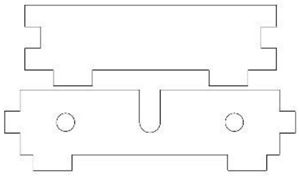
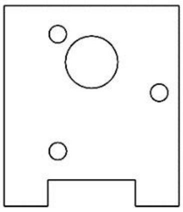
Figure 3: Big Blade in the Christchurch Botanical Gardens (2000)

UC engineering is continuing to work with the Len Lye Foundation on its goal of producing 10 new works over the next 10 years.

Equipment

In this lab, you will need:

Shuttle	
 1 x shuttle board	 1 x driveshaft (1 x M4 threaded rod, and 2 rod ends.)
 4 x bearing housings and inserts	 1x crankshaft
 1 x clamp (screw top, collet, clamp base)	

<table>
<tr><th colspan="2">Frame</th></tr>
<tr><td>
1 x base board</td><td>
2 x shorter side panels,
2 x longer side panels</td></tr>
<tr><td>
1 x motor mounting plate</td><td>
2 x Guide rails (M6 bolts and nuts)</td></tr>
<tr><th colspan="2">Electronics and Fasteners</th></tr>
<tr><td>
1 x motor</td><td>

1 x motor driver board</td></tr>
<tr><td colspan="2">
1 x power supply</td></tr>
</table>

	6 x M4 nuts 6 x M4 screws 8 x M3 nuts 4 x longer M3 screws 7 x shorter M3 screws

Assembly

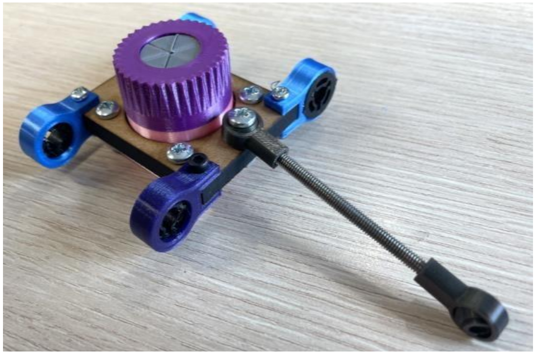
Shuttle

1. Thread two rod ends onto the threaded rod to make the driveshaft. If it's quite stiff, use pliers to hold the rod.

2. Snap the four bearings into each bearing housing. These should go all the way down. One side of each bearing may have a lip, so be careful which way you press these in.

3. Screw bearings onto the four corners of the shuttle board using 4 x longer M3 screws and 4 nuts. Make sure these are fastened tightly.

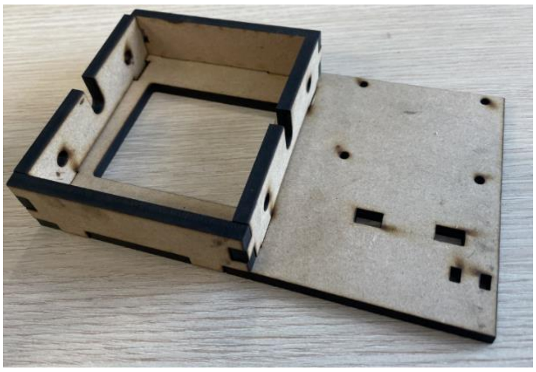
4. Assemble the clamp bottom, collet and top. Screw this into the shuttle board using 4 x M4 screws and nuts.



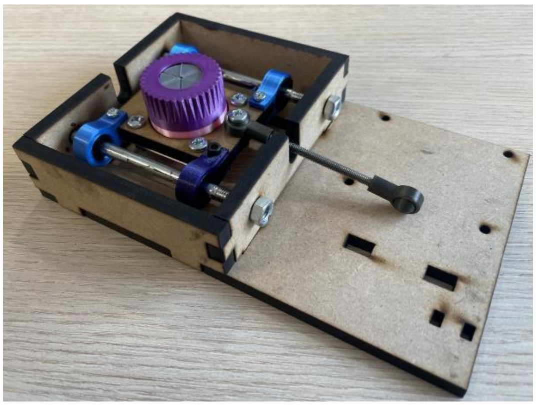
5. Bolt the driveshaft onto the front of the shuttle using an M4 screw and nut. Make sure the flange on one rod end is pointing down.

Frame

1. Snap the four sides into the base board. These may be reasonably firm to assemble.



2. Holding the shuttle in position, push the 2 long M6 bolts through the holes in the side plates, and through two bearings on each side.

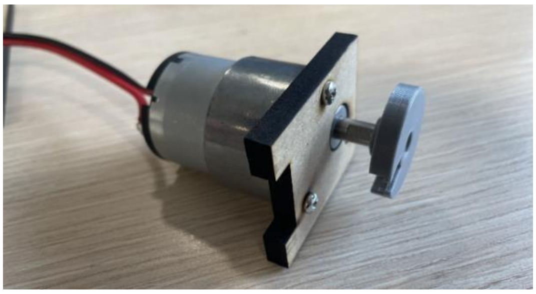


3. Fasten the M6 bolts using two M6 nuts. Check the shuttle can slide forward and backwards easily.

Motor

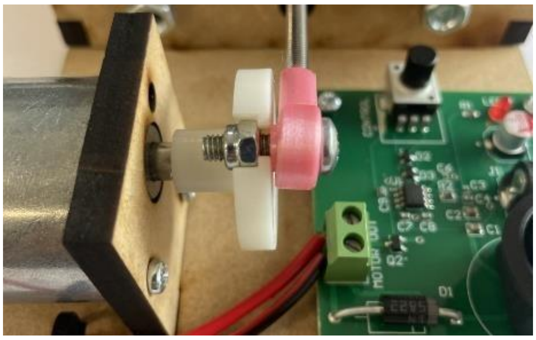
1. Screw the motor to the motor mounting plate using 2 x shorter M3 screws. Check the motor spins freely after screwing it in. Using longer screws may prevent the motor from spinning.

2. Then, press the crankshaft onto the motor shaft. The crankshaft is quite stiff, and needs to be pressed most of the way on. Ask if you need help with this!



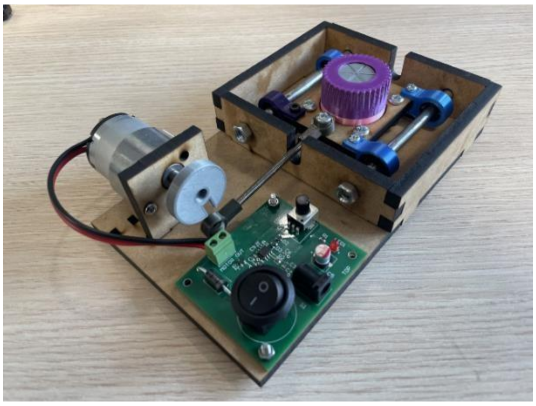
3. Screw the motor driver board gently onto the base board using 4 x shorter M3 screws and nuts. Then, push the wires from the motor into the two green terminals on the motor driver board and tighten these down. It does not matter which way around these go. Finally, snap the motor mounting plate into the base board.

4. Screw the other end of the driveshaft to the crankshaft, using an M4 screw, and the M4 nylock nut. This will prevent it from rapidly loosening.



5. Check the motor mounting plate is relatively firm so the motor will stay in place while the mechanism is running. If it wobbles easily, it’s time for hot glue.

6. Show a technician before connecting the power supply.



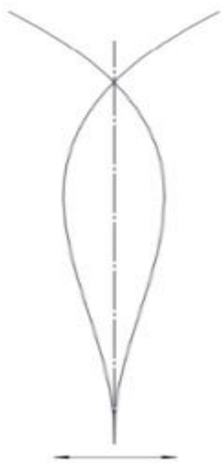
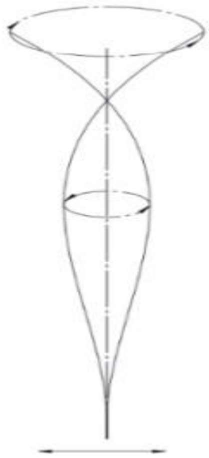
Congrats! You’ve built the shaker!

Producing Figures of Motion

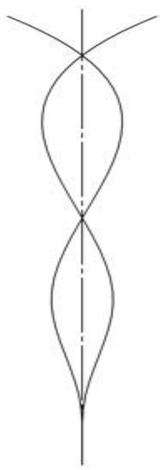
The technician should give you a short wand and a longer wand. Push the longer wand through the collet and tighten it down. The wand should be difficult to pull out, try inverting the collet and retightening if you can't get it tight.

The longer wand should be able to make 2 distinct *Figures of Motion,* which correspond to the 2nd mode resonance frequency of a cantilevered beam. On the motor driver board, there is a knob which controls the motor speed.

- Adjust this knob and see if you can obtain each of the following forms.
- How large can you make the amplitude of these forms?

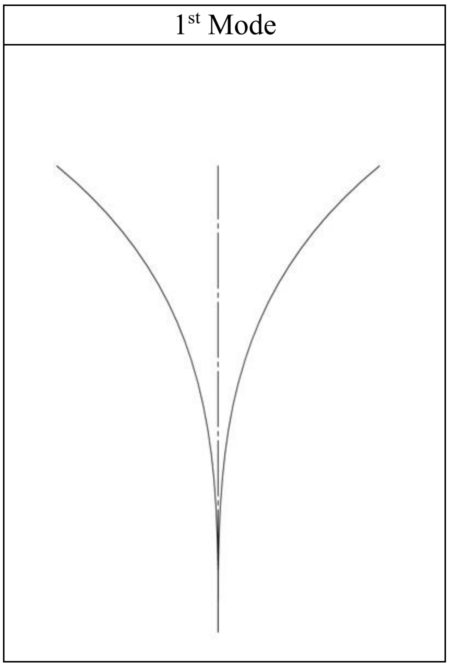
2nd Mode (Planar)	2nd Mode (Whirling)
	

If you turn the motor speed up to maximum, you might notice a different shape starting to form. We could produce a large amplitude version with a slightly faster motor, but this will break the pole.

3rd Mode


The shorter pole should produce the 1st mode resonance frequency.

- Attempt to obtain the planar and whirling forms of this mode, like you did the 2nd mode.



There are an infinite number of these vibratory modes, and each mode is associated with a particular input frequency.

- What do you think the 4th mode resonance frequency might look like? Can you draw this shape?

- Why do you think the shorter pole only makes the 1st mode (and maybe the second), but the longer pole can make the 2nd (and 3rd modes)?

- What do you think would happen if a building was vibrated at a resonant frequency, and how might you prevent this from happening?