Lab Book Part III Project 2021/22

Measuring surface tension

BGN: 8266X

(14/05/22) There are large gaps in this document towards the end as the majority of the time was spent on writing the report. I've uploaded some files to https://github.com/8266X-ptIII/PartIII-project also.

(16/05/22) - I also kept a physical notebook. This mostly contained notes from meetings and diagrams from the initial design stages as well as diagrams while leant to use surface evolver. I have included some of the pages from this book here.

16/10/21 - Created file structure and Latex templates.

- Ensured that all work will be backed up to drive (14/05/22 - doing this was such a good idea)

19/10/21 - Investigating image analysis in python

- Scikit-image
    - Free
    - Does appear to be used in other publications
    - Lots of filters including edge detection
- Thinking about it engage may work depending on the data
    - Would allow export of CSV.

24/01/22

- Met Pietro
- Discussed possible solutions
- Discussed open-source microscope as a possible option
- Discussed challenges with using an inverted microscope
- The importance of pure water and how to obtain

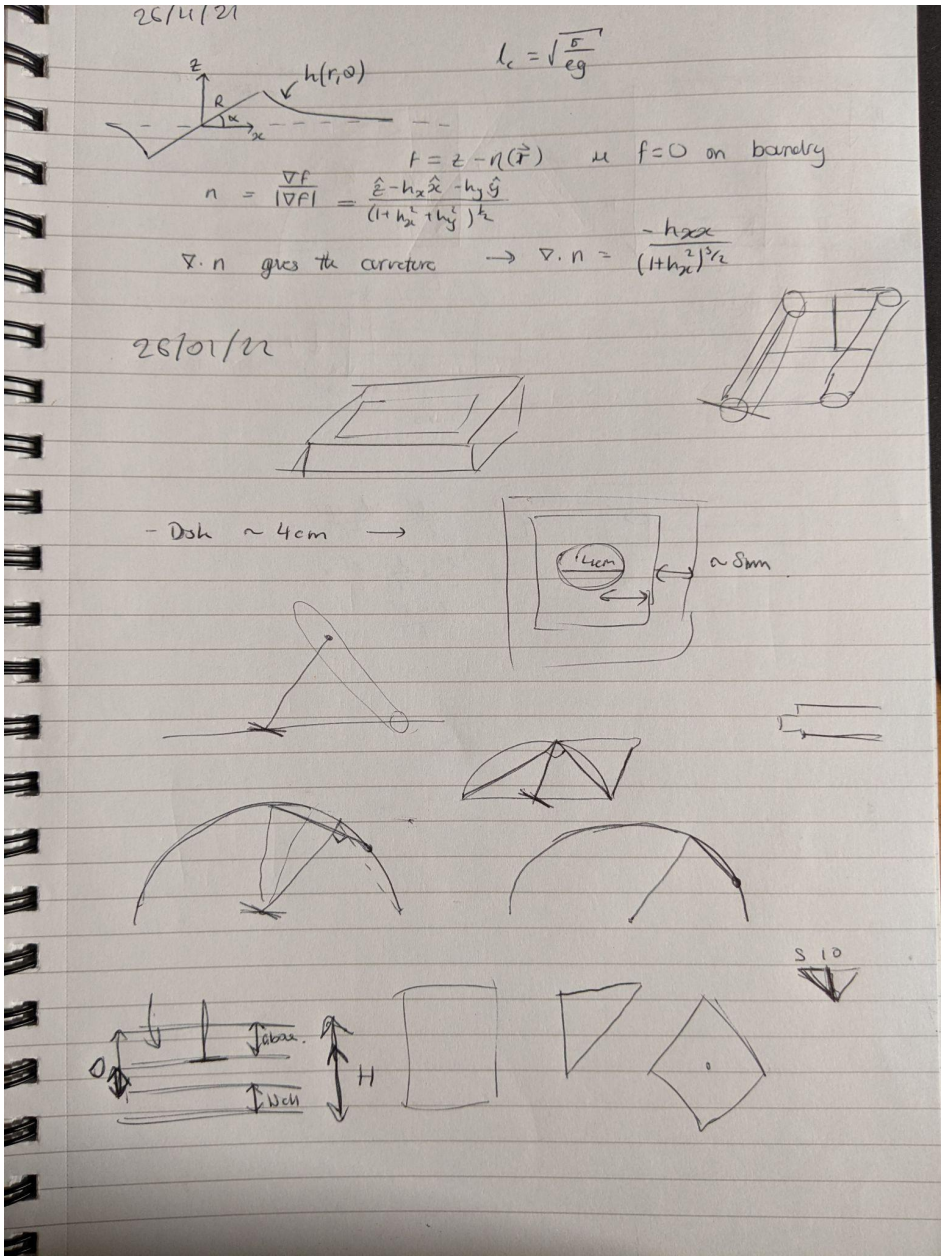
- Met with Samuel to get some knowledge in OPENscad and cura
-

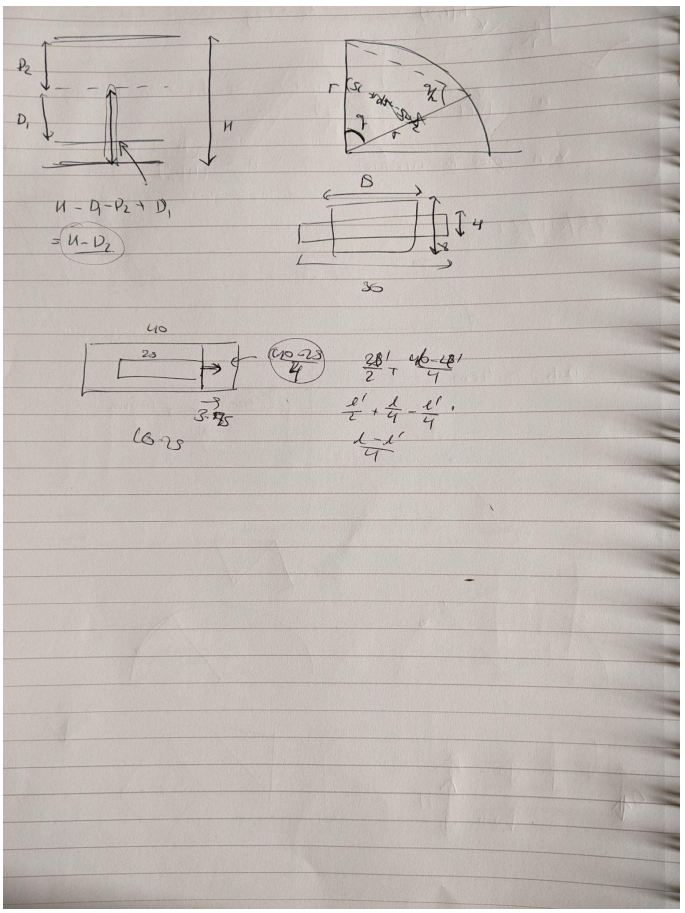
25/01/22

- Worked on setting up an environment for coding OPENscad
- Downloaded and opened cura

26/01/22

- Began work on the model
    - A simple model of the device
    - Had an idea to use a lead screw to define the angle of the disk. With known threads per mm can use to determine the angle of the disk
    - Also use a hard stop for the 90 point
    - This would also allow easy use of a motor to control the angle as easily attach to the screw to change the angle

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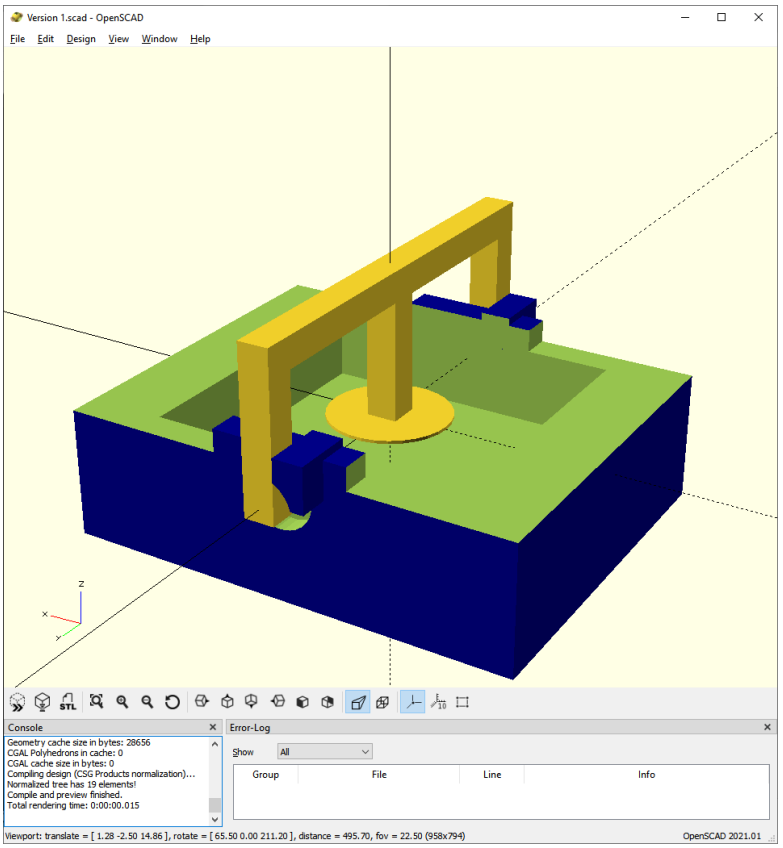
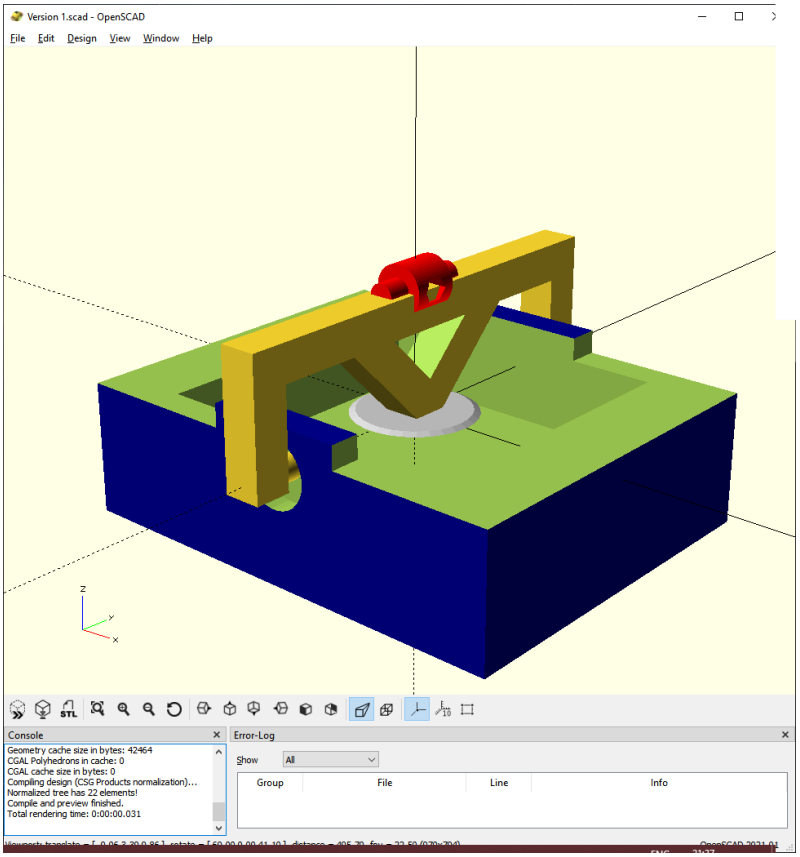

Version 1.scad - OpenSCAD
File Edit Design View Window Help
Console
Geometry cache size in bytes: 28656
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized tree has 19 elements!
Compile and preview finished.
Total rendering time: 0:00:00.015
Error-Log
Show All
Group File Line Info
Viewport: translate = [1.28 -2.50 14.86], rotate = [65.50 0.00 211.20], distance = 495.70, fov = 22.50 (958x794)
OpenSCAD 2021.01

- 

- Also looked into the diffraction method - didn't make much progress but did explore the git repository for Matlab that could work - need to explore further. (14/05 - This was the code that I ended up using throughout the project)

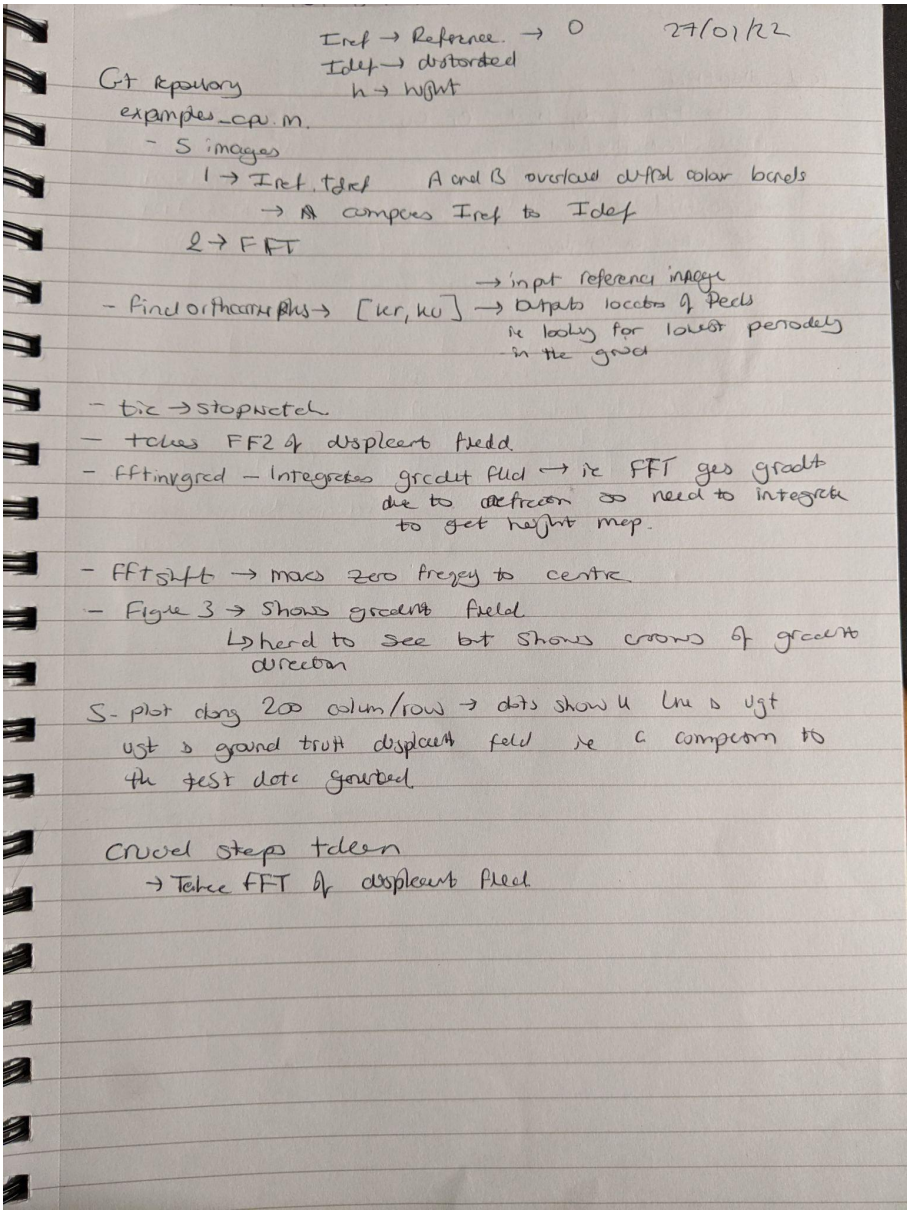
Trough ow	120mm
Trough iw	100mm
Strut heights	50

27/01/22

- Downloaded the models from the original paper and was able to open them so can compare their design features to mine.
- More work on the initial model
    - Think need rubber bands to remove backlash
    - May need to work on a system of measuring the angle of the disk
    - Also need to check the reproducibility of the disk movement system possibly using the difference in images taken from a static camera.

- More work on the git repo
    - Downloaded Matlab and got their code working
    - Spent time deciphering their code and algorithm

    - Had thoughts on needing to image the grid without water then with water but no displacement than with displacement
    - Spent time researching the paper that accompanies this code to get a better understanding of the algorithm



- Asked sam for help doing some initial printing and buying hardware.
    - Sam required a list of hardware
        - Stepper motor and someway to drive it
        - 4x 8mmx22mmx7mm ball bearings
        - M4 hardware
            - Some nuts and threaded rods

        - Whatever glue you recommend to attach 3d prints together
            - Maybe also some epoxy to join 3d prints to metal etc
        - Generic screws of various sizes etc
        - Will also need some spirit level (small) type things

28/01/22

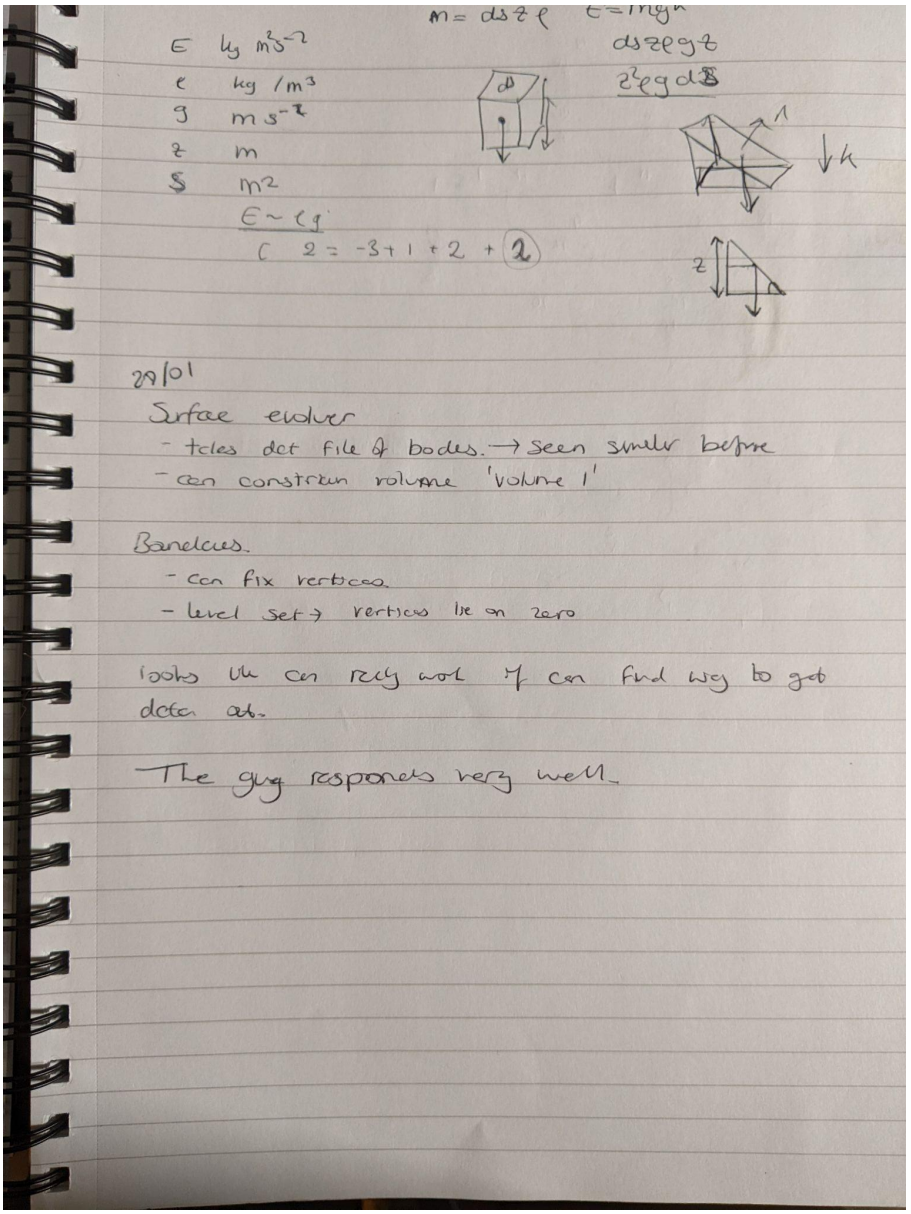
- Coded up Dominic's solution in python
    - Put in realistic parameters for water and the disks
    - Difference to 0 of the meniscus was 0.001cm within 2mm of the disk and 0.0006cm in 4mm (alpha = 0.1)
        - Ie the curve decays very rapidly of the order of the capillary length
        - Large values of alpha meant the curve took longer to decay (4mm -> 0.001cm for alpha = 0.2)
        - So considering probably need a range of a few tenths of a radian (small-angle approximation) then need of the order of maybe 1cm around the disk at least to ensure that the boundary does not affect and likely a few l_c due to the effect that the boundary might have on the meniscus at the disk
        - So ~15mm maybe around the disk.

- Played around with surface evolver
    - Definitely could work as a method of modelling the surface and then comparing to dominics solution
    - Difficulties getting the data off
    - Emailed the creator who is really helpful and would likely help in future if stuck
    - Managed to get this working and data off
        - Found a git repository of some code to turn the dumps into visualisations which might help in extracting the data.

- Saw another 3d printing surface measurement device
    - Used contact angle measurements
    - a 3d lab jack to adjust the height of the drop to the camera
    - https://pubs.acs.org/doi/10.1021/acs.jchemed.1c00098

- https://www.sciencedirect.com/science/article/pii/S0169433221009545
    - Focus on nanofluids and two-phase systems
    - Based on the ring method but used a conventional balance as a force sensor
        - This is possibly an option that could be explored in this project but would need to calculate the expected force on the disk

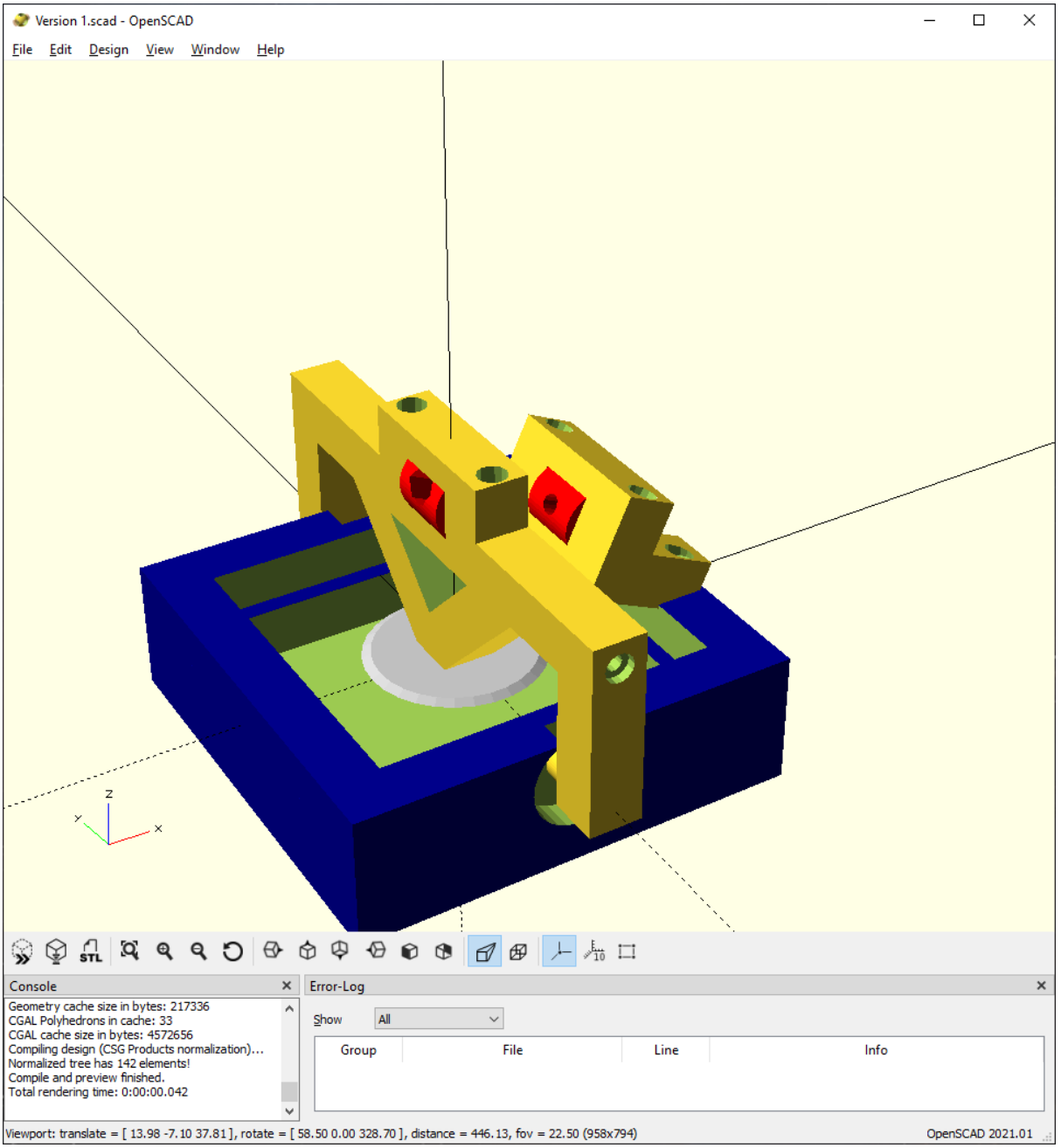
- https://pubs.rsc.org/en/content/articlehtml/2021/nr/d0nr08787d
- https://www.sciencedirect.com/science/article/pii/S2351978921000524

- https://link.springer.com/article/10.1007/s11340-021-00720-x
    - Using surface evolver and the 3d printer as an extruder of the fluid to be measured
- https://aapt.scitation.org/doi/figure/10.1119/1.5081051
    - Using the checkerboard pattern with water waves
- https://srd.nist.gov/jpcrdreprint/1.555688.pdf
    - Good reference data for water
- 

29/01

- https://all3dp.com/2/waterproof-3d-print-pla/
    - Some info on waterproof printing

- Limited information on how to condition 3d prints to limit the leaching or materials into the water or how big of a problem this might be.
    - Certainly going to need some acetone

- Worked more on the initial design
    - On sams recommendation have added screw holes to bond together
    - Also hoping that these will act as references to key parts together but this will need to be tested
    - Need to add places to add rubber bands to remove backlash
    - Possibly will in future reduce the overall volume of the thing as fluids can be expensive
    -
    - 

30/01

- Did a lot of work gaining more skills using surface evolver and getting my own models working

31/01

- More work in surface evolver
- Doing some research into which filament might be best for the job
    - Strength isn't really a concern but want little flex to ensure geometry is stable
    - Want chemically stable and won't leach into the water
        - https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0217137
            - Some information but not sure how relevant
- Met with sam
    - Discussed changed to my model that would help to improve the design and 3d printability of it
        - Importantly the idea of flexure (research needed) came up as an alternative to the pivot arrangements I had. This is good
        - Made my first 3d print of the disk support as a test and verification of the size of things this will help inform other information on how to proceed
        - https://aip.scitation.org/doi/10.1063/1.4941068
        - Also discussed a motor that sam has spare that would work well and will start designing a model to accommodate this motor
        - Will consider this the end of version 1 and start modelling version 2 as will make significant changes.
- Need more space in the lab

Disk measurements - rough / mm These are just for making the prints. Likely better measurements of the diameter will be taken depending on the errors but I expect these to be more than close enough for now considering the printer resolution is ~0.1mm

Thick 0.87
0.86
0.87
0.88
0.87

Diam
48.30
48.24
48.28
48.29
48.30

Hole
3

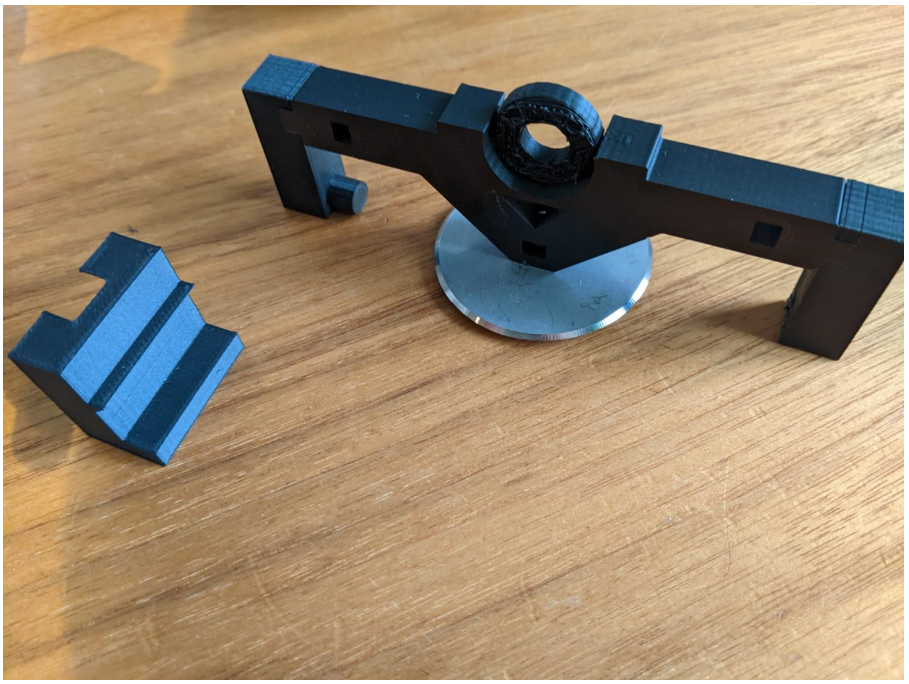
-https://www.sciencedirect.com/science/article/pii/S0141635914000312#fig0005

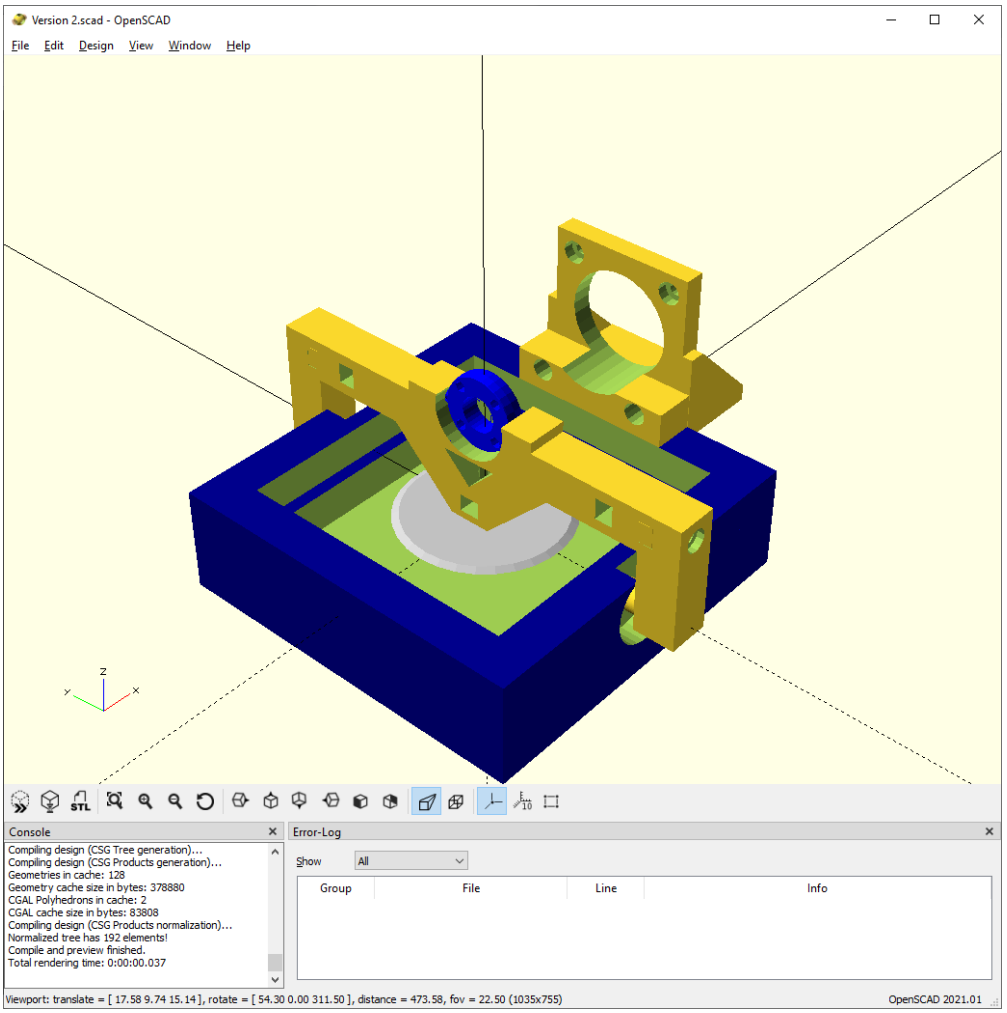
01/02/22

- Met Pietro
    - Generally pleased with the progress
    - He made the suggestion of a magnetic rotary encoder this is something that I will build in as this is a great idea
    - Discussed the many application of the device
        - Oscillating the disk
        - Jerking the disk
    - Maybe change the boundary condition to be a concentric circle but possibly make this an interchangeable part so that different outer boundaries could be tested.

- Printed test flexure
    - 2.5mm diam and 5mm length for the flexible portion
        - Had good flexibility but possibly too weak. Likely need less flexibility but a little more strength might be an idea so will increase the diameter
        - Fitted 5mm square into 5.5mm hole this was a good fit when the brim was left but poor, once the brim was removed so, will likely move down to 5.2 mm for the next test.

-





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- An updated design showing the new motor mount and the flexible nut structure.

    - This has simplified the design
    - The way the code is written it is very easy to change both the nut and the motor depending on how this hardware ends up.
- Also increased the overall dimensions of the device as the disks were slightly larger than expected.
- https://3dprinterly.com/how-to-make-your-3d-prints-waterproof-airtight/
    - Discussion on how to make prints watertight
        - 3 wall layers
        - 4-6 bottom layers

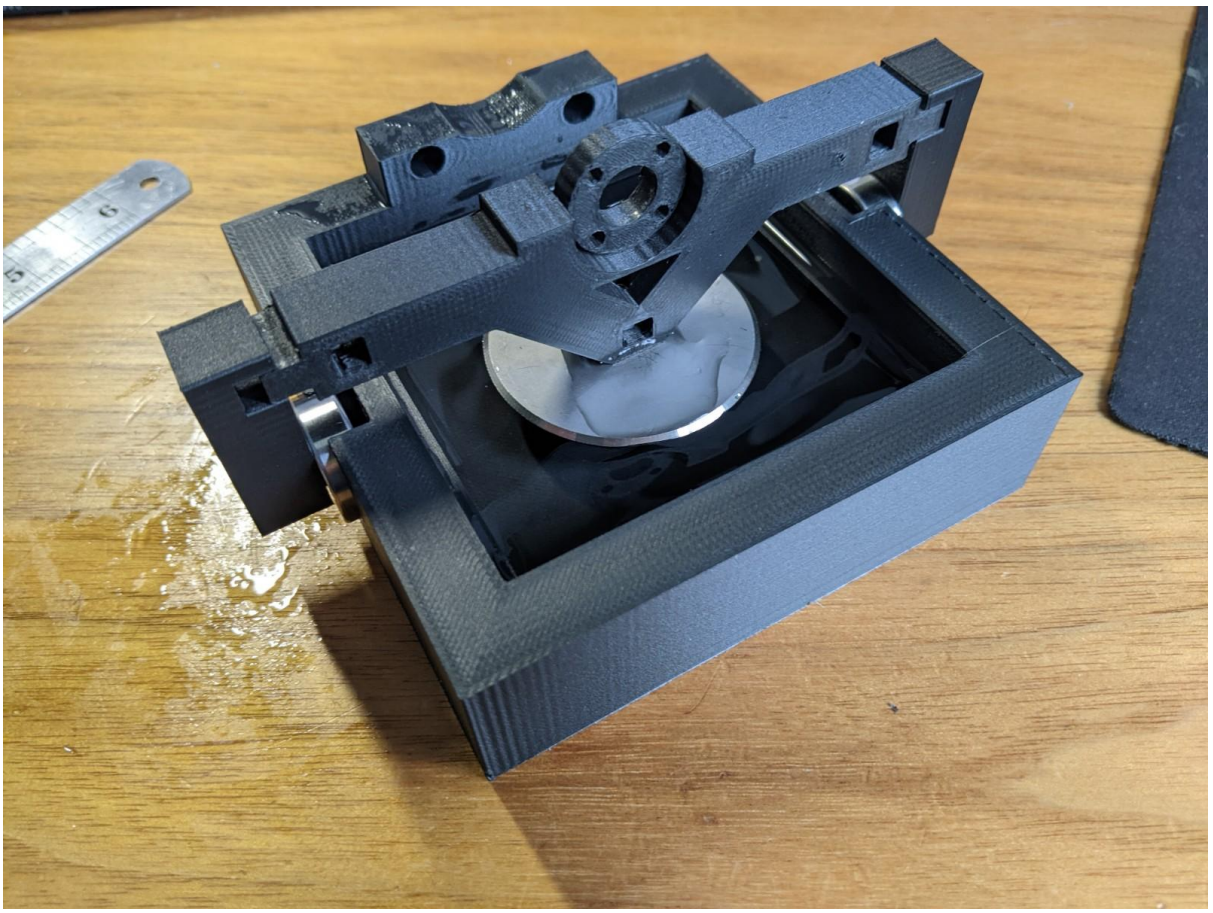
- Pietro also gave me some more books and some focus on the research.

Physics and chemistry of interfaces - Butt and Graf

- Chapter 2
    - Quotes water ST ~71.99 @25C. Also has some other values.
    - young -Laplace = deltaP = gamma(1/r + 1/R)
    - R and r are the radii of curvature (max and min at a point)
    - P 14-16 discusses some of the methods to measure ST
    -

  Chapter 7
    - Contact angle equation
    - Capillary rise

Photo of the current implementation filled to test the water retention of the trough



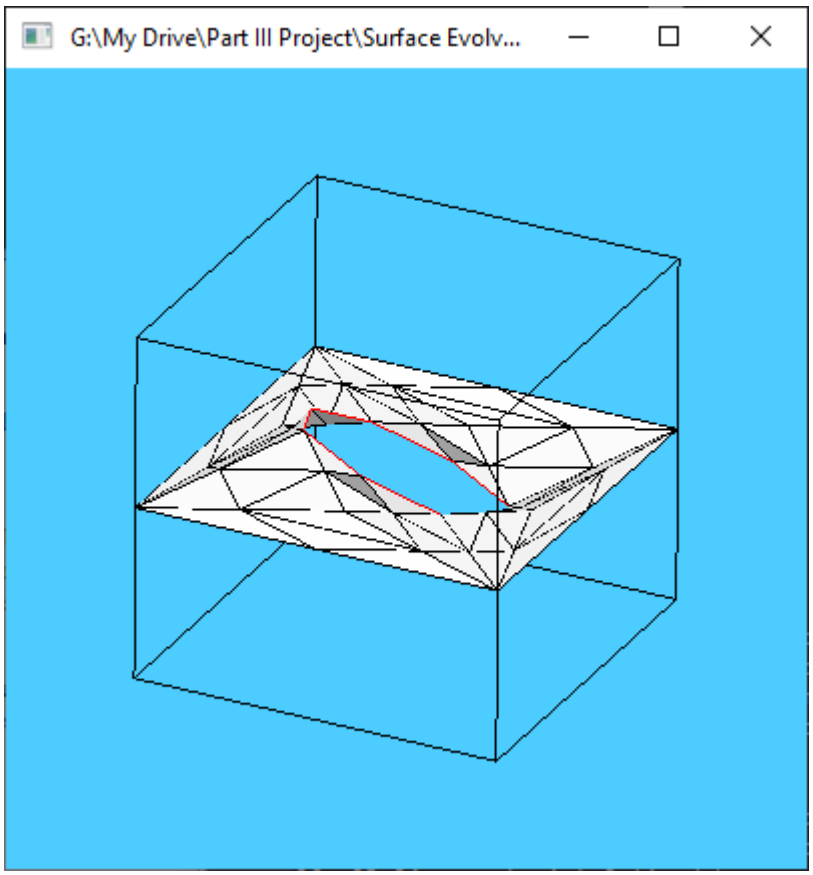
02/02/22

- Printed the disk support again TODO(add photo). There were some issues
    - Bearings too tight in the trough
    - The union between the vertical and horizontal support was not large enough so made larger also moved some of the captive nut areas for the shorter screws

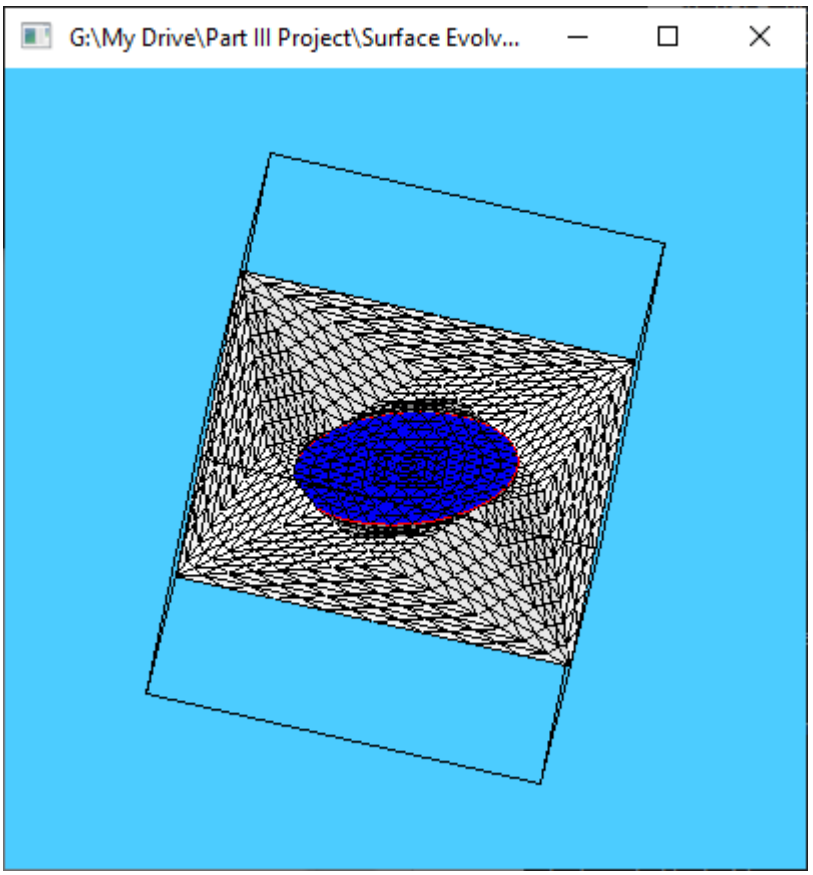
    - The flex appeared to work really well and printed better than expected
    - Disk secures nicely to the bottom
    - Bearing fits are close
    - The fluid lip printed well

- Made some changes and printed the first print of the trough (5hours)

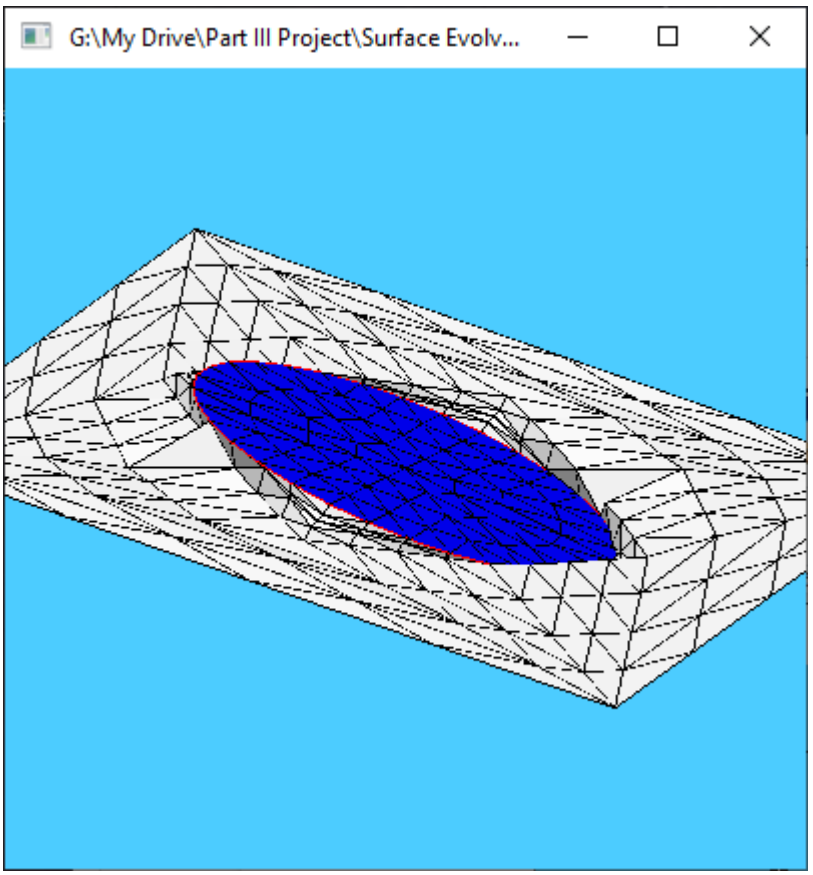
- Also spent more time in surface evolver on some revelations on how it worked last night
    - Found more documentation now saved
    - Began making a model for the final implementation

- 

- Shows the basic structure of the model
- Initially made from the capillary.fe demo document but removed the surface tension and made it into a square for simplicity and testing my understanding
- Now implemented a square in the centre. This is done by making the surface shown out of 4 trapeziums with parallel sides being one outer edge and one inner edge of a square
- This inner square then has the constraints that confine these edges/vertices to the edge of the tilted disk
    - Dominic's solution came in handy here with his definitions
- Running it doesn't work yet

- 

- Made some more progress
    - Learnt more on how redefining works
    - Increased the central square to an octagon to hopefully help there
    - Still having issues

- 

03/02

- Got a servo running on an Arduino as proof of concept
- Crucially fixed an error in the height of the disk that was previously made although this may get changed
    - The discussion is whether to have the 3d element of the disk above or below the water line currently above but could be moved below? - this might just be something that has to be tested when getting a microscope involved
- https://www.youmagine.com/designs/28byj-48-step-motor
    - OpenScad of motor that might work
- https://www.thingiverse.com/thing:64008/files
    - For Arduino boxes

04/02

- More prints of the device
    - Mounted servo to trough
    - Made a coupler from servo to the screw
- Looking at the image above with fresh eyes this might not be as inaccurate as I thought as something very similar happens in the real device

- Had the interesting idea of attaching a grid to the disk and then using the microscope to image and determine the angle this is pretty standard and documented extensively.

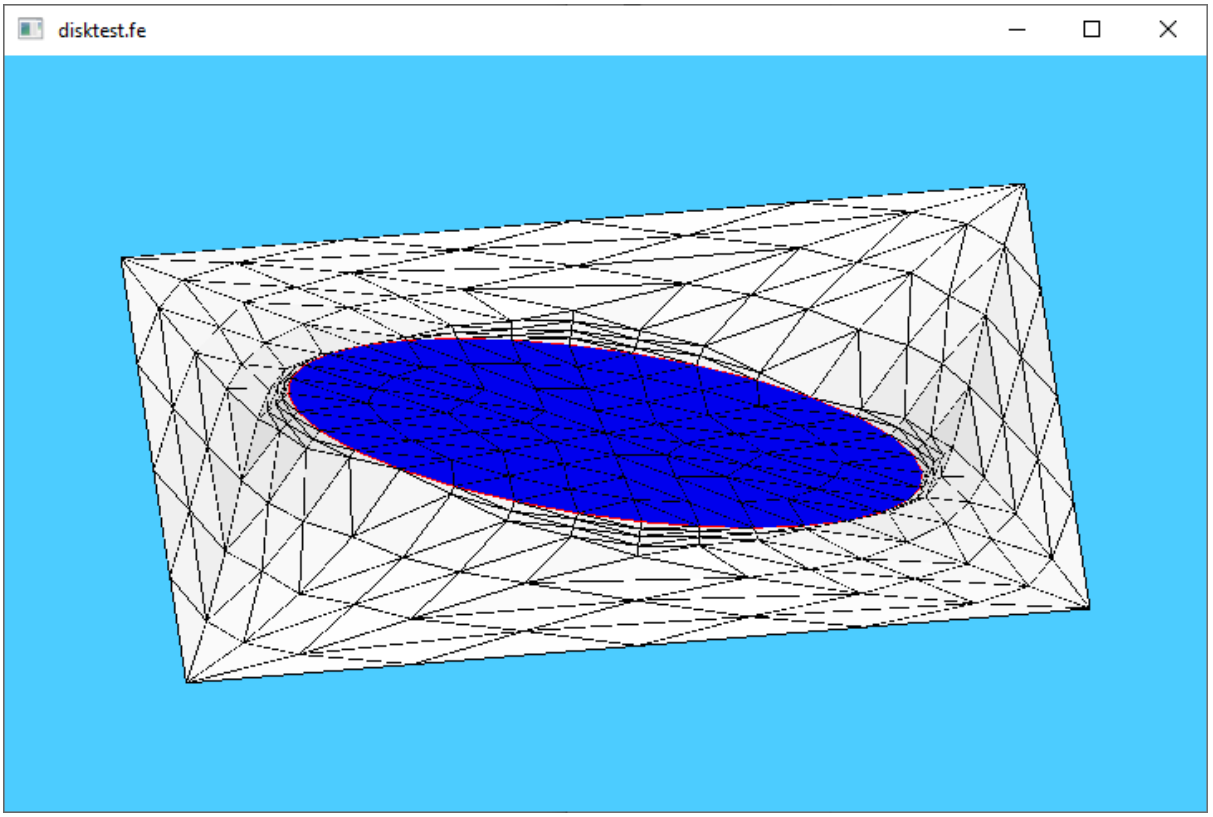
- Looking through: https://link.springer.com/article/10.1007%2Fs00348-018-2553-9
    - smallest relevant wavenumber in the physical signal ks should be smaller than half the distance between the carrier peaks Δkc in k-space, that is, ks<12Δkc.
    - Roughly, the first criterion says that the lattice spacing in the background pattern should be smaller than the smallest wavelength in the physical signal
    - Ie we are going to need a very small lattice
        - This does work with random noise and the printer can print to 0.1mm maybe
    - According to condition (9) it is advantageous to design a pattern with a wavelength which is as small as possible so that the peak spacing in the Fourier domain is as large as possible. However, the finite sampling resolution of the digital image sensor of course puts a lower bound on this. According to the Nyquist–Shannon sampling criterion, aliasing occurs for a perfect sine wave when its period is smaller than two times the sampling rate, that is, smaller than 2 image pixels. To additionally prevent aliasing of the superimposed modulation signal, a minimum pattern wavelength of 2+2–√≈3.4 px would be required for an ideal sine wave background pattern (such as in Fig. 2). However, it is often not easy to produce a pure sine wave background (one needs a properly calibrated printer for example), so that a significant signal is present in higher-order carrier peaks [i.e., amn≠0 for m,n>1 in Eq. (2)]. In practice, pattern wavelengths above about 6 px work well. Together with the magnification of the optical setup and the camera pixel size, this sets [through a condition (9)] the smallest physical wavelength that can be resolved.
        - 6px minimum so need to know the camera and magnification that will be used.
    - The background patterns were printed on fine translucent tracing paper using a laser printer with a resolution of 600 DPI

- https://opg.optica.org/DirectPDFAccess/7A7849C4-9765-4BA5-A89BE51C5DF03BBB_284172/oe-22-9-10559.pdf?da=1&id=284172&seq=0&mobile=no
    - Figure 7 shows the deformation process of a liquid surface. The deformation field is continuous and smooth which indicates the TLGPA method is feasible to measure the dynamic deformation of a liquid

surface. In this experiment, the sensitivity of measuring the liquid surface height is 2.5 μm under the condition of a lattice frequency of 0.4 line/mm with a calculation step of 0.147 mm and a water depth of 6 mm

- https://www.researchgate.net/publication/256973585_A_novel_orthogonal_transmission-virtual_grating_method_and_its_applications_in_measuring_micro_3-D_shape_of_deformed_liquid_surface
    - Pre-processing to the decoupled patterns such as image smoothing, denoising and contrast enhancement will facilitate the subsequent processing.
    - Depth 50mm, 1line/mm
    - Select the appropriate optical lens and adjust the optical layout such that the coin and the deformed fringe pattern can be observed by the CCD camera clearly. record an image, which will be used for the afterwards computation.

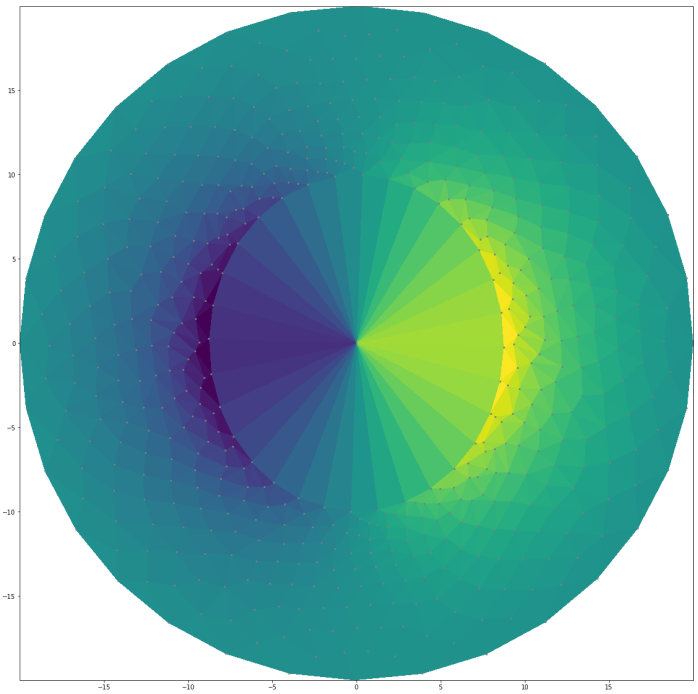
05/02



Upped the tension and kinda works now !!!!!!!

- Cleaned up the file and now is working beautifully. The next step is to pull this into python so can compare it to Dominic's.

    - Crucially learnt about u and V commands to improve refinement - Which has totally changed the way I can get the system to work
    - Also removed the height feature as is not necessary
    - Now in all the same metrics as Dominic's solutions so just need to find a way of extracting
- In terms of the comparison thought would initially do a percentage difference heat map
    - Need to compare in extreme cases
        - Dominics only valid for small angles so would expect to see this break down for large angles - This is somewhat observed in the surface evolver
        -
- Wrote some python code that extracts the vertex data from the dump file that surface evolver outputs. And was able to plot on a contour plot as a start
    - Looks very different than I thought but shows how quickly the meniscus decays



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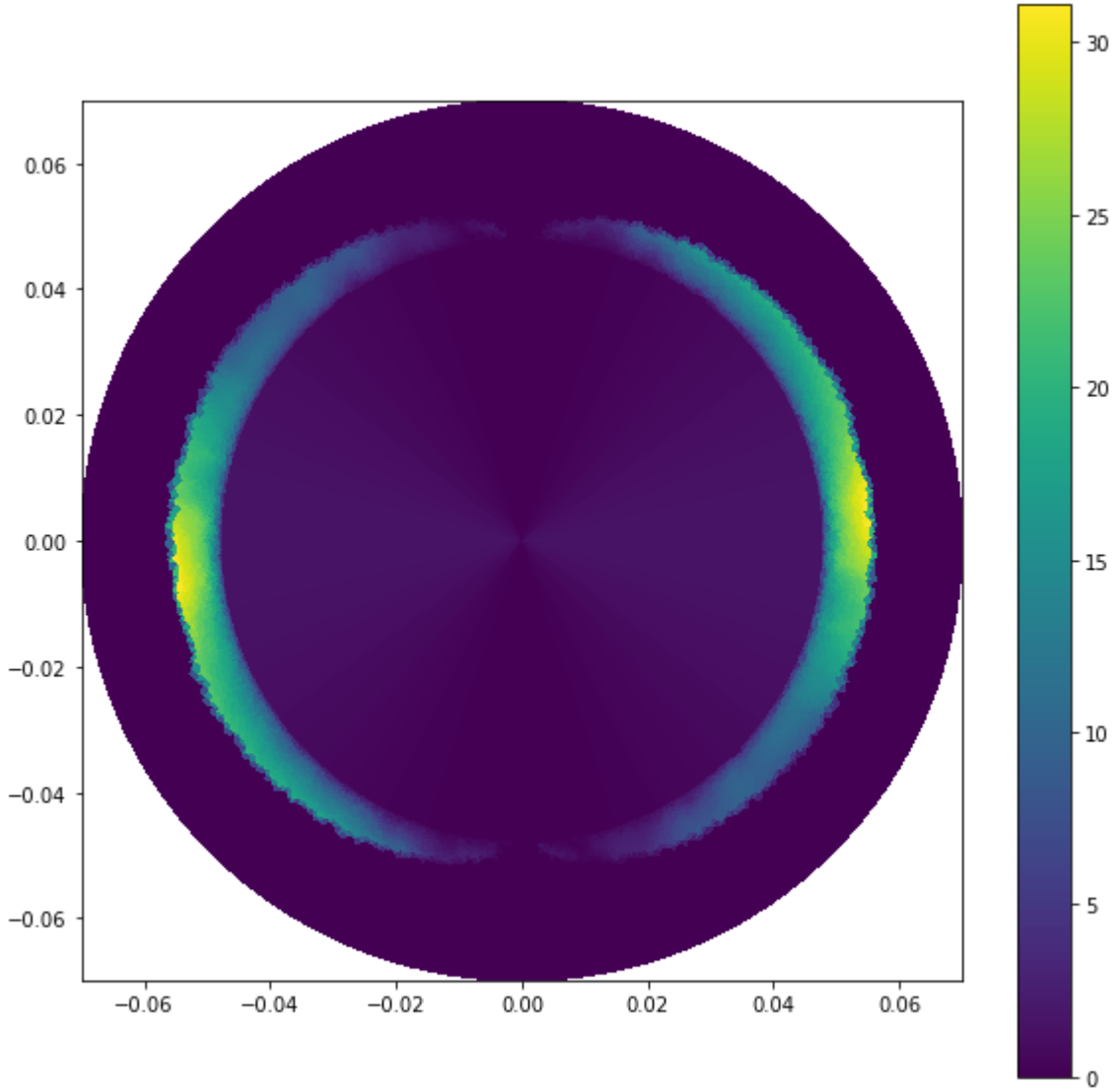
06/02

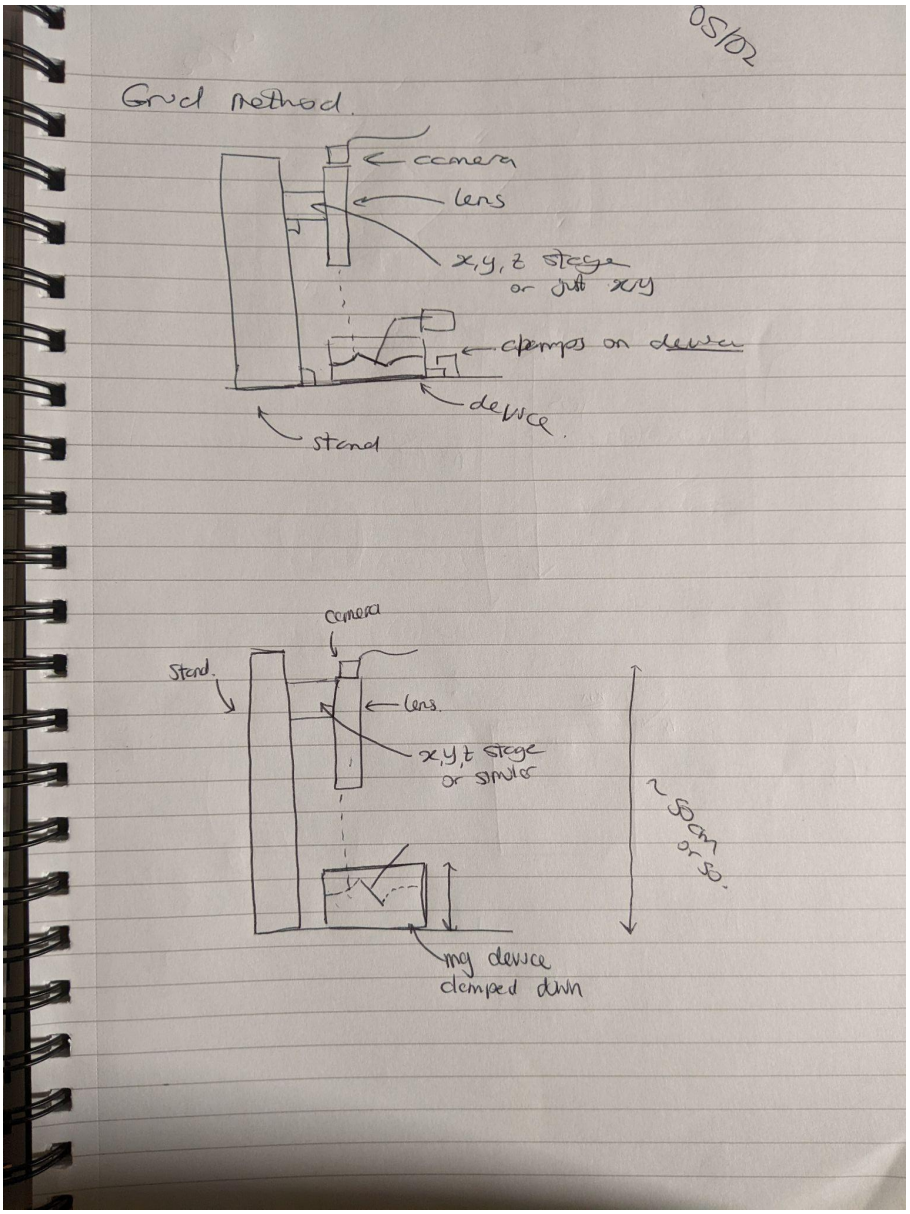
Approximate analytical solution to non-linear Young-Laplace equation with an infinite boundary condition
-https://www.lcpe.uni-sofia.bg/files/publications/2001/2001-23-Book2.pdf



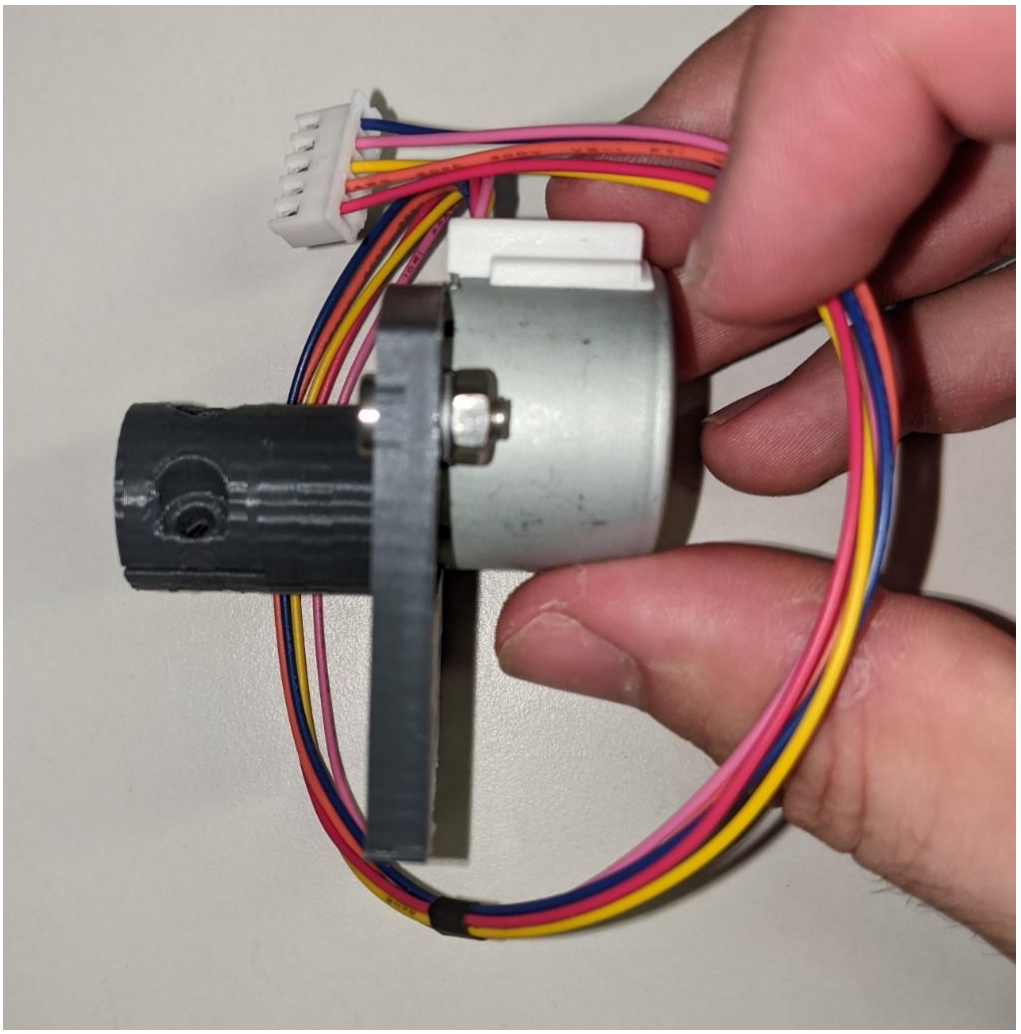
07/02

- Met in the lab
- Space has been cleared
- Changed back to the NEMA motor which is for the best but annoying
- Changed scad so that can move disk below the surface

- Made a magnet encoder mount

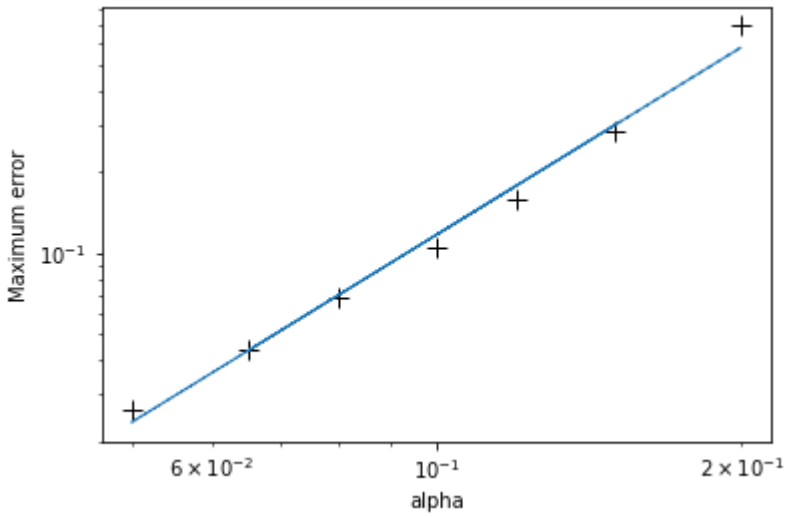


- Tested printing a lattice and this worked very well and shows promise

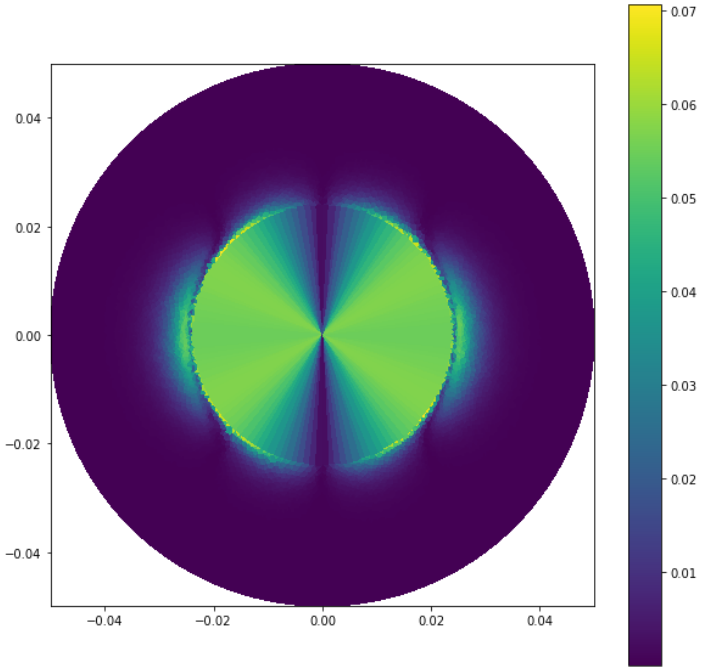


08/02

- Pietro got covid and now isolating
    - This is a major setback
    - Cant contact him as is too ill to a video call
- Spent time designing the general setup
    - Put some breadboards together
    - Found some lasers
    - Found a post and camera and attached to the lens
- Met with Dominic
    - Mapped error against alpha and found more than quadratic dependence
    - Will aim to find next order term
- Got the NEMA motor working



Gradient 2.3



Above with the alpha^3 adjusted showing the cos(3 theta) dependence that is kind of expected from the expansions. This shows some progress and the overall errors can be approximately halved

Found a reasonable way to approximate the error is (z_dom - z_SE / z_max) otherwise the tiny errors as z->0 become the dominant error which really isn't interesting or would be measurable in practice so this allows comparison of different alpha while preserving the errors of interest.

09/02

- Worked some more on improving Dominic's solution trying alpha cubed terms but nothing concrete
- Printed some test pads of lattices
- Worked on how to mount the device to the breadboards
- Got the encoder working just need a magnet for it

10/02

- Began setup
    - Created a post for the camera
    - Mounted a breadboard on its side so that optics can be mounted later
- Designed a new base part that can be clamped to this structure

11/02

- Got motor working properly
    - Now have control over the motor and can position the tilt to the desired angle from the Arduino console

    - Had some teathing issues with cables and current limits but all fixed
    - This simply works by moving the motor in short steps until the angle reads the prescribed angle.
        - The limiting factor here is that now we need to know what a square is?
    - Will need very different code if want to do oscillations etc.
- Kept looking for optics parts where Pietro said but nothing concrete really needs his help to move forward in that respect
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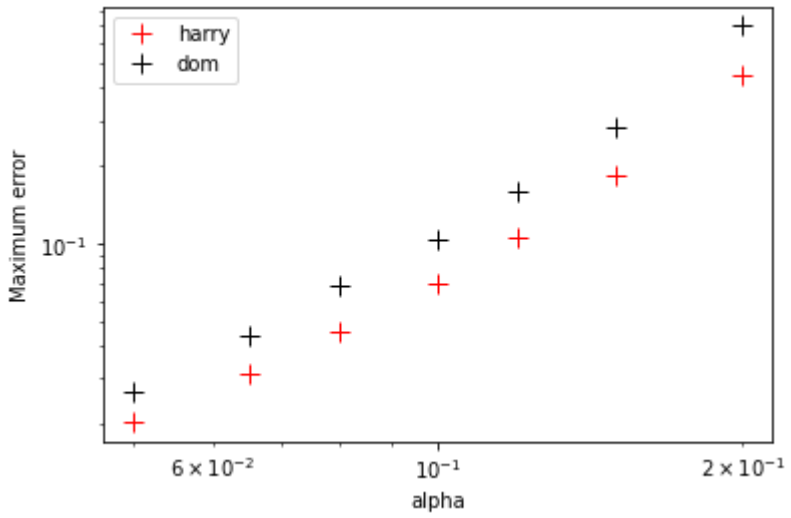
12-13/02

- Developed my own solution to the problem where I expanded the next order terms



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- Can see that this yields an improvement, however, the glaring problem is that the error still grows as alpha squared which I still don't understand as the terms can only be alpha cubed.
- I have tex'd up the 'proof' to look back on.
- Possibly want to look at the symmetries of SE and see if the assumption of it being odd in alpha is in fact true?
- More research into lattice-based methods based on the week
    - Found another paper by a group that I had already found a paper of
    - Had a more step by step guide on how to do it and some helpful hints but still lacking on the basic method of actually coding the thing.

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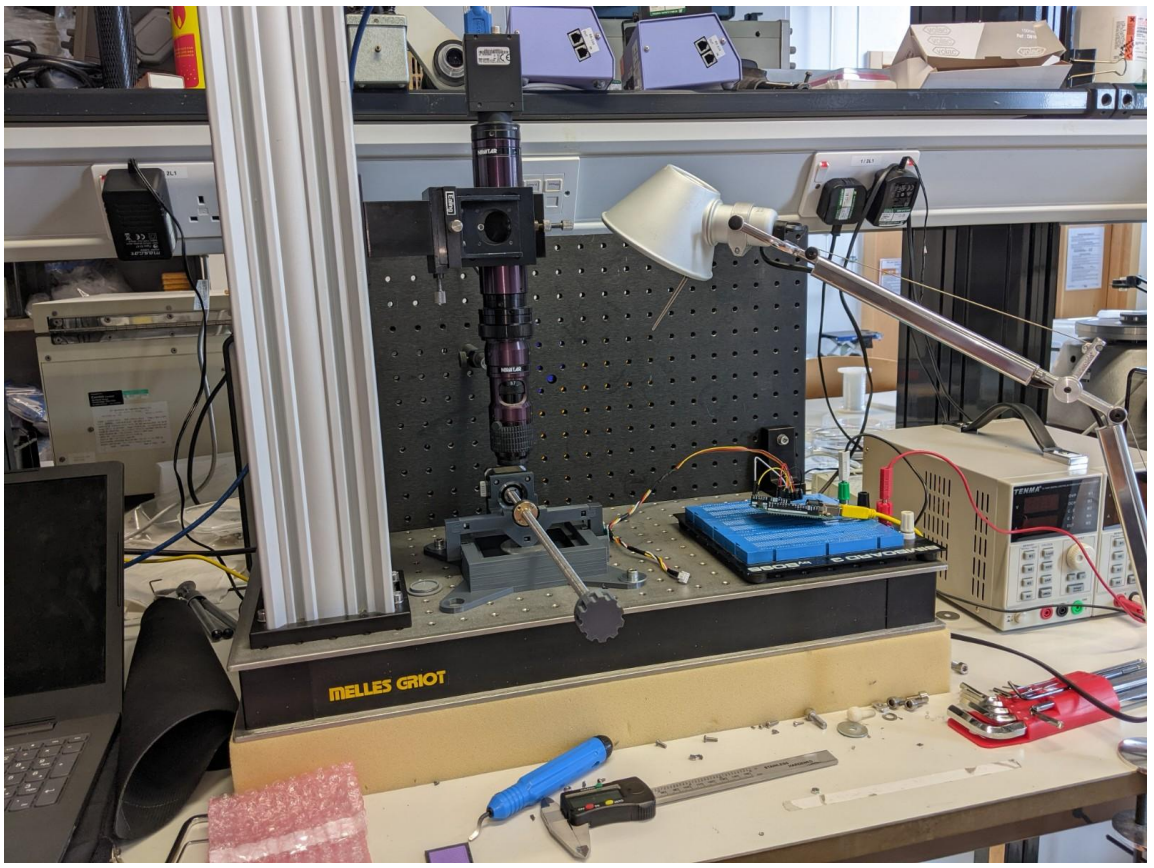
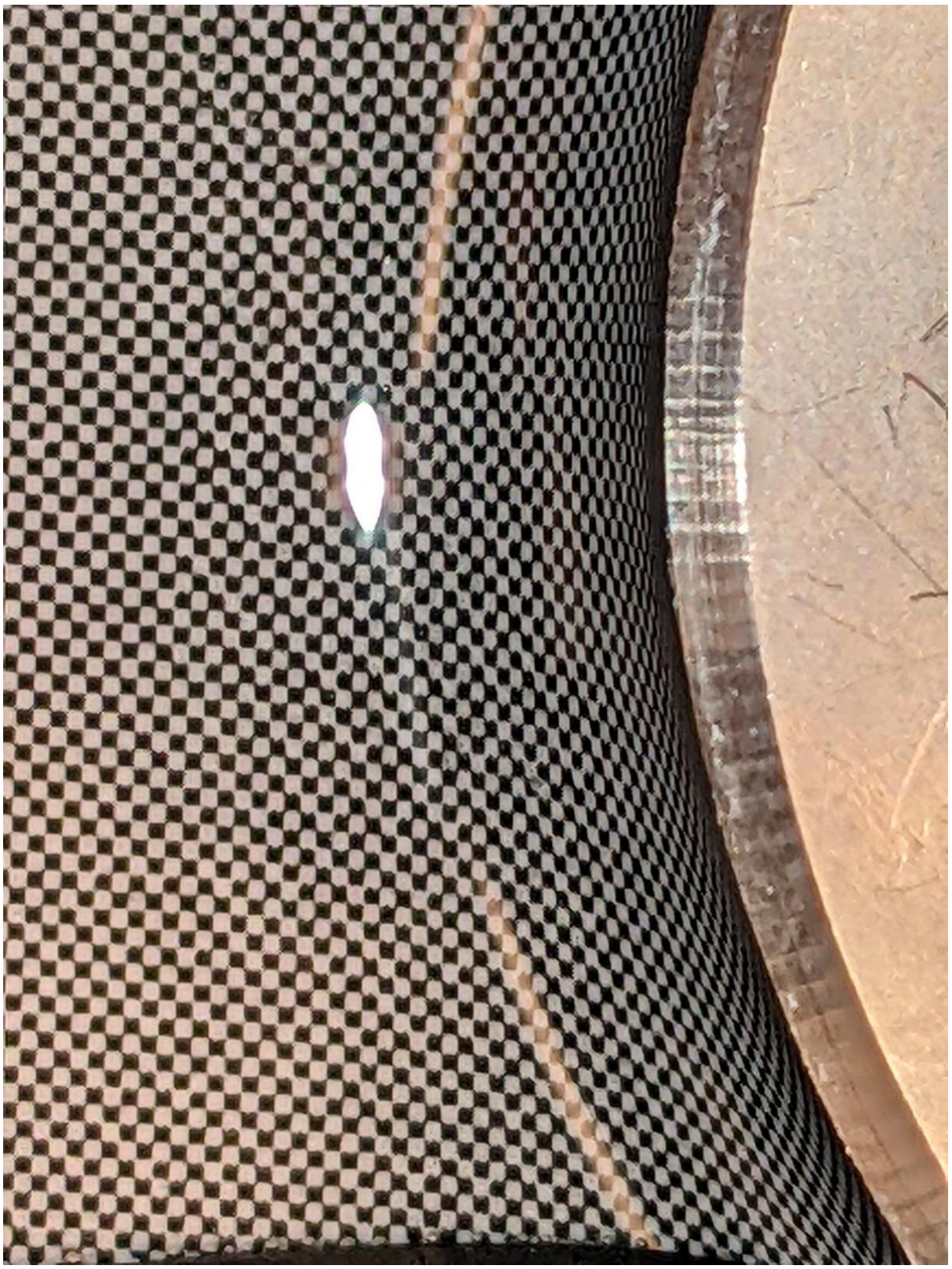

MELLES GRIOT
TENMA



14/02

- Mounted all electronics in a simple box to avoid wires becoming disconnected etc
- Talked to Pietro over video
    - He was impressed with the Dominic work.

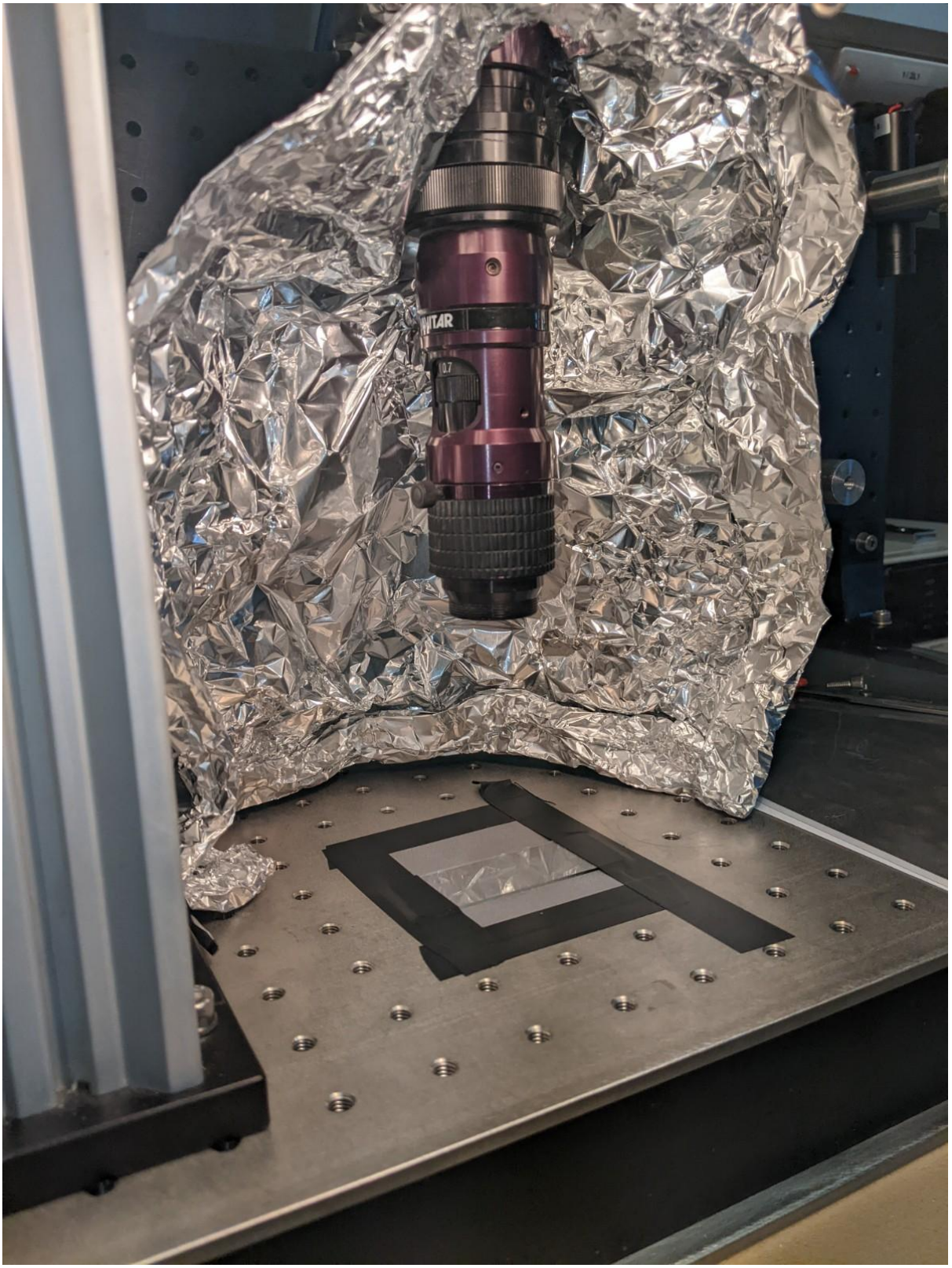
        - Suggested that should look at crosssections
        - Also to look at the effect the surface tension might have on the profile ie how big a difference is a true profile to the solutions
    - Found a beam splitter together
    - Discussed different laser methods
        - To raster the surface with the laser
            - Need very fine laser and very precise control
        - To use the reflection to interpret the surface over a larger area
            - This seems somewhat more doable
            - Pass the laser through a beam splitter then to the surface which the reflection is then reflected by the beam splitter to a camera
- Played with the camera settings
    - Want a low aperture so that have a large depth of fields so can focus on both the surface and the lattice below. Possibly could get away with just the lattice but the distortions might make this not work so need to have lots of light
        - The incandescent lamp I've been using gets waaaaaay too hot and needs to be replaced. LED bulbs are on order otherwise this will likely cause problems in the future
    - The focus on the current lens is really too small and is limiting the field of view that I have.

15/02

- Started to use the matlab code on GitHub to investigate the images taken of the disk
    - Found that laser printer was enough to print 0.25mm checkerboards onto paper
    - Then sandwiched this between microscope slides and sealed edges with electrical tape
    - Filled the trough with distilled water using a syringe to get to the required level but only filled it by eye for now
    - Used 83 degrees as the flat which certainly looks close to good but needs calibrating.
    - Tilted for integer degrees and took photos
    - Analysed using the script

    - Found it essential to have the phase wrap ON otherwise is completely useless
    - Produced some encouraging results of curves. Nothing concrete
        - Discovered that the scaling from px to mm might be the main problem obviously can use the checkerboard as a reference - may be in Fourier space to make it accurate?

- Placing lots of tinfoil around the camera does seem to help. This both reduces the ambient light which creates light spots that aren't good but also reflects the light that I control to create a more uniform field.
    - A diffuser would be better



- Played with the laser and the surface.

- Was able to get a reflection of the meniscus.
- This reflection was suuuuper unstable and would not pass through the beamsplitter in a way that I could make sense of
- Also tried looking at how I might measure the angle of the disk with the laser.
    - Reflected the laser off the bottom of the tank
        - Moved the tank around to see how stable the reflection was - was not at all.
        - Would have expected the point to stay in the same place if the printed bottom was flat.
        - The reflections off the disk were just as bad if not worse as the disk is not polished so creates a large amount of diffusion
        - Moving the disk moved the central spot however showing it may be that a laser is not the way to go.

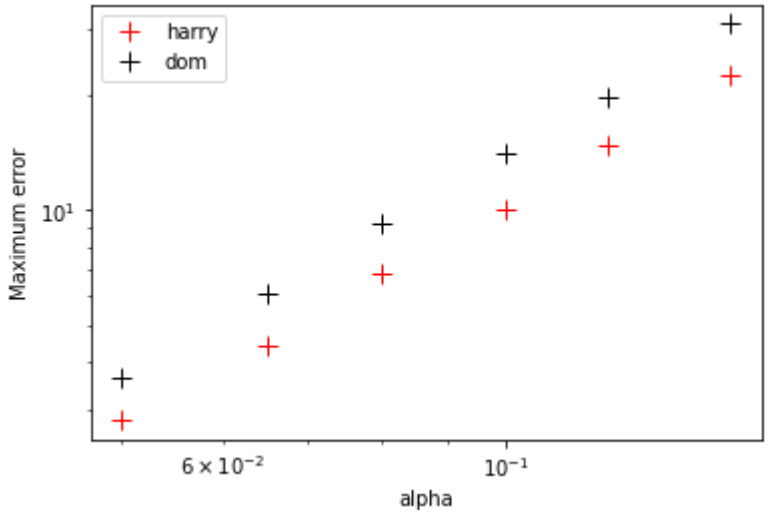
16/02

- Wanted to provide some more verification of the method
    - Found some plano-concave lenses as used in many of the demonstrations of the technique
        - Got encouraging results but without data on these lenses there is little way to provide any evidence for anything
        - Also made some small investigations to the noise floor - need to do more
            - In terms of the current h scale ~800
            - Real observations 10^4 so significantly smaller
            - Testes what happens if i press things
            - Tested iff could see fingerprint on the glass - could not
    - Wanted to try a drop on a surface to image the spherical cap
        - Initially tried on microscope slide
            - Doenst work
            - Too much wetting and the drops are either too small or not spherical or even circular
            - But did show that the technique can work
        - Tried on acetate sheet which had a printed checkerboard on it
            - Failed
            - The drops work much better
            - However the small changes in the acetate when producing the drops and how the light plays with the acetate does seem to ensure that the technique doesn't work at all.

- This does demonstrate the need for the lattice to be absolutely fixed and is something that needs to be sorted as even the motor movements might cause the lattice to move

- I have yet to try how the light conditions affect the result although this can't be good.

- Played with the solutions some more at Pietro's suggestions



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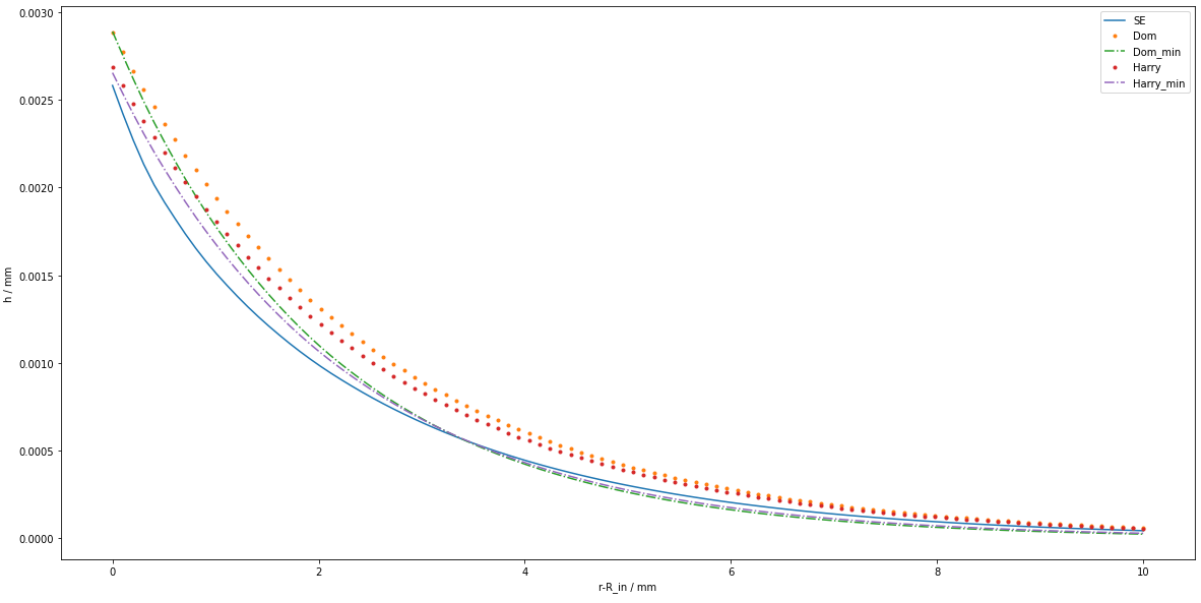
- This is a plot of the percentage difference between the SE value of l_c and the l_c that each of the solutions would have outputted if they were fitted to the SE solution. See exactly the same behaviours of mine is slightly better than Dominic at all alpha but both show exactly the same trend in alpha^2 again showing that there is definitely something off about the whole affair.
- These ‘better’ l_c solutions aren't even that good. They are slightly better for large r but still poor for low r.



-

- A thought might be to look at these errors as a function of the radius of the disk? as there are only 3 parameters this only looks at 1. Investigating l_c I suspect is not worth it only that this is the parameter we hope to extract and don't have control over in the experiment.
- The more I look at how bad this solution is the more I feel we might need a good reason to keep using a disk.

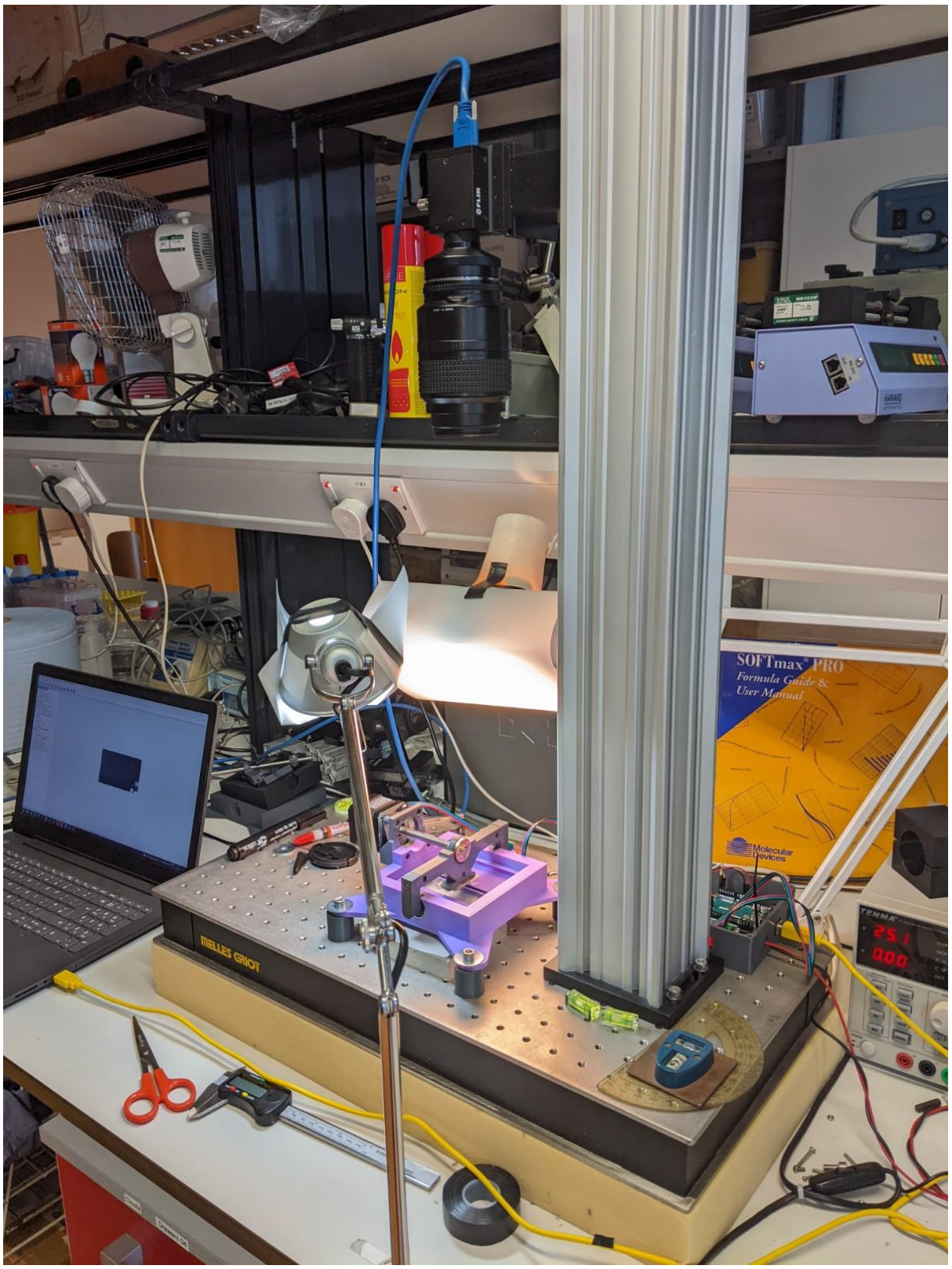
\

Why not use a square on the tilt. Everything else remains the same although the likely hood of a decent solution being found might increase. The same measuring techniques work

This might not have been done by the original group due to their side on the method meaning that to image this would have added additional complexity.

17/02-20/02

- Decided to use a screen for the grid
    - Spend a few days developing a watertight seal for the bottom of the tank
- Spend many hours with lenses making sure the checkerboard algorithms work



21-23

- Setup on stabilised table to reduce vibrations - also auto levels
- Delayed a few days waiting for parts to arrive crucially a screen and the pi

- Kept working on the water tight seals - tests shown below

- Tested many different lenses to work out which will work best - want best height to tightness

24-26/03
-Things really starting to kick off
- got the screen working and loaded pixel chekerboars on
- validated tha the procedure might work
- printed parts to make everything secure and reduce potential sources of error

- Did loads or tests on friday to test different configurations

Test	Mean	std	range	grad	ince	R^2		
76-10	0.3136		0.11050.3579				0.3	Crap
76-4	0.39	0.117	0.393			Crap		
76-4-jp		0.439	0.007	0.02	0.0003	4e-6	0.9888	
76-2	0.4244		0.08	0.288				
76-2-jp		0.474	0.044	0.12	0.0003	-0.0012		0.9961
50-10	0.417	0.013	0.0389		0.0015	-0.005	0.9674	
50-10-jp	0.424	0.007	0.022	0.0008	0.0006		0.977	
50-4	0.408	0.006	0.0236		0.0018	-0.0004		0.9966
50-4-jp		0.414	0.003	0.01	0.0015	0.0001		0.9937
50-2	0.422	0.029	0.1	0.0017		-0.001	0.9799	
50-2-jp		0.441	0.012	0.036	0.0011	-0.0003		0.9992
20-10	0.24	0.037	0.11					
20-10-jp	0.24	0.039	0.11	0.6	-0.37	0.866		
20-4-100s	0.26	0.01	0.02					
20-2	0.26	0.034	0.1					
20-2-jp	0.27	0.005	0.01	1.7	0.4	0.9678		

20-4-L	0.26	0.017	0.04
20-4-60s	0.26	0.02	0.07

The 20s have very offset slopes very inconsistent and I dont like

The slopes for the 50cm appear to be the clearest

76 are variable vut have some very stright lines

Learning it might be important to recalibrate the 0 and that resetting isnt nesissarily the best way to do it

- need to test its consistency

clearly going from positive to negitive is a terrible way to do this - will stick to positive in the future.

Feel like ~4px 50cm is the best but this might just be because it was the first. 10px looks way too low res at all tests done

checked the other integrator and produces much closer and more meaningful results in terms of the vertical scaling - except is 10x slower

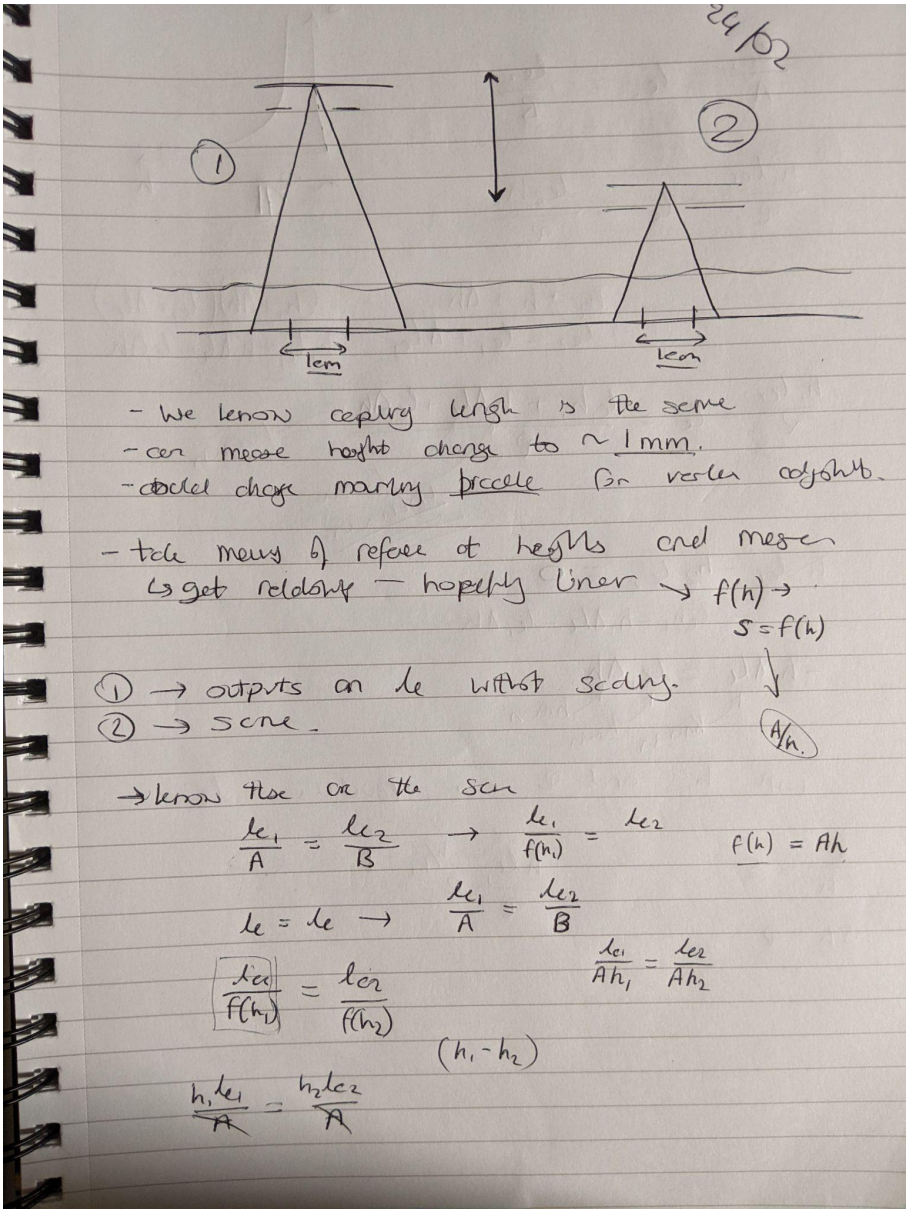
Unsurprisingly the best line and lowest intercept come from the very first measurements taken - shows the importance of setup +ve makes slightly worse probs just due to less data

no obvious change when locked the platform.

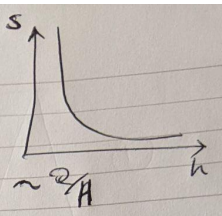
Played with the scaling - changing the scaling leads to a proportional change in the capillary length. The question is can we do a difference measurement

$S \sim A/h$

The above is a mess but the conclusions are accurate and will form the basis of the next week
Crucially I need to perform better calibration techniques.



$$\frac{k_{s1}}{A} = k_s = \frac{k_{s2}}{B}$$



$$\frac{h_1 k_{s1}}{Q} = k_s = \frac{k_{s2} h_2}{Q}$$

$$h_2 = h_1 + \Delta h$$
$$\rightarrow k_{s2} = k_{s1} + \Delta k_s$$

$$(h_1 + \Delta h)(k_{s1} + \Delta k_s)$$
$$h_1 k_{s1} + h_1 \Delta k_s + k_{s1} \Delta h$$

$$\frac{h_1 k_{s1}}{Q} = k_s = \frac{k_{s1} h_1 + h_1 \Delta k_s + k_{s1} \Delta h}{Q}$$

known

known

unknown

$$h_1 k_{s1} - h_2 k_{s2} = 0$$
$$- k_s h_1 - h_1 \Delta k_s - k_{s1} \Delta h$$

$$-h_1 \Delta k_s = k_{s1} \Delta h$$

known known known

with h_1 and Q can vanden k_s.

$$\frac{Q}{h} = S$$

$$\underline{S}\,\underline{h} = Q$$

$$\frac{h k_s}{Q} \quad e^{w/h_1 - 1}$$

$$\frac{h_1 l_{c1}}{R} = \frac{(h_1+\Delta h) l_{c2}}{R}$$

$$h_1 \Delta l_c = \Delta h\, l_{c2}$$

$$\boxed{\frac{\Delta l_c}{\Delta h} = \frac{l_{c2}}{h_1}} \quad l_{c_1} + l$$

$$\frac{h_1 l_{c1}}{R} = \frac{(h_1+\Delta h_n) l_{cn}}{R} \qquad h_2 = h_1 + \Delta h_n \qquad l_{c_1} - l_{cn}$$

$$h_1 \Delta l_{cn} = l_{cn} \Delta h_n$$

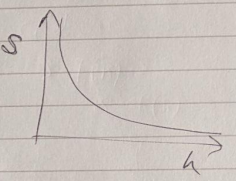
$$\frac{\Delta l_{cn}}{\Delta h_n} = \frac{l_{cn}}{h_1} \qquad \frac{\partial l_c(h)}{\partial h} \quad l_c(h)$$

$$\ln(l_c(h)) = -h/h_1 + C$$

$$\ln(l_{c_1}) = 1 + C$$

$$l_c = A e^{-h/h_1}$$

$$l_c(h) = l_{c_1} e^{-h/h_1}$$



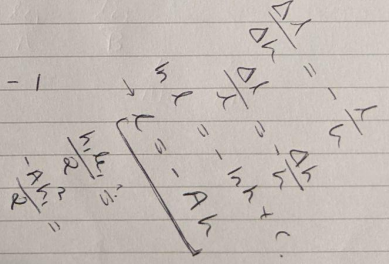
$$l_c = \frac{h\, l_{c_1} e^{-h/h_1}}{R} \qquad \frac{l_{c_1} h}{h_1} e^{-h/h_1}$$

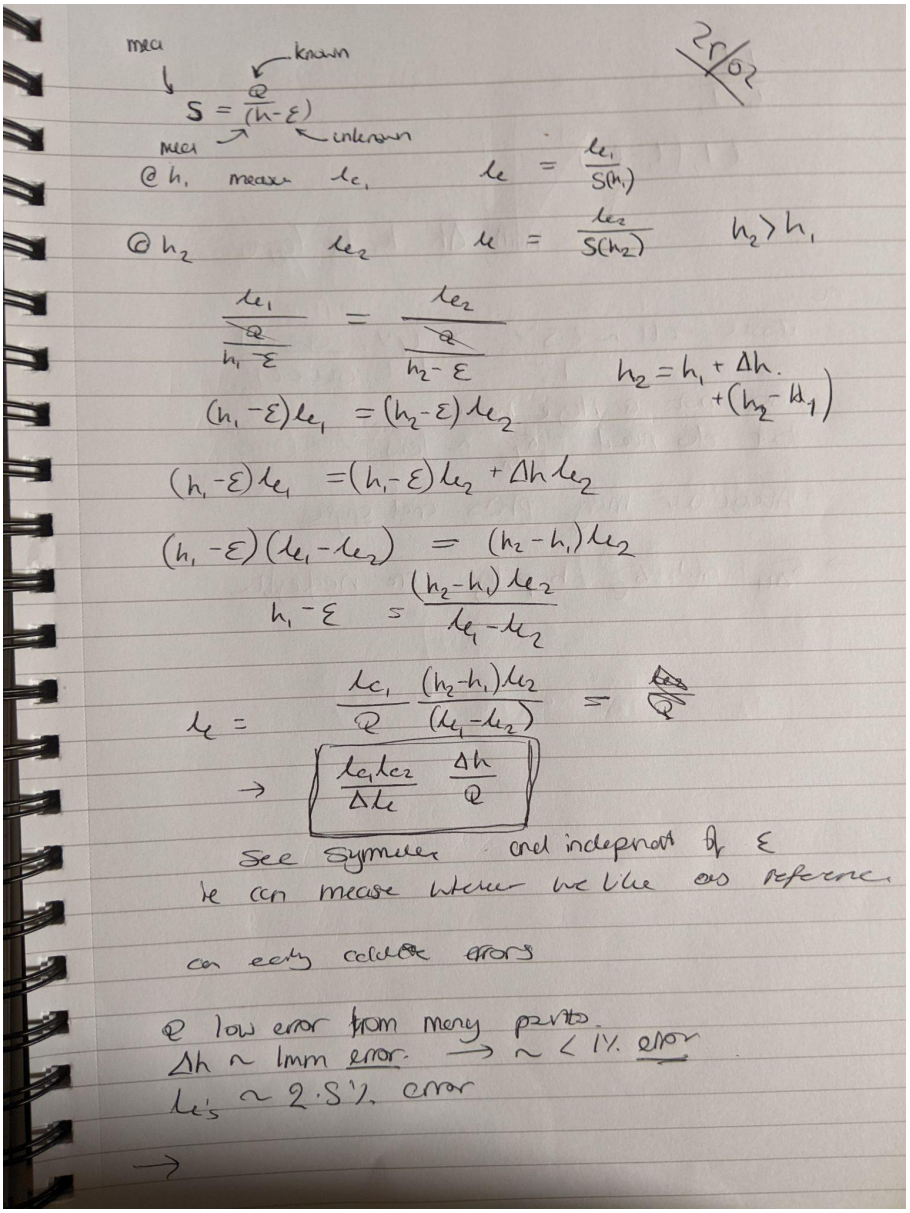
$$l_c = A e^{-h/h_1} \qquad h = h_1 \; l_c = l_{c_1}$$

$$l_{c_1} = A e \qquad A = l_c/e$$

$$l_h = l_{c_1} e^{-h/h_1 - 1}$$

$$l_{c_T} = \frac{h}{h_1} l_{c_1} e^{-h/h_1 - 1}$$

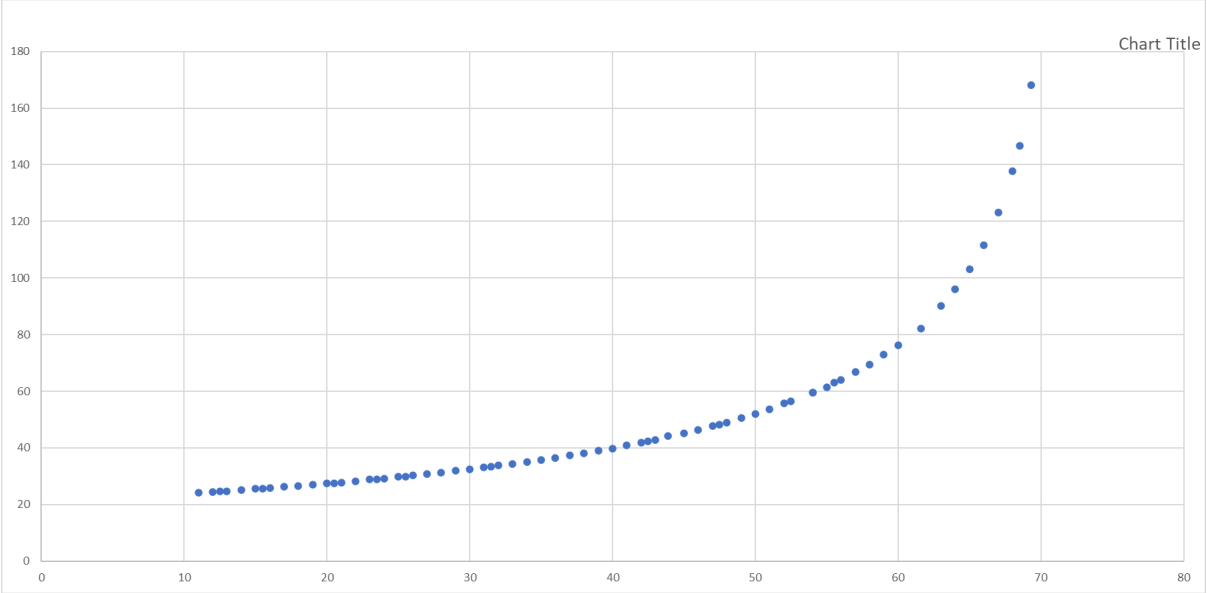




28/02

- Found a ruler in the 1A labs that I checked. showed a good calibration to a known good
- Set up the ruler - prints worked well
    - These mounting points must never move again otherwise the calibration will fall apart - at least while taking this data
- Attempted the method of measuring a ruler
    - Collected data
        - Used both a steel rule and the 1cm microscope slide placed in the centre of the frame.
        - Used both to have some comparison and has this changed how much the error is associated with the thickness of the lines and with the estimation of where the lines are

- Collected for a large range of distances
- Was able to easily estimate the distances up to 1mm precision
- Plotted the curve. The horizontal scale is backwards due to the ruler being used.



(15/04) - Looking back on this while this was made redundant later the plot and the loss of the 1/x law for low (here high) distances does help give confidence that the lens is of quality and does not produce too much aberration.

0103

- Realising that more data needed to be collected on the curve so did that
- Plotted with additional data is above showing distance vs SF.

- Played with this plot
  - 1/x is a good fit as expected for the smaller values of x (plot above is reversed due to the ruler being upside down)
  - As the height gets smaller -> larger SF the small-angle approximations begin to break down and therefore so does the 1/x
    - This places lower bound on the height the camera should be placed at.

- Collected data to allow the comparison using the difference method derived
  - This completely failed
    - Arguably the result is slightly better than just using a single sf from 1 image
  - Taking 4 or 5 sets and then creating a matrix for each of the comparisons these showed very little consistency showing the method does not work at least in the method tried

0203

- Pietro suggested that the important point missing in the method above is that the optical path length is not the same as the path length used to measure the SF
- By playing with the numbers
    - Look at the SF required for each of these sets and see if there is a connection and work out what went wrong
    - This all transpired that the offset - ie the 0h->inf SF point was a few millimetres off ~3mm from where it would have needed to be
        - This shows how sensitive this kind of measurement is and how difficult this might be to resolve and how much care must be taken
- based on the position the offset (0->inf) was predicted to be from this data guessed that the checkerboard might be the best way to perform this scale factor.
    - Tested this and found that it worked reasonably well
    - The next idea is then to instead of measuring the checkerboard itself in LibreCad but use the Fourier transforms already being taken to do it
- This works very well and uses the whole screen to take the measurements rather than just a section done by hand

- Took several sets of data at different heights to compare them using this method
    - Found a good height that has good consistency between data and accuracy

0303

- Took more data at different heights
- Spent more time writing up the code to be more efficient
    - Loops through folders and outputs to files
    - Made some other small meaningless optimisations

0403

- Bumps kinda took over
- Spend more time taking data

0603

- Prepared for the presentation

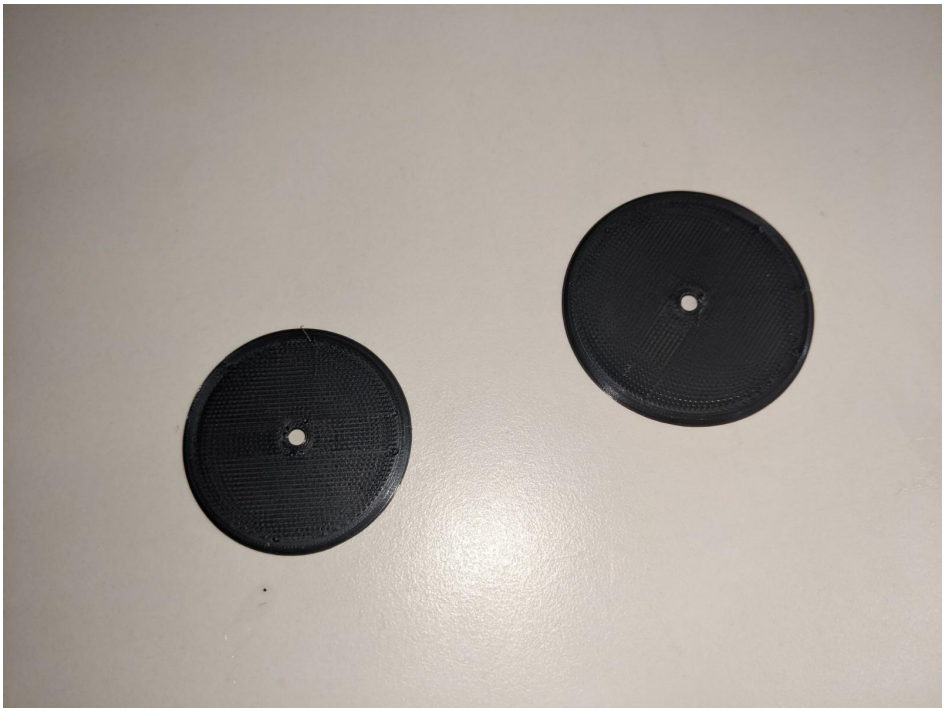
0703

- Did the presentation
    - Went well
        - Include more of the decisions made
        - Check into the filler explanation of the Fourier method
        - Make sure to include all citations

08-09/03

- More data collection with a disk
    - Coded up the model
    - Found that needed to average over more photos due to the more intricate profile
    - Cant collect much of the profile but can collect enough to see the curve
    - Had to redesign to allow me to see more

- Tried 3D printed disks
    - Edge was okay
        - Some evidence to suggest the disk was warped
        - Edge was fragile
        - Edge didn't have any problems like the metal one making slightly easier to get a clean reference image.

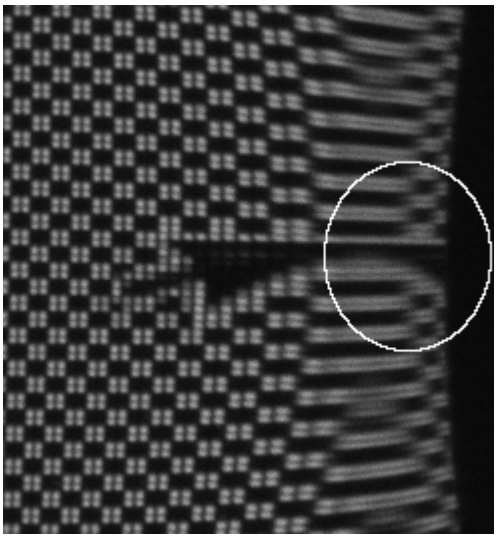


- Talked to Pietro
    - Discussed how to compare the disk solutions and produce numerical results
    - Discussed hysteresis of the device
    - Time exposure
    - Movement of the checkerboard on a per-pixel basis

11/03

- Took hysteresis data
    - Showed some interesting behaviours
        - Passing through 0 has some disastrous effects
        - Passing back after reaching the top has little effect
- Took long time data
    - A little unsure as placing a new part in so may show evidence of leaching

1403

- 
- Shows the problems of negative angles
    - Shows a reflection of the mouse - this means that anything beyond this is nothing worthwhile
- Tested that the angles recorded are accurate
    - Did this through comparison with the stepper motor steps
    - Showed very good agreement
- Tested the parallax
    - Showed little deviation
    - Did this using a lens placed at the 4 corners of where of the possible view space
- Took some other hysteresis and long time data and disk data

1503

- In oxford

1603

- Spent time recording references
    - Collating the hardware used specifics so that data sheets etc can be found
    - Same for software
- Spent time collecting what people need to be acknowledged in the report and for what
    - Also acts as a list of where the hardware needs to be returned to
- Spent hours preparing to write the report - formatting and developing the structure and headings as well as the metta structure of how the latex is structured in order to keep the report neat and allow it to be written quickly
- Spent some time learning to use inkscape to draw diagrams for hte report
- Started a list of ideas of things that didnt work and a list of ideas to try

1703

- Long time data
- Tried data where moved the checkerboard to each of hte 8 unique positions
    - Found that 8 is actually a lot
    - Found that I need a very concrete way of keeping track of whcih board I am on
    - Found the data is reasonably inconclusive

1803

- Long time and hysteresis data
- Took a few sets of data for 4 of the eight checker board
    - This data takes a long time to collect and shows little promise of returning interesting results so not sure how much more data is in teresting to collect

21/03

- Woke up very ill
- Had a meeting with Dominic and Pietro
    - Dominic will attempt a solution for the razor blade

2203

- Still ill
- Dominics solutions are great
- Spent time writing up these solutions in ordet to understand them better
- Desmos - shows the exponential solution is still very good and that my second order solution isnt so bad

2303

- First use of lipids (4hours)
- Had to learn the procedure and find utensils to do it with
- Appears to work quite well

2403

- Tried again with the lipids for different tilt angles. (5hours)

2503-2803

- Spent time analysing the data
- This got me worried about the quality of some of the data. Looking at the data of different heights and decided that more data would need to be taken
    - Not much deviation was seen between heights
    - Starting to see either a sharp increase or decrease for very small angles. Most of this is probably due to the poor fitting possible in this region.
- Saw that possibly the larger heights lead to a better - more parabolic curve so I will collect more data at a higher camera height.
- Also realised that a lot of the different checkerboard data is quite poor and needs to be redone.

- Started to write the intro and theory sections of the report

2903

- Went back into the lab to collect more data as discussed above (4hours)
- Took photographs of the device for the report
- On return this was the best data collected - makes sense as was taken with the best method so far

3103

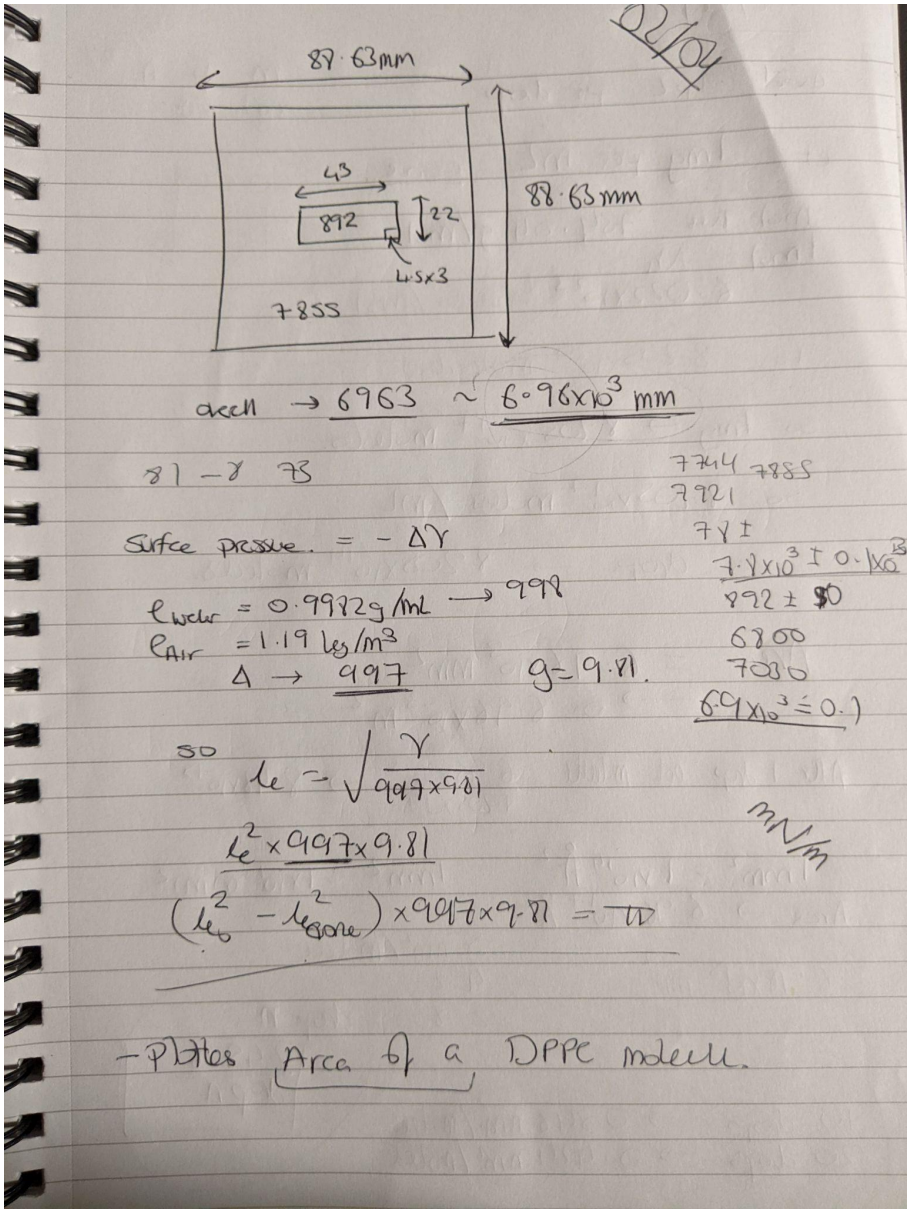
- Collected more checkerboard size data (4hours)
- Spent some time analysing some of the disk data
    - Fits well at small angles
    - Fitts worse at lager angles
    - Have no confidence and would want to compare to SE
        - Tried to code this but realised it will be quite challenging

0104

- Attempted to add more rotations to the fitted solutions
- Found that this vastly improved all of the data - importantly it reduced the standard deviation for a particular angle. As nothing changes between photos this suggests some of this rotation is a product of the integration rather than a physical effect.
- Reran all the data with these new rotations (5 hours)

0204

- spent time writing the report and making the message clearer
- Spent time understanding DPPC monolayers and the general format of the data and how to calculate the conversion from my data to theirs.



02/04

m μ n
×10^-3 ×10^-6

used 1 μL per drop

at 1mg per ml conc.

mol wt 734.04 g/mol

1 mol : Na
6.022×10^23 molecules/mol

1g = 8.205×10^20 molecules.

so 1mg → 8.205×10^17 molecules.

so 8.205×10^17 molecules/mL

1 drop → 8.205×10^14 molecules

Area = 6.98×10^3 mm^2
⟶ 6.98×10^-3 m^2

After 1 drop each molecule $\frac{6.98\times10^{-3}}{8.205\times10^{14}}$ → 8.48×10^-18

1mm^2 = 1×10^14 Å^2
Area → 6.98×10^17 Å^2

1mm^2 = 1×10^12 (nm)^2

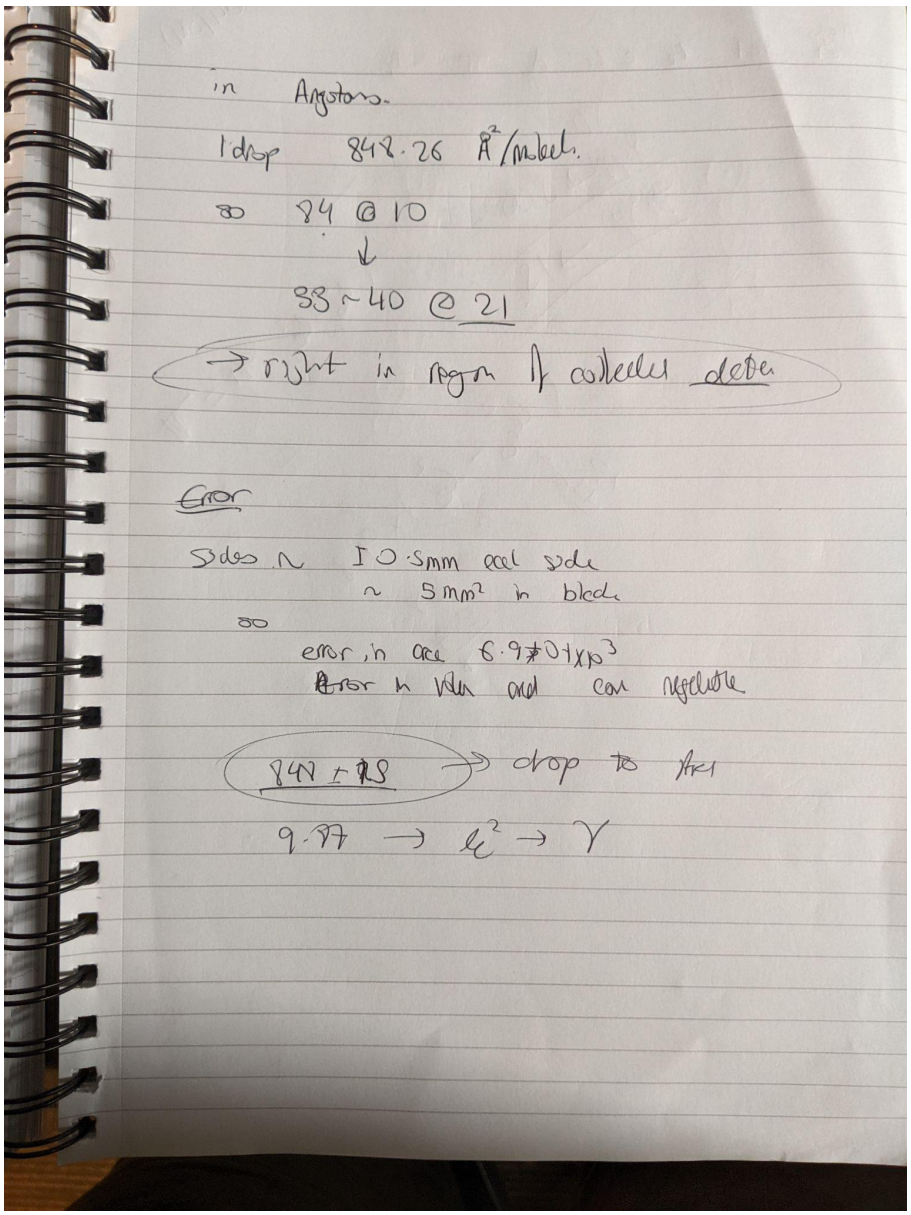
6.98×10^5 mm^2

8 nm^2/molecule
4.2
2.8
.
.

drop n

$\frac{8.4926}{\text{drop } n}$

10 drops → 0.848 nm^2/molecule
20 drops → 0.424 nm^2/molecule



0404

- Worked on processing the lipid data
    - Found a dramatic difference between the data and the expected data
    - Likey due to the concentration being somewhat unknown
    - Some obvious problems show there is so much of the device that needs to be explored further.
- Met Pietro

    Discussed looking in the Fourier domain to see why there is a difference in the sets.

0504

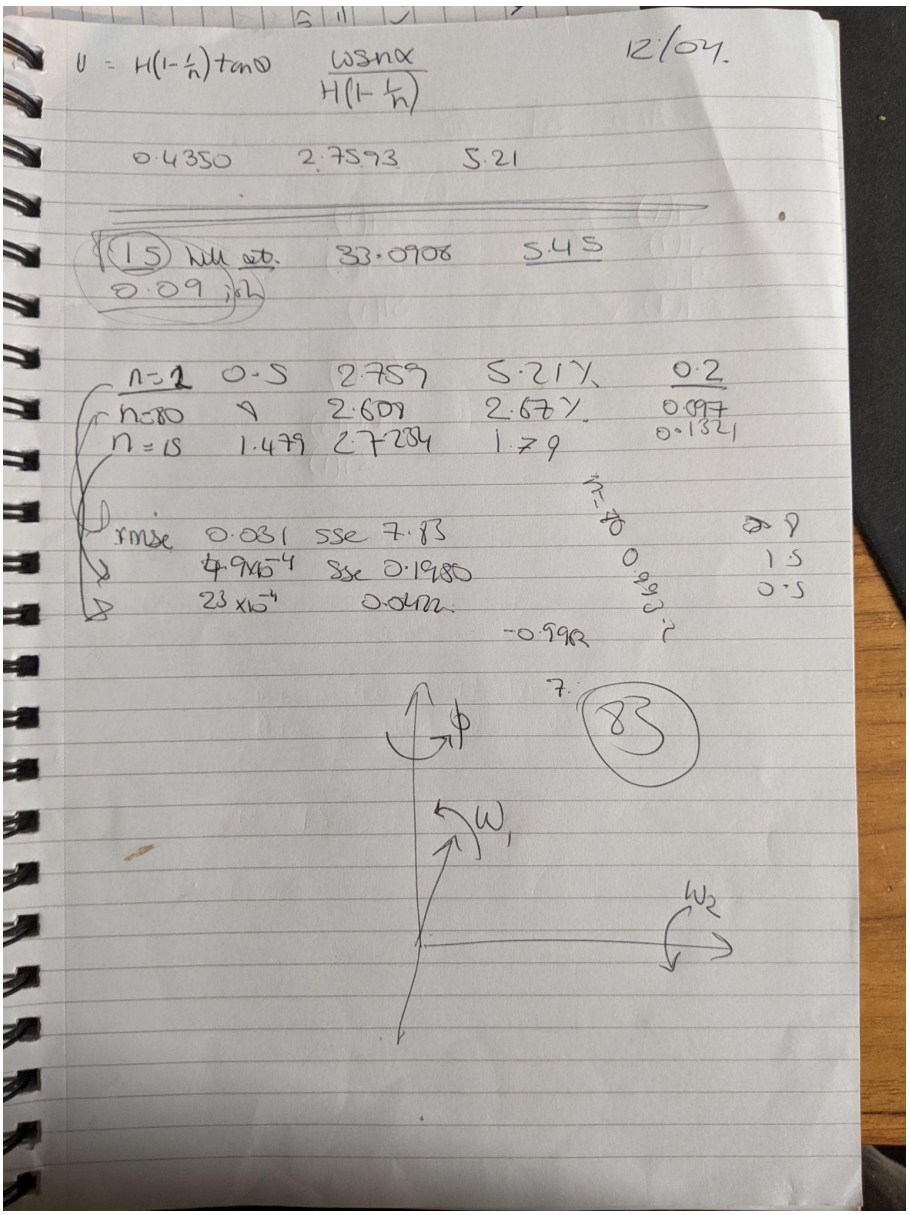
- Worked on writing the report (6-7hours)
- Got some more of the graphs etc to add to the report

- Workshopped some titles

0604

- Wrote code to look at the peaks in the Fourier domain (6 hours)
    - Fitted Gaussians and looked at the STD and amplitude but nothing conclusive
    - Realised that if you look at tilted data then this creates a skew
    - Fitting skew Gaussians and looked at the skew
    - Again nothing conclusive
    - Looked at the scale factor and the position of the peaks for the different sets and looked at comparisons including the perpendicularity etc and while there were some trends nothing that aligned with the observed shifts
- Started trying to condense the report

0704-1304 — WORKED ON THE REPORT - DETAILS ARE IN THE REPORT



1404

- Went and collected data for filling
- Developed a skew measure (6hours)
- Shows promise - have directly written into the report
- Met Pietro
    - Got further with the title
    - Agreed that the thing is very close

4/05

- Spent more time on the filling data tried lots of different possibilities.
- Tried landau distribution which looks good but cant form symmetric peaks
- Changed the skew measure to a modified johnson SU distribution - have written a lot of this directly into the report

- Spent hours trying to improve this distribution and other distributions and can't find anything better.