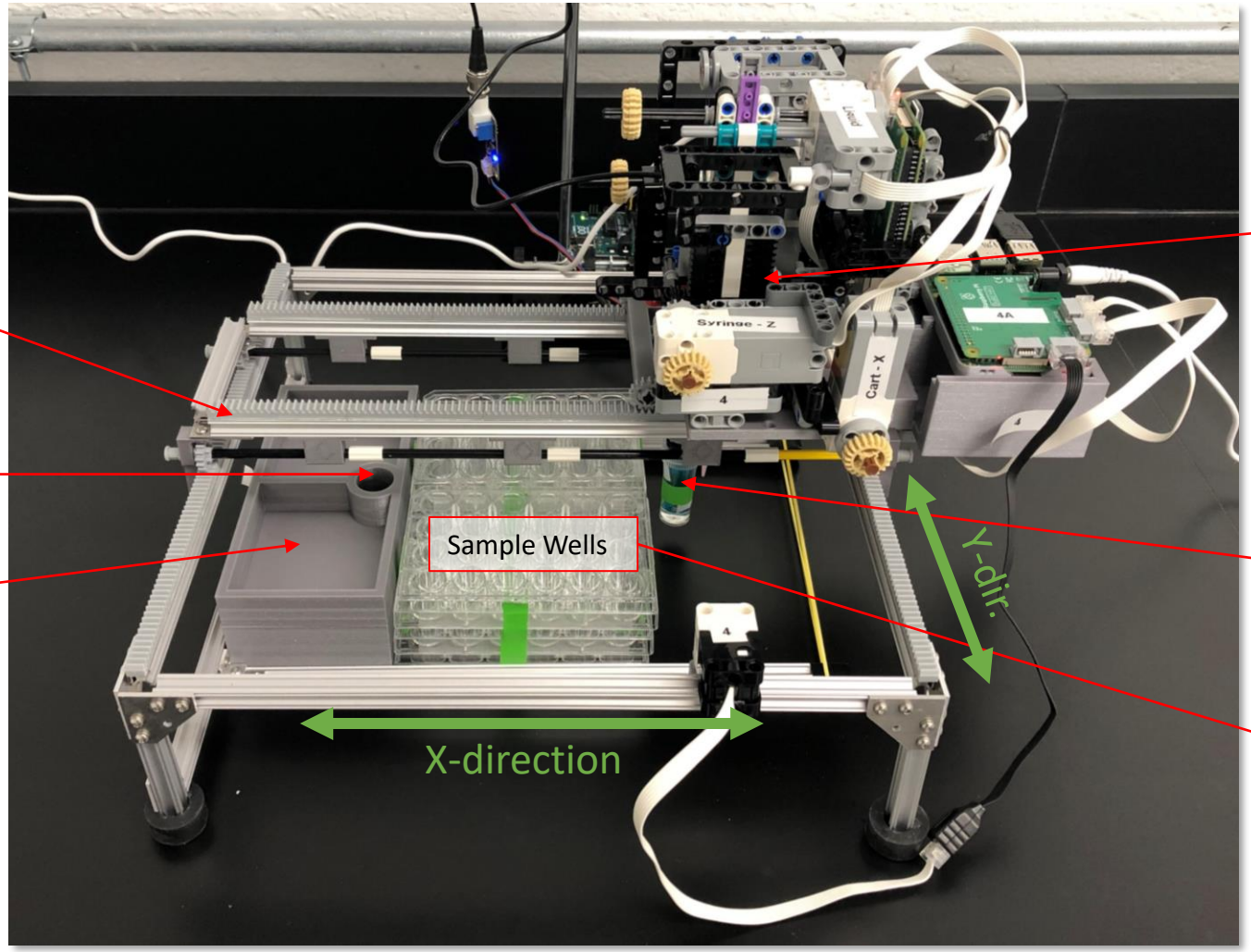
LEGOLAS
Calibration and
Use Guide

The LEGOLAS System

Motors are labeled as to their use.
You can use the tan gears to gently move them (or black gear for the y-motor)



3,0	3,1	3,2	…	…	…
2,0	2,1	2,2	…	…	…
1,0	1,1	1,2	…	…	…
0,0	0,1	0,2	…	…	…

rows

columns

Wire Management

Each LEGOLAS had a chemistry stand with a ring behind it to raise up the pH sensor wire. If you are having problems with wire management, please consult the Wiring Guide to see the optimal setup. Most problems are due to the pH sensor wire getting caught and not allowing the sensor to drop, which can be fixed by giving it more slack, as well as identifying where it is getting caught and moving it away from that area prior to an experiment.

To Do

1st Time using LEGOLAS

- Connect to Wifi Router
- Install Anaconda w/ Jupyter Notebooks
- Download and unzip necessary files

Every Time you use LEGOLAS

- (Re)calibrate LEGOLAS *(or at least verify calibration)*
- Remove pH sensor cap prior to using
- Do not knock cart off tracks!! (or you might have to recalibrate ☹)
- Return pH sensor cap after using

Before Final Experiments:

- Calibrate pH Sensor using buffer solutions and Arduino Code

1st Time: Connect to Wifi Router

The wifi router is located in the back of the lab.

Name: ~~TP-Link_BC08~~

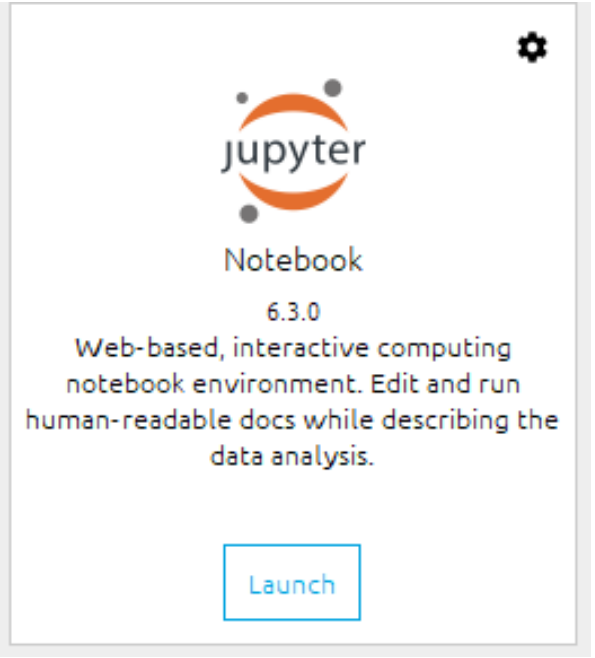
Key: ~~98043828~~

Note: *We use a local wifi router because the school blocks use on eduroam. If you need access to the internet on the same device you are using to control LEGOLAS, you will have to switch back to eduroam. You can only control LEGOLAS if you are connected to the TP-Link local network.*

1st Time: Install Anaconda

Please download and install Anaconda:
https://www.anaconda.com/products/individual

Run Anaconda Navigator and then launch Jupyter Notebook *(install if needed) - This will open a page in your browser.*



1st Time: Download Files

Download the Use Files from github

- manual.py *(use to calibrate LEGOLAS)*
  - *Once calibrated, export as "config.yaml" to serve as configuration file*
  - *You will likely update config.yaml every time you come to the lab*
- core.py *(contains movement and deposition functions for reference)*
- ref_config.yaml *(reference config file, will be replaced by config.yaml)*
- LegolasDemo.ipynb *(Demo to test calibrated values)*
- LegolasOutline.ipynb (*Template for solving challenges)*

You will use the **"Anaconda Prompt"** to access and utilize *manual.py*

You will *edit LegolasDemo.ipynb & LegolasOutline.ipynb* in Jupyter notebooks which you can launch from the "**Anaconda Navigator"** screen

Every Time you Use LEGOLAS

- The following slides show how to calibrate and set up LEGOLAS, which you will need to do every time you use it and will have to redo if you knock the cart off the tracks in the x or y direction (or if you move the sample wells/reservoir). Therefore, it is in your best interest to be careful with how you interact with LEGOLAS once you have set it up.
- You should conduct the steps in the order they appear in this ppt.

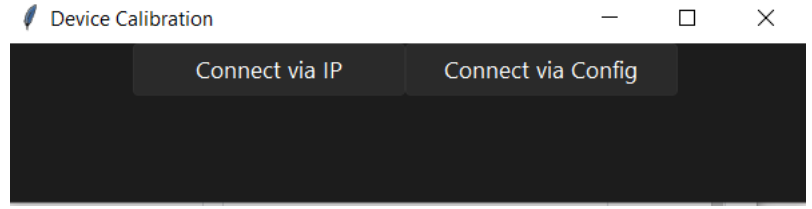
Tips:

- Adjust motors using the tan gears (or large black gear for y-direction)
- Ensure that the pH meter and/or syringe are in the “full_up” position before manipulating the carts x & y position (to prevent collisions with sample wells)
- Run the code blocks in LegolasDemo.ipynb to ensure calibration has been done correctly

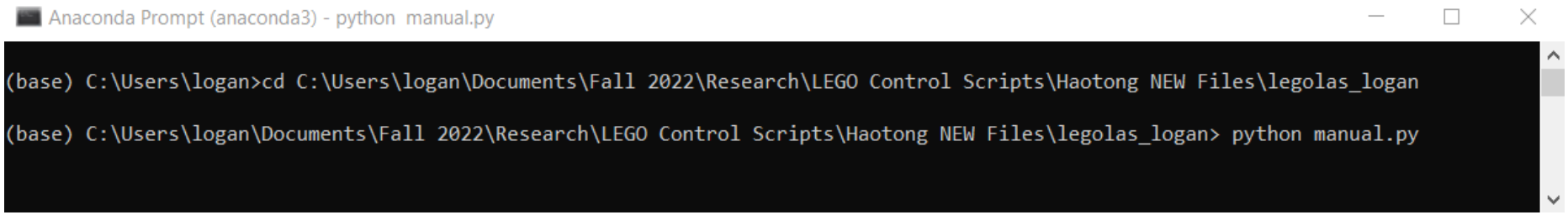
Access Calibration Window

- Search in your windows search bar for “Anaconda Prompt” and open it
- Go to the location or of the folder containing your files and copy the “PATH” (*ex: C:\Users\logan\Documents\legolas_files*)
- In the prompt, type: **cd PATH** *(insert your “PATH” here)*
  - Now you are in the proper file directory
- Type: **python manual.py**

This should appear



Prompt Example

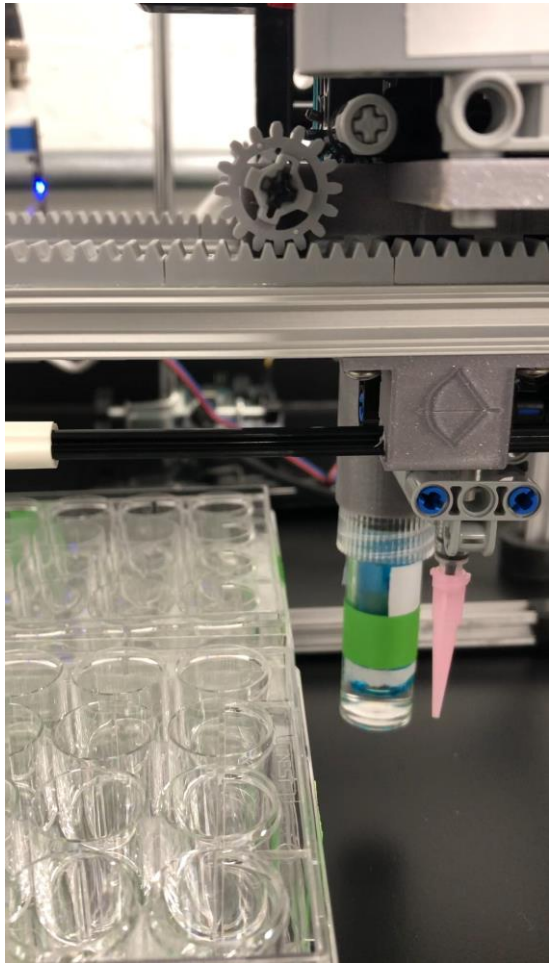


Initial Physical Adjustments

- **(1)** Before moving on with calibration:
  - Unscrew the cap of the pH sensor
  - Gently slide off the gasket and top
  - Place aside, being careful not to spill the cap with the electrode storage solution
    - if you do spill, there is extra storage solution, just ask a TA.
    - You need to assure there is enough solution in the cap prior to putting it back on, or else the electrode may dry out and not be useful (bulb must be submerged in solution)
  - Use the yellow gears for the “Syringe-Z” & “pH-Z” motors to move the z-height of the syringe and pH sensor above that of the sample wells
- **(2)** Adjust the “liquid” motor so that the syringe plunger is at the bottom (i.e. no liquid in syringe).

Initial Physical Adjustments (Pics & Video)

(1)



Video: removing cap and gasket-top, then raising pH sensor and syringe out of the way of sample wells

Note:
Be careful not to squeeze the end of the pH sensor or it will break as it is brittle

(2)

Syringe Plunger is fully down (black)

Connecting to the Raspberry Pi's

For the first time you connect to the 2 raspberry Pi's on your LEGOLAS, use the "Connect via IP" option

- After you have completed this once, you can select your exported .yaml file when you click "Connect via Config" (then you can continue to calibrate from there)

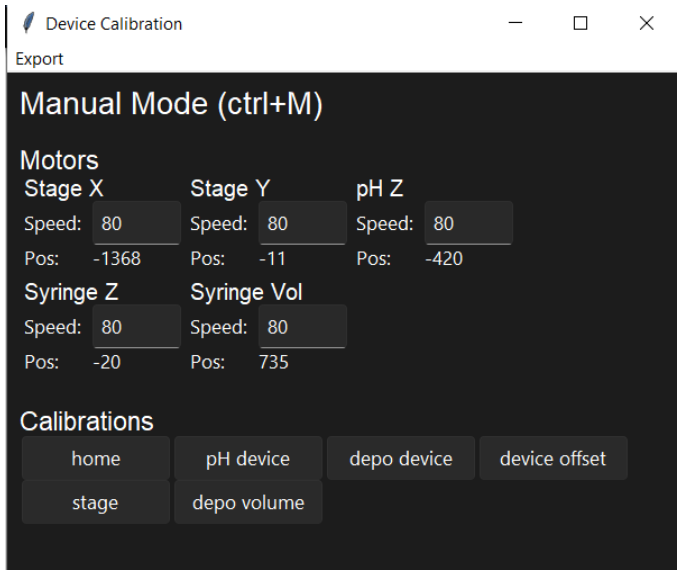
When prompted for R Pi 1 IP Address, use the IP address for "*Group#*A", and use "*Group#*B" for R Pi 2.

IP Addresses

1A: 192.168.0.2	3A: 192.168.0.6
1B: 192.168.0.3	3B: 192.168.0.7
2A: 192.168.0.4	4A: 192.168.0.8
2B: 192.168.0.5	4B: 192.168.0.9

General Calibration Usage

Once you have connected to the Raspberry Pi's and adjusted the physical system, you should see the calibration screen (*shown right*)



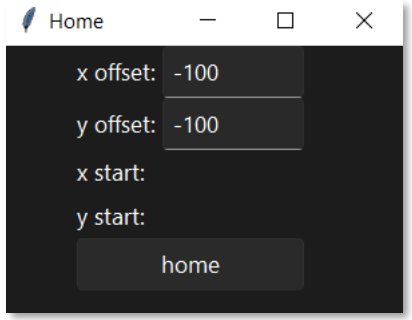
- **Pos:** shows the position (*in degrees*) of each motor & this will update if you move the motors via the keyboard controls or manually
- **Speed:** is the speed at which the motors will move if you use the keyboard controls (*suggested to keep at 80*)
- **Keyboard Controls (press ctrl + M to access) – Not Recommended:**
  - pH Sensor - Z: (1 = up, 2 = down)
  - Syringe - Z: (Q = down, W = up)
  - Syringe Plunger (Liquid): (E = down, R = up)
  - Cart-X: (← = left, → = right)
  - Gantry-Y: (up arrow = up, down arrow = down)

- **Manual Controls (Recommended):**
  - You can use the tan or black gears to manipulate the motors yourself
  - This gives a higher degree of control, as the keyboard controls are not the best
  - The motors will update their position when you move them this way as well, but be careful not to knock the cart off the tracks

Home Calibration

Make sure the gantry is perfectly perpendicular to the base frame and that the gears sit in the teeth of the rack for both the gantry and cart assemblies

Select “Home” in the calibration window, and this screen will appear:



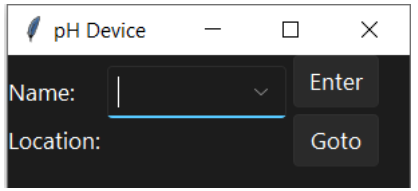
Set x offset and y offset to -100. These define the number of degrees the x and y motors will backtrack once they have contacted the push sensors on their axis. This helps create a reference position for all further calibration steps.

Press “home” and see the LEGOLAS glide down the x and y axis and then come to a rest.

From here on out, you do not want to knock LEGOLAS off the tracks or you will likely have to restart…

pH device Calibration

Select “pH device” in the calibration window, and this screen will appear:



Use the x & y motor manual operation gears to align the pH sensor guide tube (grey cylinder) above the 0,0 cell (*see slide 2 for sample well numbering*). The pH sensor should be up inside the tube currently.

Use the manual operation gear on the motor labeled “pH-Z” to lower the pH sensor into the well so that it is just touching the bottom of the well (not too much slack on the line)

- Under “Name,” select “full_down” and click “Enter”. This sets this position as the lowest point that we will lower the sensor to

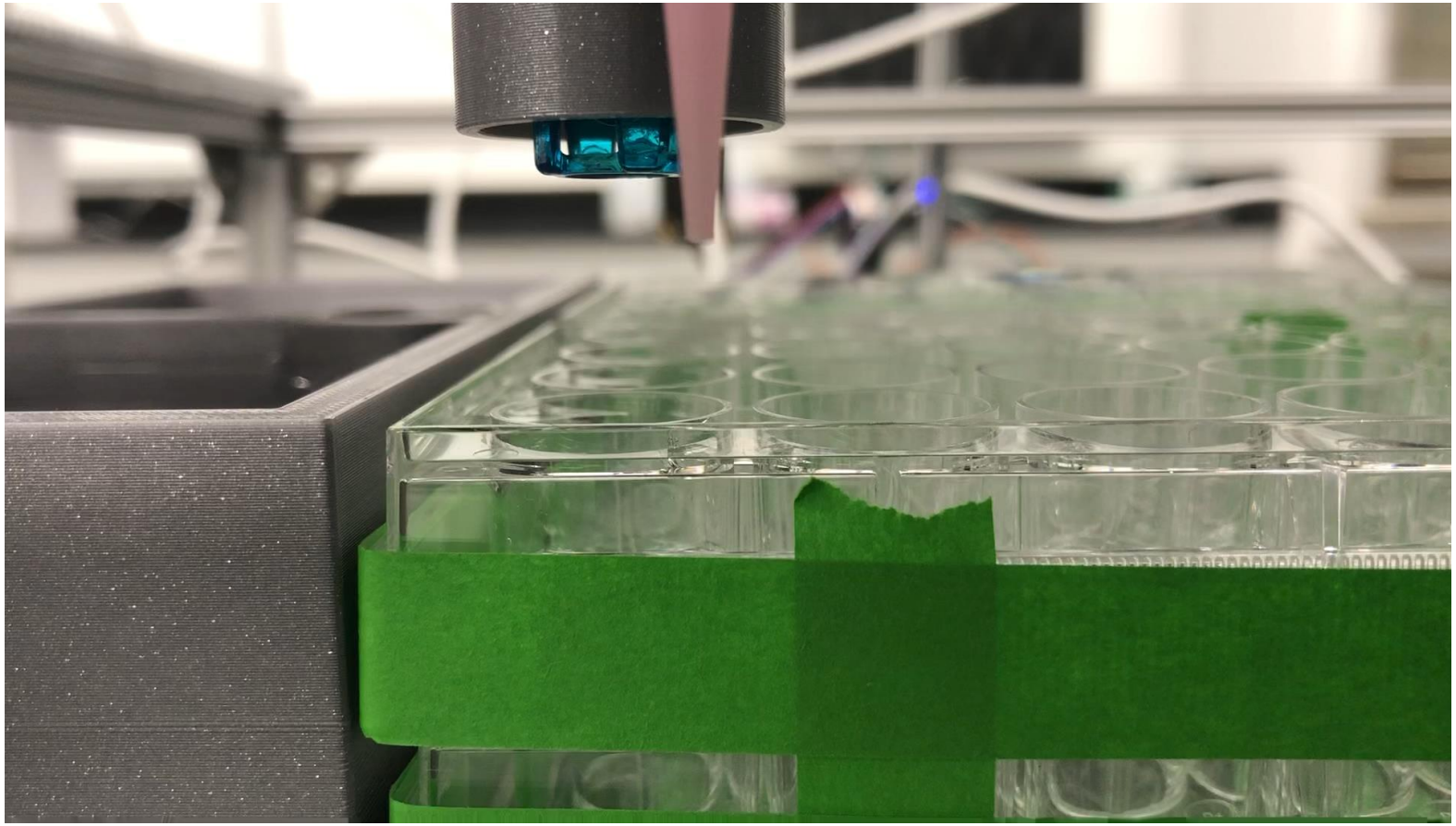
Again using the manual operation gear, raise the pH sensor up so it is just back in the tube again

- Select “full_up” and click “Enter”

You can reselect full_up or full_down and click “Goto” to test your calibrated values

Manually or through the “Goto” function, ensure the pH sensor gets lifted out of the cells so you can move onto the next steps without it colliding with the sample wells…

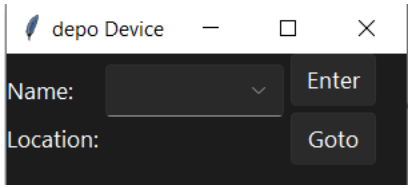
pH device Calibration (Video)



Testing full_down and full_up using the “Goto” button after the values have been set

Deposition Device (Syringe) Calibration

Select “depo device” in the calibration window, and this screen will appear:



Calibrating the syringe is similar to that of the pH device

Use the x & y motor manual operation gears to align syringe above the acid or base reservoir.

Use the manual operation gear on the motor labeled “Syringe-Z” to lower the syringe into the reservoir as far as possible.

- Under “Name,” select “full_down” and click “Enter”. This sets this position as the lowest point that we will lower the syringe to

Again using the manual operation gear, raise the syringe up so it is as high as possible.

- Select “full_up” and click “Enter”

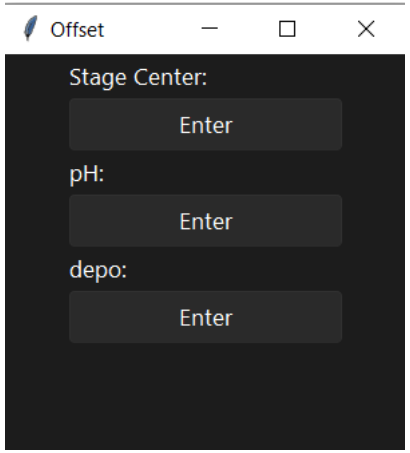
You can reselect full_up or full_down and click “Goto” to test your calibrated values

Manually or through the “Goto” function, ensure syringe gets lifted out of the reservoir so you can move onto the next steps without it colliding with the sample wells…

Device offset Calibration

We will now create a value for the device “offset,” or distance between the pH sensor tip and syringe tip in the x and y directions.

Select “depo device” in the calibration window, and this screen will appear:



We will define the pH sensor as the “stage” and align this again with the 0,0 sample well. To make sure it is fully aligned, you can reopen the pH device calibration window and select full_down to see if it aligns correctly.

Once it is aligned with the 0,0 well, press “Enter” for both “Stage Center” and “pH”

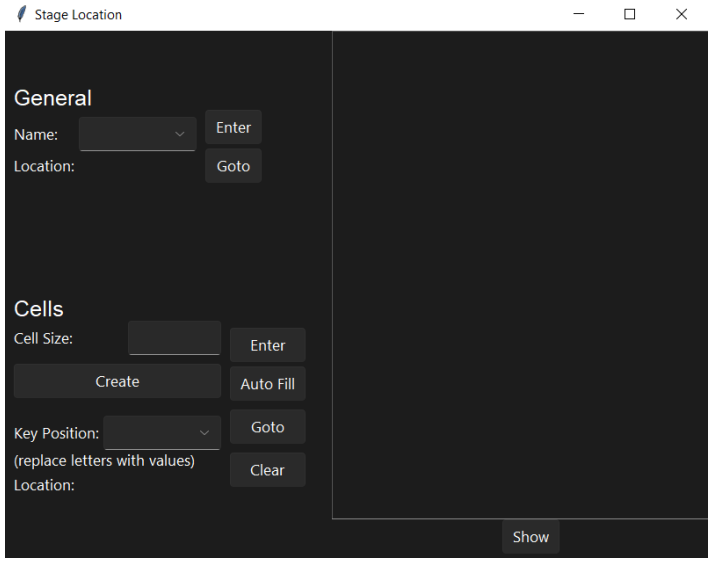
Ensure the pH sensor is lifted to full_up, and then manually move the syringe so it is aligned with the direct center of the 0,0 well.

Now click “Enter” for “depo”

Stage Calibration

We will now map out important areas in the experiment space, using the **pH sensor** as the alignment point (device offset from the prior step will allow us to align the syringe when needed).

Select “stage” in the calibration window, and this screen will appear:



Move the pH sensor guide tube above the leftmost reservoir (any point above it)

- Enter “acid” in the “Name” bar and click Enter

Move the pH sensor guide tube above the rightmost reservoir

- Enter “base” in the “Name” bar and click Enter

Move the pH sensor above the cleaning reservoir (use full_up & down if needed to align)

- Enter “base” in the “Name” bar and click “Enter”

Cell Calibration

Now we will map out the sample wells, again using the **pH Sensor** as our alignment point. We are only using the bottom 4 x 6 sample wells for any experiments you will be conducting.

Enter “4 6” in Cell Size and click “Enter”

Align the pH sensor with the 0,0 sample well (bottom left corner)

- In “Key Position,” enter “0 0” and click enter

Move the pH sensor to the 3,0 sample well (top left)

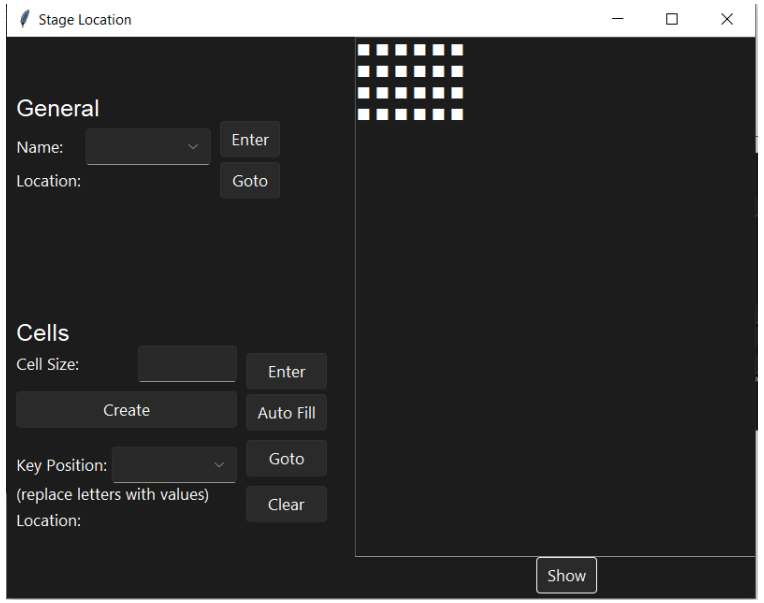
- In “Key Position,” enter “3 0” and click enter

Move the pH sensor to the 3,5 sample well (top right)

- In “Key Position,” enter “3 5” and click enter

Move the pH sensor to the 0,5 sample well (bottom right)

- In “Key Position,” enter “0 5” and click enter

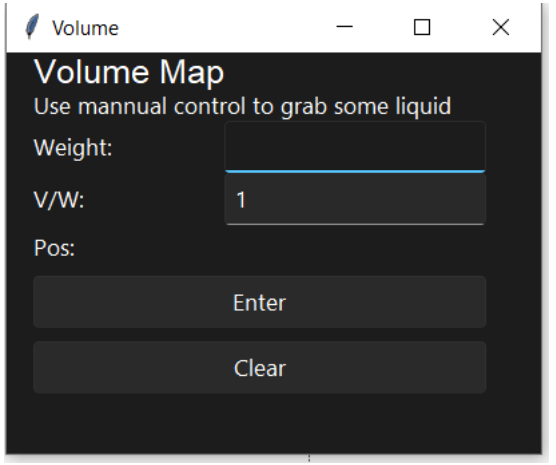


Now select “Auto Fill” and “Show” to see that you have mapped out the 24 cells (they will appear solid white)

Use “Goto” and fill out arbitrary row and column numbers in “Key Position” to test your calibration

It is suggested you lower the pH sensor into each well for every point to ensure it is a proper location in the x & y. (*The pH sensors are close in size to the sample well so if you are off by even a little bit it may be hindered in lowering*).

Deposition Volume Calibration



Select “depo volume” in the calibration window and you will see this window (enter V/W as 1):

- V/W = 1 because… 1 g of water = 1 mL of water

Set up the scale with the orange cap (full to brim with water) to the right of the sample wells.

Align the syringe (with plunger fully down) with the cap and place the tip into the water.

Zero the scale (press the T button).

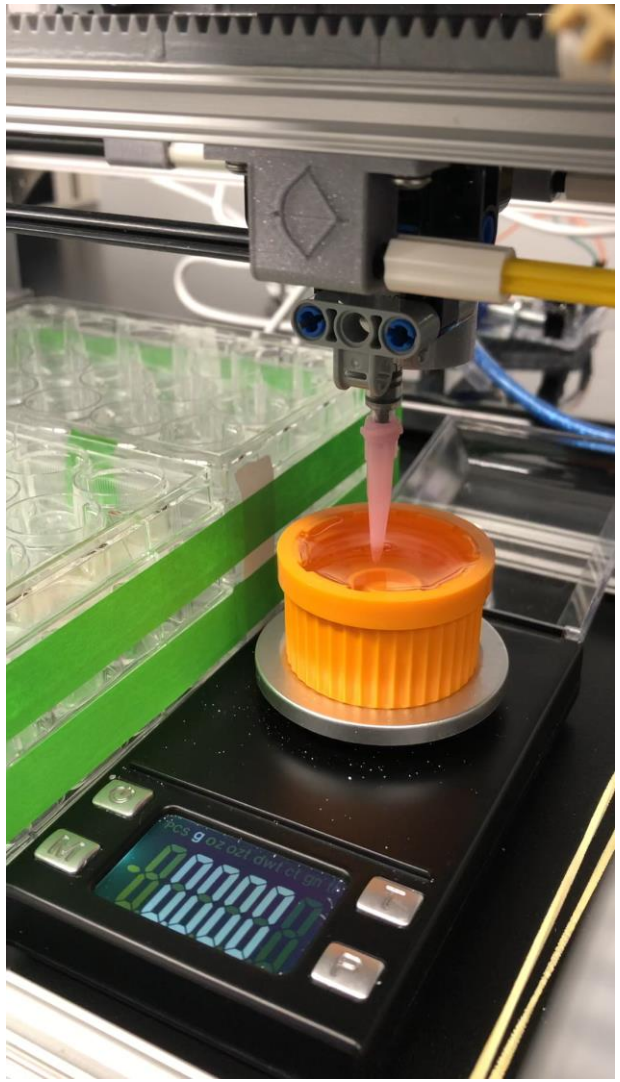
In small increments (approx. 0.1 grams at a time), raise the syringe plunger using the “Liquid” motor with the manual operation gear (tan).

At each increment, **record the exact Weight in grams as a positive number** (it will be negative on the scale) and select “Enter.” Do this for at least 6 points up to 0.7 grams of liquid (0.6 grams is the most we will be taking up at one time in our experiments).

You can press “Clear” if you mess up and want to redo the calibration.

Make sure to deposit the liquid back into the cap at the end, and **let another group use the scale**, as we only have one at the moment.

Deposition Volume Calibration (Video)



Packing up the LEGOLAS

At the end of each session using the LEGOLAS, it is important to take the 3D printed reservoir and sample wells to the sink and dump out and solution/DI water. This will prevent contamination in further experiments. You can remove these easily by removing the rubber band around the sample holder posts, and then sliding the wells and reservoir out.

You must also place the gasket-top of the pH sensor on and then screw on the cap (with sufficient electrode storage solution so that the bulb is submerged). This can be a little difficult so do not hesitate to ask a TA for help so that you do not break the pH sensor tip. The video below shows one way to approach placing it back on. **DO NOT** pull on the blue section or squeeze its tip while trying to put everything back on. Rather, use the wire above the pH sensor for leverage while putting the cap back on.

Before Final Experiments (Calibrating pH)

The pH sensor measures a voltage across two electrodes that is linearly related to the pH of the solution. Before conducting a final experiment, you want to conduct a 2 point calibration of this relationship using the buffer solutions provided in the lab.

Refer to the **pH Sensor Calibration Document** for information on how to do this. Feel free to ask a TA for help if needed.